An Essential Guide to Optimize Selective Soldering Processing

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Abstract

Selective soldering has grown to become a standard production process within the electronics assembly industry, and now accommodates a wide variety of through-hole component formats for numerous applications. Most through-hole components can be easily soldered with the selective soldering process however, several critical parameters need to be optimized to ensure optimum results and guarantee the utmost end-product quality.

Key Terms: Selective soldering, flux selection, flux application, thermal processing, no-clean thermal processing, flux residue mitigation, solder nozzle design, system flexibility, gold embrittlement, gold removal, solderability testing

Flux Selection

While often overlooked, the choice of which flux used for the selective soldering process has a tremendous impact on solder joint quality, long-term reliability, and overall selective soldering performance. Liquid fluxes fall into one of three basic categories: 1) low solids/no-clean fluxes, 2) rosin-based fluxes (full or high solids rosins), or 3) water-soluble fluxes. Three key attributes that define these flux categories are: 1) activity level, 2) solids content, and 3) material, or flux, type.

Flux Type	Activity Level	Flux Composition	Solvent	Solids Content
Low Solids/No-Clean Flux	Low to moderate	Rosin or resin	Alcohol	1.5%-2.5%
VOC-Free Flux	Medium to high	Organic	Water or alcohol	1,5%-6%
Non-Rosin Flux	Medium to high	Resin	Alcohol	2%-8%
Rosin-Based Flux	Medium to high	Rosin	Alcohol	15%-45%
Water-Soluble Flux	Highly active	Rosin	Water	11%-35%

Table 1. Summary characteristics of most common flux types used for selective soldering.

Low solids/no-clean fluxes typically have less active chemistry than other flux types and can be more challenging to solder in comparison to rosin-based or water-soluble fluxes. However, they have the key advantage of eliminating post-soldering cleaning. This key attribute makes low solids/no-clean fluxes generally the best option for selective soldering. Rosin-based fluxes can have low activity but typically are in the range from the medium to high activity levels. With a long process life they must always be cleaned following the selective soldering process.

Water-soluble fluxes are excellent for soldering and typically have a high amount of activity that readily cleans the base metals to be soldered and are virtually burned off during the soldering process. However, these chemistries generally leave residues that are very aggressive and corrosive and will continue to react after soldering and therefore must be cleaned.

Flux Type	Pros	Cons
Water-Soluble Flux	Excellent soldering with wide process window. Excellent to very good for high-reliability applications but depends on cleaning process and product demands. Good for high-heat applications.	Requires more preheat than other flux types. Residues must be absolutely cleaned. The cleaning process and floor space can be expensive. Must be closely monitored with ionic testing. Cleaning must occur within the time specified by flux manufacturer. Increased machine maintenance since chemicals attacks equipment. Contaminates fixtures, totes, and other work surfaces. Requires spray fluxer to handle high solids content. Slight post-soldering residues can cause field failures.
Rosin-Based Flux	Very good to excellent soldering with wide process window. Very good to excellent results for high-reliability applications. Very good to excellent for high-heat applications. Has a long process life.	Requires more preheat than other flux types. Requires more machine maintenance and can pose difficulty for downstream processes such as ICT, AOI, etc. Often requires an optional fluxer upgrade. In some applications residues can be a reliability concern. Flux resides need to be cleaned, some RMA fluxes can be left on boards.
Low Solids/No-Clean Flux	Good to very good soldering. Less post-soldering residue that may allow for no-clean processing. Can allow for lower preheat processes versus wave soldering and non-water-based fluxes. Wide variety of flux choices and can work well for variety of applications. Easy on equipment.	Less activity and smaller process window versus rosin or water-soluble fluxes. Can pose difficulty and have reduced process window with high-heat applications. Residues may still need to be cleaned by edict or the flux amount required may leave an undesirable or unsafe volume of residues.
VOC-Free Flux	No volatile solvent and can be more active and have a longer process life versus non-rosin alcohol flux.	Requires more preheat than other flux types and can increase total cycle time. More preheat is needed to dry water-based flux since a wet board will cause splatter. Cannot necessarily be as clean as non-rosin, alcohol flux.
Non-Rosin Alcohol Flux	Burns off very cleanly.	Short process window.

Table 2. Pros and cons of various flux types regarding their usage for selective soldering.

One of the most important aspects of liquid flux is its activity level and its ability to form a high-quality solder joint. This is accomplished by wetting the through-hole component lead, the plated through-hole and the annular ring rapidly and completely to form a strong solder joint.

