PHASE CONVECTION™: THE LEAD-FREE SOLUTION

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In Europe, the Restriction on Hazardous Substances (RoHS) Directive prohibits the use of lead in electronics beginning July 1, 2006. At the same time the lead-free initiatives of Japanese manufacturers, putting pressure to eliminate lead in electronics assemblies is increasing. Transition to lead-free is accelerating and when considering constraints related to lead-free and conventional solder pastes, one concern is rising: flexibility. It would be dangerous to commit to lead-free only while the technology is not yet stabilized. Manufacturers need to consider all of the issues related to lead-free and need to find flexible equipment which are able to adapt to both conventional and lead-free constraints.
Soldering has been traditionally seen as a non value added process but is becoming critical when speaking of the transition to lead-free.
This transition to lead-free and the lack of flexible high-end ovens in the SMT soldering market led ViTechnology to innovate and to launch the revolutionary new Phase Convection™ technology, under the brand name eXelsius™. The Phase Convection™ technology brings better flexibility, enhanced productivity and lower cost of ownership.

The requirements of the lead-free process have revealed new constraints in addition to the existing issues related to the soldering process. All of those constraints come down to the following basic rules:

- Reduction of the ΔT°C on assembled PCB's because lead-free alloys require higher liquidus temperatures which is getting closer and closer to the maximum temperatures allowed by components manufacturers.
- Need to improve effectiveness and ease-of-maintenance of the flux trap systems because of higher contamination due to the increase of the organics portion in the alloys composition and to decrease downtimes.
- Ensure PCB's integrity despite the going above and beyond the Tg.
- Need for increased flexibility, including that of the manufacturing equipment, to better answer quick shift turnaround in production due to low volume high mix.
- Need for enhanced quality control throughout the soldering process due to the narrower process window of lead-free.

All of these constraints have led to an evolution of reflow ovens which are becoming longer and longer, with an increasing number of zones and parameters. With these equipments, the set up of reflow profiles is becoming more and more complex and complicated and the control of the process is essential to reassure final customers!
Existing in-line ovens are thus giving quite good results as solutions have been developed to answer the constraints enumerated before but the industry is still seeking for the best compromise between performance, flexibility and cost of ownership. The solutions known today are short term solutions which allow current technology to work within the narrow process window required by lead-free but they cannot give entire satisfaction as they all have drawbacks related to quality, flexibility or cost of ownership. These are a few examples of limitations in regards to the thermal dispersion of the new ovens is concerned:

- Increasing the length of the oven enables to decrease the thermal dispersion but the ovens footprint increases in an environment where space is expensive and line layouts not very flexible.
- Increasing the convection speed is another solution but it can cause components to move and it increases Nitrogen Consumption.
- Create gas barriers between the zones but these barriers generate disturbances on the convection process.

The revolutionary new technology developed by ViTechnology, Phase Convection™, is the only solution available today to answer manufacturers' needs for better flexibility, better productivity, lower cost of ownership, enhanced quality control and, of course, better thermal performance.

PHASE CONVECTION™: THE SOLUTION TO CURRENT AND FUTURE REFLOW ISSUES

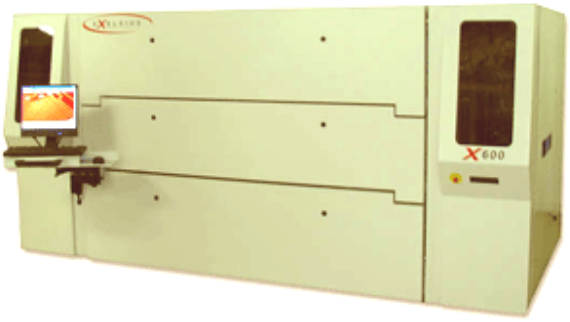
For many years, different companies in the reflow market had tried to find a solution to all of the issues relating to current Reflow ovens. Requirements included:

- Reduced floor space
- Higher throughput with increased flexibility
- Excellent temperature homogeneity
- Elimination of conveyor warpage and distortion
- Closed loop temperature control with pyrometers

- Reduce electrical and nitrogen consumption
- Self-cleaning system
- Environmentally friendly

The new technology of Phase Convection™ meets ALL of these requirements and many others. It has been described as being a technology, which has all of the advantages of Vapor Phase technology (which it isn't), but without the disadvantages, such as using liquids, low throughput and tombstoning of small chip components such as 0402 and 0201 and is in fact using convection.

