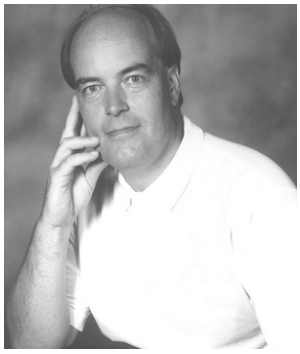
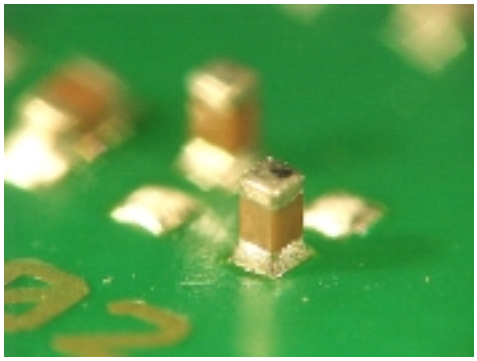
Vapour Phase is Back for Lead-Free Soldering

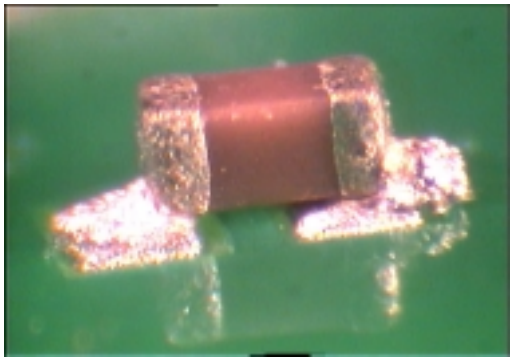


Bob Willis

Vapour Phase Soldering (VPS) has been around in the industry for many years and was one of the only two serious options during the early introduction of surface mount technology. In the early days engineers had the option of brown belt for single sided products, infra red and VPS. The first reflow system used by this author was VPS preferring the simplicity of the process and process set-up over the problems of accurate loading, board belt positioning, profiling and over heating flux residues.

A well designed board worked very well and gave high soldering yields. A poor design particularly on passive components, would amplify the number of lifted and tombstoned components. All vapour phase systems can show a difference in component lift due to the fundamental nature of the process. As the vapour condenses on the surface of the board and turns to liquid component movement can occur. Is this a reason to dismiss VPS? No it's often just an excuse to stick with the poor design. A recent lead-free trial comparing VPS with convection showed an increased number of lifting defects with VPS, but if you only looked at the total PPM levels one may say that VPS was the cause but the defects were all on one component size hence the need for good documentation during design reviews and NPI at contract assembly companies.





Tombstone 0402 chips on VPS but not 0201, incomplete reflow and poor particle coalescence with convection reflow on 0201 chips not on VPS

One lead-free process defect which has been apparent with a number of lead-free trials on 0201 chip resistors and capacitors is not seen with VPS. When soldering 0201 chips on boards with a wide range of other components including QFP, BGA and through hole connectors there can be a large delta T. To optimise the process and decrease delta T the surface of the board including the 0201 paste deposits will often be at elevated temperatures, just below reflow, for long periods. This can cause flux exhaustion prior to reflow leaving incomplete coalescence of all the solder balls as the example shown above and the SEM image below. With modern VPS this does not occur but it did use to happen with old VPS processes when using a secondary vapour layer.

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There is no argument that VPS soldering provides a better wetting performance with tin/lead and lead-free alloys and on different solder finishes when compared to air convection. However the results can become blurred when compared with nitrogen convection. It is often stated that VPS soldering is an inert soldering process and that is true when the board assembly enters the vapour layer. Prior to that, or when the board in some designs is not in a vapour during cooling, this may not be the case.

Vapour phase as a process has always been around as an option in the industry and there will be new engineers that select the process. There will also be existing engineers who will move back from convection to VPS as a solution for lead-free.

It was interesting two years ago to be listen to development staff of a major machine supplier discuss where noticeable improvement in convection technology could come from. There are areas of cooling and energy savings still to be achieved but was a re-launch of VPS the solution?

In the original batch vapour phase system the primary fluid is boiled, and generates a vapour layer. In order to contain this vapour within the size constraints of the holding tank, it was necessary to cover the vapour to prevent it escaping, and this was done with a secondary fluid which also produced a vapour layer boiling at a lower temperature. The condensing coils used cold water running through them at a very low flow rate to recondense the vapour, the fluid then circulated back through filters. Above the primary coil another coil was used to reduce the loss of the secondary blanket of vapour sitting on the top of the primary fluid.

