IEC/PAS 62647-23

Edition 1.0 2011-07

PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

colour inside

**Process management for avionics – Aerospace and defence electronic systems containing lead-free solder –
Part 23: Rework and repair guidance to address the implications of lead-free electronics and mixed assemblies**

IEC/PAS 62647-23:2011(E)

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ELECTROTECHNICAL
COMMISSION

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

Part 23: Rework and repair guidance to address the implications of lead-free electronics and mixed assemblies

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Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned may transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of 3 years starting from the publication date. The validity may be extended for a single 3-year period, following which it shall be revised to become another type of normative document, or shall be withdrawn.

This PAS is based on GEIA-HB-0005-3 and is published as a double logo PAS. GEIA, Government Electronics and Information Technology Association, has been transformed into TechAmerica Association.

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

0.1 General

This PAS is intended to facilitate the development of procedures and processes for use when undertaking the rework/repair of Aerospace and High Performance (AHP) electronics systems. It is intended to contain sufficient information to support the processing of equipment that incorporates either Tin-Lead (SnPb) or Lead-Free (Pb Free) solder alloy, SnPb or Pb-Free piece parts and printed wiring board finishes, or a combination thereof.

This PAS may be used by Original Equipment Manufacturers (OEMs), contract manufacturers (CMs) and commercial depots. This document may also be used by personnel performing rework/repair at the Organizational (O) level, Intermediate (I) back shop level, and Depot (D) overhaul level.

The purpose of this Working Group is to generate a series of industry standards and documents intended to facilitate the maintenance of suitable equipment quality and reliability standards within the AHP industries during the general industry migration to Pb-Free.

This PAS is intended to work in concert with IEC/PAS 62647-1 (GEIA-STD-0005-1), IEC/PAS 62647-2 (GEIA-STD-0005-2), and IEC/PAS 62647-21 (GEIA-HB-0005-1).

This PAS may be referenced in proposals, requests for proposals, work statements, contracts, and other aerospace and high performance industry documents.

0.2 Pb-Free and Legislation

Recent Directives and Legislation by Nations around the world mandated elimination of Lead and other hazardous material usage in sectors of the electronics industry by 2006. In electronics, Lead (Pb) has been a primary component of Tin-Lead (SnPb) solder used in piece part attachment and PWB finishes for over 50 years, and more recently in the solder spheres for attachment of Ball-Grid-Array (BGA) packages. Since there is no “drop-in” replacement for SnPb solder alloys, multiple Pb-Free alloys have emerged in the manufacturing industry as replacements. These multiple replacement alloys are being used in Printed Wiring Boards (PWB) / Printed Circuit Boards (PCB) finish, piece part termination finish and as solder alloys, leaving the rework/repair technician with literally hundreds of possible combinations of metallurgy in the finished repair.

The majority of the Pb-Free alloys being considered have melting temperatures 61 °F to 79°F (34 °C to 44 °C) higher than that of SnPb eutectic solder. These higher Pb-Free processing temperatures require significant changes to convective rework/repair procedures and minor adjustments in conductive hand soldering procedures to ensure that quality products will be produced.

Another major concern is the potential re-emergence of Tin Whiskers as an additional equipment failure mechanism. Tin Whiskers are electrically conductive, crystalline structures of Sn that grow under compressive force from surfaces where Sn [especially electroplated Sn] is used as a final finish. Tin Whiskers have been observed to grow to lengths of several millimeters (mm). Numerous electronic system failures have been attributed to short circuits caused by Tin Whiskers that bridge closely-spaced circuit elements. Tin Whiskers have been successfully suppressed for decades by the addition of Pb to Sn plating used in high reliability applications. With the global shift to Pb-Free solders, Tin Whiskers have re-emerged as a major concern to reliability. IEC/PAS 62647-2 (GEIA-STD-0005-02) further discusses Tin Whisker issues and mitigation techniques.

This document will provide guidance to the organization performing rework/repair on various combinations of SnPb, Pb-Free and mixed technology assemblies likely to be seen as the global transition to Pb-Free solder continues. The organization typically consists of program management, procurement, process engineering, bench technician, and quality assurance personnel.

Procedurally, conductive Pb-Free rework/repair is similar to that of SnPb. However, adjustments must be made to accommodate the generally poorer wetting ability of Pb-Free solders as well as differences in appearance and inspection criteria. Convective rework/repair will require redevelopment of profiles to accommodate the higher melting temperature of Pb-Free alloys. Also, Pb-Free rework/repair has a tighter process window leaving a smaller margin for error in comparison to SnPb. With the proper materials, preparation, skill, and the use of fundamentally sound procedures, Pb-Free rework/repair can be successfully and reliably accomplished[1].

1 http://www.solder.net/leadfreerepair.asp

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

Part 23: Rework and repair guidance to address the implications of lead-free electronics and mixed assemblies

1 Scope

This PAS provides technical background, procurement guidance, engineering procedures, and guidelines to assist organizations reworking/repairing aerospace and high performance electronic systems, whether they were assembled or previously reworked/repaired using traditional alloys such as SnPb or Pb-Free alloys, or a combination of both solders and surface finishes. This PAS contains a review of known impacts and issues, processes for rework/repair, focused to provide the technical structure to allow the repair technician to execute the task.

This PAS focuses on the removal and replacement of piece parts. For the purposes of this PAS, the term "Rework/Repair" is used as applicable.

NOTE The information contained within this PAS is based on the current knowledge of the industry at the time of publication. Due to the rapid changing knowledge base, this PAS should be used for guidance only.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC/PAS 62647-1, *Process management for avionics – Aerospace and defence electronics systems containing lead free solder – Part 1: Lead-free management*

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

IEC/PAS 62647-21, *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder – Part 21: Program management – System engineering guidelines for managing the transition to lead-free electronics*

IEC/PAS 62647-22, *Process management for avionics – Aerospace and defence electronic systems containing lead-free solder – Part 21: Technical guidelines*

GEIA-STD-0005-1, *Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder*

GEIA-STD-0005-2, *Standard for mitigating the effects of tin in aerospace and high performance electronic systems*

GEIA-HB-0005-1, *Program management / Systems engineering guidelines for managing the transition to lead-free electronics*

GEIA-HB-0005-2, *Technical guidelines for aerospace and high performance electronic systems containing lead-free solder*

3 Terms and definitions

For purposes of this PAS, the following terms and definitions apply:

3.1
alloy composition
is stated as weight in percent. For instance 63Sn-37Pb corresponds to a mixture of 63 % by weight of Tin (Sn) and 37 % by weight of Lead (Pb)

3.2
assemblies
are electronic items that require electrical attachments, including soldering of wires or piece part terminations; examples include circuit cards and wire harnesses

3.3
backwards compatibility
refers to Pb-Free materials compatible with a SnPb process

3.4
ball grid array
BGA
is a surface mount package type that uses a grid of solder balls arranged in an array to provide direct electrical interconnection between the part substrate and the circuit board

3.5
coefficient of thermal expansion
CTE
is the linear dimensional change of a material per unit change in temperature

3.6
conductive
refers to the use of a contact heat source such as a soldering iron, hot bar, or resistance to transfer heat to the assembly

3.7
convective
refers to the use of a non-contact heat source usually heated air, Nitrogen or infrared light to transfer heat to the assembly

3.8
copper dissolution
is the excessive loss of copper from plated-through-hole barrels and pads caused by wave or solder fountain processing primarily with high Tin (Sn) content solders

3.9
critical
item or function, if defective, will result in the system's inability to retain operational capability, meet primary objective, or affect safety

3.10
customer
refers to an entity or organization that (a) integrates a piece part, soldered assembly, unit, or system into a higher level system, (b) operates the higher level system, or (c) certifies the system for use. For example, this may include end item users, integrators, regulatory agencies, operators, original equipment manufacturers (OEMs), and Subcontractors

3.11
delamination
is a separation between plies within a base material, between a base material and a conductive foil, or any other planar separation with a printed board that may propagate under thermal stress

3.12
depot level maintenance
D
is maintenance requiring major overhaul or a complete rebuilding of parts, assemblies, subassemblies, and end items, including the manufacture of parts, modifications, testing, and reclamation as required. Depot maintenance serves to support lower categories of maintenance by providing technical assistance and performing that maintenance beyond their responsibility

3.13
dissolution
is the process in which one substance is dissolved in another by chemical action

3.14
electroless nickel / immersion gold
ENIG
is a two technology process for the application of a desired finish where Nickel is applied using Electroless plating, requiring the presence of a proper reducing agent in a plating bath that converts the metal salts into metal and deposits them onto the substrate. The immersion plating process deposits a new metal surface (Gold) by replacing the base metal; in this process, plating stops when the surface of the base metal is completely covered, thus only a limited coating thickness can be obtained through the immersion process. The control of the kinetics associated with both processes is vital to plating results

3.15
eutectic *(Solder)*
is the alloy composition at which a solder alloy melts/freezes completely without going through a pasty (partially solid) phase

3.16
high performance system
requires continued performance or performance on demand, or equipment down time cannot be tolerated, or end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems

3.17
intermediate level maintenance
I
includes limited repair of commodity-orientated piece parts and end items, job shop, bay, and production line operations for special mission requirements; repair of printed circuit boards, software maintenance, and fabrication or manufacture of repair parts, assemblies, piece parts. Intermediate maintenance consists of repair of aircraft and engine components, WRAs, and LRUs forwarded to the Intermediate level by the organizational level flight-line activities. WRA and LRU repair is accomplished by the removal, troubleshooting, and replacement of faulty SRA and SRU, pieces, and parts within the WRA/LRU

3.18
lead
Pb
in this PAS, if the element "Lead" is implied, it will be stated as either Pb or as Lead (Pb)

3.19
lead-free
Pb-Free
is defined as less than 0,1 % by weight of Pb in accordance with Waste Electrical and Electronic Equipment (WEEE) guidelines