Figure 1. eXelsius™ X-600 Phase Convection™ System

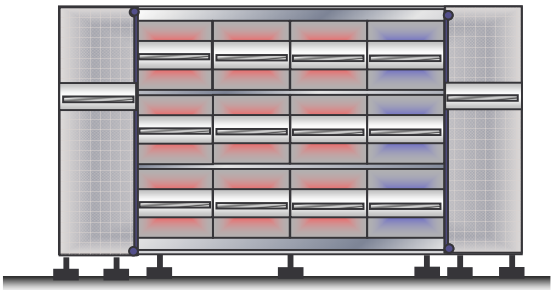


REDUCED FLOOR SPACE

The X-600 Phase Convection™ system from ViTechnology has the smallest footprint of any oven in its category. The system is only 3.35 meters in length, including the loading and unloading systems on each side. This reduced length would be the technical equivalent of a 24 zone conventional reflow oven.

The system is designed with two loading and unloading lifts, one at the entrance and one at the exit of the system. These are used to load and unload the boards, boats or strips into and out of each of the three stacked Phase Convection™ levels. Each of these 3 levels is made up of four Phase Convection™ units that are each controlled individually. This is not a vertical oven which have proved their inefficiency in the past, but a completely new revolutionary design for a new revolutionary technology, Phase Convection technology™.

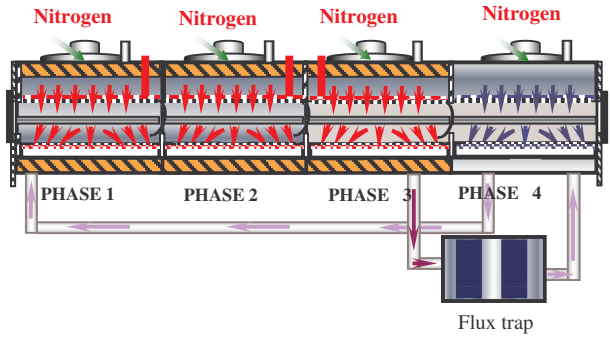
Figure 2. eXelsius™ X-600 lay-out



HIGH THROUGHPUT WITH FLEXIBILITY

The four Phase Convection™ levels can each receive up to four or eight boards at a time depending on the board size, taking one or two in each of the phase units at a time. By loading each level one after the other (FIFO), a total of 12 (24 if small boards and / or boats) can be processed simultaneously. This offers excellent throughput and productivity. As each of the "Phase Units" and each of the levels are all controlled individually, different profiles can be run on each level if required, offering total flexibility of the system.

Figure 3. X-600 level detail

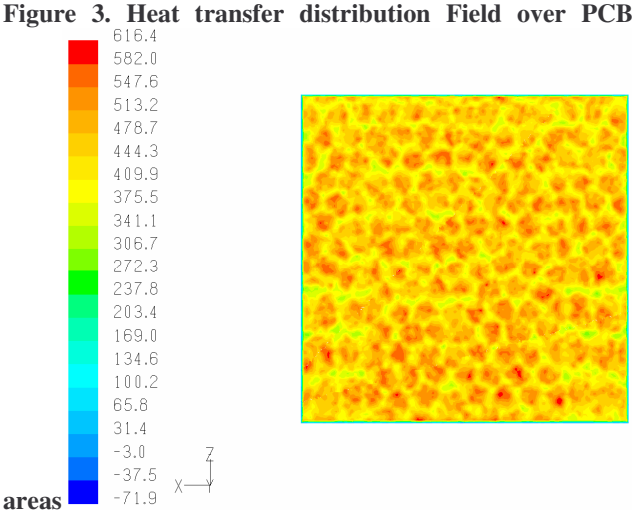


UNPARRALLELED TEMPERATURE HOMOGENEITY

Each level has 4 convection phases, 3 heating phases and 1 cooling phase. The PCB moves from one to the other phase thanks to an advanced technology board transport system specifically designed for this application. The PCB remains static during each phase time which corresponds to pre-heating, soak, reflow and cooling phases.

