



AEROSPACE RECOMMENDED PRACTICE

ARP6415™

Issued

2019-07

Use of Pb-Free Ball Grid Array Component Soldered Using SnPb Solder

RATIONALE

Aerospace, defense, and high performance (ADHP) manufacturers have avoided a transition to Pb-free for most products, but the limited availability of ball grid array packages with SnPb alloy solder balls has driven the use of parts with Pb-free solder balls. There have been numerous studies on the use of the Pb-free parts in a SnPb assembly, and this document provides a consolidated summary of the industry best practices and issues related to use of these Pb-free parts.

TABLE OF CONTENTS

1.	SCOPE.....	3
1.1	Purpose	3
1.2	Background	3
1.3	Misconceptions	4
1.4	Intended Use	4
2.	APPLICABLE DOCUMENTS.....	5
2.1	SAE Publications.....	5
2.2	Other Publications.....	5
3.	METHODOLOGIES FOR UTILIZING PB-FREE BGAS	5
3.1	Reballing	5
3.1.1	Reball Process	6
3.1.2	Advantages and Disadvantages of Reballing	7
3.1.3	Further Considerations for Reballing	7
3.2	Mixed Alloy Soldering (Pb-Free BGA Balls with SnPb Assembly Alloy).....	7
3.2.1	Advantages and Disadvantages of Mixed Alloy Soldering	8
3.2.2	Further Consideration for Mixed Alloy Soldering	8
3.3	Mixed Alloy Soldering with Underfill.....	11
3.3.1	Advantage and Disadvantages	12
3.3.2	Other Considerations for Mixed Solder Alloy with Underfill	12
3.4	Other Options for Pb-Free BGA Use	12
3.5	Advantages and Disadvantages Comparison.....	13
3.6	Selecting a Suitable Methodology for Using Pb-Free BGAs in SnPb Assembly	14
3.6.1	Cost and Risk Identification	14
3.6.2	Other Items of Consideration	16
3.6.3	Case Studies	17
4.	REFERENCES.....	17
5.	NOTES	18
5.1	Revision Indicator.....	18

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2019 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER:
Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
<http://www.sae.org>

SAE WEB ADDRESS:

Full document details: SAE ARP6415

SAE values your input. To provide feedback
on this Technical Report, please visit
<http://standards.sae.org/ARP6415>

Documents
Document Sharing Hub

APPENDIX A	WHISKERS FROM RARE EARTH ELEMENT ADDITIONS IN SOLDER ALLOYS.....	19
APPENDIX B	EXAMPLE OF BGA INCOMPATIBLE WITH REBALL PROCESS.....	21
APPENDIX C	REBALLING	23
APPENDIX D	MIXED ALLOY SOLDERING.....	27
APPENDIX E	MIXED ALLOY SOLDERING WITH UNDERFILL	31
Figure 1	Global solder consumption (source: IPC Global Solder Statistical Program, 2014).....	3
Figure 2	General process flow for reball of a BGA.....	6
Figure 3	BGA solder joint: fully SnPb solder joint (left), incomplete mixing of Pb-free ball in SnPb solder process (center), complete mixing of Pb-free ball in SnPb process (right) profile generation.....	8
Figure 4	Typical process flow for consideration of methods to address usage of a Pb-free BGA.....	14
Table 1	Advantages and disadvantages of methods to address Pb-free BGAs.....	13
Table 2	Risks associated with product use environment and methods to address Pb-free BGAs.....	15
Table 3	Comparison of cost considerations associated with methods to address Pb-free BGAs.....	16

1. SCOPE

This document contains information and guidance on the use of Pb-free ball grid arrays (BGAs) in an aerospace, defense, and high performance (ADHP) product, or other products which demand a high reliability.

1.1 Purpose

This document contains a review of known impacts, issues, and processes for the use of Pb-free BGAs. It is organized to provide the technical structure needed to allow the designer to evaluate the options for using Pb-free BGAs in an assembly that has not converted to full Pb-free assembly.

Further, it addresses the processes and risks associated with converting a Pb-free BGA to SnPb (reballing), soldering of Pb-free BGAs using SnPb solder (mixed-alloy soldering), and the application of underfill as a risk mitigation.

