Reprinted with permission from Process Heating Magazine, August 2001

Smart Profiling: Tips for Optimizing Thermal Process Performance

By Dr. Greg Jones, PhD, KIC

"When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is… unsatisfactory"
— Lord Kelvin

"Define, Measure, Improve"
— GE Quality Approach

INTRODUCTION

Thermal profiling is the charting of the temperature at multiple points on a given product as it passes through a thermal process (See Figure 1). The reason for thermal profiling is that whenever manufacturing requires a heat-processing step, there must be some method to ensure that the product is heated to a specified temperature for a specified period. Utilizing state-of-the-art thermal process setup and monitoring equipment offers significant improvements in thermal process performance and reductions in production costs. This article provides a starting point for improving thermal process performance.

DEFINE

The first step for improving the thermal process is to define the process. The basic question is "How hot for how long?" For most processes, the required temperature is defined as a range. This range is called the "Process Window". Although it seems obvious, it is critical that this process window be defined. In many facilities, it is not. The oven or furnace has been setup by a technician from the oven manufacturer, product has been run successfully, and the furnace is run without any form of process control until there is a problem. When the inevitable problem occurs, an expensive technician or consultant is called in to fix it.

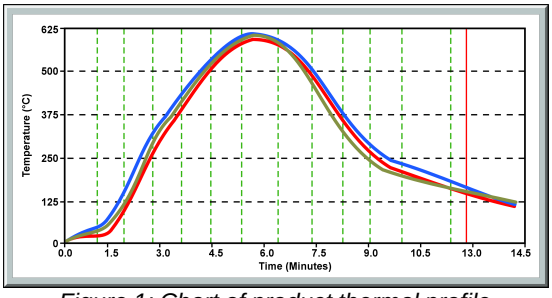

Figure 1: Chart of product thermal profile

In order to gain control of any process, it must be defined. The place to start is with materials suppliers. Adhesives, coating, solder and brazing pastes, etc. all have recommended process limits. Some software packages now include databases of process specifications for various applications.

MEASURE

Once the process has been defined and process limits set, the next step is to measure the process. For thermal processes, the most common measurement tool is a profiler, though in some applications, a strip chart recorded is still used. There are many types of profilers available, ranging from simple data loggers to modern real-time systems (See Figure 2). Most profilers only record the product profile and process data. They do not allow the user to set process limits, relying instead on "Target" temperatures. The problem with "Target" temperatures is that they do not indicate how well the profile fits the process window.

Figure 2: Real-time thermal profiler

One method for simplifying process measurement is to use profiling software that ranks profile performance with the "Process Window Index." The Process Window Index is a statistical method for instantly determining whether a thermal process is in or out of spec and ranking the profile based on its fit to a specified process window. Generally when a thermal profile is run, it is judged as being either in or out of spec, and perhaps subjectively judged as being OK, good, or really good. The Process Window Index allows users to rank process profiles on the basis of how well they "fit" the critical process statistics. The center of the Process Window is defined as zero, and the extreme edge of the process window as 99%. A PWI of 100% or more indicates that the profile

will not process product in spec. A PWI of 99% or less indicates that the profile is in spec and tells users what percentage of the process window they are using. The Process Window Index tells users exactly how much of their process window a given profile uses, and thus how robust that profile is (See Figure 3). The PWI allows users to find the single best profile that a given process is capable of achieving. And with the PWI, users can implement a "true" SPC program for the reflow process with a minimum of effort.

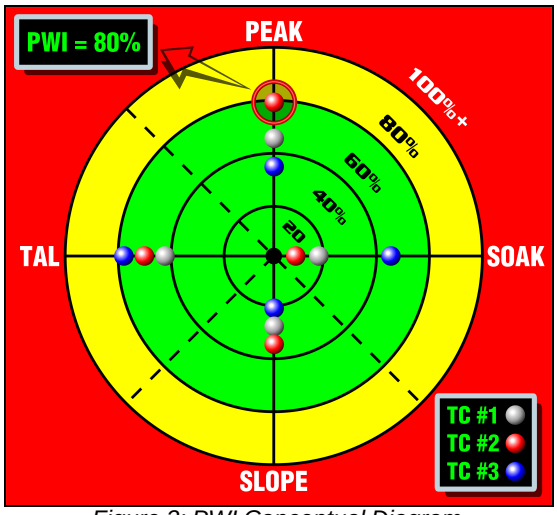

Figure 3: PWI Conceptual Diagram

Another key to measuring the process is ensuring that the profile is an accurate one. Several factors can affect the accuracy of the profile. The most common are improper thermocouple attachment and thermocouple wear. Improper thermocouple attachment can cause noise (fuzzy lines) on the profile graph, higher than normal temperature readings, lower than normal temperature readings, and erratic temperature readings. A good thermocouple attachment will yield a profile that is very smooth. Good thermocouple attachment is defined as solid contact with the surface of the product and there are numerous ways to achieve this. For applications under 250°C, Aluminum Tape provides a simple, effective, and nondestructive method of thermocouple attachment.[1]

It's important to be aware that thermocouple wire deteriorates over time. Thermocouples should be checked with a thermocouple simulator on a regular basis to verify correct readings. Also, keep in mind that the higher the temp, the shorter the life of the thermocouples. At process temps below 300°C thermocouples can last for upwards of 30 profiles, while process temps of 1000°C can destroy a thermocouple in less than 10 profile runs.

It is valuable to simulate production as closely as possible when profiling. Have the board enter the oven in the same manner as it would during production. If possible, profile the product with a fully loaded oven, as the oven's characteristics can vary significantly between loaded and unloaded. It is also necessary to allow the product to cool to room temperature between profiling runs. If the product is not allowed to cool down between multiple profiling runs, this will introduce an exponential error.

IMPROVE

Once the process has been defined and measured, the final step is to improve it. Process improvements can yield multiple benefits:

- Reduced defect and scrap rates
- Increased efficiency and cost reductions
- Improved labor and equipment utilization

Technology is now available to automate thermal process improvement. The two most significant technologies are automated oven setup tools and automated thermal process management tools. Automated oven setup tools utilize an oven recipe search engine to find the "One Best" profile for a given product in a given oven in under a minute. The oven recipe search engine analyzes literally billions of possible setups to find the optimal oven setup and drastically reduces process setup time, facilitating increased line uptime and improved utilization of engineering resources.

The installation of an automated thermal manager allows users to be assured that their process is in-spec 24/7. This technology includes automatic SPC charting, will alarm on any process drift, and can be set to automatically shut off the feed conveyor in case of a process failure. The system automatically stores all process data and can be used with a bar coder to provide complete thermal process traceability. With advanced thermal process technology, users can be assured that they have setup the possible process for their product spec, and that every product that goes through their oven or furnace will be processed at that spec.

Many users only turn to thermal profiling when there is a problem with the process. This is an important first step, but it is only the first step. With automated process tools, users have the opportunity realize significant improvements in their thermal processes.

---

[1] "A Comparison of Methods for Attaching TCs to PCBs for Thermal Profiling" by Cameron Sinohui, KIC. Presented at Nepcon West 1999.