Practical Methods for Evaluating and Qualifying Selective Soldering Systems

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Abstract

There are some conditions in which wave soldering or manual soldering are inefficient for board level assembly including those with tall through-hole component heights, tight component spacing, uneven heating or dense concentration of through-hole components. For these cases selective soldering provides a highly effective solution with a controlled process and highly repeatable results ensuring increased productivity and greater yields. When considering candidate selective soldering systems, the appropriate process controls should be examined to ensure optimal solderability. A well-defined protocol should be followed to evaluate and qualify appropriate selective soldering systems for the range of required applications.

It can be quite common to question if the right selective soldering machine was chosen after the purchase. Since capital equipment is a major expenditure and it makes sense to consider whether one is equipped with the right solution for the given range of applications. Research has shown that people may continue to research products after a purchase. The reason being they want to confirm, in their minds, that they've made the correct decision after the fact.

Key Terms: Selective soldering, current and future application requirements, specification and feature analysis, key process parameters, machine qualification protocol, flux application methods, system flexibility, system quality verification, operational costs

Future Requirements

The first step in choosing a selective soldering system is to review your organization's needs at the present time and into the foreseeable future. This includes the volume of units you plan to produce, anticipated future growth, and requirements including the maximum board size and product mix. Also consider the design complexity of future products, and if your operational mode will require either a standalone system for batch or low-volume production, or a conveyorized in-line system for high-volume requirements.

A critical requirement to consider when choosing a selective soldering system is the mix of through-hole and SMT components your products will contain which in turn will determine the interconnections your selective soldering system will have to produce which will define the types of solder nozzles required. If the complexity of your future products together with the mix of SMT and through-hole components cannot be defined, it is recommended that the flexibility of the selective soldering system be a major determining factor in the decision-making process.

Specification and Feature Review

When conducting a peer-to-peer comparison of candidate selective soldiering systems, all equipment specifications and system features should be taken into consideration. These include maximum board size, flux type compatibility, board edge clearance, and component clearance above and below the printed circuit board (PCB) assembly. Other factors to be considered include solder pot capacity, solder height detection, solder nozzle sizes available, adjacent nozzle clearance, fiducial alignment control, preheating capability, as well as X, Y and Z-axis accuracy and repeatability.

Parameter	System Specification	Compliance
Handling of assemblies	Maximum board size: 600x600mm Minimum board size: 25x25mm Height clearance: 75mm top; 75mm bottom PCB edge clearance: 3mm	Yes/No
Key functional requirements	Standalone or in-line configuration In-line SMEMA operation with conveyor system System repeatability: ±0.25mm	Yes/No
Fluxing module	Drop-jet and/or spray fluxer with pressurized fluxing tank Automatic flux level control Dual flux chemistry capability Control of fluxing frequency and spray time Flux frequency adjustable range: 2ms to 900ms Monitoring of flux spray and flow	Yes/No
Preheat module	IR preheat with closed-loop temperature control Preheat output to accommodate proper board temp. before soldering	Yes/No
Soldering module	Solder pot compatible with lead-free solder alloys Closed-loop solder pot temperature control Closed-loop solder nozzle height control Wettable and/or non-wettable quick change solder nozzles	Yes/No
Software and programming	Simple, easy to use and user-friendly programming Control of Z height, dwell time, dip speed and pull-off speed Fiducial recognition and correction Auto program changeover Live teach-in system programming Dual monitors standard at no additional cost Off-line programming with PC workstation	Yes/No
Overall requirements	Programming and process viewing cameras UL and CE certified In-line roller, belt, or chain conveyor capable of handling PCBs or pallets Minimum board transport speed: 1mm/sec	Yes/No
Air supply requirement	Minimal pneumatic consumption	Yes/No
Exhaust requirement	Fume extraction system to remove overspray and flux fumes	Yes/No
Nitrogen requirement	Nitrogen purity level of 99.999%	Yes/No
Manufacturer's warranty	System warranty: two (2) years with 3rd year optional Solder pot warranty: four (4) years No cost software upgrades	Yes/No

Table 1. Typical technical specifications and feature verification for candidate selective soldering systems

Equally of importance are factors including ease of programming, consumption of consumables such as nitrogen, replacement solder to compensate for dross generation, the entire system and solder pot warranty, as well as the availability of software upgrades at no additional cost.