A lead-free control plan (LFCP) or statement of work (SOW) flowed-down by a customer may include restrictions on the use of Pb-free BGAs, or may contain specific requirements on qualification of their use for one of the methods described in this document. The LFCP and SOW should be reviewed for any such requirements and followed as appropriate.

1.2 Background

The European Union directives of 2011/65/EC restriction of hazardous substances (RoHS) and 2002/96/EC waste electrical and electronic equipment (WEEE) and similar regulations enacted by other governing bodies have impacted the use and availability of lead (Pb), which is widely used in electronic solder and electronic component (piece part) terminations, specifically ball grid array (BGA) solder balls. Figure 1 illustrates how global solder usage trends show the replacement of tin/lead (SnPb) solder alloys with Pb-free solder alloys since 2004 [1].



Figure 1 - Global solder consumption
(source: IPC Global Solder Statistical Program, 2014)

ADHP manufacturers have avoided a transition to Pb-free for most products for two main reasons; the Pb-free materials and processes are relatively immature and not fully understood (including a full understanding of performance under harsh conditions), and ADHP is one of the few major industrial sectors that still repair circuit card assemblies (CCAs) (i.e., existing SnPb products may require repair/rework.) The low market share of ADHP manufacturing has not been sufficient to prevent a continued decline in availability of BGAs with Pb-containing balls. When available, the SnPb versions of BGAs typically have extended lead time and cost impacts compared to Pb-free. These factors have driven ADHP designers to consider the use of Pb-free BGAs (predominantly SnAgCu-SAC alloy) in an overall SnPb product, either in new design, or due to part obsolescence.

The use of Pb-free solder may affect electronic interconnection performance due to differences in fatigue characteristics under thermal cycling, vibration, and mechanical shock relative to traditional SnPb eutectic SnPb solders. A similar risk is present in solder joints formed from a combination of alloys, such as SnPb and SAC. Methods for addressing or minimizing this risk is the subject of this guideline.

Product design teams that continue to use SnPb soldering processes are faced with the dilemma of how to direct the processing of BGA components that are only available with Pb-free solder spheres. The combination of a SnPb solder paste alloy with a BGA component with Pb-free solder balls results in a “mixed metallurgy” solder joint microstructure that may have poor solder joint integrity in some product use environments. Three primary industry solutions have emerged as acceptable methodologies to prevent or address the potential solder joint integrity issue of a mixed metallurgy assembly, i.e., Pb-free parts used on a SnPb assembly. These solutions are listed below.

Potential methods to address the use of Pb-free BGAs:

- Remove risk of mixed solder alloys through reballing:

Send the Pb-free BGA component to an external service provider to be reballed (i.e., the Pb-free solderballs are removed and replaced with SnPb alloy solderballs). This will eliminate the risks associated with mixed metallurgy.

- Minimize risk of mixed solder alloys by ensuring complete alloy mixing:

Utilize a solder reflow process to homogenize the BGA solder joint microstructure and minimize solder joint microstructure segregation.

- Mitigate risk of mixed solder alloys through mechanical reinforcement:

Reflow the Pb-free BGA component in an SnPb soldering process and apply an underfill material to supplement solder joint integrity.

1.3 Misconceptions

This document discusses a risk mitigation method of soldering Pb-free BGAs which will result in a mixture of Pb-containing and Pb-free solder. This topic should not be confused with risk mitigations applied to prevent tin whisker formation by ensuring the presence or application of 3% Pb minimum in the Sn-plated surface finish of solderable components (leadless or leadless). The 3% minimum rule is relevant only to plated surfaces (such as those on the leads of electronic components) and not bulk solder as found in the interconnect attachment of those leads or leadless devices (including BGAs) to a printed circuit board (PCB). When soldering a Pb-free BGA using SnPb solder, a 3% Pb content does not imply any guarantee of solder joint performance. At the expected low Pb content range expected in this application (1 to 10%), the solder properties vary highly and can have a significant impact on solder properties and performance relative to traditional SnPb solder.

NOTE: Industry investigations using BGA solder ball alloys containing rare earth elements (REEs) have been shown to generate whiskers. (See Appendix A.)