Flux Application

Some flux types require a fluxer capable of processing fluxes with high solids content, thus it is recommended to choose a selective soldering system that has both a spray fluxer and a drop-jet dispenser. The drop-jet flux dispenser can ensure fluxing of liquid flux precisely down to the individual droplet processing in both individual points and entire lines for connectors in a single pass. The spray fluxer is applicable for mass flux application as well as handling fluxes with solids content up to 35%. Selective soldering systems such as those offered by Hentec/RPS are available with both dual spray and drop-jet fluxing and include separate plumbing for each fluxing system which is preferrable.

Figure 1. Drop-jet flux dispenser (left), and dual spray and drop-jet fluxing system (right)

Additional advantage of drop-jet dispensing is that it provides both complete control of an adjustable droplet size together with low consumption of the liquid flux being applied. Because no-clean flux residues are completely consumed when using selective soldering, a drop-jet flux applicator has a distinct advantage over wave soldering using aperture wave pallets since no-clean flux residues cannot become entrapped underneath wave soldering pallets. Another distinct advantage of using a drop-jet flux applicator for selective soldering is that it allows for true no-clean processing and mitigates the need for post-soldering cleaning as well as reduced rework and repair.

Thermal Processing

Preheating is necessary for all flux types to activate the flux and dry the solvent, as well as to reduce the risk of component thermal shock. Open-loop preheating systems that rely on an operator to set preheat temperature and exposure time are typically less efficient and therefore not recommended for certain applications. Closed-loop preheating systems which provide pyrometer-based control that monitors target temperature and adjusts the power automatically are preferable.

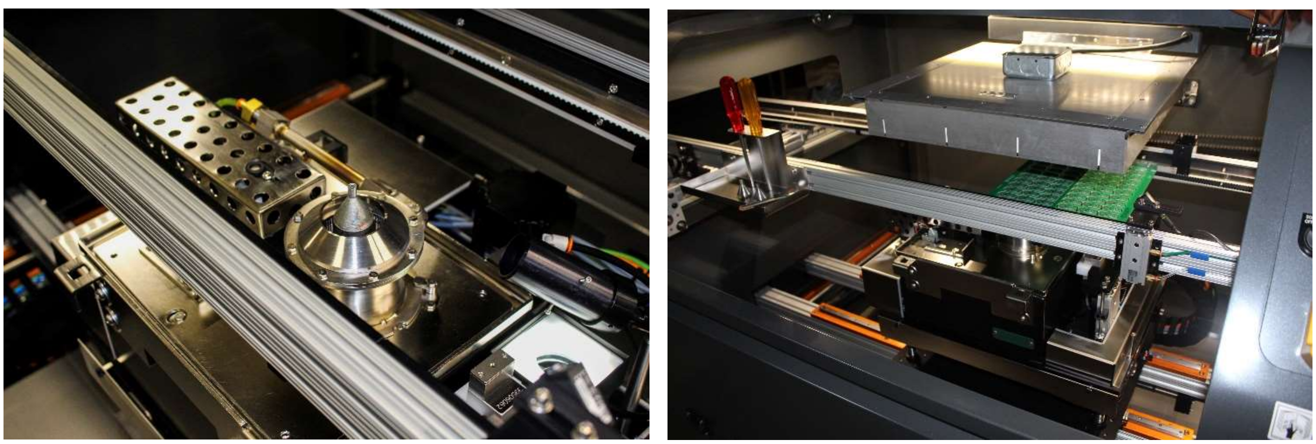

Figure 2. Electropolished solder pot and drop-jet flux module (left), and topside infrared preheater (right)

Preheat temperature, which is the temperature assumed by the printed circuit board at the end of the preheating period, is generally specified for the proper conditioning of a specific flux type. The dwell time, also referred to as solder contact time, and the solder temperature determine the total heat flow to the soldering area. Time-temperature profiles of the circuit board are affected by the thermal mass differential of the components and the circuit board as well as the rate of heat dissipation.

No-Clean Thermal Processing

Most no-clean fluxes have active ingredients that are typically low concentrations of mild organic acids. In contrast to rosin fluxes with high fluxes that have an activation temperature above which the flux becomes active and below which the flux is inactive, the active ingredients in no-clean fluxes may be active from the time of application until they are consumed by reaction or volatized by heat.

