Maximizing process control with controlled convection rates

Process engineers, who are seeking to achieve the most effective and reproducible thermal transfer process, look to today's forced convection ovens for applications such as flip-chip, BGA, and lead-free soldering. A forced convection process to maximize thermal uniformity can be best accomplished by employing static pressure generation in what's known as 'closed loop convection'.

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Introduction

Today's convection ovens are equipped with several key control elements. One is temperature, obviously. Another is belt speed. A third is the gaseous atmosphere used. Convection control is an additional, albeit optional, means of control that directly impacts heat transfer efficiency. The more controls the user has at his disposal, the more means he has to adjust for variations in his process. The more controls an oven can offer, the more overall control, repeatability and increased reliability can be accomplished, leading to improved yields.

Closed loop convection

Closed loop can be defined as a system providing continuous feedback and measurement of convection rates under control with adjustments being made, as necessary, through the operating software. Static pressure set points are input into the software and static pressure is continuously monitored via pressure transducers. Pressure is continuously maintained by utilizing the oven controller and blower frequency controllers.

Closed loop convection provides the ultimate process control, able to maintain constant heating and cooling transfer rates. It ensures real repeatability and facilitates ease of recipe and process transfer, so profiles developed in one location can be transferred to a processing facility nearby, in another country or on another continent, and not be influenced by variations in temperature, voltage or even altitude.

For example, a closed loop convection control can compensate for variations in motor speeds, providing the same convection rate at 50hz or 60hz, regardless of voltage variations. It can also compensate for differences in altitude at which the oven may be operating – at sea level or at a mile high – so that its convection profile will be the same in Singapore as it is in Denver.

The closed loop convection control option, monitors convection rates using static pressure in the oven's blower plenums and applies the signal to frequency controllers, which vary the blower speed of designated zones. This type of additional control, which is applicable to both heating and cooling zones of the oven, is the most accurate method available for controlling the convection rate, and affords the widest range of control. This is particularly so when it comes to use of lead free solders requiring higher thermal transfer rates and the processing of outsized boards providing little head room.

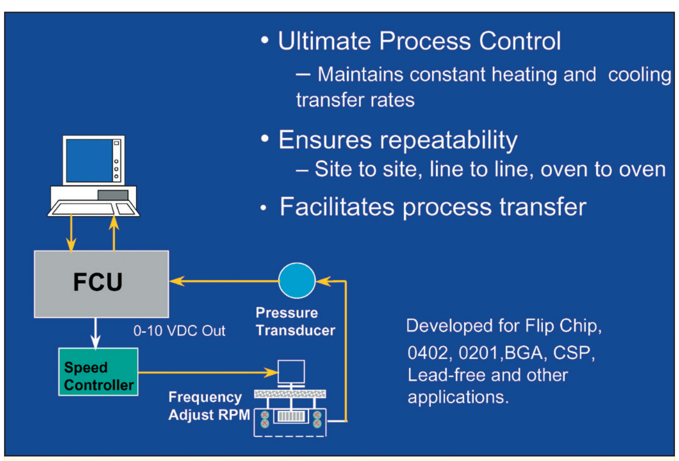

Figure 1: Closed loop convection control

Static pressure

There are various ways to sample convection rates. The key to closed loop convection is the constant sampling of static pressure generation. Static pressure developed within the blower plenum produces true forced convection as gas is distributed from side to side within the oven's process chamber. Increased static pressure not only maximizes thermal transfer, it reduces zone-to-zone temperature set points and improves ΔT.

A typical closed loop convection system provides the means to control, zone by zone, the oven's convection rates by increasing or decreasing the rate, as required. Decreasing the static pressure (or increasing it as required for processing denser, heavier parts, for example), and then holding it at that pressure, is the key behind the 'control' in closed loop convection. This up and down control factor helps reduce ramp rates (for both heating and cooling), eliminates component movement, and improves overall thermal uniformity.

As parts move through the oven the process might require a change in the rate of heat transfer or in the quantity of heat. Applying more heat to the bottom of a board than to its top might also be required. (The density of components is also a factor

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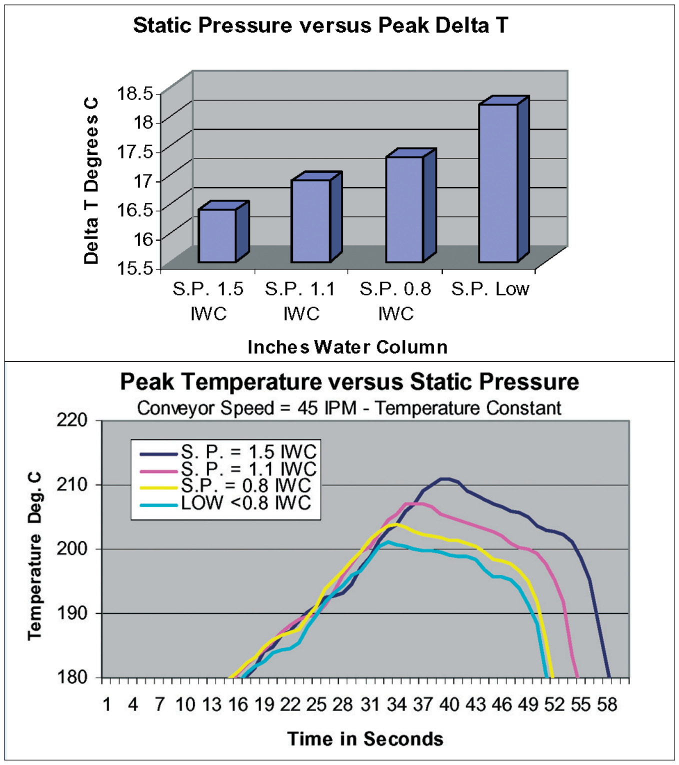

