

## LESS IS MORE – VAPOR PHASE – QUALITY IMPROVEMENT UNDER OXIDATION FREE SOLDERING CONDITIONS

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### ABSTRACT:

Due to the switch to lead-free, high packing density, extrem mix of light/heavy components manufacturers are faced with multiple new challenges. Simple processing, successful soldering for various products, high quality and user-friendliness are the basic requirements that current soldering systems have to provide. Vapor phase soldering meets these demands. However, individual systems vary greatly when looking at important details.

Vapor phase soldering systems feature cutting edge technology with their fully flexible temperature gradient control (DYNAMIC PROFILING), oxidation free atmosphere, low peak temperature (230°C max. lead free), zero delta T. These systems provide process reliability and repeatability especially for very complex soldering application.

Vapor phase soldering was developed by Western Electric, Princeton, in the beginning of the Seventies. Those systems were based on the two-phase-technology. Due to high loss of medium a secondary medium (often CFC) was initiated over the primary vapor layer. The ban of CFC around 1990 led to the end of these 2-phase-systems and caused success of infrared and convection soldering. However the disadvantages of the infrared and convection technology, such as different warm-up time of components with varying heat requirements, high peak temperatures, oxidation caused this technology to reach its limits for challenging products. The past years have seen increasingly complex assemblies (e.g. layout, differences in mass) which pose challenges to the soldering technology that are becoming more and more difficult for convection soldering to overcome. Vapor phase soldering was introduced once again. Today backplanes can have up to 96 layers, carbon fibre or metal core, inner cooling layers etc. The risk of a thermal damage during thermal treatment is always present with convection technology.

Today's state of the art single-phase vapor phase provide the solutions needed for lead-free soldering in combination with

a very challenging product design and requirements for a void less solder joint.

Why is Vapor Phase growing, and at what point should CEMs/OEMs consider Vapor Phase as an appropriate alternative to the convection systems most CEMs use and many OEMs themselves still employ? The answer is:

- Zero overheating
- Zero delta T
- Low voiding potential
- Oxygen free environment
- Superior joint integrity
- fully flexible profiling
- vacuum capability
- Fast start - 20 minutes from cold start
- Operational energy efficiency - 60% better than convection
- Low volume product run flexibility (high mix/low volume)
- Complex board design/heavy products/many layers
- Environmental safety
- Competitive cost of ownership
- Reliability of the end product

### Vapor Phase Working Principle In Comparison With Convection

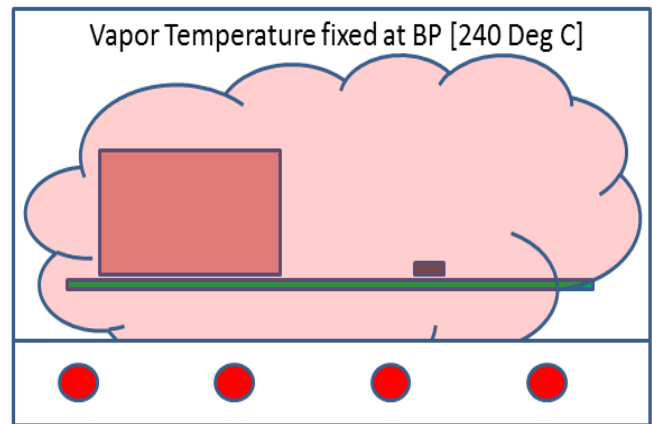
The process is brilliantly simple, and can be compared to a boiling pot of water on the stove top – but rather than water a Perfluoropolyether (PFPE) fluid is used (hereinafter referred to as “fluid” or “medium”). PFPEs have high boiling points between 200° - 260° C that can be selected to meet the needs of the alloy being used to solder the board. This, as with a pan of water, limits the maximum possible temperature any component can be exposed to in an absolute physical manner, rather than by a machine's program parameter. This eliminates a source of process control error. The use of an inert fluid with a specific boiling point [230 deg C for example] ensures the

circuit and all of the components mounted on it cannot reach a temperature in excess of 230 deg C.

The second element of reflow profiles is time. With the vapor phase system the process duration is a simple two step profile – immersion period followed by the cooling period. The immersion period is determined by the size and mass of the circuit being reflowed. The larger the circuit the greater the energy needed to raise its temperature to the 240 deg C level. Heat transfer in a PFPE inert environment is significantly better than a gaseous environment. PFPE's have a higher specific heat capacity and so per unit volume of vapor they carry a greater energy load. They also have a higher thermal conductivity so they are more efficient in the transfer of the energy from the vapor blanket to the circuit board and the attached components. This level of thermal efficiency also means the process is very energy efficient.

