# CASE STUDY Advanced thermal process management for wave solder application —

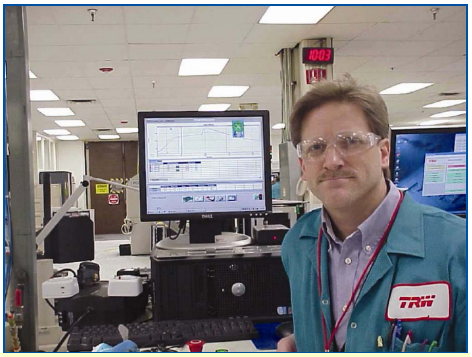

**Figure 1. James Hall, senior process engineer at TRW in Auburn, N.Y.**

TRW, a full-service organization, from design to assembly, is a major player in the highly competitive automotive electronics contract manufacturing market. In this market, top-notch quality and on-time delivery are always expected. In addition, new requirements for full process traceability are not uncommon. But even this is not enough to secure success. Intense competition for all new contracts puts immense pressure on prices.

Therefore, TRW is constantly on the lookout for new technologies and more effective ways of doing business that enable the company to remain profitable while exceeding client expectations. James Hall, senior process engineer at TRW in Auburn, N.Y., contacted KIC about developing new tools for improved wave solder operations. The dynamic wave solder process is more challenging than reflow in terms of both initial process setup and ongoing production. No-clean VOC-free emulsified flux chemistries compounded by higher operating temperatures require a tighter process window and tighter control over thermal slope, preheat range, dwell time, parallelism and solder temperature.

This article describes the implementation of a continuous thermal process monitoring tool, the KIC 24/7 Wave, on a wave solder machine at TRW for a lead-free process. The KIC 24/7 Wave utilizes a custom probe inside the wave solder machine to record real-time thermal process data for each and every product. This includes the profile for each PCB and how well the profile fits the established process window.

One of the challenges TRW faced was establishing a method to understand the interactions between belt speeds, preheat and solder immersion time. Because the wave is a dynamic process, engineers frequently have to modify belt speeds to compensate for how preheat and the solder wave interact with the circuit board. Thermal monitoring is more critical with Pb-free solder and emulsified flux chemistries, which are both slower to thermal response. Therefore, engineers need a thermal monitoring system with prediction capability to aid in process development and verify (in real time) that the process can maintain its process parameters over time. "It can become a timely task if you have to go back and run a bunch of profiles to figure out where you are at after

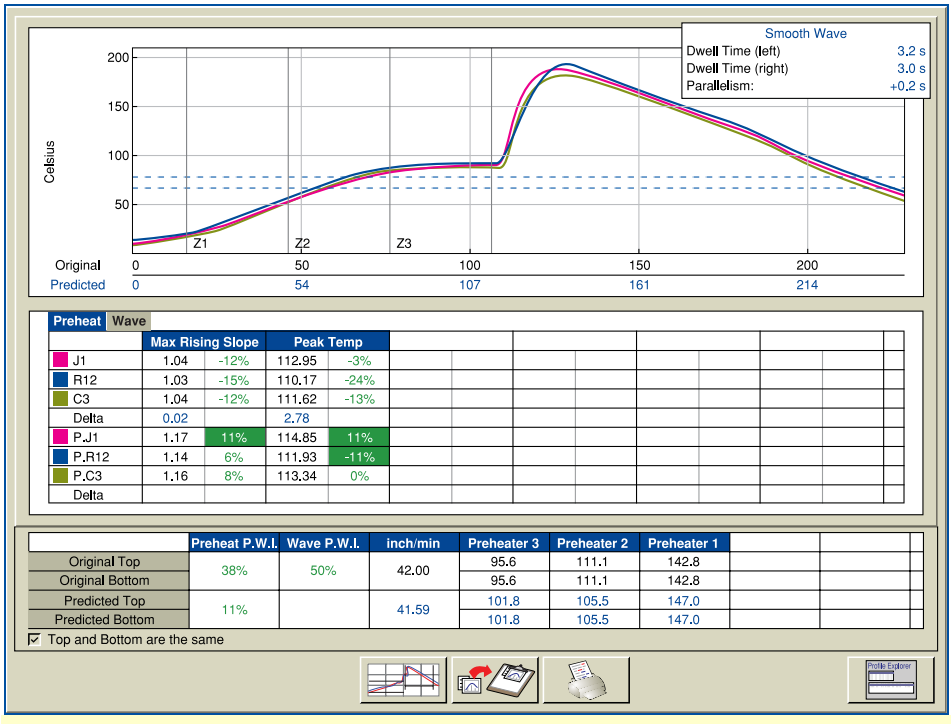


**Figure 2. Process data is automatically charted for all critical process specs and plotted on real-time control charts.**

making any incremental adjustments to the process," says Hall.