3.20
lead-free control plan
LFCP
refers to an aerospace or military system Supplier's document that defines the processes that assure the plan owners, their Customers, and all other stakeholders that aerospace and high performance high-reliability electronics systems containing Pb-Free solder will continue to be reliable, safe, producible, affordable, and supportable. Technical guidance for a LFCP can be found in IEC/PAS 62647-21 (GEIA-HB-0005-1)

3.21
line replaceable unit
LRU
is a black box of electronics removed and replaced at the flight-line level

3.22
liquidus
is the minimum temperature at which all components of a mixture (such as an alloy) can be in a liquid state. Below liquidus, the mixture will be partly or entirely solid

3.23
measling
is a condition that occurs in laminated base material in which internal glass fibers are separated from the resin at the weave intersection. This condition manifests itself in the form of discrete white spots or "crosses" that are below the surface of the base material

3.24
organic solderability preservative
OSP
is a thin organic compound that selectively bonds with Copper (Cu) used to preserve the solderability of bare Cu on printed wiring boards (PWB's)

3.25
organizational level maintenance
O
is maintenance normally performed by an operating unit on a day-to-day basis in support of its own operations. Organizational-level maintenance typically includes "inspections," "servicing," "handling," and "preventive maintenance" and is limited to the replacement of electronics assemblies at the WRA and LRU (black box) level of major aircraft and engine components. There can be an exception is where troubleshooting and piece parts level repair are accomplished at the Organizational level

3.26
Pb-Free tin
is any Tin alloy with <3 % Lead (Pb) content by weight. This means that some Pb-Free finishes other than Pb-Free Tin, such as Tin-Bismuth and Tin-Copper, are considered to be "Tin" for the purposes of this document. Many of these alloys have not been assessed for whiskering behavior

3.27
Pb-Free tin finish
is Pb-Free Tin final finishes or underplating either external or internal to a device, PWB, or other hardware. This includes all terminations and surfaces, even those coated, encapsulated, or otherwise not exposed. It may include finishes on electrical piece parts,

mechanical piece parts, and PWBs. It does not include Pb-Free bulk solders, assembly materials, solder balls, or those devices where the Pb-Free Tin finish has been completely replaced

3.28
piece part
is an electronic component that is not normally disassembled without destruction and is normally attached to a printed wiring board to perform an electrical function

3.29
procurement
is the process of obtaining services, supplies, and equipment

3.30
plated-through-hole
PTH
is a Cu-plated hole in a circuit board used to accommodate a through-hole piece part termination

3.31
quality assurance
is a planned and systematic set of activities to ensure that requirements are clearly established and that the defined process or product complies with these requirements

3.32
repair
is the act of restoring the functional capability of a defective article in a manner that precludes compliance of the article with applicable drawings or specifications

3.33
rework
is the act of reprocessing non-complying articles, through the use of original or equivalent processing in a manner that assures full compliance of the article with applicable drawings or specifications

3.34
rework/repair
is the term used in this PAS where the processes identified apply to either rework or repair

3.35
SAC (Tin Silver Copper)
refers to the family Pb-Free alloys containing Tin (Sn), Silver (Ag), and Copper (Cu) used in surface mount technology or sometimes in wave solder processes. The alloys typically have a composition near the eutectic (Sn3.5Ag0.9Cu)

3.36
shop replaceable assembly
SRA
is a component assembly inside a black box (LRU or WRA) typically consisting of individually replaceable circuit cards

3.37
shop replaceable unit
SRU
is a component assembly inside a black box (LRU or WRA) typically consisting of individually replaceable circuit cards

3.38
should
indicates that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain course of action is deprecated but not prohibited

3.39
SnCu (Tin Copper)
solder or alloy refers to Pb-Free alloys that are comprised of Tin-Copper (Sn-0.7Cu)

3.40
SnCuNi (Tin Copper Nickel)
solder or alloy refers to Pb-Free Tin-Copper with trace Nickel concentration alloy (Sn0.7Cu0.05Ni). Some formulations also include other minor additions such as Germanium (Ge)

3.41
SnPb (Tin Lead)
solder or alloy refers to Tin-Lead alloys at or near the eutectic composition (63Sn37Pb)

3.42
soldered assembly
is an assembly of two or more basic parts interconnected by a solder alloy. A Pb-based soldered assembly is one in which the solder alloys are solely Pb-based. A Pb-Free soldered assembly is one in which the solder alloys are solely Pb-Free

3.43
system
is one or more units that perform electrical function(s)

3.44
termination
is the term used in this document to identify the area to be soldered of the piece part termination, castellations, or metallized surface(s) of an electronic device

3.45
ternary alloy
is a solder alloy containing three component metals

3.46
Tg
refers to the glass transition temperature of laminate material

3.47
High Tg
refers to the glass transition temperature of laminate material ≥ 338°F (170 °C)

3.48
tin whisker
is a spontaneous crystal growth that emanates from a Sn surface. They may be cylindrical, kinked, or twisted. Typically they have an aspect ratio (length/width) greater than two, with shorter growths referred to as nodules or odd-shaped eruptions. See IEC/PAS 62647-2 (GEIA-STD-0005-2) for further description of Tin Whiskers and their physical attributes

3.49
underplating
is the plating made as a base of a surface overplating usually required as a barrier to prevent leeching of two dissimilar metals into one another

3.50
weapons replaceable assembly
WRA
is a black box of electronics, replaced at the flight-line level

3.51
X-ray fluorescence
XRF
is a form of metallurgical analysis that uses x-rays to identify composition of solder alloys and termination finishes

4 Symbols and abbreviated terms

Ag	Silver
AHP	Aerospace and High Performance
Au	Gold
Bi	Bismuth
BGA	Ball Grid Array
C4 Ball	Controlled Collapse Component Connection Ball
CALCE	Center for Advanced Life Cycle Engineering
CBGA	Ceramic Ball Grid Array
CCA	Circuit Card Assembly
CM	Contract Manufacturer
CTE	Coefficient of Thermal Expansion
Cu	Copper
D	Depot Maintenance Level
ENIG	Electroless Nickel Immersion Gold
EU	European Union
Fe	Iron
I	Intermediate Maintenance Level
ImAg	Immersion Silver
In	Indium
iNEMI	International Electronics Manufacturing Initiative
JG-PP	Joint Group on Pollution Prevention
GEIA	Government Electronics and Information Technology Association
HASL	Hot Air Solder Leveling
LFCP	Lead-Free Control Plan
LRU	Line Replaceable Unit
mm	Millimeter
MSD	Moisture Sensitive Devices
Ni	Nickel
O	Organizational Maintenance Level
OEM	Original Equipment Manufacturer
OSP	Organic Solderability Preservative
Pb	Lead
Pb-Free	Lead-Free
PCB	Printed Circuit Board (also known as PWB)
Pd	Palladium
PTH	Plated-Through-Hole
PWB	Printed Wiring Board (also known as PCB)
QFN	Quad Flat No Leads package
RoHS	2002/95/EC Restriction of Hazardous Substances
SnAgCu	Pb-Free solder alloy of Tin (Sn), Silver (Ag), and Copper (Cu)
SAC	Pb-Free solder alloy of Tin (Sn), Silver (Ag), and Copper (Cu)
SACB	Pb-Free solder alloy of Tin (Sn), Silver (Ag), Copper (Cu) and

	Bismuth (Bi)
SMT	Surface Mount Technology
SMTA	Surface Mount Technology Association
Sn	Tin
SnBi	Pb-Free solder alloy of Tin (Sn) and Bismuth (Bi)
SnCu	Pb-Free solder alloy of Tin (Sn) and Copper (Cu)
SnCuNi	Pb-Free solder alloy of Tin (Sn), Copper (Cu), and Nickel (Ni)
SnPb	Tin/Lead (normally 63 % Tin / 37 % Lead)
SRA	Shop Replaceable Assembly
SRU	Shop Replaceable Unit
WEEE	2002/96/EC Waste Electrical and Electronic Equipment
WRA	Weapons Replaceable Assembly
XRF	X-Ray Fluorescence

5 Pb-Free Concerns

The transition from SnPb to Pb-Free rework/repair has a variety of concerns. IEC/PAS 62647-1 (GEIA-STD-0005-1) identifies five major areas that must be considered. Those areas include reliability, configuration control, risk management, effects of Sn in the system, and rework/repair. If the concerns in the first four areas are not properly identified, planned for, assessed, managed, and documented, rework/repair of those assemblies becomes extremely difficult. A quality Lead-Free Control Plan (LFCP) will identify and mitigate potential concern areas and provide the technician with clear requirements for rework/repair.

5.1 Reliability

The program manager should understand how the transition to Pb-Free solder and piece part termination finishes or mixing SnPb and Pb-Free solders may affect the reliability of the assembly. Additionally, the effects on package types/geometry, piece part termination finish, and laminate materials and finishes, must be clearly understood when authorizing and introducing the use of alternate materials.

The reliability of the original solder joint is dependent upon the integrity of the solder in the joint and the metallurgical interfaces to the terminations and PWB lands. The solder joint reliability is influenced by the final solder alloy composition and microstructure, the shape of the solder surface and the termination-to-solder interfacial strength. The initial composition of the solder used to form the joint is typically modified to some extent during the soldering process as the pad metallization and finish are dissolved into the solder joint. The amount of dissolved piece part and pad metal typically does not significantly alter the initial alloy composition. The exceptions to this rule are Ball Grid Array (BGA) type devices where the ball solder volume represents a significant amount of the total solder volume, and pad interface finish elements that have a tendency to segregate to either the piece part or the PWB pad interfaces or grain boundaries such as Gold (Au) and Bismuth (Bi) alloys contaminated with trace amounts of Pb.

5.1.1 Mixed metallurgy reliability

In a reworked/repaired solder joint, metallurgy mixing is a major reliability concern to electronics equipment suppliers and users. As SnPb BGA ball metallurgy and SnPb finished piece parts are being quickly replaced by Pb-Free alternatives, Pb-Free solders may be either intentionally or unintentionally mixed with SnPb solder and/or Pb bearing finishes throughout their service life and during repair activity. Annex A lists a number of the termination finishes that potentially could be encountered. Annex B provides a summary of the Tin Whisker propensity for the various elemental additions to Sn.

