# An Engineer's Guide to Component Re-Conditioning Using the Robotic Hot Solder Dip Process

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## Abstract

Immersion gold over a copper base metal is highly resistant to the effects of corrosion since gold does not oxidize and provides a protective layer with a highly solderable surface that is very bondable for both gold and aluminum bonding wires within semiconductor devices. However, since gold is soluble in solder at a relatively low temperature, the inclusion of gold within a solder joint can result in gold embrittlement when combined with other metals to form the solder connection interface.

Gold dissolves rapidly during the soldering process and reacts with both tin and lead in their liquidous state to form a brittle intermetallic such that the remaining gold within a solder joint can weaken the integrity of the interconnection. If the level of gold dissolution is excessive during the solder alloy's liquidous phase formation, the composition and mechanical properties of the resulting solder joint can change, and the inclusion of excessive levels of gold can result in gold embrittlement when gold is combined with other metals as the solder joint cools and is formed.

**Key Terms:** Robotic hot solder dip process, gold embrittlement, gold removal, tin whisker mitigation, BGA de-balling, BGA re-balling, component re-conditioning, outsourcing, insourcing, component solderability test methods

## Gold Embrittlement

As gold plating dissolves rapidly during the soldering process, the remaining gold within a solder joint can weaken the integrity of the interconnection. If this gold dissolution is excessive during the solder alloy's liquidous phase formation, the composition and mechanical properties of the resulting solder joint will change. Gold embrittlement within tin-lead (SnPb) solder joints is a well-known failure mechanism. Commonly used lead-free solder alloys including tin-silver-copper (SAC305) and tin-nickel-copper (SN100C), are more capable of maintaining their mechanical properties when combined with gold partially due to the greater tin content, however lead-free solder joints will also degrade with increased gold inclusion.

Gold embrittlement can be a significant reliability issue with the risk of embrittlement dependent upon several variables including the amount of gold expected to be leached from plated surfaces, the volume of the resulting solder joint, and whether the solder is from an infinite source such as a wave or selective soldering process, or from solder paste. In most cases the source of excessive gold dissolution is from gold-plated component leads rather than gold contribution from the printed circuit board finish such as electroless nickel immersion gold (ENIG) or electroless nickel electroless palladium immersion gold (ENIPIG). These types of board finishes are typically too thin to contribute to gold embrittlement since their average thickness of approximately 0.10µm (4 microinches) is below the 0.25µm (10 microinches) threshold considered as minimal contribution to gold embrittlement.

## Gold Removal

Beginning with the IPC J-STD-001 Rev F requirements in 2014, and continuing with the current Rev H, it has been stated that gold shall be removed from: at least 95% of the surfaces to be soldered of through-hole component leads with 2.54µm or more of gold thickness, from 95% of all surfaces to be soldered of surface mount components regardless of gold thickness, and from the surfaces to be soldered of solder terminals plated with 2.54µm or more of gold thickness. With this criterion, gold removal is therefore required for all high-reliability Class 2 and Class 3 electronic products and therefore affects almost everyone in the electronics manufacturing industry.

The removal of gold plating from component leads can be facilitated by a pre-tinning process which removes the gold as it is solubilized in the molten solder during the re-tinning process. A double tinning process or dynamic solder wave should be used for gold removal prior to soldering the components into a board assembly as improper removal of gold on component leads and terminations prior to board level assembly can potentially result in solder cracks and/or field failures.

The ideal method to facilitate the removal of gold plating from SMT and through-hole components is to use the robotic hot solder dipping process. It is recommended that this re-tinning operation be carried out using a lead tinning machine utilizing controlled flux application, preheating, and dual solder pots, nitrogen inerting as well as defined process control. A defined process of this type is highly recommended in lieu of manually dipping components into a static solder pot to reduce solder contamination, minimize non-wetting issues and enhance solderability.

A static solder pot is typically used for the first pot to remove gold plating, oxidation, or other residues and a dynamic solder pot is used for the second pot for precise control over solder depth. A nitrogen inert atmosphere helps the appearance of the resulting solder finish while mitigating icicles and dross buildup. Immersion of the component lead or termination into the flux and solder should be controlled to allow the flux and solder to flow up the lead or termination to a controlled depth. A defined withdrawal or extraction speed should be used in the second solder pot to control the re-tinning solder thickness and solder pots should be tested regularly for copper, nickel, and other contaminants.

