

Improving Hand Soldering Operational Costs and Process Control

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Manual soldering and process control can go hand-in-hand.

With Pb-free wave and reflow mass soldering processes for the most part approved and implemented, focus is now appropriately shifting toward the peripheral soldering processes such as rework and hand soldering. To guarantee quality in a Pb-free environment, stricter attention must be paid to hand soldering practices and equipment. Hand soldering quality is determined by two factors – operator skill and soldering iron efficiency. With regard to repeatability, all solder joints should be made in the same amount of time, during which the solder iron tip temperature must remain constant. However, soldering irons generally do not recover lost heat fast enough. This results in the operators often using higher set temperatures – in some cases as high as 380° to 440°C. These already high temperatures will need to be even greater for Pb-free soldering since the process temperature increases by as much as 40°C.

Pb-free thermal control.

Long considered as the weakest link in the Pb-free process control chain, Pb-free hand soldering requires rigorous control of the thermal process given the higher processing temperatures and the reduced process window. The paradox between higher process temperatures of Pb-free alloys and the narrower thermal threshold of components forms the basis of the Pb-free process challenge. Thus, there is a greater need for increased thermal stability and repeatability during the hand soldering process.

In a study of board assemblers actively involved with Pb-free implementation



ERSA i-CON with i-TOOL

published in late 2004, hand soldering was reported to be more problematic to implement during the transition to Pb-free than Pb-free wave or reflow soldering.¹ Poor wetting and cold solder joints occurred when solder tip temperatures were not high enough, or when flux activation was insufficient. Excessive solder tip temperatures also resulted in dewetting and thermal damage to boards and components. Using the correct solder tip temperature with adequate (not excessive) heat transfer is essential for creating reliable solder joints.²

Senior Management Awareness.

The three factors that directly affect the quality of Pb-free hand soldering are the selection of capable solder tools, sufficient training of operators and management's focus on the process. Senior management should be focused on all process steps throughout their assembly operations. Typically

management will focus attention primarily on the "capital investment" areas (screen printing, placement, soldering, test and inspection), and overlook the importance of manual soldering; hand soldering tool selection, operator equipment and training decisions get relegated to line personnel.²

Because senior management may not place a high priority on all aspects of the Pb-free transition, their lack of support to fully fund the necessary re-equipping and retraining of the production floor to successfully implement Pb-free hand soldering often presents a critical limitation. Hand soldering is an operator-dependent process; an inadequately equipped or trained hand solder technician is, in general, not capable of correctly guiding the process. It is estimated that only 10 to 25% of assemblers implement IPC-certified hand solder training.³

Consequently, many third-party rework and repair providers see increases in

desperate phone calls from assemblers complaining of hand-solder rejects as they begin to implement Pb-free in volume production. Frequently, the assembler requests repairs to the lot of assembled boards, but fails to identify and rectify the problem's source within their internal Pb-free line.

Management will eventually take notice when inferior hand soldering is revealed in a significant loss of product that cannot be shipped or in feedback from an unsatisfied customer. This can hurt a company's finances, image and customer relations. Yet sometimes that's what it takes for management to take notice of the importance of Pb-free hand soldering.

Thermal stability.

A repeatable, stable process depends on three factors: time, temperature and operator technique. The dwell time of the solder iron tip on the joint and the technique are dependent on operator skill and training. Temperature however, is governed by the actual temperature of the solder iron tip during the soldering process and depends completely on the technology of the soldering iron.

How well the solder iron recovers heat and puts back the heat lost at the tip, and the time the tip remains on the joint, ultimately determines the actual joint temperature. Slow recovering irons will lead to inconsistent joint temperatures (**Figure 1**).

Older soldering irons have sensors located far away from the tip; this can result in inconsistent solder joint quality. The tip loses temperature into the joints but does not recover fast enough before the next joint is made. In this situation, each consecutive solder joints is potentially colder than the previous joint. Solder iron manufacturers are developing better performing irons, many with the tip attached directly to the heating element cartridge. Subsequently, the tip temperature can overshoot; the cost of replacing the tip can be excessive. Such irons force assemblers to throw away still good (and expensive) heating elements simply because the small copper tip is worn out.

