Section 6: Reflow Oven Convection Methods

Convection Oven Technologies

While convection is a relatively simple technology, there are several technical aspects to consider. This section discusses some of the key differences including:

- Forced convection versus natural convection
- Turbulent flow versus laminar flow
- Fresh gas input versus recirculated gas input
- Defined convection flow path versus uncontrolled flow path
- Methods of forcing convection gas flow

Natural convection occurs when the air (or nitrogen) surrounding an object is at a different temperature than the object. The density differences between the hot and cool air causes a physical motion to occur, which assists in heat transfer. Forced convection occurs when an independent device (such as a fan) forces the air over the product. Typically the convective coefficient is greater with forced convection than with natural convection, which results in improved heating of the product. Early infrared/convection ovens relied on natural convection to help improve heating uniformity. Forced convection ovens usually have better heating uniformity than the infrared/convection ovens.

Forced convection can be either laminar or turbulent. Laminar flow is characterized by very stable flow patterns. Convection heat transfer requires contact between the air and the object. (See Figure 6-1.)

Thus, a stable gas jet allows more air to come in contact with the object. Because of this contact, laminar forced convection can have heating efficiencies of greater than 30 percent. Turbulent flow is characterized by vortices, eddy currents, and high heating rates. Thermal efficiencies are typically only 10 to 15 percent.
Defined vs Non-Defined Reflow Oven Flow Patterns

There are two methods of directing the flow within convection ovens. The defined flow path oven (Figure 6-2) moves the gas from zone to zone. It does not allow the same gas to become trapped in a given zone, which could become excessively contaminated with fluxes. These ovens will typically stay cleaner by preventing flux buildup.

The non-defined flow path ovens (Figure 6-3) do not direct the flow from zone to zone. Gas eventually reaches the exhaust and leaves the oven. These ovens work satisfactorily thermally, however they usually have oven flux cleaning issues associated with high-volume PCB production.

**Figure 6-1. Forced convection flow patterns.**

with fluxes. These ovens will typically stay clean (free of flux residue). Also see Figure 5-4.

**Figure 6-2. Example of a defined flow pattern - process gas is recirculated to the previous zone. Flux is removed via exhaust collectors. Fresh process gas keeps oven clean (free of flux residue).**
Recirculated Gas: Too Much
Recirculation Means Flux Cleaning

Air introduced into a heating zone may either be fresh or recirculated. Fresh gas input requires heating the air from ambient to the zone temperature. In comparison, recirculated gas input requires only heating the air a small amount, since the gas is already “hot”. Thus, an advantage of recirculated flow is a lower power requirement to heat the zone.

Recirculated flow has the disadvantage of picking up contamination each time the air is re-used. No-clean fluxes prevent solids from building up on the PCB. These solids end up in the reflow process gas and will collect in the heater cavity if the oven is not designed properly. The result is a dirty process atmosphere or machine downtime due to the need for oven flux cleaning.
Ways to Generate Forced Convection in Reflow Ovens

There are three methods of generating forced convection in reflow ovens – fans, compressors and flow amplifiers.

Fans
Fans are an inexpensive and reliable method of moving high volumes of air. Fans typically have low pressure generating capability, so exit velocities may be limited. However for most board profiles this should not be a problem. Most convection reflow ovens use fan forced convection.

Compressed Gas Sources
Compressed input gas sources (such as compressed air or nitrogen) are also used to create forced convection. The pressure must be regulated in order to achieve constant flow. Compressed sources have the advantages of providing a controlled atmosphere, which is free of particulate contaminants.

If compressed air is used, the humidity can be controlled using an inline dryer. Flow velocity is easily controlled with flow meters. Compressed sources have high pressures, allowing high velocities if desired. An air compressor or compressed nitrogen supply is required.

Compressed gas reflow is used when the application requires an extremely accurate thermal profile with filtered process gas.

Flow Amplifiers
The third common method used to create convective flow is the flow amplifier. The flow amplifier uses a compressed source to induce flow. In a flow amplifier, compressed gas flows through the inlet into an annular chamber. The gas is then throttled through a restriction at high velocity. The compressed gas flow towards the outlet adhering to the outside wall. A low pressure area is created in the center, which induces flow.

The advantage of a flow amplifier is that flow volumes are similar to a fan without any of the fan life issues. However, a major drawback to the flow amplifier is that the flow amplifiers tend to clog with fluxes. The ring nozzle causes the gas to expand and cool. The cooldown of the gases causes flux to precipitate out of the flow. There is also a thermal efficiency loss with the gas cooldown.