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# Down-Selecting Low Solids Fluxes for Pb-free Selective Soldering

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**ABSTRACT:**
Although many predicted the demise of through-hole components, they are alive and well with tens of billions used each year. In mixed SMT/through-hole PCBs, through-hole components, and especially connectors, are often used for their mechanical robustness. A typical example would be a USB connector in a laptop PC. Typically an SMT connection just doesn't have the mechanical robustness needed to support multiple connector plug-in and removals. However, performing a full wave soldering process to assemble a few through-hole components on a mostly SMT PCB doesn't usually make economic sense and may damage the PCB. In such situations, the best option is often to assemble the through-hole components and connectors with a selective soldering process.

This paper touches on identifying favorable flux properties, down-selecting low solids fluxes for lead-free selective wave soldering, the selective soldering process itself, and testing criteria. Topics reviewed will be the flux selection, optimizing the selective soldering process by varying the flux concentration, pre-heat parameters, soldering temperatures, and dwell time. The paper will finish with a summary of the work and a systematic process to select a flux and optimize the selective soldering process for high yields and quality.

**What is selective soldering?**
Selective soldering is simply the use of a specialized machine to apply liquid flux and a molten solder "fountain" to a specific area of the underside of a printed circuit board (PCB), similar to a traditional molten wave-type machine, except that the entire board neither sees the temperature excursions from the entire heat profile nor the heat from the molten solder itself. A selective solder machine attaches the same through-hole components to a PCB as a wave-type machine does, but utilizes a fine fountain of solder.

Selective soldering differs from a "selective wave" process in that a pallet is not used to cordon off the areas of the board that are not intended to have flux applied or come in contact with the molten wave. This process localizes thermal transfer to the PCB, with the option of pre-heating the entire board or just the area to be soldered.

When using an automated selective soldering machine there are many things to take into account. Sometimes the type of flux has already been chosen by the customer or supplier. Other times the flux is dependent upon the flux removal method. Other factors include the degree of hole-fill and wetting, residues that can be left on the board, and whether the flux deposited in these areas needs to be activated and burned off during the process. The objective is to ensure that no active residues are left on the board that can cause shorts to occur later on in the PCB's life.

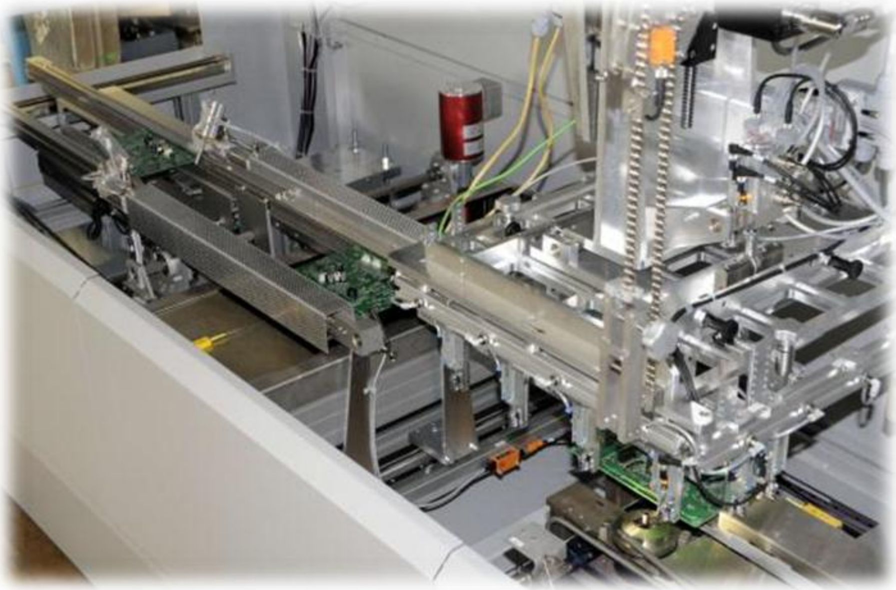

**Figure 1: A common type selective soldering machine. Photo courtesy of JUKI.**

Since a high percentage of selective solder customers run low volume/high mix processes, it is important to have a machine with a lot of flexibility. Machines are available in a batch configuration, where the PCB enters and leaves the machine on the same side, or an inline configuration, where the PCB enters from one side, runs through the machine, and exits from the opposite side and the fluxing, pre-heat, and soldering can all be done simultaneously for maximum throughput. Other options available include a single solder fountain nozzle, or multiple nozzles, where up to 4 nozzles can run at the same time. In addition, solder fountains can have an array of nozzles, including a "non-wetted" nozzle where the board is angled 7-10° like a traditional wave machine, or a "wetted" type where the PCB is soldered at 0°. These nozzles can be used autonomously for soldering a varying array of PCB designs without change-over.

Figure 2: Solder fountain with "non-wetted" nozzle (left) and "wetted" nozzle (right). Photo courtesy of JUKI.

**Why low solids?**

Low solids fluxes pose a dichotomy in the soldering world in that the activity of the flux must provide all the attributes needed for a good solder joint – hole-fill, wetting, and fillet formation – and yet, to be considered "low solids" it should not leave a visible residue or impede electrical probe testing. The visual aspect of not having any flux residues, which has been traditionally looked at as a negative to using a no-clean flux, is an added value.

Another benefit of low solids fluxes is the ability to use a more precise way of adding flux to the board, commonly referred to as a "micro-dot-drop-jet". Without the higher concentrations of dissolved solids, such as rosin and the chemical activators of traditional fluxes, a low solids flux will not have the propensity to clog smaller flux applicators.