Key Process Parameters

Of the process parameters involved with selective soldering, the most important are X-Y positional accuracy, flux deposition, solder height control, and preheat efficiency. Accuracy and repeatability of both the flux and solder gantries is critical to ensure accurate flux application and to achieve optimal solder joint formation. Repeatability and consistency of the solder wave height is required to ensure board impingement is maintained between the solder nozzle and the bottom of the printed circuit board throughout the entire soldering cycle. Preheat temperature must be achieved prior to, and during the complete soldering cycle to properly activate the liquid flux, as well as to dry the flux vehicle or carrier whether alcohol or water, and properly activate the flux solids.

Feature	Sub-System	Qualification Run	Measurement Method	Specification
Fluxer	Fluxer gantry	X-axis repeatability	Measurement to fixed reference point	±50µm
		Y-axis repeatability	Measurement to fixed reference point	±50µm
	Gantry parallelism	Gantry parallelism	Measurement at extremes of travel	±50µm
	Flux drop size	Flux dot size repeatability	Visual inspection	5mm
	Flux verification	Flux verification sensor	Disconnect flux tube from nozzle	Pass/Fail
	Flux level monitoring	Test flux level function and alarm	Remove flux to level below lower limit	Pass/Fail
Preheat	Preheat temperature	Topside preheat repeatability	Measure temperature at top surface	±5ºC
		Bottom-side preheat repeatability	Measure temperature at bottom surface	±5ºC
		Temperature uniformity across PCB	Measure temperature at various points	±5ºC
		PCB temperature profile	Follow profiling best practices	±7ºC
Soldering	Solder gantry	X-axis repeatability	Measurement to fixed reference point	±50µm
		Y-axis repeatability	Measurement to fixed reference point	±50µm
		Z- axis repeatability	Measurement to fixed reference point	±50µm
	Solder wave temp.	Temperature repeatability at nozzle	Measurement with thermocouple	±3ºC
		Test over temperature function	Simulate temperature over max limit	<400ºC
	Solder wave height	Repeatability of wave height	Use wave height check function	±2%
	Solder level	Test solder pot low level sensor	Use low level solder function check	Pass/Fail
Conveyor	Conveyor width	Repeatability at 100mm opening	Use dial indicator at 30mm increments	±50µm
Safety	EMO function	Test each EMO function and alarm	Functional check	Pass/Fail
	Door interlocks	Test all door interlock functions	Functional check	Pass/Fail

Table 2. Acceptance criteria and machine qualification requirements for candidate selective soldering systems

Additional consideration should be given to the emergency off function (EMO) and accessibility to all e-stop switches and door interlocks to ensure they comply with all applicable local safety regulations.

Machine Qualification

To ensure that a complete and thorough qualification is conducted of a candidate selective soldering system, the functional operation of all critical processes should be verified and recorded in terms of a process capability index (Cpk). This includes the consistency and repeatability of flux dot size as well as the flux gantry positional repeatability.

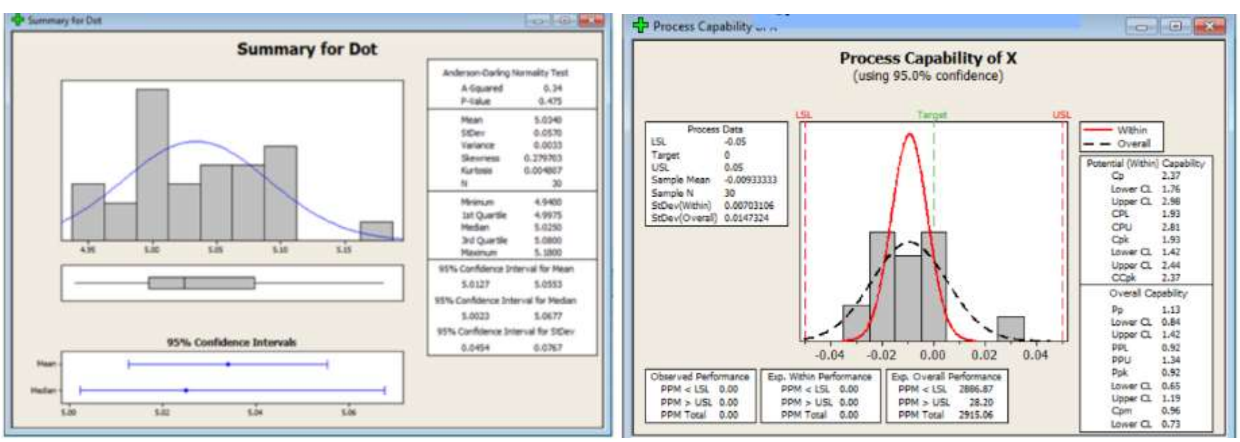


Figure 1. Flux dot size repeatability (left), and flux gantry positional process capability (right)

Preheat uniformity should be verified to ensure thermal repeatability for all locations across the entire printed circuit board assembly, variations in component thermal mass notwithstanding.