Soldering Pb-free BGA balls with SnPb solder will not yield a SnPb eutectic joint. Soldering Pb-free BGA balls with SnPb solder may require disclosure in a LFCP because fatigue and property substantiation is needed over the range of expected Pb concentration and service conditions.

1.4 Intended Use

This document is intended for use as technical guidance by ADHP electronics system customers, i.e., aerospace and military vehicle integrators, operators, and regulatory organizations, and their suppliers, i.e., system original equipment manufacturers (OEMs) and system maintenance facilities as they incorporate Pb-free BGAs into existing or new SnPb assemblies (new, rework, or part changes/tech insert).

It is intended for guidance with the development and fielding of ADHP products; however, it may also be referenced for other products with similar characteristics, e.g., low volume, rugged use environments, high reliability, long lifetime, and need for reparability.

A series of standards and handbooks focused on the use and handling of Pb-free solder, piece parts and PCBs in ADHP has been published by SAE under the GEIA-STD-0005 series. This guideline is intended to work in concert with those documents. This document will establish guidelines for deciding if reballing or mixed alloy is appropriate for a specific application and provide recommendations for the use of Pb-free BGAs and mixed SnPb/Pb-free alloy solder joints while maintaining the high reliability standards required for aerospace electronic and electrical systems. For consideration of general Pb-free risk mitigation, use the GEIA-STD-0005 family of documents.

The information contained herein is intended to make product design teams aware of the risk of using mixed metallurgy BGAs in ADHP electronic systems and to provide possible mitigation/use options to address that risk. Users of this document are cautioned that a complete characterization of the performance of mixed metallurgy BGA solder joints may require qualification/validation testing. In order to avoid the issue of BGA mixed metallurgy solder joint integrity issues, component suppliers offer parts packaged as a land grid array (LGA), with a termination finish that is suitable for both SnPb and Pb-free assembly. This may be a viable alternative to using a Pb-free BGA.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

- GEIA-HB-0005-2 Technical Guidelines for Aerospace and High Performance Electronic Systems Containing Lead-Free Solder and Finishes
- 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 Whiskers in Aerospace and High Performance Electronic Systems

2.2 Other Publications

- IEC TS 62647-4 Process Management for Avionics - Aerospace and Defense Electronic Systems Containing Lead-Free Solder - Part 4: Ball Grid Array (BGA) Re-Balling
- IPC-7095 Design and Assembly Process Implementation for BGAs
- IPC-9701 Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments

3. METHODOLOGIES FOR UTILIZING PB-FREE BGAS

3.1 Reballing

One option for addressing the use of a Pb-free BGA is to send the component to an external service provider to be reballed, i.e., the Pb-free solderballs are removed and replaced with SnPb alloy solderballs. This results in a typical SnPb solder joint once assembled to a PCB.

Interconnect reliability testing has generally shown that the risk to reliability is low for reballed BGAs, as long as the reball process is controlled in accordance with IEC 62647-4 or similar method, although reballing a part will void the original manufacturer's warranty. (See Appendix C for more information.)

The reballing of a BGA component requires the control of several key process parameters; package moisture sensitivity level, solderball removal/attachment temperature/time and cleanliness of the reballed BGA component. Functional component testing is necessary subsequently to ensure that no process or component defects result from the reballing process.

3.1.1 Reball Process

The general process flow for reballing is shown in Figure 2. IEC Technical Specification 62647-4 details concerns and critical parameters for the reballing process. These should be reviewed with potential vendors and include:

- Flux use, activity level, and allowable contamination levels on the finished component post-cleaning [2].
- Component compatibility with all processes (e.g., multiple reflow cycles, cleaning compatibility).
- Process requirements and controls (e.g., thermal profiles, solder alloy removal).
- Quality and inspection requirements.
- Qualification and production testing.
- Identification/marketing.