5.1.1.1 Pb-Free terminations in SnPb joints

One result of the WEEE/RoHS directives and the responding piece part fabricator initiative is the introduction of piece parts with Pb-Free surface finish terminations into existing traditional SnPb soldering processes. The variety and compositions of the Pb-Free surface finishes being delivered into the electronics industry is extensive. Many of these piece parts materials will find their way into the inventory of aerospace and Defence assembly processes under government acquisition reform initiatives. Electronics assembly design teams must be knowledgeable on the potential impact of the Pb-Free surface finish piece part and pad interface on solder joint integrity. The impact is not universal—solder joint integrity degradation can range from slight to severe depending upon the use environment.

5.1.1.2 SnPb terminations in Pb-free joints

The introduction of SnPb terminated piece parts in a Pb-Free solder system is likely during the early stages of Pb-Free assembly processing while the piece part supply stream still contains SnPb terminated piece parts.

5.1.1.3 Bismuth (Bi)

The addition of Bi to SAC has been shown to yield a solder joint that has improved durability. However, the principal concern is that when Bi and Pb are intermixed, a low melting point SnBiPb Ternary alloy can form, particularly at the grain boundaries. The melting point of the ternary alloy is 205°F (96 °C) and the solder can lose strength during hot mission environments.

5.1.1.3.1 SnPb finish in SnBi solder alloy

Trace amounts of Pb were found to have a detrimental effect (e.g., Kirkendall voiding, embrittlement, etc.) on solder life of Bi containing solders (Sn91,8Ag3,4Bi4,8 and Sn92,3Ag3,4Cu1,0Bi3,3) and resulted in catastrophic failure of Sn58Bi solder joints. Since AHP products have a 20 year service life, a repair depot infrastructure will have both SnPb and Pb-Free alloy configurations for a significant amount of time.

5.1.1.3.2 SnBi finish in SnPb solder alloy

Bismuth bearing solder alloys are noted as a concern in IEC/PAS 62647-1 (GEIA STD- 0005-1). However, there are some piece parts that are only available with a SnBi termination finish. Preliminary testing suggests that trace amounts of Bi in SnPb joints are not detrimental to solder life. For further information see IEC/PAS 62647-22 (GEIA-HB-0005-2).

5.2 Configuration management

The need for configuration management is paramount to the Pb-Free transition. Studies have shown that mixing SnPb and Pb-Free solders or the mixing of Pb-Free solders of different alloys and/or piece parts (solders or finishes of different alloys) may have detrimental impact on the long-term reliability under high stress (e.g., military, commercial aerospace, or space) environments. All parties involved in the rework/repair process should understand the appropriate configuration controls (e.g., traceability) that are necessary for the program's environment.

There are applications within AHP systems where acceptance of alternate materials may be acceptable. Any deviation from the assembly drawings must be approved and promulgated by the responsible engineering authority or the delegated representative.

Introduction of alternate solder alloys and piece part termination finishes that deviate from the assembly drawing may or may not affect the user's configuration management process. The use of Pb-Free termination finishes in SnPb assemblies may not be considered a configuration change. However, the use of alternate solder alloys on that assembly may result in a configuration change. The authorized deviation to assembly drawing requirements should be accompanied by clear, well documented rework/repair procedures.

NOTE Commercial part Suppliers may or may not modify part numbers when converting to Pb-Free or changing existing Pb-Free finishes.

5.3 Risk management

Risks need to be identified early and a mitigation strategy engaged. The appropriate Systems Engineering process of Risk Identification, Risk Analysis, and Risk Mitigation should be followed. Risk identification and risk assessment should be performed for any deviation (transition to Pb-Free or mixed assembly, etc.) for the particular end-use conditions of the assembly. The program manager has the responsibility to conduct analysis and complete a risk management plan that identifies risk and provides mitigation methods. This plan should include impacts to rework/repair and provide revised procedures as necessary.

5.4 Tin whiskers

Whiskers are elongated single crystals of pure Sn that have been reported to grow to more than 10 mm (250 mils) in length (though they are more typically 1 mm or less) and from 0,3 μm to 10 μm in diameter (typically 1 μm - 3 μm). Whiskers grow spontaneously without an applied electric field or moisture (unlike dendrites) and independent of atmospheric pressure (they grow in vacuum). Whiskers may be straight, kinked, hooked, or forked and some are reported to be hollow. Their outer surfaces are usually striated. Whisker growth may begin soon after plating. However, initiation of growth may also take years. The unpredictable nature of whisker incubation and subsequent growth is of particular concern to systems requiring long term, reliable operation. More information is available in Annex B – Tin Whiskers of this document and IEC/PAS 62647-2 (GEIA-STD-0005-2).

5.5 Copper dissolution (erosion)

The high Sn content of the common Pb-Free alloys (those typically >95 % wt Sn) used in through-hole wave soldering has created rework/repair issues with solder fountain methods. Solder fountain rework/repair of connectors and other multi-termination piece parts is causing excessive dissolution of the PWB pad and barrel. In some cases where prolonged time in the solder wave can occur, one Pb-Free rework/repair can completely dissolve the plated hole at the knee. Under common conditions, the dissolution rates may be so high that traces are almost completely dissolved within 20 s to 30 s. Stabilized alloys composed of Sn, Cu, and small amounts of Ni have proven to offer several advantages for wave soldering applications, including brighter solder joints, low copper dissolution rates comparable to SnPb, good flow characteristics, and reduced defects such as bridges and icicles.

Due to the high probability of copper dissolution in high Sn content Pb-Free alloys, solder fountain rework/repair using these alloys should be avoided. Continuous vacuum extraction methods should be employed to maximize plated-through-hole integrity allowing for potential future rework/repair.

Separate solder fountains should be maintained in situations where rework/repair is being performed on legacy SnPb and Pb-Free assemblies. See Subclause 7.2 for additional solder fountain details.

6 Materials

6.1 Solder

Some examples of solder alloy types are listed below.

6.1.1 Solder alloys

IPC/JEDEC J-STD-609 designations (***e0*** – ***e9***) are listed after some of the common Pb-Free alloys:

- Contains Pb >0.1 Wt % ***e0***
- Tin-Silver-Copper (SAC) family of alloys; ***e1***
- Tin-Copper; ***e2***

- Tin-Copper-Nickel “Stabilized”; ***e2***
- Other alloys containing Bismuth; ***e6***
- Tin-Silver-Copper-Bismuth (SACB); ***e6***
- Solders containing Indium; ***e7***
  - Melting temperature is less than 302°F (150 °C)
- Other Pb-Free alloys
  - Currently over 200 different formulations exist

6.1.2 Solder forms

Pb-Free solder is available in many of the same forms as SnPb solder including wire, paste, spheres, ribbon or foil, ingot or bar, and preforms. Pb-Free solders may not be easily distinguishable from SnPb solders or other Pb-Free alloys so it is important for technicians to keep all solder alloy materials clearly marked in the manufacturer’s original packaging. Wire solder or solder paste with missing labels may render the material unidentifiable without testing. It is especially important to maintain 100 % control of solders where multiple alloys are present at the rework/repair station and cross contamination could occur if mixed.

6.1.2.1 Solder wire

A wide range of solid and flux-cored Pb-Free solder wire is commercially available. The diameters for rework/repair have not changed with standard sizes between 0.062” and 0.015” being common. Due to the inherent stiffness of Pb-Free solder wire, some Pb-Free alloys are difficult or impossible to extrude in the 0,010” diameter.

6.1.2.2 Solder paste

In appearance Pb-Free and SnPb solder paste look identical. At least one manufacturer has tinted the flux chemistry in the paste green as a method to identify it as Pb-Free. In general, paste application methods using a syringe or stencil have not changed. To enhance solderability, the rework/repair site lands or pads should be properly tinned especially when reworking/repairing OSP, which oxidizes rapidly making rework/repair difficult. Although flux formulations are vastly different and wetting may be reduced, the application and use of Pb-Free solder paste is very similar to SnPb paste.

6.1.2.3 Solder preforms

Solder preforms are used in a variety of manufacturing and rework/repair applications that require precise amounts of solder. Pb-Free solder preforms have few notable differences from SnPb preforms. Reduced solderability and wetting, an inherent difference in Pb-Free soldering can be expected. This can be minimized through proper site preparation during rework/repair.

6.2 Fluxes

The transition to Pb-Free solders has driven the requirement for new fluxes formulated for the higher melting temperature and slower wetting characteristics of Pb-Free solders. Compatibility of Pb-Free alloys with the flux chemistry is critical for acceptable results in both assembly and rework/repair. Fluxes contained in wire solder, flux pens, and dripper bottles should be fully compatible with the assembly fluxes and cleaning materials. All fluxes should be labeled properly for positive identification at the bench. Fluxes used for Pb-Free are available in the same liquid, paste, and gel forms as used in SnPb rework/repair.

NOTE See J-STD-004, “Requirements for Soldering Fluxes,” for additional information on flux composition and activity level categories.

6.3 Piece parts

The transition to Pb-Free solder affects the piece part termination finish, not the function of the part. Pb-Free through-hole and surface mount piece parts still require the same practices and precautions for receiving, storage, handling, preparation, and use. At facilities that rework/repair SnPb and Pb-Free assemblies, parts bins, staging locations, and piece part packaging should be clearly marked and segregated to prevent unintentional mixing of material.

6.3.1 Termination finishes

Some of the Pb-Free finishes being applied to piece part terminations include the following:

- Tin (Sn), including matte Sn and bright Sn
- Tin Silver (SnAg)
- Tin Copper (SnCu)
- Tin Silver Copper (SnAgCu)
- Nickel Palladium (NiPd)
- Nickel Palladium Gold (NiPdAu)
- Tin Bismuth (SnBi)

Piece part manufacturers typically offer few, if any, finish alternatives for each part type. When soldered, some of the piece part finish dissolves into the solder, and may cause detrimental intermetallic phases in the finished solder joint. In some cases, a small percentage of an incompatible piece part finish can significantly reduce reliability. A SnPb finished piece part introduced into a SACB soldered assembly is a prime example of this potential for reduced reliability in mixed rework/repair. Annex A -Termination Finishes lists piece part termination finishes and their corresponding compatibility with solder alloys. Table B.2 -Tin Whiskers lists various termination finishes and their risk for whisker growth.