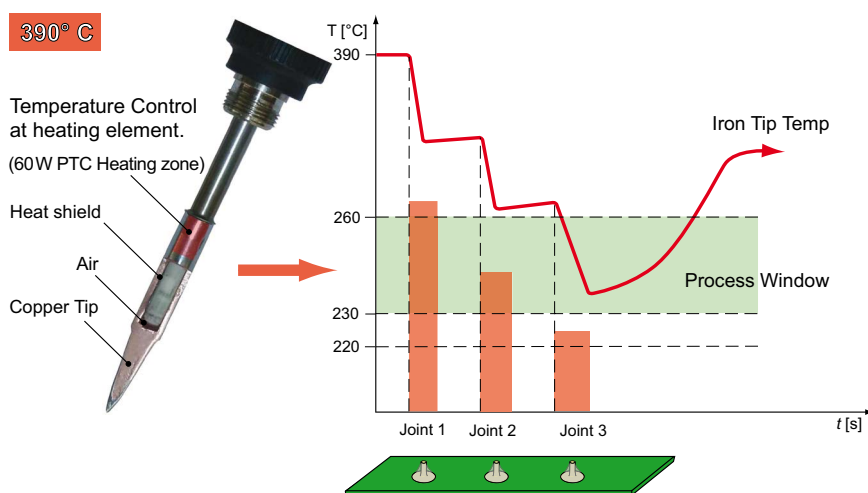


FIGURE 1: Conventional soldering iron heat recovery challenges.

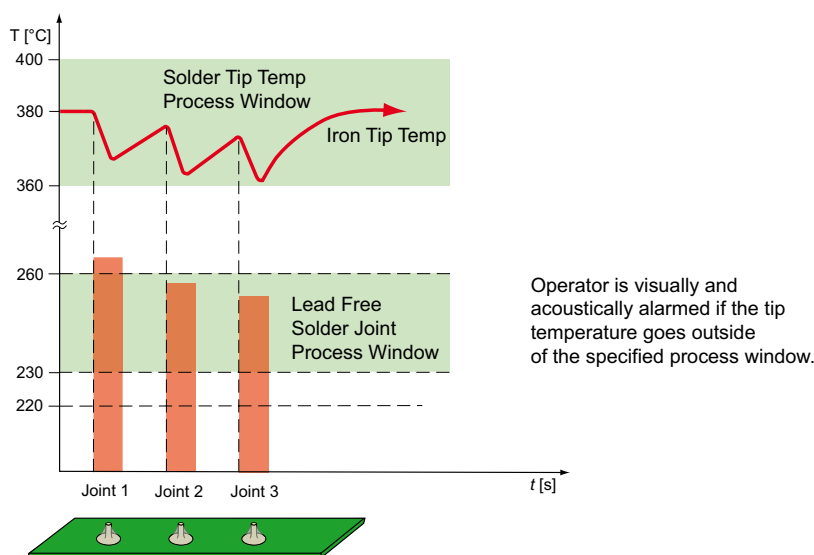


FIGURE 2: Enhanced process stability and repeatability.

Solder tip consumption will rise for Pb-free. A novel solder station (called *i-Con*) uses a patent-pending, 150W micro heating element technology (called *i-Tool*) that permits performance similar to soldering irons equipped with expensive heating element cartridges. The micro heating element permits use of standard, low-cost tips that can be removed without replacing the heating element each time a solder tip needs to be replaced. This technology heats from room temperature to 350°C in approximately 9 sec., and from standby to 350°C in 3 sec.

The tool is equipped with an electronic motion sensor chip that recognizes and monitors when the iron is being used.

The iron automatically goes into a lower standby temperature when the iron is put into its stationary holder or is no longer moving, overcoming problems with stations that use a micro switch in the holder but cannot detect when the iron is not placed exactly into the correct position. This improves process control.

Furthermore, an alarm documents and alerts the operator with a visual and acoustic signal if the solder tip gets too hot or too cold. This permits a process window to be specified (**Figure 2**), ensuring that every solder joint is made with the proper temperature.