In operation, a basket loaded with assembled boards would be simply lowered through the secondary layer and into the primary. After the work had reached re-flow temperature, the basket would be raised. On the way up, it was allowed to dwell in the secondary blanket, in order to contain primary vapour and fluid. Ideally the board or basket would be very slightly angled to allow condensed fluid to run off. The basket would then be raised out of the machine and allowed to cool.

The following are a listing of some materials which were available originally for use in vapour phase units.

Manufacturer	Liquid type	Boiling point
3M	FC70	215oC
3M	FC5311	218oC
Montedison	Galden LS	228oC
Montedison	Galden HS	255oC

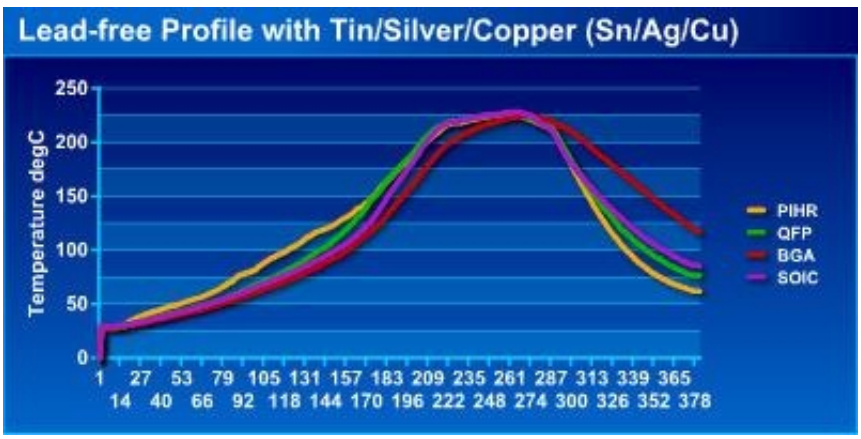
Today the supplies are limited and the primary material for lead-free may be either 230 or 240oC Galden material available in the UK from Solder Connection www.solderconnection.co.uk

It can be seen that it is perfectly feasible, by using more than one Vapour phase system, to carry out sequential soldering processes at different temperatures. This may be a benefit to some companies and often for non PCB applications. A point on the cost of these Liquids, they cost in the region £70-80 per kilo). Due to this cost, it is clearly imperative that the design of the machine that is to be used with these fluids should be maximised in terms of not allowing vapour or fluid loss from the system. A typical batch process is quoted with a running cost today of between £2-3 per hour. This also means that the PCB design should not have, for instance, any fluid traps which could carry this extremely expensive fluid out of the system. It should be remembered, that the only reason for the secondary layer on older machines, was a "sacrificial blanket", to prevent the loss of the primary vapour. In the batch and in-line vapour phase systems of today, systems do not have a secondary vapour blank.

From a profiling point of view the goal is to solder joints with the minimum delta T across the board and at the lowest peak temperature. Minimise the time joints are in a liquid state and control the speed of temperature rise to reflow. Gone are the concerns of damage of the boards due to excessive temperatures. Care does need to be taken on fixturing of small or light boards on carriers. If they are lost into the boiling sump there is no way to retrieve them until the fluid cools. In the case of designs which employ a heated plate for vaporising the fluid as opposed to the traditional sump systems retrieval may be easier but still not recommended.

Examples of the new VPS designs from IBL represented in the UK by AD Automation both batch and inline systems

There are still differences in the delta T on the board surface and under components but it is very small at the peak temperatures provided the time is allowed for the profiles to converge. The initial temperature rise through preheat does have recordable differences just like convection but can be smaller depending on the machine design.



The profile above shows the temperature cures for double sided product featuring fine pitch, BGA, 0603, 0201 and intrusive reflow connectors

Cooling can still be a delay in the process just like standard convection reflow. However new developments in liquid cooling will benefit the industry and may provide a solution to fillet lifting on lead-free through hole joints which does occur. Fillet lifting is probably the only new process defect associated with lead-free. It does not seem to affect reliability but it is difficult for quality staff to accept its existence.

A new interactive CD-ROM on “Lead-Free Hand Soldering and De-Soldering“ has been developed by Soldertec. It is one of three training CDs covering lead-free reflow, wave and hand soldering and will be released in November. The Reflow CD covers the use of VPS.

Bob Willis is a process engineer working in the electronics industry, providing training, consultancy and product failure analysis. Bob offers workshops on lead-free on site for customers. He runs production lines for suppliers at exhibitions and also provides seminar and workshops worldwide. For further information on lead-free training workshops, training materials and lead-free process support visit www.leadfreesoldering.com

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