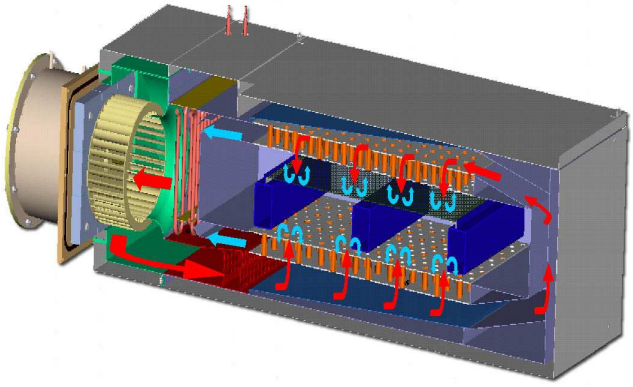
The static state of the PCB within a chamber which is uniform in temperature enables to heat the whole PCB area at the same time, thus eliminating the temperature gradient between the beginning and the end of the PCB as usually demonstrated on standard reflow ovens. This temperature gradient on standard ovens causes board warping, solder joint weakening and adversely affects temperature heterogeneity.

Figure 3. Heat transfer distribution Field over PCB areas



The physical separation between each of the heated and cooling phases added to the thermal breaks along the patented board handling system avoids edge effect from zone to zone and heat transfer between zones. On standard reflow ovens the conveyor rails cause transverse temperature heterogeneity, although balanced thanks to side heating modules on some reflow ovens.

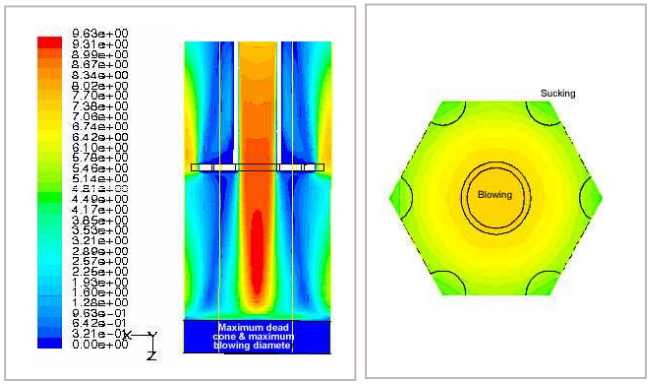
Figure 4. X600 Patented Convection Design with Limited Cross-Flow



The patented top & bottom forced convention device, with reduced cross-flow, enables homogeneous and efficient heat transfer on the PCB area. The layout, design and distribution of the convection nozzles has been developed to make the impact cone of the hot air on the PCB the most homogeneous as possible and to make sure that the areas of impact of each cone are perfectly adjacent. Thanks to this distribution of the convection nozzles, the air which gets cooler on contact when heating the PCB does not flow on or over the board but returns toward the fan. All of these parameters, including the convection nozzle diameter, their distribution, the distance between the blower unit and the PCB, have been mathematically simulated in order to be fully optimized and have been patented.

This distribution enables a very low temperature gradient between the heated air and the PCB at the end of each phase, and an optimized thermal transfer to limit thermal dispersions depending on the component mass.

Figure 5. Thermal Efficiency and Thermal Uniformity

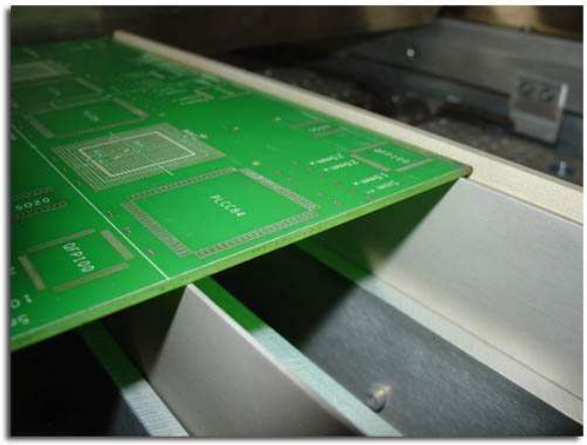


This feature, an industry first, enables to process a large number of different PCBs with the same profile. The Phase Convection™ technology brings to the X600 an important degree of flexibility and gives the opportunity to reduce the number of qualification procedures as well as the requirement for manufacturing control.