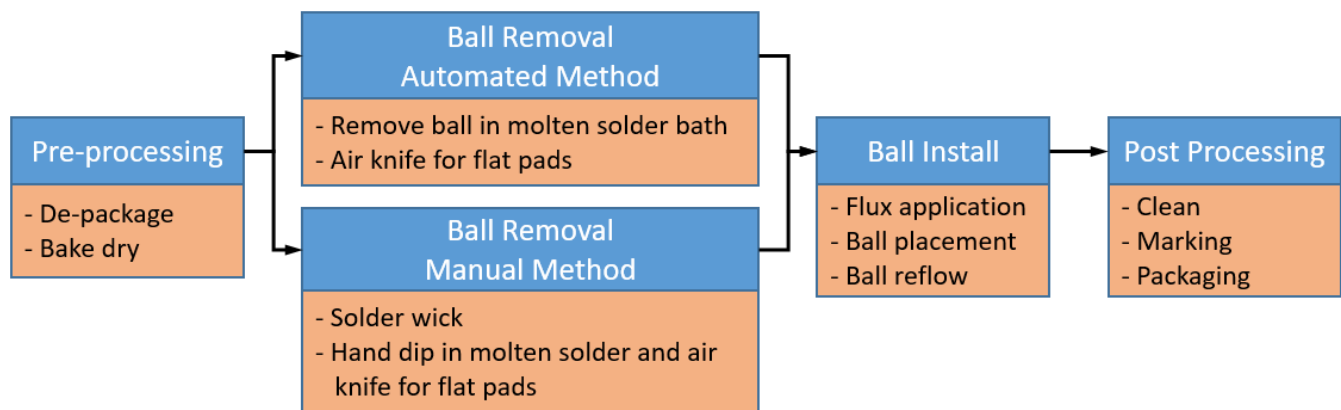


Figure 2 - General process flow for reball of a BGA

It should be noted that automated solderball removal is the preferred option versus manual solderball removal. The primary reason for this preference is the inherent variation of manual processing in contrast to automated processing. However, there may be cases where the package is not compatible with a standard automated removal method (e.g., packages with large lids/die where unbalanced heating can cause warpage issues) and manual soldering is considered. Manual solderball removal by a skilled operator can be an effective and viable methodology, but may require an exception when working to IEC 62647-4. Manual solderball removal process considerations include:

- Selection of soldering iron tip and temperature.
- Physical contact pressures and time durations.
- Operator training.
- Cleaning.
- Automated Optical inspection to verify pad diameter after ball removal.
- Solder mask scratches that expose base metal are cause for rejection.

3.1.2 Advantages and Disadvantages of Reballing

The main advantage of reballing a Pb-free BGA component is that it is transparent to a SnPb soldering process; no changes to the assembly process are required.

The main disadvantages are the cost and time (additional span time in procurement) required for the reball process. The cost impact includes the vendor cost for reballing (e.g., non-recurring (NRE) cost, recurring costs), any material loss through manufacturing defects (i.e., process yields), and destructive production testing. The vendor reballing NRE cost is associated with qualification efforts. Internally, NRE is associated with generation of documentation, such as an altered-item drawing.

3.1.3 Further Considerations for Reballing

3.1.3.1 Altered Item Drawing

Typically an Altered Item drawing is used to document the requirements for reballing of a BGA. The document would indicate the original vendor and part number of the Pb-free BGA, reference the process requirements (e.g., internal specifications, IEC Technical Specification 62647-4), and provide any specifics relative to the IEC document that will be communicated to the reballing vendor, including repackaging, marking, and identification requirements.

3.1.3.2 Part Identification

Visually, the reballed part is not obviously different from a non-reballed part, which could result in confusion between the parts if they are not properly segregated. This can be mitigated by marking of the part as part of the reball process as required in IEC 62647-4, and ensuring awareness of this marking at process points such as incoming inspection and assembly.

3.1.3.3 Guidelines for Incoming Inspection of Reballed parts

No special inspection of reballed parts may be necessary by the user if IEC 62647-4 or a like specification is invoked for the processing. IEC 62647-4 includes multiple inspection points for the reballing provider as part of both qualification and production lot verification.

3.1.3.4 Rework in the Reballing Process

The IEC 62647-4 specification restricts rework operations on the BGA piece part since each attempt exposes the BGA to elevated temperature processing with each additional reflow profile applied. Since BGA manufacturers typically place a limitation on the number of recommended reflow cycles, the total number of rework procedures and temperature excursions should be controlled.