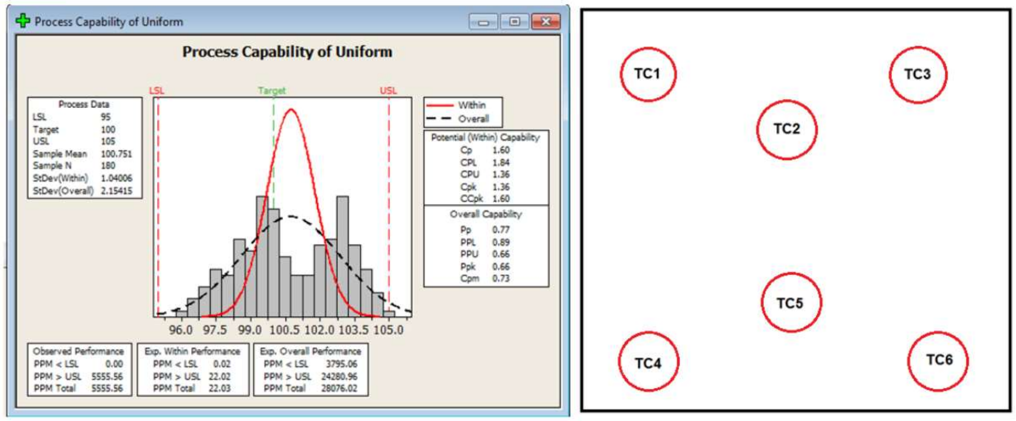


Figure 2. Preheat uniformity process capability (left), and thermocouples attachment locations (right)

The X-Y positioning accuracy and repeatability of both the flux and solder gantries should be verified to ensure that adequate board-to-board process repeatability can be achieved.

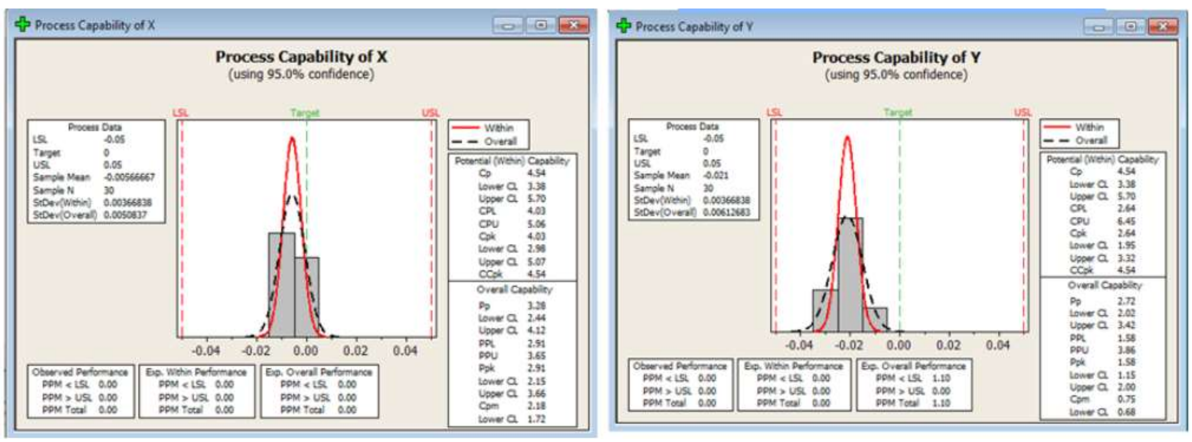


Figure 3. X-axis positional process capability (left), and Y-axis positional process capability (right)

Solder nozzle temperature consistency and solder height repeatability should be confirmed to ensure that consistent board impingement is maintained and optimal solder joint formation is achieved.