PATENTED BOARD HANDLING SYSTEM

This Patented board handling system was adapted specifically for the Phase Convection™ technology. It ensures quick transfer of the PCBs from one phase to the other with no vibration and brings versatility: ability to support a board of less than 20 mm width and a technical edge of less than 5 mm, ease of use when positioning the board support systems and the ability to easily use the same system for dual lane applications.

Figure 6 Board Handling System

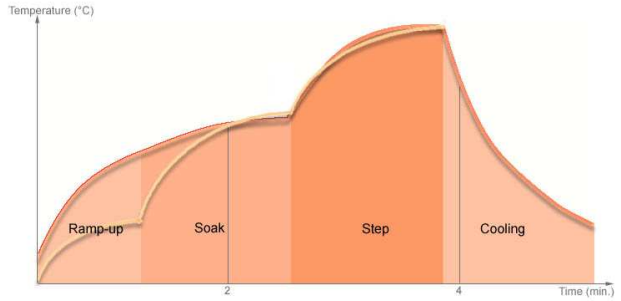


FOUR PHASE CONVECTION™ UNITS

The four Phase Convection™ units of the three levels can each be controlled totally individually. The board enters the first Phase Convection™ unit where the board is heated slowly respecting the temperature ramp up velocity of the components. The board is heated until it reaches the soak

temperature required by the programmed profile. Once achieved, the gate between the first and second unit opens quickly and without any adverse effect on the profile to allow the board to move into the second Phase Convection™ unit.

Figure 7. Examples of Phase Convection™ Profiles



The board then enters the second Phase Convection™ unit, where it is maintained at the soak temperature for the required time within the set profile. Once the correct time and temperature have been reached, the board will move to the third Phase Convection™ unit where the turbo convection is used to ramp up the temperature quickly to the reflow temperature. This offers a better thermal segregation between the soak temperature and the peak ramp, as is often necessary according to certain lead free applications.

Once the reflow temperature has been reached and the solder paste is above liquidus, the gate between the third and fourth Phase Convection™ unit opens to allow the board to pass into the cooling unit. Once inside the cooling unit, the cooling airflow allows the board to be cooled at whatever speed required. The whole board area is cooled uniformly which limits risk of board distortion and solder joints weakening. Using this cooling phase the exit temperatures of the board are well below anything able to be achieved by conventional ovens.

STATISTICAL PROCESS CONTROL

The convection system is totally closed loop and the regulation of the temperature is achieved using pyrometers in each phase unit. The Pyrometer measures the exact temperature on the PCB not only the air flow around it. In a normal reflow oven both the air and the board are moving and the regulation is made depending on the temperature of the airflow within the tunnel and the speed of the conveyor. Here, the board is static, the airflow is closed loop and the regulation is made in relation to the exact temperature on the PCB and not of the surrounding air.

Because the units are self contained and the convection units are closed loop with no outside connection or perturbation, the Nitrogen Consumption, when Nitrogen is used, is reduced by up to 50% with a very low oxygen levels throughout the oven.

The fact that the regulation is carried out using Pyrometers measuring the exact temperature on the PCB, this data can be collected in real time. This allows a full SPC capability in the software, which collects the exact temperatures and profiles that each board has been subjected to and stores them for SPC trend analysis and tracking. If a board is not seeing the correct temperatures due to the Boat or other thermal issues, the temperature can be increased in real time, offering closed loop process control.