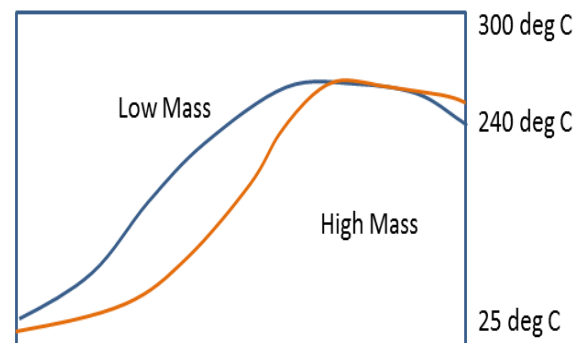
Typical power usage when evaluated against a comparable convection system is less than 60% and start times are just 20 minutes from cold.

Vapor Phase operates in an Oxygen free environment and by its very nature the process places less stress on the flux chemistry than any other system. It gives the OEM or CEM the option that active agents in the flux might be reduced. The functions that fluxes are designed to play can be exploited to the full extent in a Vapor Phase machine because the maximum temperature limit is determined as the boiling point of the fluid which protects the fluxes from excessive thermal stress. (Figure 1). Source Temperature is no higher than the needed energy level to boil the fluid and create a vapor blanket. In a complex PCB the small parts on the panel will heat faster as they have less mass but they will not exceed the desired temperature peak and so will never oxidize.



**Figure 1.** Vapor Phase Fluid BP determines peak temperatures for ALL components.

Component rate of temperature increase (Fig. 2) is affected by mass, materials and situation on the panel. In a Vapor Phase process its peak temperature cannot exceed the boiling point of the fluid and so cannot overheat.

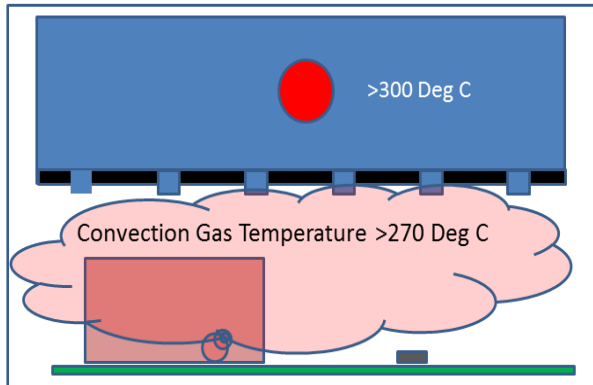


**Figure 2.** Ramp rates in vapor phase will vary with extreme components but peak temperature convergence is assured.

It is not uncommon in a convection system processing a high mass/high mix PCB for fluxes to become exhausted around smaller components as they reach elevated temperatures in the period of dwell while waiting for the high mass parts to reach an adequate peak temperature. Good joints can quickly become bad joints when elevated temperatures increase the surface reactivity in the joint in an oxygen rich environment. So today the Vapor Phase process benefits the mission critical product companies as well as the manufacturers who have a high mix / low volume customer base.

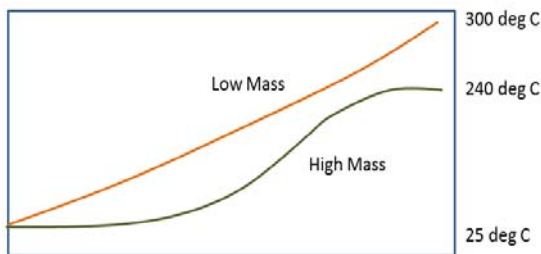
The heat source radiates energy at a higher temperature than the air flow and air temperature is higher than desired peak temps. In a complex PCB the small parts on the panel will continue to heat above their suggested limits

and be exposed to oxidation and stress. Fig. 3 shows the divergence of temperature from heating source to product in a convection oven.



**Figure 3.** Convection soldering - Excessive source temperature can affect low mass parts

Radiated peak temperatures and actual distributed air temperatures will affect the peak temperature reached by lower mass parts, often >260 deg C (Fig. 4)

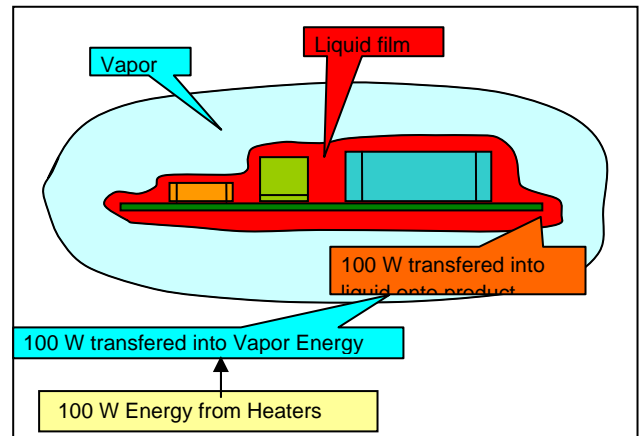


**Figure 4.** Convection soldering - Peak temperature extremes

### Controlled Soldering in Saturated Vapor

The vapor phase process zone is located directly above the medium container. The medium is heated by heating plates and generates a saturated vapor layer directly above the medium fluid. As the vapor is heavier than air it cannot elude up in the system. When the product enters the vapor zone the saturated vapor layer collapses. The vapor condenses across the entire product surface; immediately forming a closed film of fluid around the product. Contrary to older vapor phase systems the system control prevents sudden exposure of the product to too much energy. Surface tension of the fluid film and its capillary forces eliminate any air from the product. A safety layer is formed that ensures completely oxygen-free soldering. After leaving the vapor zone this fluid film evaporates completely, leaving no residues on the product.