3.1.3.5 Part Compatibility with Reballing Process

Manufacturers should verify that a specific BGA is suitable for the reballing process. BGA reballing service bureaus have reported rejecting some BGAs for reballing as they have been received without a barrier metallization (Ni) on the component pads. See Appendix B for an example. Compatibility with the cleaning process should also be considered. Vented BGAs, for example, can permit the introduction of cleaning fluids and contaminants under the lid which may remain and cause damage.

3.1.3.6 Handling Damage Risk

Reballing involves additional handling of BGAs as they are unpackaged, processed, re-marked, and repackaged. Any handling of parts imparts some amount of risk of damage. This risk can be minimized through proper handling procedures at the reballing provider. Customers are advised to review handling procedures with their reballing providers as a normal part of vendor selection.

3.2 Mixed Alloy Soldering (Pb-Free BGA Balls with SnPb Assembly Alloy)

A second methodology for using Pb-free BGA components is to place those BGA packages directly onto a SnPb assembly. The package Pb-free solder balls are assembled onto PCB pads stencil printed with SnPb solder paste and creating a mixed alloy after reflow.

In general, studies have shown that mixed alloy soldering of BGAs have acceptable interconnect reliability when full mixing of alloys in the solder joint is achieved. When full mixing is not achieved, the solder interconnect may have a shorter life which should be considered for each application. Since accelerated testing protocols based on legacy SnPb solder models may not be equivalent for use with mixed solder alloys, the accuracy of these test results is unknown. The combination of multiple solder alloys (in various ratios) may affect electronic interconnection performance due to differences in fatigue characteristics under thermal cycling and vibration relative to traditional solders. While there have been no documented issues related to products built with this method, the imperfect knowledge of the long-term impacts of the resulting solder joints means that risk can be minimized by controlling the process, but it is not eliminated in this method. This guideline was developed based on results of industry studies which typically involved SAC305 as the BGA alloy, and the use of other alloys when mixing solders may provide different results. (See Appendix D for more information.)

3.2.1 Advantages and Disadvantages of Mixed Alloy Soldering

The main advantage of mixed alloy soldering is that parts are more readily available for procurement and use, and without any additional costs (either from the manufacturer or from third party reballing). In addition, the user is not compromising any warranty offered by the manufacturer. The reballing process is avoided, which negates any need to document the part level change, add schedule for the reballing process, or accommodate yield and destructive test losses from a reballing process.

The two main disadvantages of mixed-alloy soldering are the NRE costs required to develop and qualify a mixed alloy soldering process, recurring costs associated with process and sample surveillance to ensure that the process remains under control and alloy mixing levels do not change, and the risk associated with unknown long-term reliability. There is no industry standard for ensuring creation of a reliable solder joint of mixed alloy, and the survivability of the joint may not be equivalent to a single alloy system in similar environments.

The non-recurring effort (NRE) includes development and verification of the assembly process and reflow profile, ensuring it is sufficient to ensure complete solder mixing, as well as safe for all other parts of the assembly. Verification typically involves destructive analysis of assemblies to metallographically evaluate the microstructure of mixed solder joints.

The recurring effort (RE) should consider the controls that will be in place and followed during the assembly process over time: aperture modifications on the solder stencil, ensuring solder paste is used in rework (at the assembly house, at repair depots, and perhaps in the field), and documentation controlling the process or requirements, changes in assembly equipment, solder paste inspection results of solder paste volume, etc.

3.2.2 Further Consideration for Mixed Alloy Soldering

3.2.2.1 Achieving Full Mixing

Since the Pb-free alloy will often have a higher melting point than SnPb, the specifics of the reflow temperature profile have a significant impact on the final configuration of the solder joint; whether the ball collapses and complete mixing is achieved, or if the solder joint is left with a distinct Pb-free region above a partially mixed region (see Figure 3).