6.3.2 Area arrays (BGA, CSP, etc.)

One of the most technically challenging issues in the transition from SnPb to Pb-Free assembly is the compatibility of the Pb-Free BGA placed in a SnPb assembly. There are two areas of concerns: solder joint yield and reliability. If an ordinary SnPb reflow profile is used, the Pb-Free balls are not fully melted, producing a non-homogenous mix of Pb-Free balls and SnPb solder paste resulting in an unreliable solder joint. The lack of ball collapse may also result in open solder joints. IEC/PAS 62647-22 (GEIA-HB-0005-2) provides more information on area array reliability.

Industry studies have shown that automated x-ray inspection systems can be effectively used to evaluate Pb-Free array package solder joints deformities, defects, and irregularities. The x-ray inspection systems may have to be optimized to take into account the contrast differences of the Pb-Free solder and the differences in solder fillet shape and length.

6.4 Printed circuit boards

6.4.1 Laminate material

PWBs are constructed out of different laminate materials depending on application. PWBs (heritage/low Tg) may be damaged during rework/repair using the higher Pb-Free processing temperatures. Both high glass transition temperature and high decomposition temperature are important to prevent damage to PWBs during rework/repair processes. If these properties are not known, careful heating application (both in temperature and soldering time) during the rework/repair process is critical to prevent damage to the PWB.

6.4.2 Surface finish

Many PWB Pb-Free surface finishes are available including:

- Tin (Sn)
- Electroless Nickel Immersion Gold (ENIG)
- Immersion Silver (ImAg)
- Organic Solderability Preservatives (OSP)
- Hot Air Solder Leveling (HASL) finishes with SAC and SnCu alloys are also available.

While the surface finish is outside the control of the technician, it may be a factor in determining compatibility with specific termination finish and solder alloys. In addition, ensure that PWB materials can withstand reflow temperatures without warpage or other damage. IEC/PAS 62647-22 (GEIA-HB-0005-2) provides more information on Pb-Free surface finishes.

6.5 Conformal coatings

Conformal coatings have been used for many years to protect printed circuit assemblies used in many high-reliability applications. Conformal coatings are used in military and aerospace equipment to primarily provide a moisture barrier for electrical circuits including piece part terminations and PWB traces. It also provides secondary benefits such as protecting the assembly from mechanical damage, dust, fungus, humidity, and other contaminants that may cause corrosion or current leakage.

With the advent of Pb-Free materials and processes, conformal coating has an additional positive attribute when used as part of a formal Tin Whisker mitigation strategy. Unfortunately, the more aggressive fluxes associated with Pb-Free solders also mean that greater care must be taken in cleaning the board prior to the application of any coating. This is especially the case after rework/repair, where only limited cleaning facilities may be available.

Conformal coatings may provide one or more of the following features:

- Tin Whisker mitigation
- Thermal heat conductivity to dissipate heat from piece parts
- Low shrinkage factors during application and curing to prevent coatings from applying stress to laminates or piece parts
- Resilience, hardness, and strength to support and protect piece parts
- Low moisture absorption
- Inorganic composition to prevent fungus growth
- Qualities of electrical insulation

7 Soldering equipment

Given the concerns with Lead contamination and the incompatibility of inter-mixing some Pb-Free alloys, each solder alloy, as designated in Subclause 6.1.1, should have its own unique set of equipment. This recommendation is to preclude cross-contamination of assemblies through use of common soldering and desoldering equipment. Segregation of soldering equipment includes but is not limited to: soldering iron tips, extractor tips, sponges, tip cleaning tools and dressings, wire solder, and solder paste. This list should also include hand and supporting tools that cannot be effectively cleaned of all residual solder and might include acid brushes and wooden alignment tools.

7.1 Hand soldering equipment

7.1.1 General hand soldering equipment considerations

Hand soldering equipment for Pb-Free soldering is no different than equipment used for SnPb soldering. The same equipment can be used for either application requiring only a tip change to prevent cross-contamination of alloys and process modifications for the slower wetting Pb-Free alloys. Improvements in soldering iron technology directly benefit Pb-Free soldering, although they were not specifically designed for that purpose.

One equipment consideration is the use of fixed temperature or variable temperature models. Fixed temperature equipment uses heater cartridges that provide better thermal management at the joint by applying additional power to maintain tip temperature under load. Hand soldering equipment with a fixed temperature rating makes them a good choice for rework/repair to minimize process variations. Variable temperature equipment is well suited for rework/repair applications where thermal load requirements vary from CCA to CCA. Many variable temperature equipments have a password protected lockout feature enabling management to disable the temperature adjust feature making them well suited for production and touch-up as well.

The use of Nitrogen-assisted soldering irons is another consideration as they help to mitigate problems associated with reworking/repairing Pb-Free solders. Nitrogen creates an inert environment around the soldering tip and work area, slowing the oxidation rate. The use of Nitrogen can open the process window, reduce flux usage, improve wetting, and produce a shinier, less grainy, finish. On equipment where Nitrogen is passed through or near the heater, the Nitrogen is warmed enroute and provides some preheat capability. This may allow the use of lower soldering temperatures further minimizing oxide formation.

For Pb-Free rework/repair, power for thermal management and tip protection safeguards are also important features. Equipment used for Pb-Free soldering should have enough power to maintain tip temperature under load without extreme swings below and then above the set temperature. Because Pb-Free tips oxidize rapidly and wear out much quicker than SnPb tips, features that turn the solder iron on/off as the iron is removed/replaced in the tool stand are highly desirable. Auto set-back/off features that idle or turn the iron off after a period of nonuse are also important features for equipment used in Pb-Free applications.

7.1.2 Tip selection

Maximum heat transfer to the work area is essential in Pb-Free soldering. Selection of a soldering iron tip with the largest mass tip practical for the application is critical to maximize heat transfer. Using equipment with high power and fast thermal recovery is highly recommended. Whenever possible, use the same soldering temperature as with a SnPb solder. Most tip manufacturers have transitioned to 100 % Sn finished soldering iron tips. These tips, when new, are compatible with both SnPb and Pb-Free processes. Once tips are used with a specific solder alloy, they should be used only with that alloy.

7.1.3 Soldering iron tip life

Tip life will be substantially reduced with Pb-Free solders. Tin is an active metal and interacts with the Iron (Fe) plating on the soldering iron tip. Iron leaches more quickly into the higher Sn content of the Pb-Free alloys. Soldering tips used for Pb-Free soldering erode approximately three to four times faster than tips used with SnPb. To enhance tip life, most tip manufacturers have increased the thickness of the iron plating on their soldering tips. See Figure 1. Tip inspection should be performed on a daily basis to ensure Cu washing of the tip core into the solder connection does not occur. Any soldering tip that shows plating cracks, wear areas, or exposed Cu core must be discarded. See Figure 2. Cleaning oxidation from a Pb-Free tip can be a difficult task. Flux-cored solder and sponge or soft brush is recommended. Steel wire brushes, files and other abrasive methods should be avoided as they will wear out tip plating quickly. Chemical methods stronger than authorized fluxes, including tip tinners, should be avoided, especially if they contain Zinc Chloride, which is an acid.

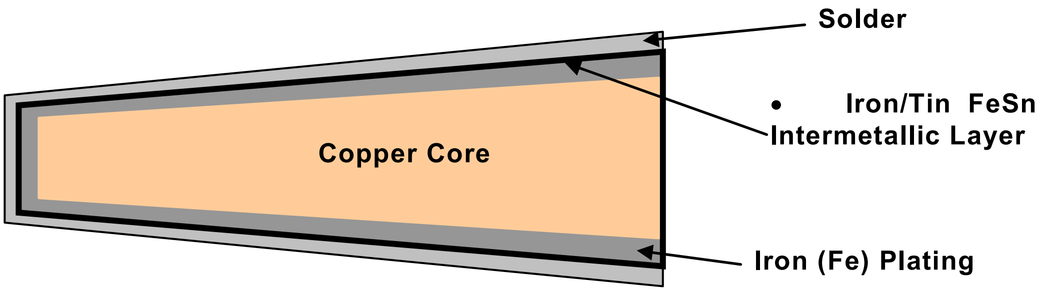


Figure 1 – Soldering iron tip construction

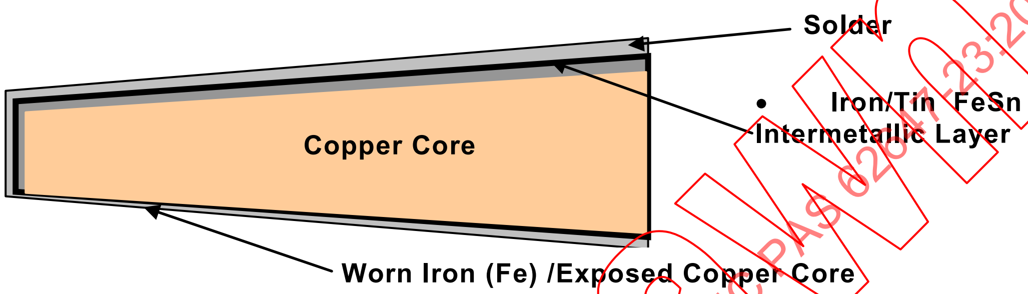


Figure 2 – Worn soldering iron tip

The following recommendations will help increase the longevity of soldering tips:

- Use the lowest possible soldering temperature:
  - 600 °F to 650°F (315 °C to 343 °C) for SMT applications
  - 650 °F to 700°F (343 °C to 371 °C) for through-hole applications
- Keep the tip clean during use by dressing it with a coating of solder
- Always apply fresh solder to the tip before placing the soldering iron back into the tool stand

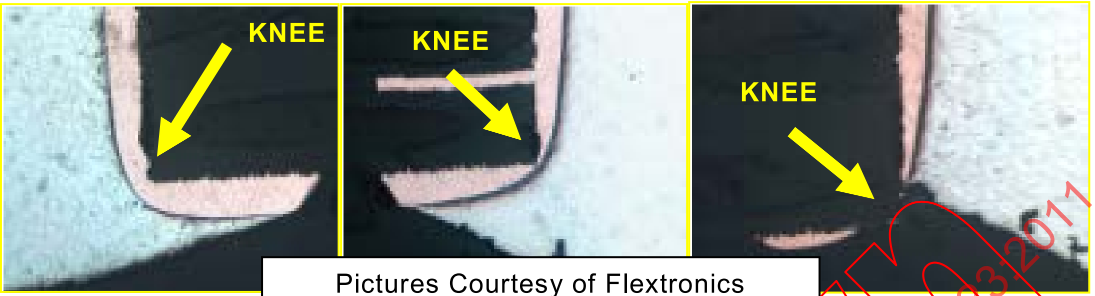
Turn off the soldering iron when not in use for 10 min or longer. If the soldering iron is equipped with a temperature setback feature it should be enabled.