The most important factor for the use of a low solids flux is how easily the flux can be displaced by the molten solder. This is because higher solids fluxes are not as easily displaced by the washing action of the solder. The more effective the washing action of the molten solder, the better the wetting, hole-fill, and surface insulation resistance (SIR) of solder joint. SIR improves because the washing action moves the flux out of the direct line-of-sight of the flow of current between pathways. Also, the easier displacement of the low solids flux decreases the chances of a solder skip or insufficient solder.

**Figure 4: Dual solder fountains on X-Y axes; 1.8mm (left) and 4mm (right). Photo courtesy of JUKI.**

**What role does rosin play?**

Rosin-free flux leaves the lowest amount of residue on the assembly after wave soldering because the flux solids volatilize with heat and contact with molten solder. In addition, the washing action of the wave removes the flux. Once rosin is added to the formulation, the flux is not volatilized with heat and contact with the molten solder, and is only partially washed from the board by the molten solder's washing action. This results in slightly more residue left on the assembly, which is a mixture of the flux activators and rosin.

Rosin-free fluxes leave a residue that is not hygroscopic, which means it does not attract moisture from the atmosphere. If excess amounts of residue remains, and the ambient conditions have enough moisture, the weak organic acids (WOA) in the residue may dissolve in the moisture, which may cause some current leakage. Rosin-containing flux will benefit not only from the insolubility of the rosin, but also from its encapsulating properties, depending on the residue's WOA to rosin ratio.

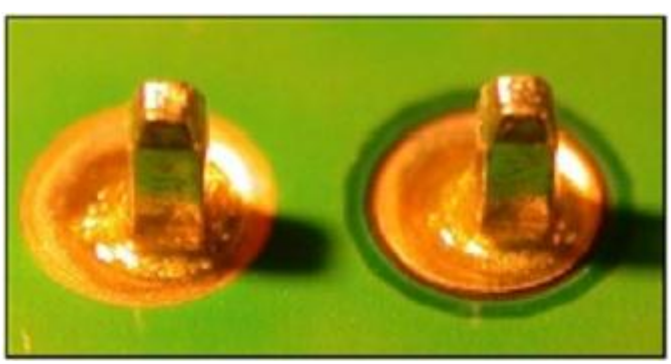

**Figure 5: High-solids flux residue around a through-hole component. [1]**

**Testing Criteria:**
Selective solder machines are used to solder through-hole components to a circuit board using a fine fountain of solder, sometimes as small as 2mm in diameter. This allows for localized thermal transfer to the PCB. Therefore the flux deposited in these areas needs to be activated and burned off during the selective process. This will assure that no active residues are left on the board that can cause shorts to occur later on in the PCB's life.

Hole-fill or barrel-fill is very important when talking about solder results. Each solder joint on every PCB assembly needs to meet Class 1, 2, or 3 criteria, which refers to the acceptable barrel-fill (see IPC J-STD-001 for details). Using a selective solder machine, one is able to apply just enough flux, solder, and heat to achieve their ideal IPC Class solder joint. When trying to achieve topside barrel-fill with a selective solder machine, one is able to dwell on a component with the nozzle, move the board closer to the solder fountain, increase the flow of the solder fountain, and if space permits, use a larger nozzle. Other methods of achieving good barrel-fill include increasing temperatures of the bottom or topside heaters, and localizing the nitrogen and/or solder bath temperatures. With these available parameters, one is able to dial into a repeatable process for fluxing and soldering a PCB. Selective soldering is faster than hand soldering, less stressful than wave soldering, and in most cases, able to produce fewer defects than hand and wave soldering.

Surface Insulation Resistance testing (SIR) is a tool used for characterization testing of a production soldering process, such as selective soldering with a low solids flux. It is a common test for no-clean fluxes to ensure non-conductivity of the flux residue under proper deactivation reflow processes. SIR is also used for examining the electrochemical reactions at different stages of the PCB production process. This is important for understanding how the solder alloy reacts within a PCB assembly within specific flux and process parameters. SIR testing is specifically designed to test for the worse-case scenario of temperature and humidity, and to bring out the activity in flux residues left on the surface of the PCB after the selective solder process is finished. An SIR test can help to dial into the least caustic process for the PCB's assembly, assuring longevity of the solder joints and components. [2]

It is important to use the same parameters for flux application and selective soldering time and temperature when processing the SIR boards to confirm the validity of the process, including flux choice. With the adaptation of the SIR testing process using more realistic atmospheric conditions, including chamber temperature, monitoring, and relative humidity, this test has become not only harder to successfully finish, but also more accurate.

## CONCLUSION:

When choosing a low solids selective soldering flux, there are many aspects of the process that need to be investigated to select the best flux for the process. Like other processes, a "one size fits all" flux is not necessarily the best choice. The flux and the process need to be tailored for the specific product manufactured.

As discussed, the level of detail needed to develop a selective soldering process should at least include the performance of the flux in situ, such as hole-fill, wetting, and SIR testing. Optimizing each flux is imperative to properly assess each of the candidates. For each part of the optimization process, machine choice, flux application, pre-heat for drying of the solvent base, and activation needs to be optimized. With careful selection of a machine, a low solids flux, and processing and testing, a reliable and repeatable process can be developed.

## REFERENCES:

[1] BERNTSON, R.B., Et. Al. (SMT Magazine; August 2004). *Through-Hole Assembly Options for Mixed Technology Boards.* Indium Corporation, 1676 Lincoln Ave. Utica, NY 13502.

[2] BASTOW, K.E. and NASH, C.J. (IPC APEX 2010). *Understanding SIR.* Indium Corporation, 1676 Lincoln Ave. Utica, NY 13502.