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White Residue and Water Soluble Fluxes

Subject: The formation of white residues on assemblies processed with water-soluble fluxes

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Introduction: White residues are often observed on the surfaces of assemblies processed with water-soluble liquid fluxes and solder pastes. These residues vary from milky, often bluish, hazes on the surfaces of solder connections to tenacious white films on solder masks. These residues are composed of fluxing byproducts – metal salts of tin and lead. These salts, which are quite stable, are inert and water insoluble. The nature and amount of these residues depend on the processing conditions, both soldering and cleaning. The amount of white residue remaining on assemblies can be minimized through controlled processing.

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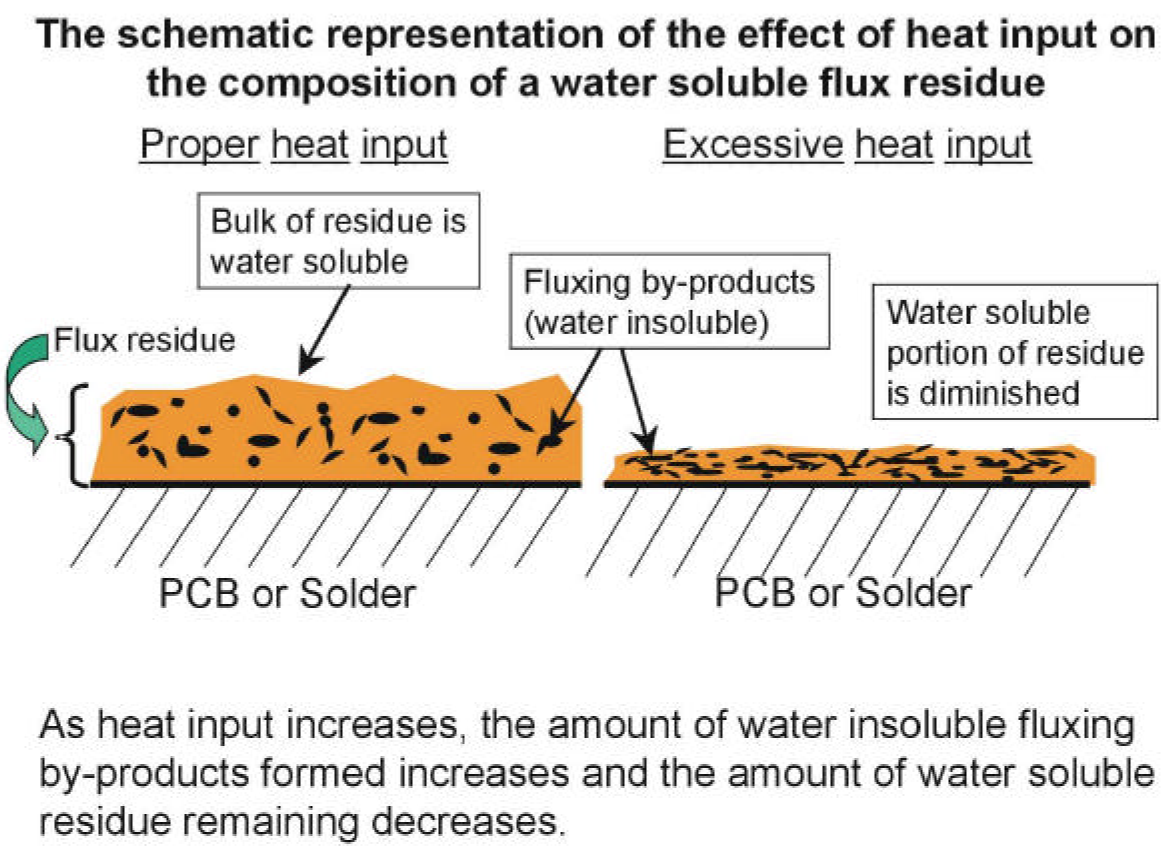
Formation Mechanism: The active ingredients, or fluxing agents, of water soluble fluxes are typically halide containing organic compounds or organic acids. These fluxing agents react with the tin and lead oxides on the solder's surface. The breakdown of these oxides allows the solder to flow and wet the surfaces to be joined. The resulting metal salts are very stable, thus, effectively inert and water insoluble. Despite their water insolubility, under controlled processing conditions most will be washed away during aqueous cleaning. With controlling the process, sufficient quantities of the flux's water-soluble ingredients remain on the board surfaces after soldering and surround the resulting metal salts. This prevents these salts from adhering to the surfaces. During cleaning the water-insoluble salts should be easily removed by the physical action of the water spray.

As heat exposure increases, the likelihood that a visible residue will remain on solder and board surfaces increases. The amount of oxide formed and, thus, the amount of metal salts formed upon fluxing increase with increased heat exposure. Also, the amount of water-soluble residue remaining decreases with increased heat exposure because there is increased volatilization of these ingredients. With a large quantity of metals salts and little water-soluble residue surrounding it, much of the metals salts adhere to the solder and board surfaces, usually quite tenaciously, and remain after aqueous cleaning. The effect of heat exposure on the amount of fluxing byproduct and flux residue is schematically shown below.



Prevention: Proper heat management is key to minimizing the amount of white residue. This includes both the soldering and aqueous cleaning processes. The formation of mechanically and electrically reliable solder connections is the most important part of the soldering process, a process that requires a fair amount of heat input. With proper management of this heat input, it is possible to produce high quality solder connections with minimum white residue formation.

A proper thermal profile for minimizing white residue formation is one that minimizes the amount of oxidation. The amount of oxidation depends on exposure time and temperature. In wave soldering, the boards are in the pot for only a small fraction of the total processing time, so changing pot temperature or pot dwell time will probably have little affect on white residue formation – unless, of course, they are excessive ($T_{pot} > 500$ ºF, $t_{pot} > 5$ s). Preheat temperature and time, on the other hand, could have a great effect on white residue formation. The purpose of the preheat is to put thermal energy into the parts to be soldered and to drive off the volatile portions of the flux. A long dwell or excessively high preheat can lead to excessive oxidation. The heat input during the preheat should be minimized to that necessary to bring the top-sides of boards to 210-230 ºF, depending on the flux, just prior to hitting the solder wave.

In terms of white residue formation, the preheat (or soak) is also important during solder paste reflow. The total surface area of the solder powder in the paste is orders of magnitude greater than that of the pool of liquid produced upon reflow. Therefore, the amount of oxide that can form during the soak portion of the reflow profile can also be great. A prolonged dwell at a fairly high temperature (> 140 ºC) prior to reflow should be avoided. A straight-ramp-to-reflow (no soak) profile is often recommended. This direct heating (at 1-2 ºC/s) to reflow temperatures minimizes the amount of solder powder oxidation during the reflow process. When soaks are needed, a low temperature (~120 ºC) should be used. Soaks also should not extend beyond the time necessary to obtain temperature uniformity.

Exceedingly high temperatures (> 230 ºC for 63Sn/37Pb solder) and long dwells (>75 s) above reflow temperature should also be avoided during the reflow process. Such conditions will increase oxidation of the solder and evaporation of the water-soluble portion of the residue.

High water temperatures during aqueous cleaning can also promote the formation of white residues. Water temperatures near 120 ºF are probably better than the 140 ºF often used. It is recommended that the lowest temperature required to obtain clean assemblies be used.

Assemblies should be washed fairly soon (ideally < 30 min, but no more than 8 hr) after soldering. Even at room temperatures, the metal salts can form on the surfaces of solder covered with active residues. Also, there can be appreciable evaporation of the water-soluble portions of the residue at room temperatures given sufficient time.