Proper processing is key to ensuring that the level of active residue is within acceptable standards. Even properly processed no-clean fluxes may leave an excessive amount of residue that can be unsuitable for certain highly critical applications. Using no-clean fluxes with soldering processes that are not adequately controlled can result in flux residues that do not reliably meet required standards. Only a certain amount of active ingredients will be consumed in the reaction to remove the oxides from the metal surfaces, the bulk of the remaining active ingredients must therefore be 'burned off' by the heat during the soldering process. Therefore, it is important to carefully control both the amount of active ingredients applied and the heat during processing.

Controlling the amount of active ingredients applied requires monitoring the amount of flux being applied, the flux concentration and acid number of the flux. Equally critical is the uniformity of application as well as thermal processing characteristics including preheat temperature, solder pot temperature and dwell time.

Mitigation of Flux Residues

Since the preheat temperature should generally be lower than the thermal breakdown points of the common active ingredients in the no-clean flux, preheat temperature tends to be more important to solderability than it is to reduction of post-soldering ionic flux residues. However, poor preheating can affect residue levels indirectly since a common first response to poor solderability is to increase the amount of flux, which can lead to residue problems.

During selective soldering, the heat from the solder pot is the highest temperature the printed circuit board assembly will experience. Solder pot temperature has a greater effect than preheat temperature on reducing post-soldering residues. Since the solder is in intimate contact with the board when it passes over the solder nozzle, increasing dwell time not only allows the board to see the solder pot temperature for a longer time, but it also helps to remove excessive flux through both physical and thermal means.

Nozzle Design

There are applications where component density requires the use of a solder nozzle with limited keep-away when soldering fine-pitch through-hole components with limited adjacent clearance. To fit these tighter clearance applications. Hentec/RPS offers a proprietary Gaussian solder nozzle that produces a taller, more stable, and precise solder height with a minimum keep away of 0.5mm that is ideally suited for soldering micro-connectors and other fine-pitch through-hole components.

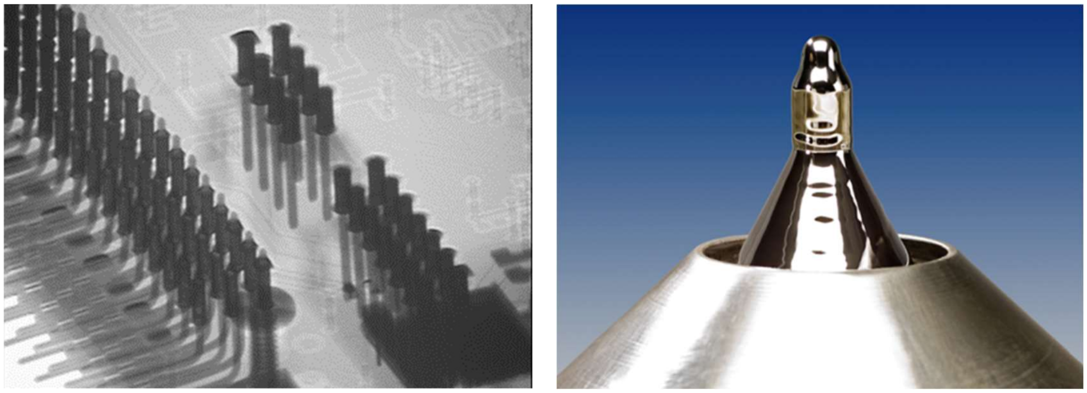

Figure 3. X-ray image of 1.0mm pitch micro-connector 100% PTH fill (left), and Gaussian solder nozzle (right)

For applications involving high thermal mass circuit boards a larger nozzle is generally required. This is due to the heat being transferred through the solder flowing from the selective nozzle which is relatively small in comparison to a wave soldering nozzle. These applications typically require longer contact times and higher solder temperatures but can potentially result in de-wetting of the annular ring if the contact time is excessively long.

Super heating of the nitrogen can assist with soldering assemblies with a high thermal mass without the use of larger solder nozzles or increased dwell time. The Hentec/RPS ProHeat system utilizes a programmable nitrogen heater capable of 400º C functioning as a localized bottom-side preheater.

System Flexibility

Wave nozzles are available for Hentec/RPS selective soldering systems that duplicate the function of a conventional wave solder process and can be used for soldering high thermal mass components such as multi-row connectors, backplanes or pin grid array (PGA) devices.