That is where the KIC 24/7 Wave comes in because of its prediction feature and real-time monitoring. "I can now run one profile through the wave solder machine," says Hall. "It will take me no longer than 20 minutes to find out where the process is at and what I have to do to optimize both belt speed and preheat zones."

When first establishing a wave program, a solder specification needs to be developed to set limits for thermal slope, preheat range (flux type), dwell time, and solder temperature. Once a wave specification has been established, engineering can run a control experiment to quickly identify process parameters. The engineer simply runs a thermal board connected to a SlimKIC through the wave solder machine. Data are then downloaded to the KIC 24/7 Wave's predictive software to analyze against the solder specification. In predictive mode, the engineer can manipulate preheat zones and belt speed to quickly optimize process parameters. This information helps engineers understand the interaction between preheat and dwell time. "The KIC 24/7 is a great tool for evaluating designs of experiments and optimizing programs," says Hall.

Because TRW is using a lead-free process, the preheat temperature is extremely important. TRW uses a waterbased flux chemistry that is designed to endure higher preheat temperatures. "Because you're using water as a carrier, preheat has to be much higher," explains Hall. "Preheat must be precisely controlled and measured to assure proper flux activation and evaporation of water to avoid micro-solder balls. Monitoring controls for preheat can no longer be treated as a given with generic settings and moderate process controls."

Also, the wave solder process for leadfree is more difficult, and the process window is tighter than with standard tin-lead because lead-free solder is not as pliable as leaded solder. It has a slower response time to wetting. Dwell times have to be expanded and more time has to be spent manipulating the solder. And more preheat might be necessary to aid in achieving 100-percent hole fill. "Preheat becomes more vital so you want to have better instruments at hand to better understand that relationship," says Hall.

## Temperature deviation

Another feature Hall finds useful in the KIC 24/7 Wave is the troubleshooting screen that shows temperature deviation. In wave soldering, the heating zones are not insulated as they are with reflow. The first time a baseline board is run through a reflow oven, because the ovens are so heavily insulated, there is very little temperature variation, typically from 5 to 10°C maximum over time. However, in wave soldering, preheat is not insulated, so there is a more heat loss, which means more temperature variation in the wave solder process. "I realized I was seeing as much as a 20°C temperature deviation," says Hall, "because it is not insulated."

When the wave solder machine is first turned on (cold start), the software in the machine indicates when the preheaters are at their set point. However, what Hall discovered is that the machine is not measuring the temperature in the entire area. "The machine gets up to temperature within a minute or so, and it indicates it is ready, but the KIC 24/7 software is indicating the machine is still about 30°C off from where it needs to be because the heaters need to heat up the surrounding environment more to stabilize the core."

To fix the problem, Hall put an offset in the startup of the wave solder machine that tells it to soak another 10 minutes before release. Using the KIC 24/7 Wave temperature deviation screen allowed Hall to add the offset. "From a cold start, I put the KIC 24/7 on immediately and went to the temperature deviation screen and set that up. Then as soon as I turned the machine on, I timed it to see how long it would take for the core to stabilize enough to allow me to say the machine is really ready to run production."