## Component Re-Conditioning

The need to convert components such as a pin grid array (PGA) device from a SnPb finish to a lead-free finish can be accomplished by component reconditioning as well as RoHS conversion whereby a component can be converted from a RoHS finish to a SnPb finish for high-reliability applications.

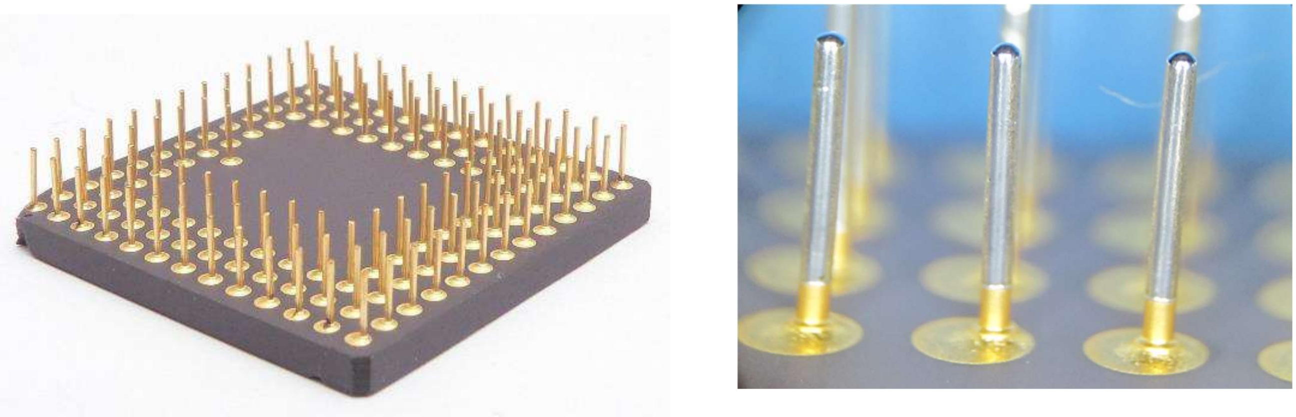

**Figure 1.** High thermal mass ceramic pin grid array (left), and re-tinned pins after gold removal (right)

Legacy components used for end-of-life (EOL) product builds, can be decades old having been stored in uncontrolled conditions leaving them generally oxidized with poor solderability which can result in poor quality solder joints. Refurbishing these components will replace oxidized, plated finishes that are deemed un-solderable, or gold-plated finishes with an intermetallic homogeneous finish that is impervious to oxide growth and will mitigate possible tin whisker growth.

## BGA De-Balling

Some ball grid array devices (BGA) may need to be converted from a SnPb finish to a lead-free finish or from a RoHS finish to a SnPb finish for various high-reliability requirements. The first step in this conversion process is de-balling so that the original solder balls are removed from the BGA device exposing the pads of the interposer.

**Figure 2.** Ball grid array device before de-balling (left), and ball grid array being de-balled (right)

This de-balling process is followed by either manual or automated re-balling consisting of fluxing, alignment, and attachment of new solder spheres of the replacement alloy, reflowing, inspection, cleaning, and re-packaging. Post re-balling can also include shear testing, XRF alloy verification, visual inspection to confirm sphere size, alignment and condition, X-ray inspection for excessive voiding and component marking using either thermally printed labels or laser marking.

## Outsourcing vs. Insourcing

It has been observed that some in the electronics assembly industry use a single or static solder pot for both alloy removal and component re-tinning. This is not a recommended practice since organic contaminants, flux buildup and accumulation of gold can be transferred to the re-tinned component leads or terminations. Those using this practice are relying on outdated standards and procedures and are not in compliance with the GEIA-STD-0006 component re-tinning requirements.

Others choose to outsource their component re-tinning and re-conditioning requirements to outside component service providers. While these component rework service providers offer a full range of services, outsourcing is expensive with long lead-times for components to be unavailable for internal board assembly and very often cannot accommodate tight schedules resulting in production backlog.