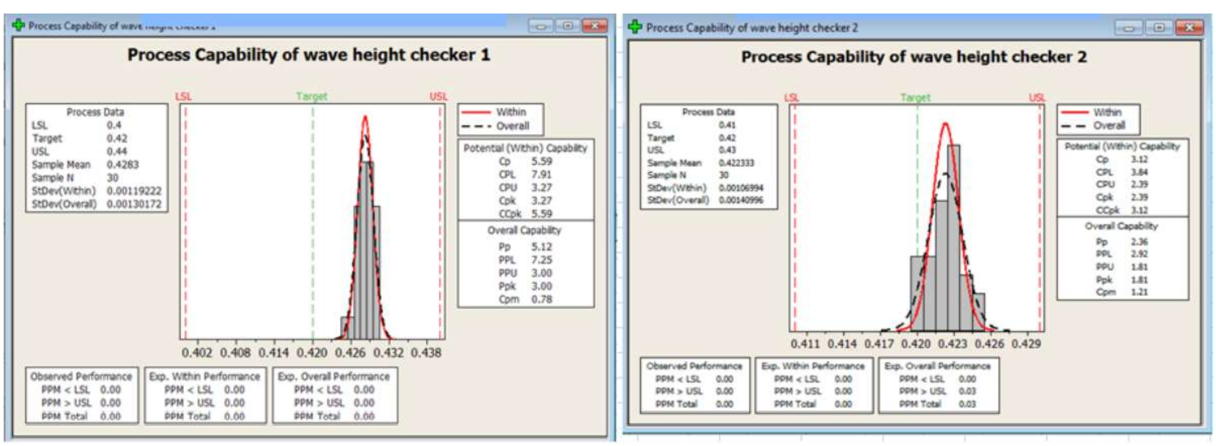


Figure 4. Solder height repeatability process capability test 1 (left), and process capability test 2 (right)

Flux Application

Liquid fluxes for selective soldering are available in many types including alcohol-based, no-clean fluxes, water-soluble fluxes, rosin-based fluxes, low pH fluxes and fluxes with high solids content. The choice of a particular type of flux for the selective soldering process is generally specified for the end application of the product and is critical with respect to the resulting solder joint integrity.

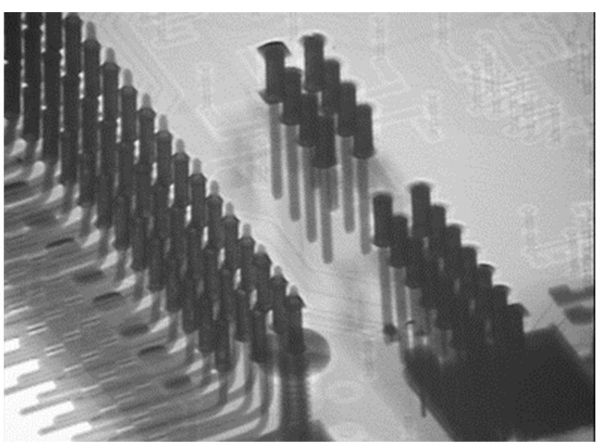
Flux chemistry selection criteria should be based on the solderability of the base metal surfaces being soldered. Base metals that are easy to solder including platinum gold, copper, tin-silver, or palladium silver can typically be soldered with either a no-clean flux, a non-activated rosin flux or a mildly activated rosin flux. Base metals that are less easy to solder such as nickel-plated brass, cadmium-lead bronze, or beryllium copper generally require either a fully activated rosin flux, a water-soluble organic flux, or a water-soluble inorganic flux. With these latter flux types, post-soldering cleaning of the board assembly is generally required in most cases.

Drop-jet flux dispensers are ideal for no-clean fluxes and fluxes with low solids content but are not well-suited for use with other flux types. Most drop-jet dispensers on the market have a maximum solids content limitation of 8% beyond which they can potentially clog and cannot function properly. Some selective soldering equipment suppliers indicate their machine warranty will be null and void if their drop-jet is used with any flux other than a low-solids that does not exceed 8% solids content. Some of these same suppliers do not offer other types of flux applicators.

All Hentec/RPS Vector and Valence selective soldering systems can be equipped with both drop-jet and spray fluxers. In addition, the Hentec/RPS drop-jet fluxer is unique in that it can process fluxes with up to a maximum of 14% solids content. These Hentec/RPS selective systems also offer a spray fluxer that has no limitation on solids content. These dual fluxers have independent nozzles and separate plumbing making them capable of processing a wide variety of flux chemistries.

System Flexibility

There are applications where component density requires the use of a solder nozzle with limited keep out when soldering fine-pitch through-hole components with limited adjacent nozzle 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 out of 0.5mm that is ideally suited for soldering micro-connectors and other fine-pitch through-hole components.