7.2 Fountain soldering

Rework/repair requirements for large through-hole piece parts and connectors, high density circuit boards, or piece parts with heat sinks can be accomplished with the use of a solder fountain system. During the rework/repair activity, only the desired specific circuit board areas are subjected to the direct contact of the molten solder and the associated thermal energy.

The increased Copper Dissolution rate is the most critical issue faced when performing Pb-Free solder fountain rework/repair of plated-through-hole (PTH) connectors and large through-hole devices. A known characteristic of solder fountain rework/repair with traditional SnPb alloys is the amount of Copper Dissolution from the pads and barrel walls of PTH. The introduction of Pb-Free alloys, specifically those with high Sn content, including the SAC family and SnCu alloys, dissolve Cu from PTH pads and barrels faster than SnPb alloys. Studies conducted to date generally support processing guidelines allowing only a single solder fountain rework/repair cycle using SAC and SnCu alloys.

The area of greatest concern for Copper Dissolution is the point, called the “knee,” where the pad and barrel wall connect. This area of the Cu pattern typically has the thinnest initial volume of plated Cu. Solder fountain rework/repair of multi-termination or multi-pin devices with Pb-Free solder can have significant impact to the reliability of the solder connections. A single rework/repair attempt can completely dissolve all or portions of the Cu interfacial connection at the knee. Solder may flow over this dissolved area at the knee and may form an acceptable looking solder joint. This hidden defect would place the solder joint at increased risk for premature failure. Figure 3 shows Copper Dissolution of a PTH measured at 20, 22 and 36 second fountain dwell time with A30C5 solder.



Pictures Courtesy of Flextronics

Figure 3 – Copper dissolution

Contact time with the flowing solder fountain, preheat temperature and increased solder pot temperature are inter-related factors influencing the rate of Copper Dissolution during Pb-Free fountain rework/repair. Contact time with the flowing solder from the fountain nozzle has the greatest impact on Copper Dissolution rates. Nozzle design also plays an important role in the rate of dissolution between PTHs near the center of the nozzle (turbulent flow) verses the ends of the nozzle (laminar flow). Higher density PWBs and thick laminates will be more susceptible to the impacts of Copper Dissolution due to their increased thermal mass and subsequent longer contact time with the solder fountain.

A group of Pb-Free solders called “stabilized SnCu” have been identified as alternatives to SAC and SnCu alloys because of their favorable Copper Dissolution rates. These alloys are doped with small amounts of Ni and may include other trace elements. Stabilized SnCu alloys reduce Copper Dissolution to near SnPb rates and produce shinier, more traditional, solder joints than SAC or SnCu alloys. Stabilized SnCu alloys typically cost less as they contain no Ag.

All PWBs have unique and varying characteristics of PTH plating quality and initial thickness. The initial Pb-Free alloy used to manufacture the assembly, laminate thickness, base material of the piece part terminations, and ground and power plane connections to the PTH all have an effect on Copper Dissolution rates. Therefore, Pb-Free solder fountain rework/repair processes will be unique for each assembly and require validation through testing. In cases where an assembly cannot support fountain rework/repair, alternative methods, including convective hot gas, infrared, or vacuum extraction methods, should be considered.

All Pb-Free solder fountain rework/repair processes and procedures should be validated by engineering to identify the risks and concerns related to laminate damage, piece part damage, and solder joint reliability. IEC/PAS 62647-22 (GEIA-HB-0005-2) provides information on Copper Dissolution. The following guidelines should also be considered for solder fountain rework/repair of Pb-Free assemblies:

- avoid SAC and SnCu alloys;
- use “stabilized” SnCu for rework/repair of SAC and SnCu manufactured assemblies, if possible;
- optimize preheat and solder fountain temperatures to reduce contact time and improve solder mobility;
- reduce the rate of solder flow through the fountain nozzle;
- select nozzle configurations with baffling to minimize solder turbulence;
- identify and record the solder contact time for all solder fountain rework/repair activities;

- increased solder pot temperature required for Pb-Free solders requires specific plating finishes for all fountain system surfaces contacting the molten solder, typically a dedicated system is used for Pb-Free rework/repair operations;
- increase the monitoring of solder bath alloy contaminate levels as a result of increased pot temperature and higher Copper Dissolution rates;
- potential for reflow of solder or damage to adjacent piece parts as a result of increased temperature and dwell times should be considered;
- inspect for cracking of vias and piece part barrel walls in the molten solder contact area due to Z-axis expansion of the laminate material;
- inspect for lifting of pads as a result of higher temperatures and contact time;
- develop alternate procedures for convective, infrared, and vacuum extraction methods.

7.3 Convective soldering equipment

7.3.1 Thermal profile issues

Convection reflow processes are the most popular of the operations currently used. Typically, these processes provide a lower temperature difference across a PWB and the installed piece part solder joints. As with all other reflow systems, uniform temperature across the PWB is the primary goal. Any thermal profile developed will contain several distinct phases, including but not limited to ramp up, dwell time, maximum temperature, and a ramp down or cooling phase. The critical parameters in the development of an effective convective soldering process involve the determination of the appropriate point where the temperature required to initiate and maintain reflow of all applicable devices is reached versus the rapid heating of the assembly to reduce the effects of oxidation, while protecting the installed parts. Parameters such as ramp rate, peak reflow temperature, dwell time above liquidus, soak time, and temperature gradients across the PWB must be closely monitored and strictly maintained.

Once the thermal profile for a given process is developed, it is vital that the heater and gas flow rates are constantly monitored to ensure repeatability. Process repeatability requires relating the specific set points to the solder processing rates and then constantly monitoring these zones. Time and temperature rates through the reflow process directly affect repeatability.

Pb-Free soldering processes pose additional concerns that must be addressed when selecting the appropriate reflow equipment. These concerns are associated with the higher temperatures involved to maintain the required soak and peak temperature levels associated with various Pb-Free solders.

8 General rework/repair considerations

All rework/repair of CCAs should be performed with the solder alloy and piece part finish composition used to manufacture the original assembly unless assembly drawings or rework/repair documentation authorize use of alternate materials. Where alternate materials are authorized for use, they should be clearly identified on all rework/repair documentation. Each electronic assembly should be evaluated on its own reliability concerns and rework/repair options available prior to any rework/repair activities being performed.

As piece part manufacturers' transition to Pb-Free termination finishes, introducing alternate materials into SnPb assemblies, engineering has the responsibility to establish acceptable procedures that provide for the reliable rework/repair of these assemblies. This may require retinning parts to mitigate Tin Whiskers and specifying alternate flux and cleaning processes to address higher process temperatures, if required.

Engineering studies to date show general backwards compatibility of Pb-Free solder alloys and termination finishes with legacy SnPb. Pb-Free solder alloys, with the exception of Bi containing Pb-Free alloys, show general compatibility with trace amounts of SnPb contamination. Industry still has concerns regarding the soldering of Pb-Free area array packages with SnPb solder. It can be accomplished, but at Pb-Free soldering temperatures instead of the soldering temperatures of the SnPb solder paste. There are long term solder joint reliability concerns resulting from the mixing of solder alloys (Pb-Free and SnPb).

Deviation from the original assembly materials may in some cases result in mixing of incompatible materials reducing the reliability of the assembly. Alternate materials should be thoroughly assessed for compatibility with the original assembly materials prior to authorization for use in rework/repair. Positive identification of the solder cannot be made through visual inspection alone. While most Pb-Free solder joints exhibit steeper wetting angles, reduced wetting and less shiny appearance when compared to SnPb, these visual characteristics will not identify the solder type used.

In OEM and CM facilities, solders used in assembly should be well documented with information available to make informed rework/repair decisions. In situations where the repair technician does not have access to assembly documentation, the solder alloy used in assembly may be very difficult to determine. Technicians should always consult with the technical documentation of the assembly to determine solder alloy used in assembly.

8.1 Rework/repair procedure order of precedence

The order of precedence in rework/repair procedure selection should be as follows:

a) rework/repair procedures identified in applicable documentation (i.e., commercial maintenance manuals, tech orders, product specific documentation, FAA's ARINC Project 671 Paper);

b) rework/repair procedures described in the applicable Lead-Free Control Plan (LFCP) identified in IEC/PAS 62647-1 (GEIA-STD-0005-1);

c) rework/repair procedures identified in IPC 7711/7721.

NOTE At the time of the preparation of this PAS, it is believed that the procedures contained within IPC 7711/7721 need not be changed or modified based solely on the presence of a Pb-Free alloy.

8.2 Technician training

Formal classroom training in through-hole and surface mount technology (SMT) rework/repair techniques including specific training in Pb-Free rework/repair to IPC 7711/7721 or equivalent internal documents is recommended. This training program should provide both theory and substantial hands-on application. Prospective rework/repair candidates should have advanced soldering experience.

