Vapor Phase Soldering Technology

Secure Lead-Free Processes and Minimize Delta T's

Due to the switch to lead-free 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 considering important details.

By Claus Zabel and Uwe Filor

Asscon's vapor phase soldering systems feature cutting edge technology with their variable temperature gradient control in saturated vapor. These systems provide process reliability and repeatability.

Vapor phase soldering was developed by Western Electric, Princeton, in the beginning of the Seventies [1]. Those systems were based on the two-phase-technology. Due to the high loss of the 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 temporary success of infrared soldering. However the disadvantages of the infrared technology, such as shadowing, color sensitivity, different warm-up time of components with varying heat requirements, soon caused this technology to reach its limits [2].

Convection soldering took its place and became the soldering technology of choice for industrial manufacturing for many years. The past years have seen increasingly complex assemblies (e.g. layout, differences in mass) which pose greater challenges to convection soldering technology that are becoming more and more difficult to overcome (Image 1). Vapor phase soldering was introduced once again. These challenges are made harder by the elevated temperature demands of Lead Free processes. Newly developed single-phase systems now provide the solution needed for lead-free soldering.

Vapor phase soldering has undergone essential developments. The result is the current technology – soldering under saturated vapor with variable control of the temperature gradient.

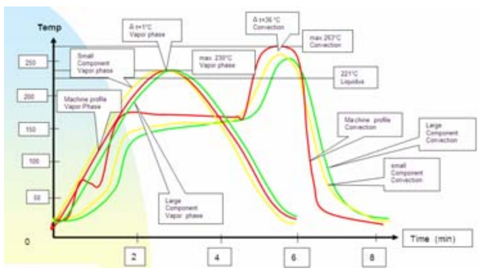

Image 1 Comparison temperature gradient vapor phase and convection

Vapor phase soldering without controlled thermal output

The first simple design generated a homogenous vapor layer of saturated vapor. Even with assemblies of very high mass this uncontrolled vapor production caused problematically high initial gradients [3]. To decrease this disadvantage pre-heat was generated via infrared heat radiators. However, this leads to oxidization of metallic components. Then as now this critical fact has to be avoided. One method was to conduct pre-heating by briefly dipping the product in the upper saturated vapor layer [4].

Compact
How can we successfully eliminate the disadvantages of early condensation systems, of soldering with unsaturated vapor and of the injection method? Vapor phase soldering systems with variable temperature gradient control in saturated vapor prevent oxidization. In addition, precise medium temperature settings eliminate overheating of the product. Variable temperature gradient control provides optimum pre-heat and soldering for ***any*** product.

The appropriate dipping depth needs to be determined for every product. If the product is dipped too deep, it will be heated to quickly and if it is not dipped deep enough pre-heating is not sufficient. And there is no satisfactory answer for the correct dipping height for simultaneous soldering of different assembly types. Trials to solve these process uncertainties by repeated dipping at low height did not prove satisfactory.

Consequently this early system technology was not considered as fully developed, leaving room for significant improvements [5].

Intermediate Stage: Injection method

Initial experiments during the 90s to eliminate the shortcomings of early vapor phase systems lead to the injection method. This method is based on a patent by Prof. Rahn [6], and used in the first modern soldering systems [7]. A predetermined amount of medium is dispensed onto a heating plate and then abruptly vaporized to pre-heat the product. The peak zone is reached by a subsequent main injection.

Excess medium is exhausted after the soldering process. With this injection method multiple parameters need to be adjusted, such as volume of medium, injection and soldering time, heating plate temperature and medium temperature. In addition the required vapor overheating reintroduces one of the critical disadvantages of convection soldering into the process - oxidization. And besides such process related problems, these systems require significantly higher operation and maintenance cost.

Controlled Temperature Gradient in Saturated Vapor

In the late Nineties injection soldering was replaced by systems with variable temperature gradient control. Contrary to the injection method this technology employs saturated vapor and combines the important benefits of vapor phase soldering to provide a stable and repeatable soldering process.

This 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 controls prevent sudden exposure of the product to too much energy. Surface tension of the fluid film and its capillary forces displace any air from the product. A safety layer is formed that ensures completely air-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 emits 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 **(Image 2).**

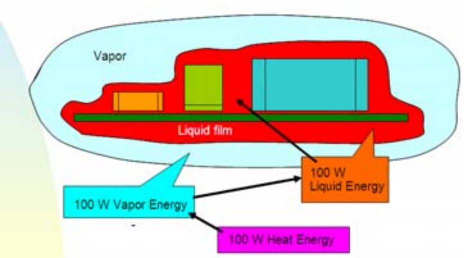

Image 2 Energy flow in a vapor phase

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 **(Image 3).** Unlike the injection method, 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.

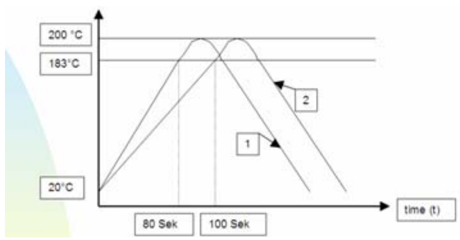

Image 3 Example: Variable temperature gradient

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.

Conclusion

Asscon's vapor phase soldering systems based on the newest technologies **(Image 4)** have eliminated the disadvantages inherent to early condensation systems, soldering with unsaturated vapor and injection systems.

Image 4 Asscon VP 2000 inline

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. The intelligent, but mechanically simple vertical structure of today's saturated vapor soldering systems allows for automatic identification of the end of the soldering process.

And finally one of the most important benefits: As almost all other process parameters remain constant when soldering in saturated vapor, the only parameter an operator needs to set is the required temperature gradient. The technology does not require setting multiple parameters as is necessary when soldering by injection or with unsaturated vapor. Therefore saturated vapor soldering with variable temperature gradient adjustment achieves maximum process stability and repeatability – factors that are especially important when considering today's switch to lead-free manufacturing.

Literature

[1] Deutsches Patenta mt Auslegungs-
schrift 24 42 180; AZ: P 24 42 180.5-24

[2] R. J. Klein Wassink, Weichlöten in der Elektronik, 2. Aufl. 1991, Kap.10.5.3, S.596.

[3] W. Leider, Dampfphasenlöten, 2002, Kap. 7.1,S.43.

[4] FSL Deutschland GmbH, MRT Vapour-phase-System MRT, Dieburg 1992.

[5] Elektronik, 2. Aufl. 1991, Kap.10.5.3, S.596.

[6] Deutsches Patentamt, Patent Nr. DE3873321 T2.