Heat is recovered quickly, so that all solder joints can be made with nearly

the same temperature. This is done via a sensor, which measures the actual tip temperature very close to the solder tip extremity.

Finally, a microprocessor that stores the temperature calibration is located on a PCB embedded in the soldering iron handle. This permits for each tool to be calibrated independent of the solder station, saving time and expense. Only the irons need to be taken for centralized calibration, a process that is much easier and requires less production down time.

Temperature overshoot.

Each time a solder iron tip touches a joint, heat is conducted into the solder joint and is thereby lost, requiring the heating element to power up to replace the heat loss. When the tip is removed from the joint, heat energy continues to flow for an instant as if the mass of the solder joint was still present. Conventional irons, with heating element cartridges, can experience tip temperature overshoot from 80° to 100°C (Figure 3). For many sensitive components and for Mil spec and medical applications, this is unacceptable: the overheating could damage components. Conversely, a solder application on a heavy mass through-hole component on a multilayer board, or the soldering of heat shields or metal parts, requires all the power available from the heating element to transfer the necessary heat.

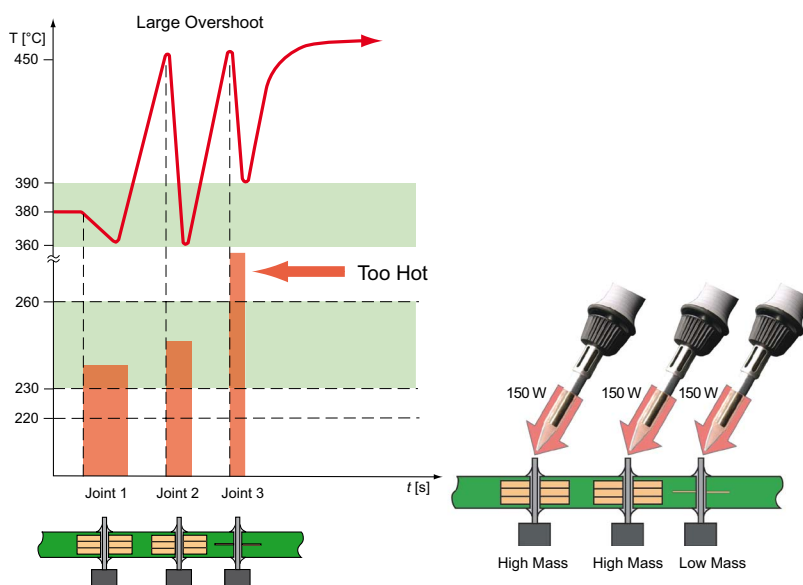


FIGURE 3: Conventional soldering tip temperature overshoot.

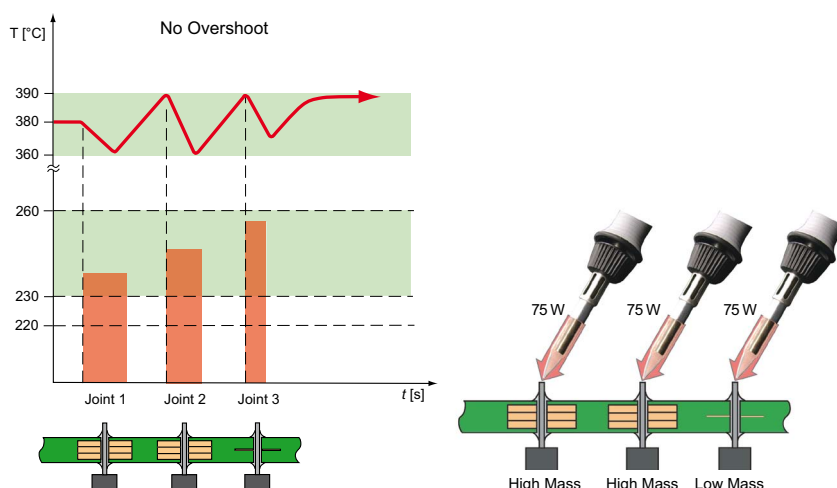


FIGURE 4: Solder tip temperature control with power limits.