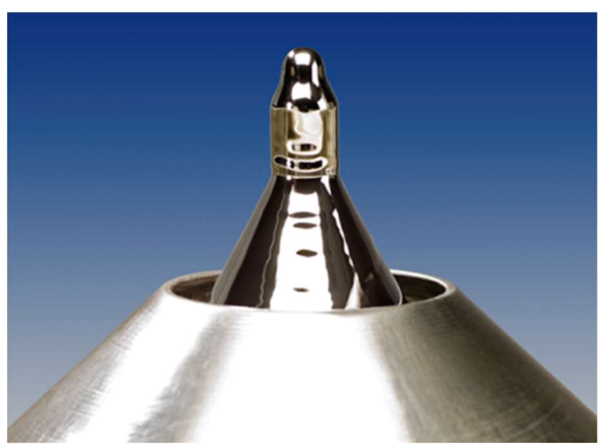


Figure 5. X-ray image of 1.0mm pitch micro-connector100% PTH fill (left), and Gaussian solder nozzle (right)

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

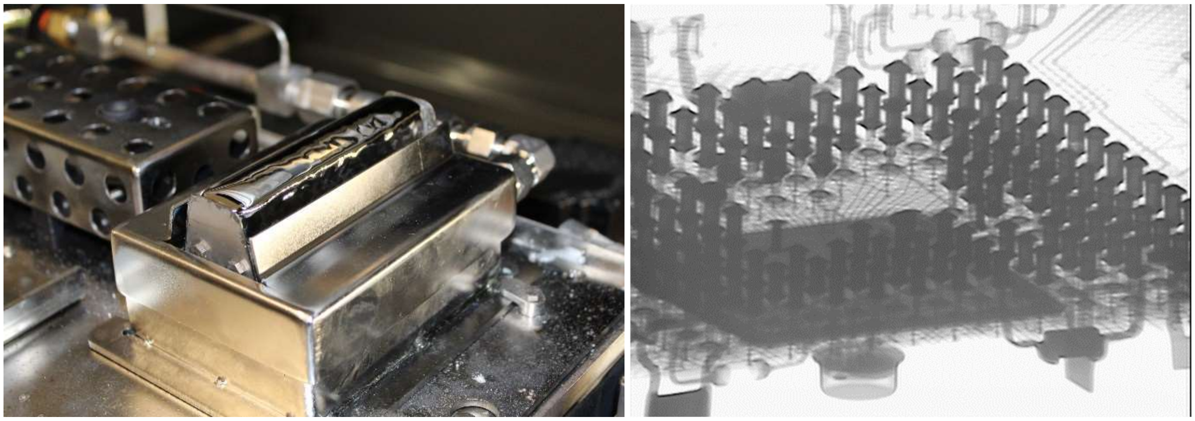


Figure 6. 4” wide wave solder nozzle (left), and X-ray image of high mass PGA with complete PTH fill (right)

Hentec/RPS offers a 4” wide wave nozzle that can be integrated into all Vector and Valence selective soldering systems for soldering of high thermal mass through-hole components.

Quality and Throughput

The first step in measuring the quality produced by a candidate selective soldering system is to select printed circuit board assemblies currently running on existing selective or wave soldering system with various through-hole component types such as connectors, fine-pitch devices, or capacitors, and benchmarking the results based on a trial run. It is suggested to select a quantity of boards containing ground planes and multi-layers and document the quality results using X-ray imaging.

To assess the operational quality of a candidate selective soldering system an additional trial run on a larger production lot should be conducted to determine the cycle time and units per hour (UPH) throughput. The program optimization and finite process control of the candidate selective soldering system should also be assessed with respect to other selective systems under consideration.

Operational Costs

The consumption of consumables such as nitrogen and replacement solder to compensate for dross generation represent ongoing operational costs for a candidate selective soldering system. Ideally a nitrogen consumption rate of approximately 1.1 cubic meters, or 40 cubic feet per hour is preferred. A candidate system with a low dross production rate is ideal, 42 grams, or 1.5 ounces of dross production in 8 hours being preferred. A candidate system with a low preventative maintenance cycle should also be considered to minimize downtime costs. A system that requires approximately 30 minutes or less to clean the solder pot once every 80 hours is suggested.

Summary

Once the trial run results and supporting qualification data have been summarized, a final assessment of the candidate selective soldering system should be made. Consideration factors generally include temperature control, good X, Y and Z-axis repeatability, the ability to provide good quality solder joints with minimal touchup, soldering cycle time and UPH throughput, with minimal changeover time.

Rapid and flexible programming by means of easy-to-use software with a clear and highly visible display that imports a scanned image of the PCB, or Gerber files, offering the user simplistic elegance in operation allowing for optimum efficiency is an essential requirement.

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