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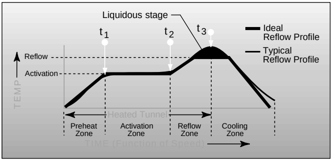

Figure 1. An example of a theoretically ideal reflow profile made up of four parts or zones - the first three are heating and the last is cooling.

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thermal compound (also known as thermal conductive cream or thermal grease) is applied to the thermocouple tip, which is then attached using a high-temperature tape such as Kapton™ (Figure 2.)

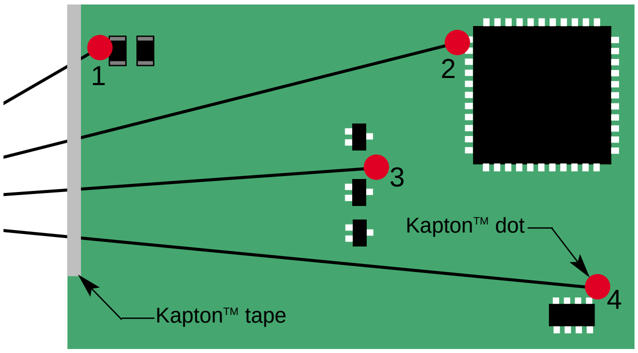


Figure 2. Fasten wires on trailing end of board with Kapton™ tape or dots to keep thermocouple wires from tangling on board.

Another method is to attach the thermocouple using a high-temperature adhesive such as cyanoacrylate. This method is usually not as reliable as the other methods.

The attachment location should also be determined. Normally, it is best to attach the thermocouple tip between a PCB pad and the corresponding component lead or metalization (Figure 3).

Figure 3. It is best to attach the thermocouple tip between a PCB pad and the corresponding component lead.

A solder paste specification sheet is also necessary. Solder paste manufacturers publish a specification sheet for each paste formula they produce. This sheet will contain information critical to the profile such as desired profile duration, paste activation temperature, alloy melting point and desired reflow peak temperature.

A basic understanding of an ideal profile is necessary prior to starting. A theoretically ideal profile is made up of four parts or zones (Figure 1). The first three zones are heating and the last is cooling. Ovens that contain more zones enhance the ability to contour the profile shape to achieve one more exacting and defined. Most solder pastes can be successfully reflowed with the four basic zones. The preheat zone, also referred to as the ramp zone, is used to elevate the PCB temperature from ambient to the desired activation temperature. In this zone, the temperature of the product is constantly rising at a rate that should not exceed 2° to 5°C per second. Raising the temperature at a faster rate may induce defects such as micro-cracking of ceramic chips, while raising the temperature too slowly may over- expose the solder paste and give insufficient time for the PCB to achieve activation temperature. The oven‘s preheat zone should normally occupy 25 to 33 percent of the total heated tunnel length.

The activation zone is sometimes referred to as the dry-out or soak zone. This zone, which normally makes up 33 to 50 percent of the heated tunnel length, is responsible for two functions. The first is to expose the PCB to a relatively steady temperature that allows components of different mass to become homogenous in temperature by reducing their ˘Ts. The second is to allow the flux to activate and the volatiles to escape from the paste. Common activation temperatures normally range between 120° and 150°C. If the temperature in the activation zone is set too high, the flux may have insufficient time to activate and the slope of the profile curve will be an upwardly increasing gradient. Though most paste manufacturers allow for some increase in temperature during activation, the ideal profile requires a relatively flat temperature so that the PCB temperatures at the beginning and at the end of the activation zone are equal. Some commercially available ovens are not capable of maintaining a flat activation profile; choosing one that can will enhance the solderability and afford the user a wider process window.

The reflow zone is sometimes referred to as the spike or final ramp zone. The function of this zone is to elevate the temperature of the PCB assembly from the activation temperature to the recommended peak temperature. The activation temperature is always somewhat below the melting point of the alloy, while the peak temperature is always above the melting point. Typical peak temperatures range between 205° and 230°C. Setting too high a temperature in this zone may cause the ramp rate to exceed 2° to 5°C per second or to achieve a reflow peak above what is recommended. This condition may cause excessive warpage, delamination or burning of the PCB material and may compromise the integrity of the components.