The KIC 24/7 Wave troubleshooting screen also helped

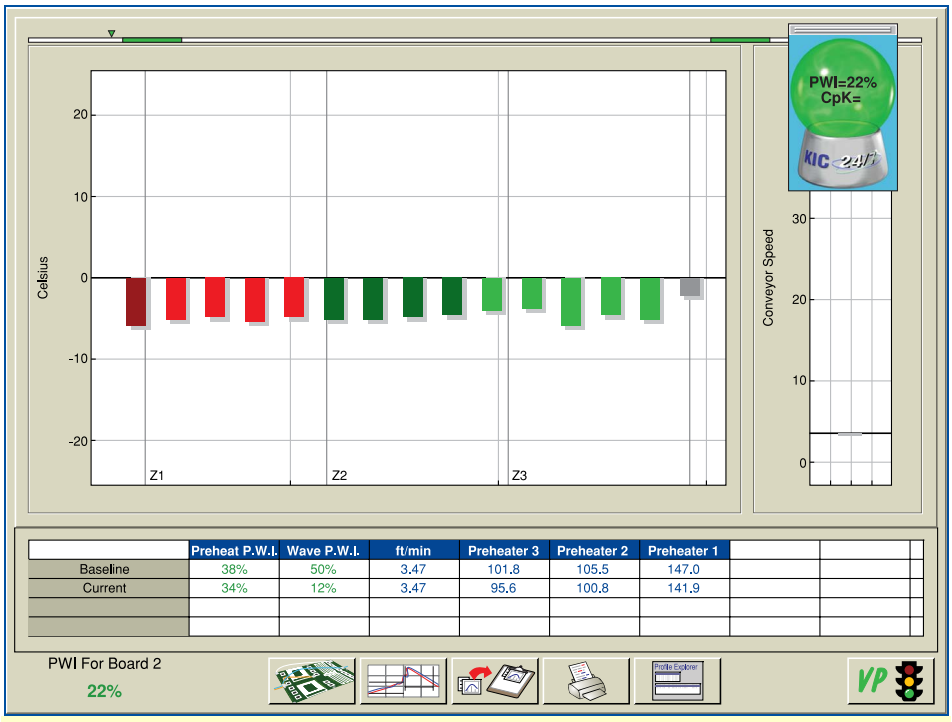


**Figure 3. Another feature Hall finds useful in the KIC 24/7 Wave is the troubleshooting screen that shows temperature deviation.**

Hall discover an issue with cabinet exhaust around preheat zones. Hall found the exhaust does influence thermal stability due to poor insulation around the preheat tunnel. The troubleshooting screen quickly identified a change in preheat temperature when adjusting exhaust flow rate. Equipment suppliers only use one thermocouple per zone, which is mounted directly to its heat source. Hall was able to determine that the wave detection system was less sensitive to detecting thermal changes above in the preheat tunnel. The KIC 24/7 Wave consists of one probe with 14 thermocouples. The probe is mounted slightly off the entire length of the preheat tunnel making the thermocouples more sensitive to exhaust flow changes that impact core temperature.

Other process variations identified by the KIC 24/7 troubleshooting screen included gaps in preheat top covers, preheat zone position on maintenance slides and obstructions in the forced air hot convection recirculation vents. "The KIC 24/7 Wave troubleshooting screen has identified several temperature variations not understood by engineering," says Hall.

The other feature Hall appreciates is that the KIC 24/7 comes with a thermocouple that can be inserted directly into the solder pot. As soon as he used it, he found a 50 to 60°C delta between what the KIC 24/7 thermocouple was reading vs. what the wave probe was reading. Hall found the KIC 24/7 system was correct and recalibrated the solder pot.

## Additional information

| Smooth Wave | |
|---|---|
| Dwell Time (left) | 1.8 s |
| Dwell Time (right) | 1.8 s |
| Parallelism: | -0.0 s |

Hall also discovered that the KIC 24/7 provides other important data, even though the Wave does not control it. During an initial baseline run, he can measure dwell time on the leading edge of the board, left to right. "My baseline board will show me what my dwell time is, but it doesn't track it via the KIC 24/7, meaning it is not live. But that's OK because it does tell me what my dwell time is, and it does tell me that my board is parallel to the wave, left to right, and that is important."

The other piece of data not controlled via the KIC 24/7 that is provided is topside board temperature. Because he doesn't want to reflow SMT parts on top of the board, Hall wants to know how hot the top of the board is getting when it is making contact with the wave.

Again, these data are not actually controlled by the KIC 24/7 system but it does tell Hall what the delta is between the preheat and the solder. "If you are wave soldering ceramic parts, for example, they are sensitive to thermal stress, so it is important to hold a delta of equal or less than 100°C. That number is the difference between the peak temperatures in preheats bottom side vs. the peak temperature of the boards making contact with the solder."

## Process traceability

Because TRW provides safety-critical production, it must provide full traceability. Customers are reassured with real-time profiling for each product profiled through the wave process. Hall finds that the process window index (PWI) in the KIC 24/7 software makes it an easy selling point. "You can quickly show your customer what your spec is for your process and what you are trying to govern, and you can plot in each graph separately how close to the target you are. It is easy to show them how the PWI works and how we are tracking it. That is a huge selling point."

The other feature to KIC24/7 Wave is the added speed encoder and board sensor to wave conveyor. "Preheat and dwell are a function of time and can not be measured real time without the encoder," says Hall.

Hall also likes that the KIC 24/7 comes with the tower light and alarm relay. Any process drift outside of control limits or defined process capability value will immediately trigger an alarm and stops the input conveyor.

Finally, KIC 24/7 Wave provides a cost savings, too. Without real-time monitoring, TRW has to run a profile every time it does a product changeover. It can take 20 to 30 minutes to manually run a profile on that machine, which extends setup time. With KIC 24/7, the associate simply turns on the wave machine and when the tower light goes green, he then turns on the KIC 24/7 Wave system, and they are off and running in auto-mode. This eliminates the need for engineers to manually run verification profiles. "Not to mention, manual profiles only show a snapshot in time and don't capture any temperature variations taking place between profiles," Hall says.

Hall's philosophy is to keep the software/ hardware interface simple, and then everyone will use the system. He adds, "KIC has devised software that is extremely easy to understand and use with less than 30 minutes of training."