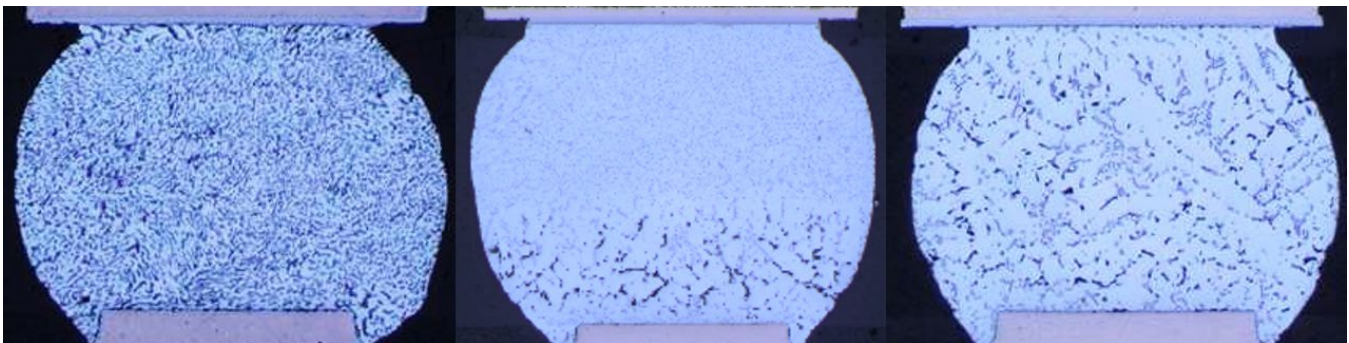


Figure 3 - BGA solder joint: fully SnPb solder joint (left), incomplete mixing of Pb-free ball in SnPb solder process (center), complete mixing of Pb-free ball in SnPb process (right) profile generation

The method for developing a reflow program and capturing the resulting reflow profile is equivalent to that for standard BGA assembly, with the exception of the target profile temperatures. Information on the process and differences can be found in IPC-7095.

IPC-7095C, however, puts too much emphasis on a narrow range of temperature (228 to 232 °C) for peak temperature, without consideration of all variables. The intent of the “hot” profile is to allow for complete reflow of the Pb-free solder ball of the BGA, which melts at 217 to 221 °C for many SAC alloys. In a backward process, however, once the Sn63Pb37 solder paste reflows, it will start to incorporate the SAC ball into the liquid mixture, and will continue to do so as long as the temperature remains higher than the liquidus point of the resulting mixture. Liquidus of the entire solder ball can therefore be achieved below the liquidus point of the Pb-free ball. One study [3] used differential scanning calorimetry and cross section evaluation to verify that full reflow could be achieved at 210 °C. This means that a larger range of thermal profiles can be used than that recommended by IPC-7095, although the lower the peak temperature used, the tighter the process window will be. Studies have shown that the ratio of SAC and SnPb alloys used can have a significant impact on both liquidus temperatures and plastic ranges [4 to 6], indicating that the particular attention should be given to all process parameters (e.g., peak temperature, alloy ratios, time above mixture liquidus) when using lower temperatures in the reflow process, as is evidenced by the number of published work showing that full mixing was not achieved at peak temperatures in the 210 to 215 °C range.

The volume of SnPb solder applied in the assembly process has a direct impact on the mixing of the alloys. Inadequate volume of solder paste can result in a solder mixture that requires a higher peak temperature to mix completely. A missing solder print will obviously result in a purely Pb-free solder joint, if the ball melts (when a Pb-free PCB finish is used). Increasing the volume of SnPb solder applied has a direct impact on the target temperature and allows a reflow profile within the nominal SnPb window to be used, although limited to the high end of that window. This effect of solder volume can be seen on various packages sizes. Larger BGAs with large solder balls will tend to have a higher ratio of Pb-free solder, which makes it more difficult to fully mix the solders without increasing the thermal profile. Smaller BGAs with smaller solder balls can more easily result in fully mixed solder joints (lower reflow profile temperatures can be used), but can be more susceptible to variations to solder volume as transfer efficiencies of small stencil apertures become relevant.