The most popular alloy used today is Sn63/Pb37. This proportion for tin and lead makes the alloy eutectic. Eutectic alloys are blends that melt at a specific temperature. Non-eutectic alloys have a melting range, sometimes referred to as a plastic state, rather than a melting point. For the purpose of this article, all examples will refer to eutectic tin/lead because it is the most widely used alloy. The melting point of this alloy is 183°C. New alloys are being used for lead free solders with melting points generally from 217° to 227°C.

The ideal cooling zone curve should be a mirror image of the reflow zone curve. The more closely this curve mimics the reverse of the reflow curve, the tighter the grain structure of the solder joint will be upon reaching its solid state, yielding a solder joint of higher quality and bonding integrity.

The first parameter to be considered in creating a profile is the conveyor speed setting. This setting will determine the time that the PCB will spend in the heated tunnel. Typical paste manufacturer specifications require a three-to-four minute heating profile (lead free solder paste: 4-6 minutes). Dividing the total heated tunnel length by the total heated exposure necessary provides the accurate conveyor speed. For example, when a solder paste that requires a 4-minute profile is used in an oven with a 6 ft heated tunnel length, the calculation is as follows:

6 feet / 4 minutes = 1.5 feet per minute = 18 inches per minute

Settings of the individual zone temperatures must be determined next. It is important to note that the actual zone temperature is often not necessarily the temperature displayed for that zone. The display temperature merely reads the temperature of the thermocouple located somewhere within the zone. If the thermocouple is located closer to the heating source, the displayed temperature may be considerably higher than the zone temperature. The closer the thermocouple is located to the direct path of the PCB, the more likely it is for the display temperature to reflect the zone temperature. Consulting the oven manufacturer is prudent in learning the relationships between setting display temperatures and actual zone temperatures. For purposes of this article, zone temperature rather than display temperature will be considered. Table 1 lists zone temperature settings used to reflow a typical PCB assembly.

TABLE 1

Typical PCB Reflow
Zone Temperature Settings

Zone	Sn63/Pb37 Zone Temp	Sn63/Pb37 Board Temp	Lead Free Zone Temp	Lead Free Board Temp
Preheat	165°C 329°F	140°C 284°F	180°C 356°F	155°C 311°F
Activation	150°C 302°F	150°C 302°F	165°C 329°F	165°C 329°F
Reflow	220°C 428°F	215°C 419°F	235°C 455°F	230°C 446°F

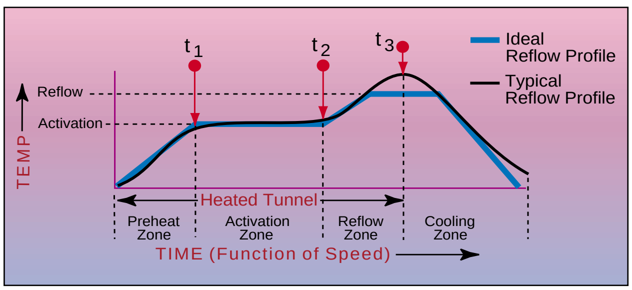
Now that the speed and temperature have been determined, they must be entered into the oven controller. Consult the oven manufacturer‘s owners‘ manual to determine other parameters that may need to be adjusted on the oven. Such parameters may include cooling fan speed, forced-air impingement and inert gas flow. Once all parameters are entered, the machine may start and profiling can begin after the oven has stabilized (i.e., all the actual displayed parameters closely match the preset parameters). Next, place the PCB to be profiled on the conveyor and trigger the profiler to start recording. For convenience, some profilers include a triggering feature that automatically initiates the start of the profiler at a relatively low temperature. Typically, this temperature is slightly higher than the human body temperature of 37°C (98.6°F). For example, an automatic trigger at 38°C (100°F) allows the profiler to start working almost immediately upon the PCB entrance into the oven, yet does not jeopardize false triggering by thermocouple handling with human hands.

Once the initial profile graph is generated, it can be compared to the profile recommended by the paste manufacturer or to the profile shown in Figure 4.