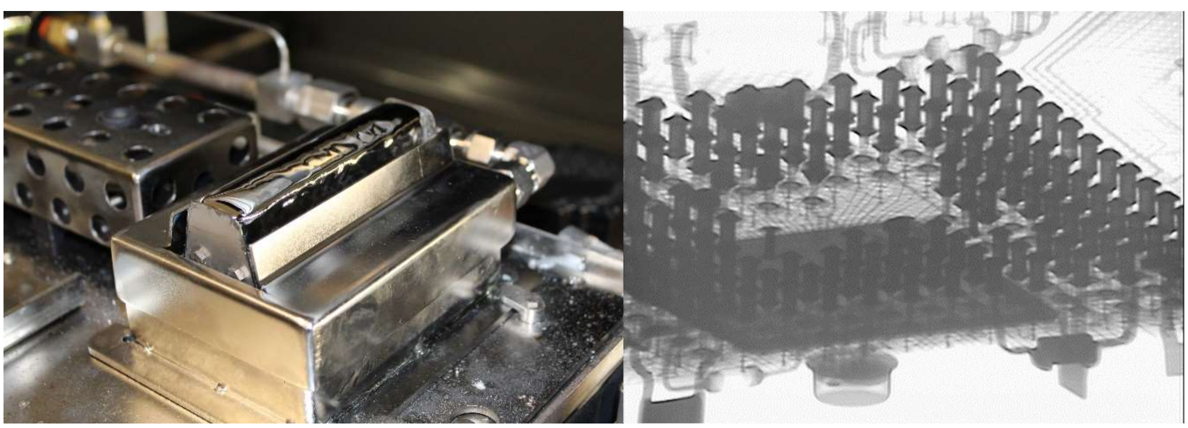

Figure 4. 4” wide wave solder nozzle (left), and X-ray image of high mass PGA with complete PTH fill (right)

Hentec/RPS offers a four inch (4”) wide wave nozzle integrated into a Vector selective soldering system for soldering of high thermal mass through-hole components or for emulating wave soldering functionality on a limited scale.

Gold Embrittlement

Gold embrittlement can be a significant reliability issue. The risk of gold 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 solder paste.

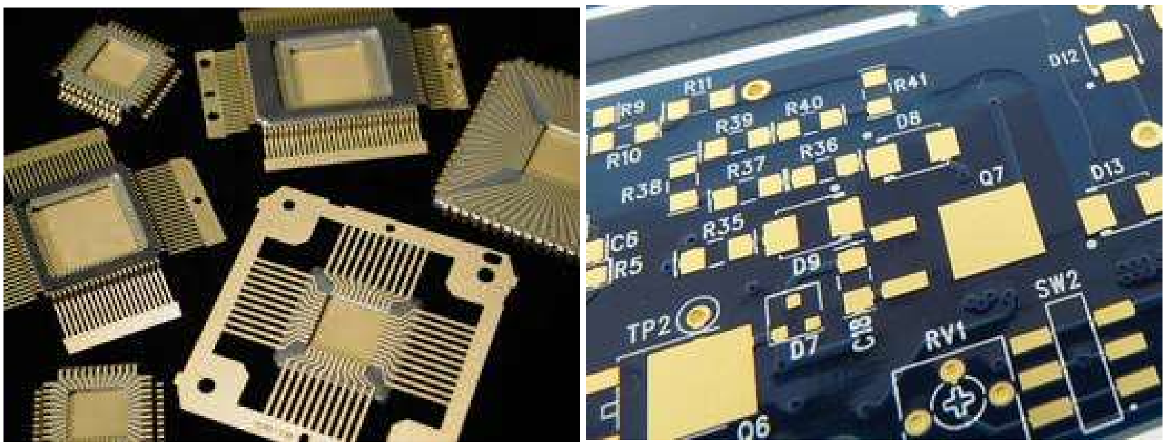

Figure 5. Gold-plated lead frames (left), and electroless nickel immersion gold printed circuit board (right)

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

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 may be used for gold removal prior to soldering the components into a board assembly. 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 a Hentec/RPS Odyssey robotic hot solder dipping system. The Odyssey re-tinning system utilizes controlled flux application, preheating, single or dual solder pots, nitrogen inerting and a well-defined process control. A well-defined process of this type is highly recommended in lieu of manually dipping components into a static solder pot. It will guarantee a repeatable process, reduce solder contamination, minimize non-wetting issues and enhance solderability.

Solderability Testing

Solderability testing determines how well molten solder will wet on solderable surfaces of electronic components. The most common solderability test methods are 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.

Although 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.