Other available hand soldering technologies must find a balance between power and control in a compromise between these two extremes, but are not optimized for either. Conventional irons have a rapid recovery on heavy mass joints such as a copper penny test, but can have a large overshoot that can damage sensitive components. By comparison, the novel tool allows the operator to balance power and control with three different power settings that control the heating element for the individual application.

At power level high, the system uses 100% of its 150W, delivering maximum heat where required and allowing rapid soldering on heavy mass applications.

Power level low holds back the heat delivery to eliminate overshoot for the safest hand soldering applications. Power level medium is a balance between these two conditions. Thus, the operator can choose the right setting for the right application. This continual balance between heating power and temperature control can eliminate overshoot (Figure 4).

Operational costs.

Periodic replacement of solder iron tips is a major component of operating costs in a Pb-free hand soldering envi-

ronment since solder tip service life is greatly reduced. Most Pb-free alloys have significantly higher tin content than their Pb-bearing counterparts. Pb-free alloys erode the iron plating on solder tips much faster due to the aggressive nature of tin at high temperature. The surface of solder tips generally exhibit signs of pitting and corrosion as the iron plating starts to dissolve due to leaching or continuous tin scavenging, thereby reducing the tip's effective life. Over time, this erosion degrades thermal performance and adversely affects the heat conductivity of the solder tip.

To increase tip life, solder tip manufacturers typically increase the iron plating thickness on Pb-free solder tips. This thicker coating is combined with tinning of a suitable Pb-free alloy. Retinning Pb-free solder tips is more critical due to the aforementioned tin erosion and should be conducted frequently following a proficient tinning procedure.

Yet increased iron plating thickness reduces the thermal performance and heat recovery of the tip. For this reason, an efficient heating system is essential. Soldering irons that use a conventional heating element cartridge tip are efficient, but more expensive in operational use when tip life is short and replacement cost is high. They are also expensive because their construction is combined directly with the heating element. Also, such tips generally yield a shorter service life due to thinner iron plating and the result of a less efficient heating system. Exchangeable tips, on the other hand, have longer service life due to thicker iron plating, a more efficient heating system and are lower in cost (**Table 1**). Operational savings can be as much as seven times greater with exchangeable tips than conventional tips when compared on a per-station basis.

Another variable affecting tip life is the tendency of some operators to press harder while soldering with Pb-free alloys, thinking they will transfer more heat. While additional pressure does not improve heat transfer, it does result in cracking and pitting of the iron plating and hastens degradation of the tip exposing the copper core and shortening solder tip life.

Conclusion

With proper emphasis from senior management regarding the evaluation of equipment, educated decisions can be made with respect to the true costs of this critical process. Guaranteeing quality in a Pb-free hand soldering environment represents a significant challenge during the Pb-free transition. When putting into practice a successful Pb-free hand soldering operation, the manual soldering process must be evaluated on three distinct levels with respect to both operator and solder iron related issues. It must be assessed from a process control and quality aspect, from a thermal stability and repeatability standpoint, as well as from an operational cost perspective.

Equipment purchase decisions for soldering stations should guarantee high process stability at low running costs. Many companies running Pb-free in volume production are consuming up to one expensive solder tip per day, on a per solder station basis, so operational costs are substantially high. Due to its lower replacement cost, the novel tool could result in significant savings.

References

1. TechSearch International, "Pb-Free Update," November 2004.
2. Peter Biocca, "Pb-free Reliability – Building it Right the First Time," Pb-free Connection, June 2005.
3. Jim Jenkins, internal BEST Inc. document, June 2006.

Table 1. Comparison of solder tip operational costs

Solder tip type	Heating cartridge type	Exchangeable type
Cost per tip	\$35.00	\$10.00
Typical solder tip life*	30-60,000 joints	60-120,000 joints
Operating cost per 1,000 solder joints	\$0.58-1.17	\$0.08-0.16

* Expected solder tip life is dependent upon several factors including tip temperature, flux and mechanical pressure.



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