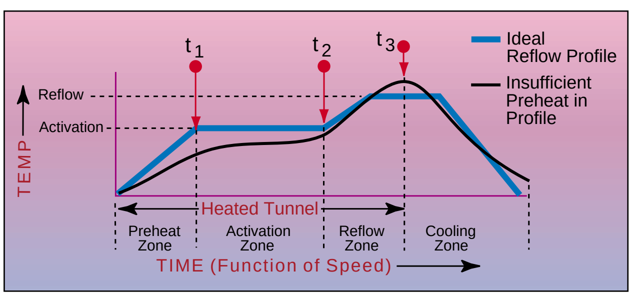
First, it is necessary to verify that the overall time from ambient temperature to the reflow peak temperature corresponds to the desired heated profile duration. If it is too long, increase conveyor speed proportionally. If it is too short, do the reverse.

Next, the shape of the graph curve must be compared to the one desired (Figure 4.). If the shape does not correspond, it should be compared to those in Figures 5 thru 12. The curve that most closely corresponds with the shape of the actual graph is chosen. The deviations should be considered from left to right (process order). For example, if a discrepancy exists in the preheat and reflow zones, make adjustments to correct for the preheat deviation first. It is generally preferable to change only one parameter at a time and rerun the profile prior to making further adjustments. This is because a change in any given zone is likely to also affect the results in subsequent zones. It is also recommended that a novice make adjustments of relatively smaller increments. Once experience is gained with a particular oven, a better "feel" will be acquired for the magnitude of adjustments to be made.

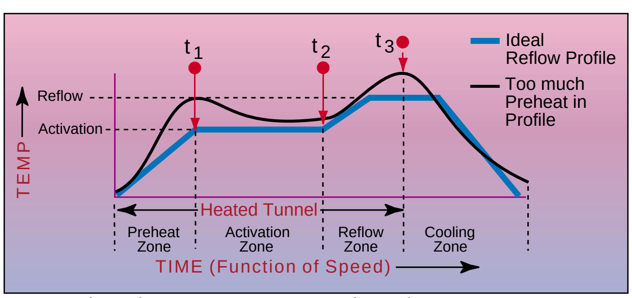
When the final profile graph matches the desired graph as closely as possible, the oven parameters should be recorded or stored for later use. Although the process may be slow and painstaking at first, proficiency and speed will be gained in time, resulting in efficient production of high-quality PCBs.



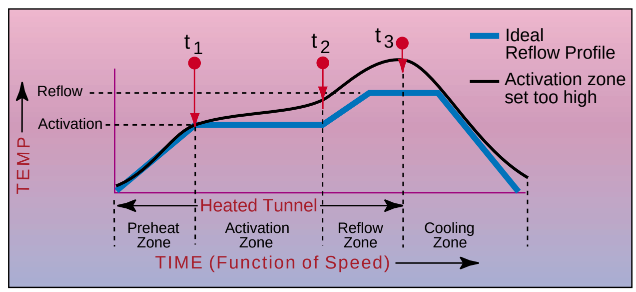
General target profile shape for three zones plus cooling Fig.4.



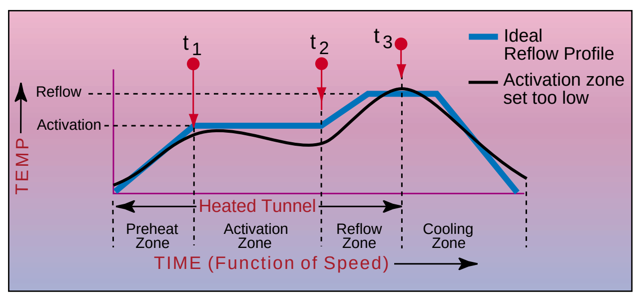
Insufficient preheat. Increase temp. in preheat zone. Fig.5.



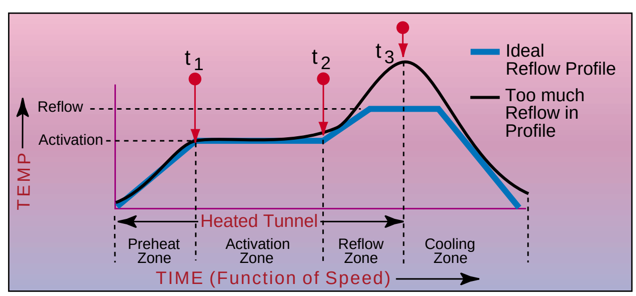
Too much preheat. Decrease temp. in preheat zone. Fig.6.