Often a traditional ‘make vs buy’ decision results in many circuit board assemblers deciding to setup an internal component re-tinning operation thereby eliminating production delays and reducing costs.

Fine-pitch quad flat packs (QFP) devices as small as 6mm x 6mm and as large as 50mm x 50mm can be re-tinned with a lead pitch down to 0.3mm (0.012') can be re-tinned with bridge free results.

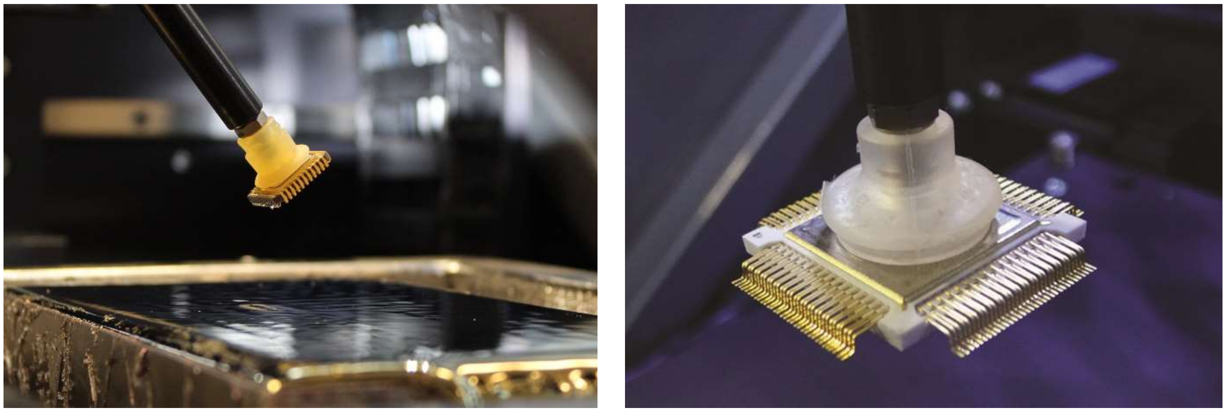

**Figure 3.** Quad flat pack (QFP) device during re-tinning (left), and QFP held with vacuum nozzle (right)

Manual load/unload, and automatic load/unload, lead tinning machines can re-condition many types of through-hole and surface mount components including dual in-line package (DIP), single in-line package (SIP), quad flat pack (QFP), ball grid array (BGA), axial and radial through-hole devices. These lead tinning machines are CE certified and feature high repeatability operation with internal preheating, dynamic or static flux baths, and single or multi-pot solder bath stations.

## Standards Compliance

In all cases component re-tinning and re-conditioning should be carried out in full compliance with all applicable industry standards. The Hentec/RPS Odyssey 925, 1325 and 1750 component lead tinning machines perform component re-conditioning in accordance with all relevant GEIA-STD-0006, MIL-PRF-38535, MIL-PRF-38524E and ANSI-J-STD-002 standards. The full line of Odyssey 925, 1325 and 1750 component lead tinning machines are MIL spec compliant and specifically designed to perform component re-conditioning including re-tinning, gold removal and BGA de-balling for high reliability and military applications.

## Solderability Test Methods

Solderability testing determines how well molten solder will wet on solderable surfaces of electronic components with the most common solderability test methods being the dip-and-look method and the wetting balance method. The dip-and-look method is a qualitative type test performed by comparative analysis after specimens are dipped in a bath of flux and molten solder. The wetting balance method is a quantitative type test based upon the interpretation of a wetting curve measuring the buoyancy of a specimen using a load cell. There are several solderability test standards, but the most common standards are MIL-STD-883 Method 2003, IPC J-STD-002 and MIL-STD-202 Method 208.

While the wetting balance test method is precise and measures the wetting forces between molten solder and a test specimen as a function of time, it requires the interpretation of a wetting curve by skilled personnel in a laboratory environment. Another disadvantage is that wetting curves can be easily distorted if the system is not properly calibrated or performed incorrectly by unskilled personnel.