Technician training should provide an overview of the following information:

- PWB/PCB land and pad finishes;
- hand soldering of through-hole and SMT Pb-Free piece parts;
- rework/repair of Pb-Free assemblies;
- cleaning issues;
- Pb-Free visual inspection guidelines;
- X-ray inspection of hidden interconnects (BGA, QFN, etc.);
- documentation for Pb-Free operation.

8.3 Pb-Free rework/repair considerations

The processes used to rework/repair CCAs assembled using Pb-Free solders are similar to SnPb solder. The same type of equipment and process steps used for SnPb soldering can be used for Pb-Free soldering. Proper training is required to understand the process and appearance differences when using Pb-Free solders to ensure the quality and reliability of the assembly is maintained. When multiple alloys are present on the production floor, multiple rework/repair lines should be established and kept separate. All materials and equipment used should be segregated to preclude contamination of either line. Not all of the materials used for Pb-Free rework/repair are compatible with SnPb solder and could degrade the solder joint reliability. While specific alloy compositions have specific traits, several general process and solder processing considerations of Pb-Free solder apply in the rework/repair process.

8.3.1 General process considerations

- All assemblies should be preheated prior to any rework/repair activity
- Higher processing temperatures may cause measling, delamination, and/or lifted pads
- Higher processing temperatures may cause plastic parts to melt or deform
- Higher melting temperatures may cause thermal shock to the piece part
- Piece part termination finish as well as PWB finish should be compatible with the solder alloy
- Convective hot gas rework/repair, specific profiles should be developed and used for the alloy type and thermodynamics of the assembly
- Higher processing temperatures affect the applied stresses or strains due to the coefficient of thermal expansion (CTE) mismatch between the laminate material, the glass fiber, and Cu
- Moisture Sensitive Devices (MSDs) in Pb-Free soldering should be properly preconditioned
- Piece part maximum core temperature ratings should not be exceeded

8.3.2 Solder processing considerations

- Pb-Free solders have a higher melting point
- Soldering iron tips will oxidize much faster with Pb-Free solders
- Conductive soldering may require longer dwell times at higher process temperatures. This is especially true on high mass through-hole piece parts and assemblies with large thermal ground planes.
- Pb-Free soldering has a tighter process window
- Pb-Free solder joints may be more difficult to rework/repair
- Solderability indicators such as wetting, wetting angles, and joint appearance will generally be different. Inspection criteria such as those contained in the IPC-A-610 can be used to help establish acceptance.
- Higher temperatures and extended dwell times may increase oxidation, hindering the soldering process
- Solder fountain rework/repair attempts of Pb-Free assemblies may be limited due to Copper Dissolution
- Segregation of SnPb and Pb-Free solder materials and equipment should be exercised
- Rework/repair should minimize excessive heating of adjacent piece part solder joints

8.3.3 Flux considerations

While Pb-Free flux formulations are different from SnPb flux formulations, their use remains essentially unchanged. All flux applied by flux pen or dripper bottle should be applied in small controlled quantities (sparingly) to prevent intrusion into unwanted areas and match (or be compatible with) the flux formulation used in the flux cored wire solder. Any remaining inactivated residual flux may cause corrosion or other unwanted issues and should be cleaned off.

The amount of thermal energy applied to a connection affects the flux performance. Significant increases in soldering iron temperatures should be avoided. Too high a soldering iron temperature will cause the flux to evaporate before it can properly activate, remove oxidation, and promote solder wetting. Pb-Free rework/repair will usually require an increase in the solder wire flux core from 1,0 % common in SnPb, to amounts in excess of 3 %. Pb-Free formulated fluxes designed to withstand higher process temperatures, higher oxidation rates and the poor wetting ability of Pb-Free, may also require some modifications in rework/repair cleaning processes. See Subclause 11.1 Cleaning.

General guidance on flux considerations.

- Use flux sparingly to prevent intrusion under adjacent parts
- Higher melting points of Pb-Free solder will require higher activation temperature flux chemistry to achieve adequate wetting
- Use flux formulated for Pb-Free processing
- The flux should not spatter or fume excessively at Pb-Free soldering temperatures
- The flux should have activator systems designed to solder a variety of Pb-Free PWB and piece part finishes
- The flux must be active enough and remain active during tip contact to compensate for the reduced wetting of Pb-Free alloys
- Due to the higher processing temperatures, flux residues may be more difficult to remove and require modifications in cleaning processes

9 Pre-rework/repair processes

9.1 Alloy identification

9.1.1 IPC/JEDEC J-STD-609

IPC/JEDEC J-STD-609; *Marking and Labeling of Components, PCBs and PCBAs to Identify Lead (Pb), Pb-Free and other Attributes* identifies an industry approved marking and labeling method to identify materials (laminate material, CCA surface finish, solder alloy (Pb-Free or SnPb solder)) and conformal coating family used in the manufacturing process. IPC/JEDEC J-STD-609 also identifies a marking system for individual piece parts termination finish identification and a labeling system for piece parts packaging. The use of IPC/JEDEC J-STD-609 whether invoked voluntarily or by contract, can aid in the rework/repair process by providing valuable information on

- the laminate material used in the CCA construction per IPC-4101
- CCA laminate material Halogen content
- CCA surface finish
- solder alloy or alloys (Pb or Pb-Free) used in reflow, wave or other soldering process
- the conformal coating type applied during the assembly process
- piece parts termination finishes when assembled parts are marked
- piece parts termination finish when identified on exterior label of replacement component packaging
- the maximum piece part temperature rating when identified on exterior label of replacement component packaging

Table 1 provides a guide to the IPC/JEDEC J-STD-609 assembly and piece part marking methods used to identify laminate type, Halogen presence, CCA surface finish, solder(s), and conformal coating. Refer to IPC/JEDEC J-STD-609 for additional information on board marking and labeling requirements.

Table 1 – Assembly and piece part marking methods

PCB BASE MATERIAL HF = Halogen Free	**BARE BOARD PLATING FINISH**	**ASSEMBLY SOLDER USED (Reflow→Wave→Other)** These codes also identify piece part termination finishes	**CONFORMAL COATING TYPE**
/ 92 HF	*b0*	*e0* Contains Pb	ER Epoxy Resin
/ 95 HF Aluminum Hydroxide Flame Retardant Tg 110 °C – 150 °C	*b1* Pb-Free HASL Sn alloys – with no Bismuth (Bi) or Zinc (Zn)	*e1* Tin – Silver – Copper SnAgCu “SAC” types	UR Urethane Resin
/ 99 HF Bromine Flame Retardant with inorganic fillers Tg 150 °C min.	*b2* Immersion Silver (ImAg)	*e2* Sn alloy combinations with no Bi or Zn excludes SnAgCu	AR Acrylic Resin
/ 126 HF Bromine Flame Retardant with inorganic fillers Tg 170 °C min.	*b3* Tin (Sn) Electrolytic or immersion	*e3* Tin (Sn)	SR Silicone Resin
Other types are available	*b4* Gold (Au) Electrolytic or Immersion Electroless Nickel Immersion Gold (ENIG) Nickel-Gold (NiAu)	*e4* Precious Metal (no Sn content) Silver (Ag) Gold (Au) Nickel-Palladium (NiPd) Nickel-Palladium-Gold (NiPdAu)	XY Paraxylylene
Base Material “slash” # is followed by “HF” if laminate is halogen free	*b5* Screened Carbon Ink	*e5* Other alloys containing Sn, no Bi Tin-Zinc (SnZn) Tin-Zinc-“other” (SnZnXx)	
For PCB’s made with more than one grade of laminate – identify the material with the lowest temperature rating	*b6* Organic Solderability Preservative (OSP)	*e6* Alloys containing Bi	
		e7 Low Temp Solders (≤150 °C) containing Indium (In) – no Bi	
	b7, b8, b9 Unassigned	*e8, e9* Unassigned	
Example: / ***95 – HF – b2 – e1 – e2 – AR***		Multifunctional Epoxy Laminate, Halogen Free, Immersion Silver PCB Finish, SAC solder used for reflow and a Tin alloy (no Bi nor Zn) used for wave, Acrylic Resin Conformal Coating	

9.1.2 X-Ray fluorescence (XRF)

XRF is a technology used in industry to positively identify the constituent metals of solder alloys, termination finishes, and PWB land/pad finishes. XRF exposes the material under test to high energy x-rays. The reflected energy is used to identify the elemental characteristics of the item under test.

XRF equipment is available in both handheld and desktop models and varies widely in features, targeting methods, software, and accuracy. While there is variation amongst manufacturers' models and types, desktop models are usually more accurate as they have smaller column sizes, better software, more advanced targeting and aiming ability, motorized stages for accurate positioning, and better resolution. Desktop units are typically more expensive than handheld units. Handheld units offer affordability and portability but lack the refinements and accuracy of desktop units. In general terms, handhelds and desktops can handle homogenous bulk solder joint identification with reasonable accuracy, but accurate identification of piece part terminations is better suited for desktop units due to their more advanced aiming and targeting features.

9.1.3 Pb swabs

Pb swabs are an inexpensive method of providing a go/no go test for Pb presence. This test method has an accuracy, claimed by the swab Supplier, of 0,1 %. Pb swabs identify only Pb, so it may be a useful tool for determining whether a solder alloy or termination finish is Pb-Free, but is not useful to determine the constituent metals in a Pb-Free alloy.

Pb swabs are based on the reactivity of Pb with certain compounds capable of forming strongly colored complexes with Pb. When Pb swabs are used, a pink color that is specific for Pb develops within 30 s and is stable for hours. Pb swabs have an indefinite shelf life, provide rapid results, are low cost, and are non-destructive and non-hazardous.

NOTE Pb swabs may leave chemical residues. It is currently not known if these residues will interact with circuitry materials causing short and/or long-term reliability issues. Testing should be performed to validate compatibility of Pb swabs with assembly materials before implementation in any assembly or rework/repair process.

Because of the above risks, the use of Pb swabs is not recommended for determining Pb content.