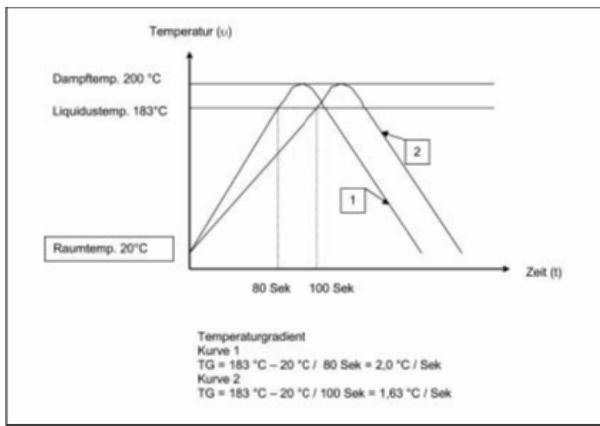
The saturated vapor layer lies directly around the fluid film. By introducing an energy amount corresponding to the required temperature gradient via heating elements, an amount of saturated vapor is generated equivalent to this energy. This specified amount of vapor now condenses into the fluid film and transfers a precisely defined amount of energy into the fluid film during condensation. Its energy concentration increases accordingly as does the temperature of the product enclosed by the fluid film. Following the laws of physics the energy introduced into the fluid film is distributed evenly across the entire product.



**Figure 5.**

This ensures continuous and homogenous heating of the entire product. The process continues until the temperature of the product equals that of the vapor. When the temperature balance is achieved condensation stops automatically.

This concept therefore allows for precise temperature control of the product by accurately controlling the energy supply. When soldering in saturated vapor the vapor temperature cannot exceed the boiling temperature of the medium. This physically eliminates the possibility of overheating an assembly. All kind of temperature profiles like linear, or ramp to spike profiles can be done very easy and repeatable.



**Figure 6.** Example Variable linear temperature gradient

In addition the vertical structure of systems working with saturated vapor allows the operator to identify the end of the soldering process at all times; irrespectively of the specific product. The soldering process can be finished as early as possible. Therefore an assembly can never remain above liquidus too long. Contrary to horizontal systems those designed vertically eliminate the need for elaborate pumping actions and mechanical methods for vapor-tight closing and opening of the process chambers, and therefore do not cause a noteworthy increase in cycle time.

As the vapor layer is heavier than air, a vertical construction also provides for a well-defined vapor layer, ensuring process stability. In order to avoid turbulences when dipping the product into the vapor layer, special care was taken when designing the control system. The possibility of choosing any user-defined temperature gradient setting provides optimum pre-heating of the product.

During each run the temperature profile is measured and can be stored for controlling or traceability purposes.

#### **Heat Transfer Fluid Galden®**

Galden is a liquid polymer. These fluids are the ideal medium for the vapor phase soldering process.

The vapor density of Galden fluids is much higher than that of air and therefore these fluids guarantee that the complete preheating and soldering process takes place in an inert atmosphere. Galden fluids evaporate quickly from the hot surface resulting in rapid, residue free drying of the parts. Galden fluids exhibit high chemical and thermal stability.

With the increasing use of vapor phase soldering in production environments, greater emphasis is being placed on the nature of the primary fluid selected with respect to safety, consumption, cost-effectiveness, temperature selection and stability, and system compatibility. These parameters are to some extent linked to the type and choice of vapor phase machine but are also governed by the physical properties of the selected fluids. The specific properties of Galden fluids make them particularly suitable for use in vapor phase heating applications.

#### **Conclusion**

Modern vapor phase soldering systems based on newest technologies have eliminated the disadvantages inherent to early condensation systems.

Vapor phase soldering offers best reflow thermal treatment technology for all kind of high tech soldering application.

By employing saturated vapor not only for the heating but also the pre-heating phase, any risk of oxidization is eliminated. In addition, precise medium temperature settings eliminate overheating of the product in any stage of the soldering process. Variable temperature gradient control provides optimum pre-heat and soldering for any product. If also a VACUUM or even MULTIVACUUM Process is intergrated into the Vapor phase soldering process best possible and void free quality of soldering is ensured.

#### **RESOURCES:**

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