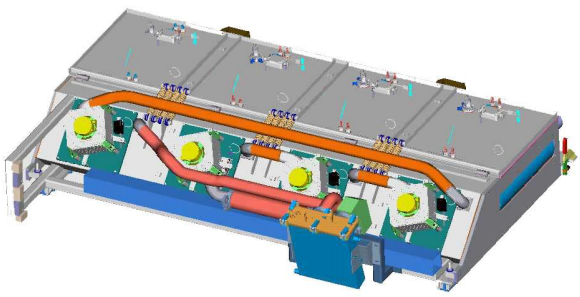
FLEXIBILITY & COST REDUCTION

Phase Convection™ is the most flexible technology available today, not only by the fact that the temperature is closed loop and controlled by Pyrometers measuring the board temperature, but by the architecture of the system. The four Phase Convection™ units allow the maximum temperature and profile flexibility for each level and can be programmed totally independently. However each level is also independent to the other two and can be programmed individually. With the programmable input and output units, we could even imagine that boards of different sizes could be used at the same time. An additional advantage is that if one or two levels are not needed due to a reduction in the throughput requirement, that one or more levels could be turned off, reducing electrical consumption. Of course another added advantage is that the oven can be started up level by level therefore reducing the current needed at the start-up of the system. Many companies are obliged to increase the power installations in the factories just to handle the start-up currents for reflow ovens which are also expensive to install and maintain.
To lower downtimes, one feature of the Phase Convection™ X600 oven is to set up a new process on one level while working on the two others.

SELF-CLEANING SYSTEM

A major advantage to new Phase Convection™ technology is the fact that the system has a built-in flux cleaning system which makes sure that each of the phase units is kept clean and free from any flux contamination. The air is recuperated after the heated phase unit and passes through a flux capturing unit on each independent level.

Figure 8. Phase Convection™ Level with flux recuperation unit.



These flux-capturing units collect the flux residues at all times during the use of the oven. Each of these flux capturing systems are connected to the flux cleaning system which is closed loop and which cleans the flux out of the flux capturing units into an easily changed flux residue collector at the bottom of the oven. The liquid in this flux collection unit needs to be changed once a week, reducing maintenance downtime of the system to less than 5 minutes per week. Once cleaned completely, the air is then recycled into the cooling phase unit before being sent back into the heated Phase Convection™ units.

ENVIRONMENTALLY FRIENDLY

The Phase Convection™ oven is totally closed loop and has no direct contact with the outside environment. This results not only in the low nitrogen consumption levels but also eliminates the need for an external exhaust for the system. No more contamination into the environment or into the direct area around the unit. No need to install costly extraction units etc. By eliminating the need for an external exhaust, this is the first oven to meet all environmental regulations for the future ISO 14000 specifications. This of course means tremendous advantages for clean room applications, which have always been an issue for conveyor type ovens.

LEAD FREE SOLDERING

One of the newest challenges facing our industry is the reflowing of lead free solders that have two major issues, higher reflow temperatures and increased flux contamination. Using Phase Convection™ technology, it is possible to heat the board to temperatures well above those required for lead free solder paste. Standard ovens have difficulties reaching these higher temperatures without issues with conveyors, reduction of the lifetime of the heaters, temperature uniformity and flux contamination. Phase Convection™ even at much higher temperatures is a technology that is controlled and clean!

CONCLUSION

Phase Convection™ is a real revolutionary breakthrough in soldering technology which the industry has been waiting for to meet the challenges of throughput, floor space and of course the environment. This technology offers amazing advantages for the reflow market due to the lowered Nitrogen consumption, temperature uniformity, Pyrometer control and cooling temperatures at the exit of the oven. As the technology is also able to handle much higher temperatures without added contamination, it is ideal for lead free soldering. The additional advantages of reduced floor space, self-cleaning, reduced downtime; no external exhaust, easy maintenance and being environmentally friendly make it a technology, which will set the standards for many years to come.

ADVANTAGES OF PHASE CONVECTION™

- Reduced floor space by up to 50%
- High flexibility
- Increased temperature uniformity
- Closed loop system
- No external exhaust
- Pyrometer control
- Self-cleaning
- Reduced downtime
- Environmentally friendly
- High throughput
- Oxygen or Nitrogen functionality
- Lead Free Soldering