9.2 Piece part and CCA preparation

The cleanliness of terminals, piece part terminations, conductors, and printed wiring surfaces should be sufficient to ensure solderability. When required, the surfaces should be cleaned by either chemical methods or tinning. Cleaning should not damage the piece part, piece part terminations, or conductors. Knives, emery cloth, sandpaper, sandblasting, braid, erasers, or other abrasives should not be used.

9.2.1 Piece part preparation

9.2.1.1 Dry bake of moisture sensitive piece parts

Many electronic parts, especially surface mount parts, have a Moisture Sensitivity Level (MSL) rating that identifies a parts susceptibility to moisture absorption. IPC/JEDEC J-STD-020 "Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices" provides MSL ratings and identifies conditioning requirements for each MSL level. Refer to J-STD-033 for bake out requirements and floor life for each MSL rating.

9.2.1.2 Hot solder dip for tin whisker mitigation

When hot solder dipping for tin whisker mitigation, use an approved, documented process.

9.2.2 CCA preparation

9.2.2.1 Conformal Coating Removal

The conformal coating should be removed and replaced in accordance with IPC 7711/7721 or other applicable documentation. Methods of coating removal vary depending on the coating type used and may include use of chlorinated solvents, heat application, mechanical abrasion, and micro-abrasive blasting techniques.

9.2.2.2 Preheating of CCAs prior to rework/repair

Preheating is recommended for every SMT rework/repair process. Preheating minimizes the risk of thermal shock to the laminate and piece parts. The technician should employ a preheat method which heats the rework/repair areas of the assembly as evenly as possible.

Preheating is typically accomplished by either a temperature controlled conductive heating plate, a controlled convective heating device, or a system that combines both conductive and convective heating.

Controlling both the rate of temperature ramp up as well as the soak temperature is critical to avoiding damage and optimizing the piece part installation or removal process. The assembly is ramped at an acceptably safe rate until it reaches a target temperature at which it is thermally soaked or evenly heated. To avoid thermal shock, the ramp rate should be between 4 °F to 9°F (2 °C to 4 °C) per second until the appropriate temperature is reached. Replacement piece parts should be preheated along with the CCA to the recommended levels. Recommended soak temperatures are as follows:

- 176°F (80 °C) for simple, single and double-sided CCAs
- 212°F (100 °C) for epoxy/glass and SMT through-hole CCAs with up to six internal layers
- 248°F (120 °C) for ceramic, polyimide, and high mass CCAs with seven or more internal layers

NOTE If the preheater does not have a temperature readout, use a thermocouple and digital thermometer to determine CCA surface temperature.

Preheating accomplishes the following objectives:

- minimizes thermal shock by elevating the assembly temperature to a level closer to solder melt temperature;
- minimizes solder reflow time;
- overcomes the heat dissipation characteristics of the assembly;
- avoids adjacent solder connection reflow on densely populated assemblies.

10 Rework/repair processes

Conformal coating removal, piece part removal, and pad preparation should be executed per approved procedures (See Subclause 8.1).

10.1 Conductive Hand Soldering

There are some notable differences between SnPb and Pb-Free hand soldering.

- SnPb eutectic solder melts at 361°F (183 °C)
- The leading group of SnAgCu and SnCu Pb-Free solders melts between 423°F (217 °C) and 440°F (227 °C)
- Higher Pb-Free melting points (compared to SnPb) may require
  - higher initial soldering iron temperatures;

- longer dwell times on the termination;
- increased thermal buildup in the laminate and land/pads; and
- increased potential for laminate or conductor damage;
- increased "Z" axis expansion of the assembly may cause cracking of plated-through-holes.

Higher Pb-Free solder melting temperatures do not automatically equate to higher solder tip temperatures. With a clean tip of the proper mass and shape, 600°F (315 °C) to 650°F (343 °C) should meet most SMT soldering requirements. The higher solder melting temperatures require more of the tip's available heat be transferred to the work surface. This is accomplished by paying close attention to tip mass and shape to provide maximum contact area, not by automatically turning up the soldering iron temperature. When CCA thermal dynamics require using higher temperatures, tip oxidation becomes an issue, making it more difficult to maintain a properly wetted tip. The soldering iron must remain clean and coated with the solder alloy. Pb-Free solders are more sensitive to the effects of a dirty soldering iron. Higher soldering temperatures can result in the soldering iron tip becoming oxidized if not cleaned and coated. The soldering performance can be improved by more active solder flux and soldering in a Nitrogen atmosphere.

The Pb-Free soldering process, just as in traditional eutectic SnPb soldering, requires proper materials selection, preparation, and execution. The Pb-Free soldering process still requires the formation of a heat bridge for rapid heat transfer, application of solder, and the removal of the solder and heat source at the same time. In Pb-Free rework/repair, the process may require additional time to achieve adequate wetting, but has a tighter process window to achieve adequate results.

Pb-Free solders typically do not wet as well as SnPb solders. Wetting speeds will vary among different Pb-Free alloys due to differences in surface tension, flux type, and melt temperatures. Due to the higher surface tension of most Pb-Free solders, icicles and bridging may be more prominent until technicians become comfortable with the nuances of Pb-Free rework/repair. These issues can be minimized or avoided using the following techniques:

- ensure the tips are designed for Pb-Free soldering;
- the soldering iron must remain clean and "tinned" with the solder alloy;
- use the same alloy originally used for production assembly;
- minimize the use of additional liquid flux during the piece part installation;
- select the lowest possible working temperature for any application;
- when applicable, pre-heat the circuit board before reworking/repairing to improve soldering efficiency;
- choose the largest possible soldering tip to allow for full coverage of the solder pad to allow for the best thermal control of the process with minimum time on the termination to perform the application;
- the use of higher "Thermal Capacity" tools, especially in Pb-Free applications, will allow the use of lower temperatures and better quality workmanship;
- ensure the flux content in the wire is at least 2-3 % by weight;
- avoid prolonged contact times;
- avoid needless rework/repair of the connection;
- enable the "Setback" or "Auto-Off" features of your soldering stations to help extend tip life;
- remove all flux residues using approved procedures.

10.2 Convective soldering process

For convective hot gas rework/repair specific profiles should be developed and used for the alloy type and thermodynamics of the assembly. SnPb profiles must not be used with Pb-Free assemblies and vice versa. Conversion of SnPb profiles to Pb-Free profiles is more complicated than adding 80°F (27 °C) [typical] to the temperature limits of the SnPb profile. Specific concerns are detailed herein.

10.2.1 Solder paste handling

Proper identification and segregation of Pb-Free solder paste is required to prevent cross contamination.

10.2.2 Paste printing

The printing process for Pb-Free pastes is equivalent to the process used for SnPb solder pastes. It is important to follow guidelines recommended by the paste manufacturers to accommodate paste specific requirements. In general, the Pb-Free paste characteristics yield similar performance in terms of stencil life, aperture release, print definition, and repeatability. One important factor that should be considered in purchasing stencils is that Pb-Free pastes have higher surface tension and do not wet or spread on the surface of pads as easily as eutectic solder pastes. This can lead to exposed pad finish material after reflow soldering, which can be rectified by modifying the stencil aperture designs to increase the paste coverage on the pads. Stencils used with Pb-Free pastes should not be used with Pb-bearing pastes due to possible cross-contamination.

10.2.3 Reflow process

10.2.3.1 Process considerations

The most demanding thermal process in a manufacturing environment is hot gas rework/repair. The high temperatures required in small, localized areas for long periods of time create several impacts that should be monitored on the assembly, including maximum piece part body temperatures, PWB laminate survivability, and maximum temperatures of both adjacent and bottom-side piece part solder joints. The objective of the rework/repair process is to mimic, as closely as possible, the primary attachment SMT reflow process to ensure that solder joint formation (and reliability) are similar. There are several challenges in making assembly reflow and hot gas rework/repair processes identical. The main difference between the two processes is that assembly reflow is a full heat excursion, while the hot gas rework/repair process is a local heat excursion. This localized heat creates local stresses within the piece part and the PWB.

In general, there are some differences of BGA rework/repair with Pb-Free solder balls compared to that with SnPb solder balls:

- the melting temperature of Pb-Free solder increases to 423°F (217 °C). As a result, longer heating times are required compared to conventional SnPb joints. The expected total process time will vary from one product to another, but a rework/repair cycle time range of 7-10 minutes per piece part is not uncommon;
- to reach proper wetting of the Pb-Free solder on the pad, the temperature at the solder joint has to reach approximately 446°F (230 °C);
- the alignment of new BGA parts must be as accurate as possible, because unlike Pb BGAs, there is less self-centering with Pb-Free BGA parts.

10.2.3.1.1 Prebake

Prebake the PWB to remove absorbed moisture content. The typical prebake temperature range is from 194 °F to 257°F (90 °C to 125 °C). The time and temperature is dependent on assembly exposure and thickness. Refer to J-STD-033 for further guidance.

10.2.3.1.2 Machine configurations

Higher thermal profiles require more support from bottom heaters. In general applications, 4000 W is the minimum wattage for bottom heaters. Nozzle designs with some form of turbulence generator can help to reduce temperature deltas across the package. Nitrogen atmospheres reduce solder viscosity, but are not required for low and medium complexity assemblies.

10.2.3.1.3 Profile development

An improper profile may result in the lifting of pads if the solder is not fully molten before removal is attempted. On the other hand, if the piece part is heated extensively, damage can occur to surrounding piece parts on the PWB. When soldering any piece part, a suitable thermal profile ensures that the piece part and PWB are not overheated and all the solder joints are reflowed.

It is necessary to monitor the temperatures at critical locations on the assembly to ensure that the temperature of the solder joints, the temperature difference across the site, and the temperature of the adjoining piece parts are within acceptable limits. A common method of monitoring employs the use of a portable data logging device that monitors thermocouples mounted onto the assembly at various locations during the reflow process. It is recommended that the thermocouples be attached as close to the corners of large piece parts (i.e., BGAs) as possible.