Figure 2: Static Pressure Effects. Higher static pressure increases peak temperature and dwell times; improves heat transfer and thermal uniformity, and improves potential for one universal profile.

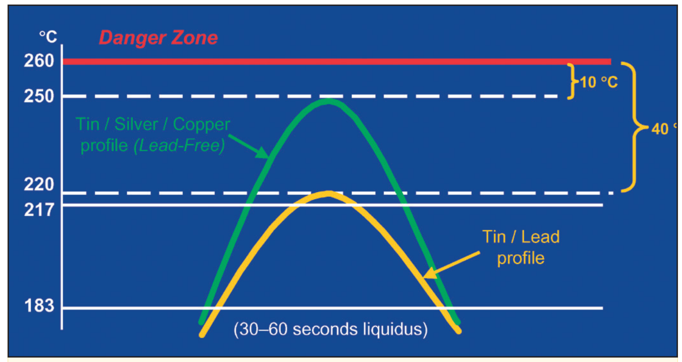

Figure 3: Lead-free process window

in making adjustments to heat transfer). Often high mass components are mixed with low-mass devices on a board; thermal compensation is desired. With closed loop convection, the oven operator can apply more heat from the bottom of the oven than from the top, accomplished by changing the set point. To this end, a more precise heat transfer lessens chances for defects.

Relationship between static pressure and uniform convection

Why is static pressure so important? First, because it directly relates to the amount of heat transfer an oven can deliver. The greater the static pressure the greater the heat transfer to the product. Static pressure with proper plenum design ensures uniform convection delivery from the plenum across the entire width of the product.

The direct relationship between static pressure and uniform convection rates has everything, ultimately, to do with ensuring repeatability in the process – site-to-site, line-to-line and oven-to-oven. Providing that ease of recipe transfer translates into time and cost savings because there is reduced need to profile the oven. With temperature, altitude and voltage variations under constant control, there is no deviation in results.

Lead free and peak temperatures

With lead-free on the near horizon, a true forced convection process becomes all the more critical due to the higher temperatures needed to achieve reflow. With lead-free thermal processing, uncontrolled higher temperatures can damage sensitive board components. Being able to heat to a higher degree, as lead-free requires, involves shortening the higher temperature time requirements – the ramp times.

Typical lead-free alloys require a temperature range of 217°- 220°C for melting to occur. But board components can be damaged by temperatures exceeding 260°C. With the peak temperature for lead-free being between 225°-240°C, the process window shrinks and tighter process control is necessary to avoid overheating smaller components especially. That tighter process window necessitates raising the temperature to a peak (above liquidus) for a shorter ramp-up time (and no more), due to the lack of headroom. It's possible with static pressure because of the controlled convection it provides. A higher static pressure increases peak temperature and dwell times even within a tighter process window.

While there are always differences in temperature on different points on a board, especially large boards, with controlled convection rates ensuring constant and uniform convection all points on a board can fit into the tight process window permitted, and reflow can take place without damage to any components.

Controlled cooling

Cooling is a very important part of the profile. While still under reflow, tight uniformity is critical to achieving good results. The ability to control the cooling rate, increasing or decreasing it as the process dictates, is therefore vital. Controlled convection rates need to be maintained at temperatures below 217°- 221°C.

Closed loop convection control in the back end of the oven where cooling takes place is especially important when lead-free solders are involved. (At that point in the process volatiles are prone to come off parts and ovens can become clogged or alter their characteristic).

Therefore, having a convection control in both the heating and cooling phases of the process is most advantageous. The reliability of the soldered joints on PCB boards using lead-free solders is actually more sensitive in the cooling rather than the heating stage.

Conclusion

Closed loop convection control provides constant and reproducible heating and cooling thermal transfer rates and gives the widest range of control. With closed loop convection it is possible to reduce the convection rate to inhibit component movement. Lowering the convection rate thereby reduces temperature ramp rates. With lead-free, closed loop convection employs higher temperatures within a very controlled, tight process window without damaging board components. It ensures repeatable heating and cooling convection rates while compensating for changes in temperature, voltage and altitude automatically, thereby ensuring process repeatability and easy recipe transfer. But the best benefit of adding the closed loop convection control will be the resulting improved yield.

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