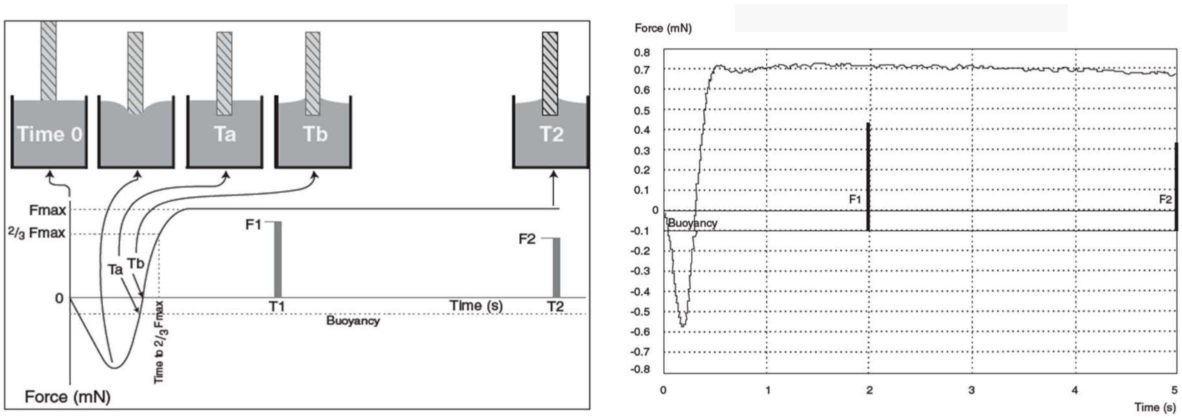

Figure 6. Wetting balance solderability test method (left), and wetting curve of highly solderable lead (right)

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. Additionally, a dip-and-look test system requires a significantly lower capital investment than a wetting balance test system.

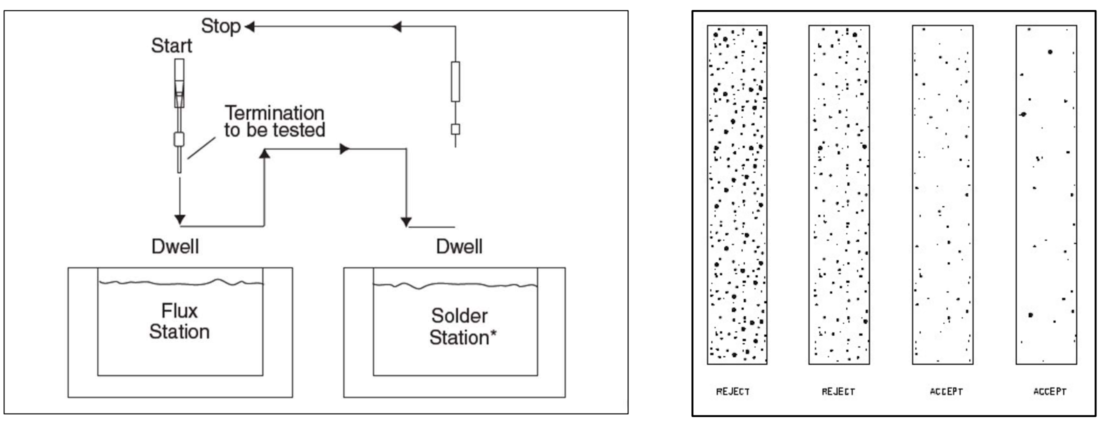

Figure 7. Dip-and-look solderability test method, (left), and dip-and-look specimens at 10X magnification (right)

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. The Hentec/RPS Pulsar solderability test system complies with all applicable test standards including MIL-STD-883 Method 2003, IPC J-STD-002 and MIL-STD-202 Method 208.

Figure 8. Dip-and-look solderability test equipment (left), and component steam aging system (right)

For some high-reliability applications additional solderability testing may be required. This can include steam aging which is used for accelerated life testing to simulate elongated storage conditions. The Hentec/RPS Photon steam aging system is designed to generate artificial aging to simulate elongated storage conditions of electronic components and is especially suited for high-reliability applications or end-of-life product builds. The Hentec/RPS Photon steaming aging system complies with all relevant GEIA-STD-0006, MIL-PRF-38535, MIL-PRF-38524E and ANSI-J-STD-002 industry standards.

Summary

Improving the solder quality and first pass yield of a selectively soldered printed circuit board assembly entails a series of enhancements to all soldering process variables. Choosing a selective soldering supply partner who offers rapid and flexible programming by means of a clear and highly visible display, easily imports a scanned image of a printed circuit board, or Gerber files, offering the user simplistic elegance in operation allowing for optimum efficiency is an essential requirement.

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