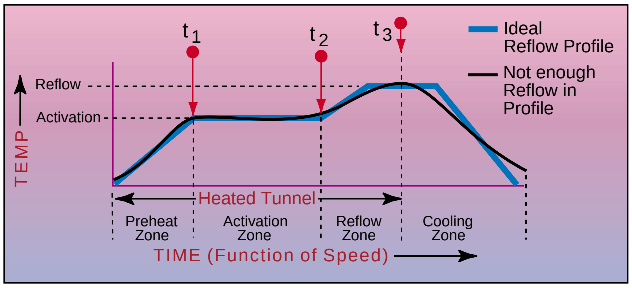
Activation heat too high. Decrease temp. in activation zone. Fig.7.



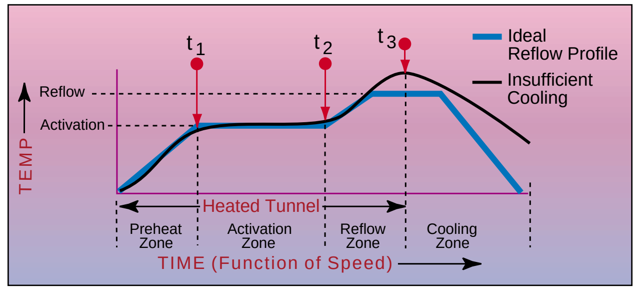
Insufficient activation heat. Increase temp. in activation zone. Fig.8.



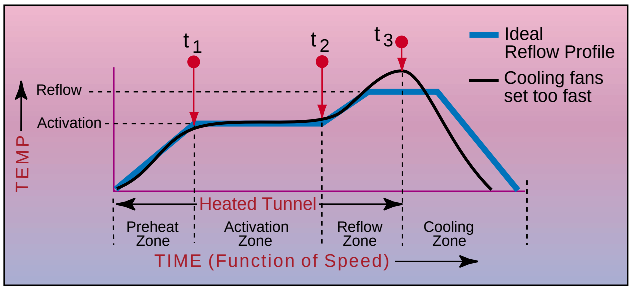
Reflow heat too high. Decrease temp. in reflow zone. Fig.9.



Insufficient heat in reflow. Increase temp. in reflow zone. Fig.10.



Insufficient rate of cooling. Increase fan speed. Fig.12.



Accelerated rate of cooling. Decrease cooling fan speed. Fig.11.

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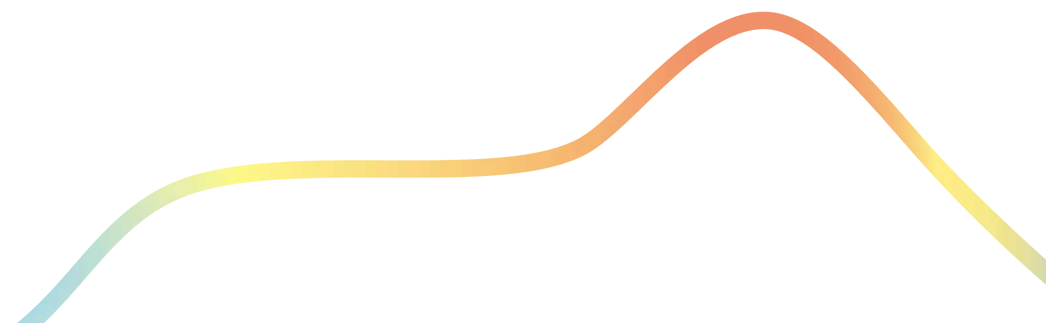
JOHN MALBOEUF may be contacted at Automated Production Systems Inc., 2840 Pine Road, Huntingdon Valley, PA 19006; (215) 938-1000; Fax: (215) 938-8480.

For general or specific information about reflow oven technology contact Novastar.
Click here for a pdf doc of the Temperature Profiling Accessory Kit.



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