The Maximum Peak temperature delta across the part should be in the range of 41 °F to 50°F (5 °C to 10 °C). This requires allowance for sufficient preheat "soak" time for the heat to be absorbed across the product assembly. Soak times are dependent on the organic component of the paste. Higher flux percentages require longer soak times.

Thermocouples must also be placed to ensure that adjacent piece parts do not exceed safe temperatures. The maximum allowable rework/repair temperature limits for Pb-Free parts is regulated by the IPC-JEDEC J-STD-020 standard.

Thermal protection/screening may be required to meet specifications and to avoid unintentional reflow. There are many deflective methods available, ranging from metal foil to ceramic containing materials to gypsum based putty that assist in protecting adjacent piece parts from excessive heat exposure.

A set of best practices created for Pb-Free BGAs requires that the peak temperature be between 446 °F and 473°F (230 °C and 245 °C). Time above liquidus should be between 35 and 65 seconds. Excessive thermal exposure can damage the PWB material and create thicker inter-metallic compounds.

10.2.3.1.4 Site Preparation

The piece part attach site should be dressed by using copper wick, constant vacuum removal, or other approved method to prepare the attach pads for receiving the rework/repair piece part. A smooth, level, solderable surface is desired. Any damage incurred during site preparation should be resolved.

10.2.3.1.5 Rework/Repair Concerns

Piece parts to be used for rework/repair should be handled in accordance with the IPC/JEDEC J-STD-033 MSD requirements table.

Replacement of the piece part occurs using the same profile after the PWB has cooled to baseline temperature.

Localized rework/repair site cleaning may be required per individual product specifications.

10.2.3.1.6 Process Validation

Successful replacement verification should include automated or manual visual inspection and x-ray confirmation for any "hidden" solder joints. Electrical test should also be performed where applicable to confirm successful rework/repair operations.

11 Post-Rework/Repair Processes

11.1 Cleaning

The cleaning effort conducted after completing the rework/repair activities must consider the method of cleaning to be used and ensure the cleaning chemistry is compatible with flux residues present. Typically, rework/repair activities are executed on completed assemblies, and cleaning of the flux residue is isolated to the area of repair. When other piece parts or devices on the finished assembly are not tolerant of "system" cleaning, the cleaning effort is conducted using "localized" cleaning techniques. This type of cleaning is commonly done by brushing the cleaning chemistry onto the flux residue to dissolve the material followed by rinsing the area to remove contaminates. These efforts may require the area to be masked off to contain the cleaning chemistry preventing contaminants dissolved in the cleaning media to spread into other areas of the assembly. Multiple cleaning sequences may be required to ensure all flux residues have been successfully removed from the area of repair and other piece parts in proximity. All masking materials, if used, should be removed and any adhesive residue cleaned from the assembly.

The entire assembly, including the area of repair, must meet the documented cleanliness requirements and should be inspected to determine the presence of any particulate matter, flux residue, or any residual cleaning chemistry.

11.2 Inspection

The resulting Pb-Free solder joints from rework/repair are often dull and exhibit a grainy surface. Solder joints may also have higher wetting angles as Pb-Free solder does not flow as easily as SnPb solder and may not form the typical concave fillet. The J-STD-001 and the associated Space Addendum requires 100 % inspection of all reworked/repaired solder joints and allows dull, matte, or grainy appearances, provided that such appearance is normal for the materials and processes involved. Technicians and inspectors will have to adjust their visual criteria for an acceptable solder joint to allow for these differences. Although the visual criteria may be somewhat different than SnPb, the acceptability requirements of IPC-A-610 have not changed.

The inspector should receive formal classroom training to applicable standards and methods for disposition of defects. Training should include the differences in appearance between Pb-Free solder joints and SnPb solder joints. Additional inspection criteria will be required when multiple solder alloys are used in the rework/repair process.

11.3 Reapplication of Conformal Coating

During rework/repair, the conformal coating is removed in accordance with applicable documentation such as IPC 7711/7721 and replaced per manufacturer's instructions. See Subclauses 6.5 and 9.2.2.1 for additional information.

Annex A
(informative)

Termination Finishes

Table A.1 – Piece-part terminal and BGA ball metallization solder process compatibility risk (see IEC/PAS 62647-22 (GEIA-HB-0005-2))

Terminal or PCB Metallization (1)	SnPb Solder	SAC Solder (SMT and Wave)	SnCu or SnCuNi wave solder	SnAg solder
Sn- 3 to 5 wt % Pb	None	Low (2, 3)	Low (3)	Low (2,3)
Sn- 37 to 40 wt % Pb	None	Medium (2, 3)	Medium (3)	Medium (2, 3)
Sn, Reflowed / Fused / Dipped (4)	None	None	None	None
Sn, Bright Electrodeposit – Avoid (5)	Shelf Life (6, 7) Solder Voids (8)	Shelf Life (6, 7) Solder Voids (8)	Shelf Life (6, 7) Solder Voids (8)	Shelf Life (6, 7) Solder Voids (8)
Sn, Matte Electrodeposit (4)	Shelf Life (6, 7) Solder Voids (8)	Shelf Life (6, 7) Solder Voids (8)	Shelf Life (6, 7) Solder Voids (8)	Shelf Life (6, 7) Solder Voids (8)
SnBi (2-5 wt % Bi content in terminal plating, which results in ~0.2 to 0.5 wt % in most final SMT solder joints); Bi finishes are not recommended for wave solder (9)	SMT Low-Medium (10)	None SMT	None SMT	None SMT
Antimony Bearing	No Data	No Data	No Data	No Data
SAC Dipped (11)	None	None	None	None
SnCu electrodeposit - Avoid (12)	None	None	None	None
Sn- 0.5 to 0.9 wt % Cu-0.05Ni Plated or Dipped Avoid (12)	None	None	None	None
Ni/Pd/Au electrodeposit	Low (13)	Medium	Medium	Medium

1 All alloy percentages are given in weight percent.

2 Some investigators have found that a SnAgPb alloy can form having a melting point of 178°C, which may impact processing [Momokawa, Y., and Ishizuka, N., "Delamination by Reheating in SMD Solder Joint Using Lead-Free Solder," NEC Res & Devlop., Vol. 44, No. 3, July 2003 pp. 251 – 255] and Karl Seelig and David Suraski "Lead Contamination in Lead-free Electronics Assembly", White paper AIM Solder.

3 Pb from the finish can contaminate the wave solder bath.

4 Organic co-deposited compounds are typically removed from the Sn coating during the reflow/fusing process.

5 Bright Sn finish is not recommended due to Tin Whisker propensity of bright Tin plating. Bright Sn is defined as having 0.2 % – 1.0 % Carbon Content with 0.5 µm – 0.8 µm grain size. Matte Sn is a film with lower internal stresses and larger grain sizes than bright Sn. Matte Sn plating is defined as having 0.005 % – 0.050 % Carbon with 1 µm – 5 µm grain size. ["Recommendations on Lead-Free Finishes for Piece-parts Used in High Reliability Products ", iNEMI Tin Whisker User Group, Herndon, VA USA, Version 4, Updated December 2006].

6 Co-deposited organics can limit shelf life and/or solderability.

7 Insufficient coating thickness can result in reduced shelf life. Recommended thickness is 10 µm nominal (8 µm minimum) when no Ni underplating is used. The minimum thickness should be 2 µm when a Ni underplate is used to ensure shelf life. ["Recommendations on Lead-Free Finishes for Piece-parts Used in High Reliability Products", iNEMI Tin Whisker User Group, Herndon, VA USA, Version 4, Updated December 2006]. The lower rate of Ni diffusivity retards NiSn intermetallic formation thus limiting the stresses which would drive Tin Whisker growth.

8	In right Sn or thicker matte Sn coatings, co-deposited organics can yield solder voids during solder reflow for some solder joint geometries.
9	Not recommended for pin through-hole, Bi may accumulate in wave solder pot.
10	Environmental reliability should be substantiated on the programs considering small amounts of total Bi in the final solder joint.
11	There may be Tin Whisker risk with SAC alloy dipped finishes where they become thin around corners and edges. Note: Thicker coatings tend to isolate the intermetallic layers and dissipate whisker formation inducing stresses.
12	Avoid SnCu due to the Tin Whiskering propensity of this plating. SnCu provides all of the raw materials for generating the intermetallics that drive Tin whisker formation. Tin whiskering propensity is high. Hot Solder Dipped SnCu is being used in some applications. ["Recommendations on Lead-Free Finishes for Piece-parts Used in High Reliability Products," iNEMI Tin Whisker User Group, Herndon, VA USA, Version 4, Updated December 2006]
13	Electrodeposited plating should be analyzed to ensure that the final solder joints will not be susceptible to strength reduction associated with Au embrittlement.

Table A.2 – BGA Piece parts

CBGA/CCGA/BGA/ C4 Ball	SnPb Solder	SAC Solder	SnCu or SnCuNi	SnAg solder
Sn37Pb (includes Sn36Pb2Ag)	None	Unlikely Combination	Unlikely Combination	Unlikely Combination
10Sn90Pb	None	High (1)	Unlikely Combination	High (1)
SnCu	No Data	None	None	None
SAC	Medium (2)	None	None	None
Cu wire column (3)	Low	Low	Low	Low

1 Smetana, J., Horsley, R., Lau, J., Snowdon, K. Shangguan, D. Gleason, J., Memis, I, Love, D., Dauksher, W., Sullivan, B., "HDPUG's Lead-Free Design, Materials and Process of High Density Packages," IPC SMEMA Council APEX (2003). In some cases, tilting of CCGA columns was observed after Pb-free reflow.

2 Mixed alloy (SAC ball/SnPb paste or SnPb Ball/SAC paste) combinations are not as reliable as the unmixed (SAC Ball/SAC paste or SnPb Ball/SnPb paste) combination. See mixing of alloys section.

3 The Cu wire column typically uses a wire that is 10 mils in diameter, 60 mils long having a finish of 0.05 µm Sn. (ref. Cole, M. et.al., "Lead-free card assembly and rework for column grid arrays", SMTA Journal Vol. 17-1 (2004).