The advantage of using a “hot” profile is minimal process parameters changes and low cycle time impact. The disadvantages of using a “hot” profile are the time/costs associated with the additional due diligence testing and laborious reflow profile generation necessary to demonstrate component/solder joint integrity acceptability. Traditionally, the industry uses SnPb solder paste reflow profiles with a maximum temperature limit of 200 to 225°C. Solder paste flux formulations and component fabricators have characterized and tested their materials to not degrade up to this temperature range limit. However, the typical Pb-free solder reflow profile has temperature excursions in the range of 235 to 260 °C. Many component fabricators will void their SnPb component warranties if the 225 °C temperature is exceeded. Some high performance product design teams have conducted testing and worked with their component fabricators to develop acceptable “hot” reflow profiles that do not introduce component integrity concerns [7, 8].

When higher profile temperatures are used, all components used in the assembly should be considered with respect to their ability to survive the process. Although the Pb-free BGA may be capable of higher temperatures, other components intended for a traditional SnPb profile may be damaged by exposure to the higher temperature. Moisture sensitive parts may have been classified at 225 °C, and the classification level may change when a higher reflow temperature is used.

Regardless of the specific peak temperature targeted in the reflow profile, the process window will be tighter, and may be difficult to achieve across the entire assembly. Additional data points in the profile generation will likely be required to ensure that no areas of the board are getting too hot, while the specific BGA solder joints in question are reaching the target temperatures. There can be variation in the temperature profile experienced between balls of the BGA due to thermal mass, die size, or location, etc., and multiple thermocouples are recommended for each BGA to characterize the range of temperatures achieved. Oven tolerance, or repeatability of the profile should also be evaluated, as the capability of the oven and impacts of loading can have an effect on the actual profile experienced from assembly to assembly. See 3.2.2.4 for more information related to process verification.

3.2.2.2 Guidelines for Inspection of solder joints

Visual inspection of solder joints on BGAs is difficult in general; only the outer rows may be visible. It may be possible to review the outer rows for ball collapse and a consistent surface texture (indicating a homogeneous mixture), but full mixing would not be easily verifiable. Process verification and control is necessary to ensure good results. X-ray inspection will not determine the level of mixing.

3.2.2.3 Process Verification

Components and assemblies vary in size, shape, and thermal mass, and these differences typically drive the need for customized reflow equipment settings. At a minimum, this means that the process should be verified for each BGA on each assembly. A standard program may not be adequate from product to product, or even from one location on the assembly to the next.

Verification of full mixing can only be achieved through cross section of representative hardware. Solder joints from the middle of the BGA should be included, as these often see the lowest peak temperature in reflow, and would exhibit the lowest degree of mixing.

Since mixing of solders is dependent on the relative volumes of solder paste and ball, these should be reviewed in the verification process. A sample with a nominal solder print may adequately mix, while a low solder print may not. Controls should be set to ensure that variation in the production process will not impact the result. Inadequate solder paste volume, a marginal reflow profile, or overloading of a reflow equipment could result in incomplete mixing of the solder joint. The process should be reviewed and monitored to ensure an adequate process window is developed to allow for process variation.

Cross-sectional evaluation is the only way to demonstrate that full mixing has been achieved. This destructive testing is most reliable when it is performed on a fully populated, representative sample of the hardware. The analysis should include multiple solder joints, based on the thermal measurements made in profile generation, or to include solder joints from the center of the part out to the perimeter. No special preparation of the cross section is required, and often visual verification of Pb-rich regions throughout the solder joint are adequate (no evaluation or analysis of distribution is required).

3.2.2.4 Process Verification (Initial)

The initial process verification should include an evaluation of the process as well as the results. Variables throughout the process and controls to limit the variation should be considered:

- Evaluation of BGA solder ball geometry and stencil design.
 - Understand variation in solder print volume.
 - Potential of package to have increased thermal variation.
- Development of reflow profile.
 - Consider impact of fully populated board versus bare or minimally populated.
 - Multiple thermocouples at BGA site(s).
 - Adequate temperature with desired process window.
 - Understand variation due to oven loading or normal temperature variation of the oven.
 - Ensure any modifications made to a profile don't impact other components.
- Build and cross section of representative test card.
 - Optimum microstructure of fully mixed composition.

Although a verification of the process variables can indicate an acceptable process, destructive analysis through cross section is the only method which demonstrates that complete mixing has been achieved. Evaluation of representative hardware may be sufficient, but a fully populated assembly sample may be required.