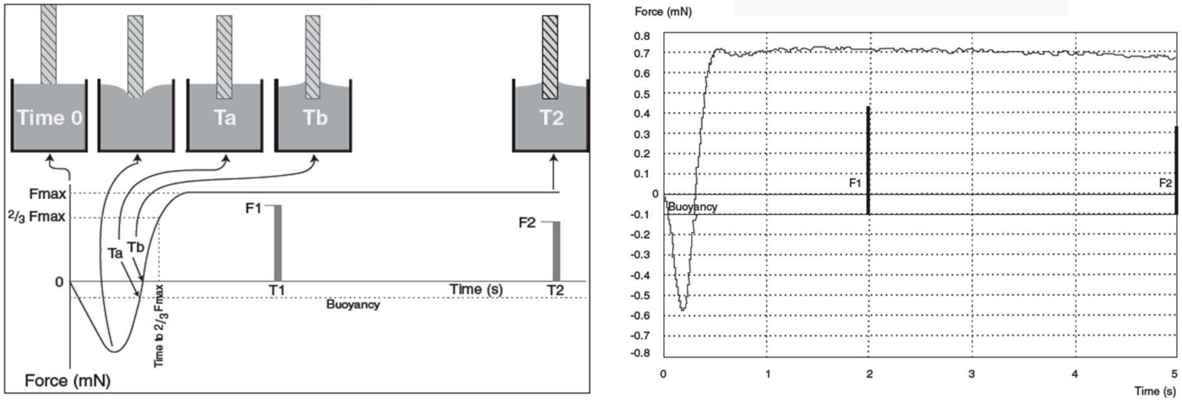

**Figure 4.** Wetting balance solderability test method (left), and wetting curve of highly solderable lead (right)

An advantage of the dip-and-look method is since it is based on comparative analysis it can be performed rapidly by shop floor personnel with minimal training as well as requiring significantly lower capital investment then a wetting balance test system.

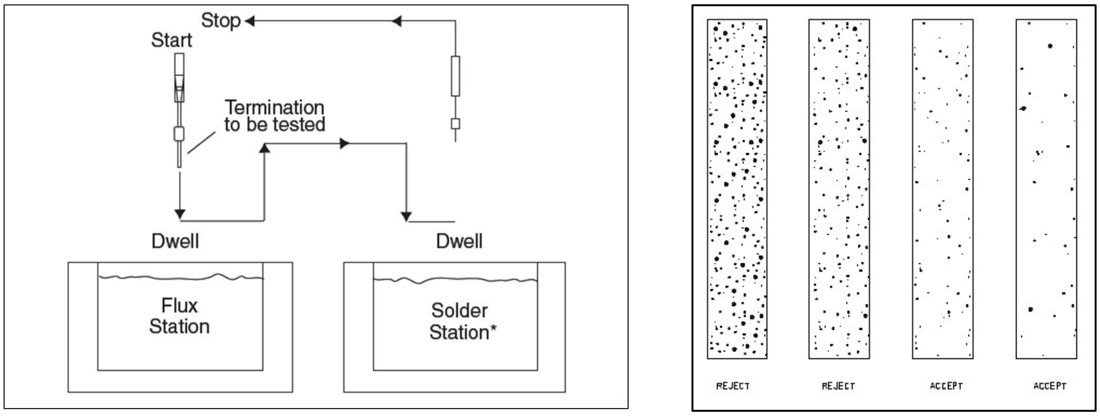

**Figure 5**: Dip-and-look solderability test method, (left), and dip-and-look specimens at 10X magnification (right)

The Hentec/RPS Pulsar dip-and-look test system can also be configured for low-volume lead tinning of component terminations that exhibit poor solderability due to oxidation or prolonged storage.

**Figure 6**: Dip-and-look solderability test equipment (left), and component steam aging system (right)

For some high-reliability applications additional solderability testing may be required and can include steam aging which is used for accelerated life testing to simulate elongated storage conditions.

## Summary

Selective soldering is an essential part of forming solder joints for most electronic packaging and circuit board assembly applications. Solderability is no longer an option for many high reliability segments of the global electronics assembly industry. With implementation of the recent Rev H of IPC J-STD-001 standard, solderability testing, gold removal and component re-tinning have become prerequisites for doing business and remaining competitive in the global electronics marketplace.

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