Process Control in Solder and Reflow

Interview by Nolan Johnson
I-CONNECT007

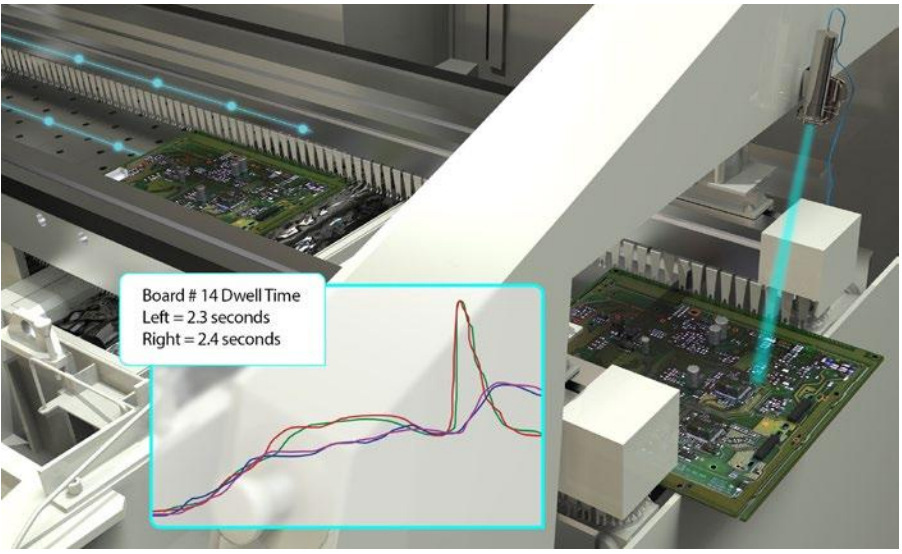
Nolan Johnson speaks with KIC's Miles Moreau to get his perspective on topics such as wave process inspection (WPI), wave solder, and vacuum reflow, and how they will fit into Industry 4.0 and smart factories.

Nolan Johnson: Miles, as general manager for EMEA, Americas, and Australia, you're watching what's going on in business around the globe. What are the general market trends?

Miles Moreau: The market trends I'm seeing—and it's been interesting the way some of this has progressed—is a change of what makes the most sense to effectively, from a global economy standpoint, produce and deliver product for the OEMs. People say, "We can do it over here in Asia—specifically in China—very effectively, and at a very low cost," but then you start to see these disruptions, and that mindset has changed.

That was just magnified by the pandemic, to where the market trends are localizing distribution points and manufacturing. Now you move from the OEM to EMS companies, and we will need to be more flexible and agile at meeting our customers' demands, not just in some manufacturing base, but anywhere that they want to move production; we must have systems in place to manage that. If I'm an EMS company, they may say, "I want you to build over here now, but you'd better build it exactly the same way you were building it in this spot." Especially when you compare OEM manufacturing vs. contract manufacturing (but it applies to both), they want to be able to deliver the same product regardless of where it's built, and they want to be able to shift something quickly and build it somewhere else.

I think that's why smart factory trends have accelerated; I've noticed in Europe and lately in the U.S., you're getting some manufacturing moving back to North America and they are looking at those capabilities, saying, "Yes, we're getting some manufacturing back here, but we want to keep it here," so we have to be just as agile about how we can manufacture. That's where these smart factory trends create the ROI; then I can say, "Here's the best way to manage that and compete against these lower cost manufacturing locations."



KIC WPI—wave process inspection. Click here to learn more.

Johnson: KIC has been working on some ongoing R&D throughout 2019-2020 that is just starting to roll out; tell me about it.

Moreau: We've had good solutions and a reputation for great reflow-related solutions around profile setup, optimization, and monitoring or inspection during production. That has been KIC's forte, and we do that across SMT assembly and semiconductor packaging. We've always had requests from our customers for other thermal processes, with wave being one in particular that's handled on the profiling side. We have some good solutions that help them set up and do a check on the machine, but it's always been a challenge during production.

Wave is a multifaceted process of fluxing, preheating, and then soldering, as opposed to the oven being continuous where it all happens during the same process and flow. How do you adapt? Because the machines can be configured a lot differently—some have convection, some have IR heat, different ways of applying the heat, top and bottom zones, sometimes only bottom, two waves vs. one wave, all sorts of different things—that makes it really challenging. There are some aspects around the mechanics of the wave that are part of what the manufacturer is trying to monitor or keep track of.

A big challenge for us was to come up with something that a fixture can do; run it through the process, get preheat topside temperatures, ramp rates, make sure you're activating the flux, and then capture some wave data as far as dwell time and parallelism with the fixture. But now what do you do during production? With a board going through a pot of liquid solder with a wave pumping and trying to have sensors and data collected so you can actually capture that data and do something in real time, this was our challenge.

The answer to that challenge was the WPI or Wave Process Inspection. It matches what our capability is on reflow with our RPI system, but it takes into account certain aspects of what the customer needs to measure when the board is going over the wave, which is dwell time. We have come up with a way, during production, to not only get the entire temperature profile of the product going through the preheat and the wave, but also a real-time dwell calculation for each and every production board. That's been a big challenge, and we've got it nailed down now.

Johnson: For those who may not be particularly familiar with the importance of dwell time and why it's a challenge, could you give us a quick primer?

Moreau: When it comes to the wave itself, the flux activation part is in the preheat coming up to that wave. Proper activation facilitates the soldering and cleans the surfaces. The dwell time is going to affect or impact the quality of the solder joint. It's how long the board is going through, and in, the wave. Most important is getting the metallized surfaces up to soldering temperature for proper wetting. Dwell is what facilitates this part of the process.

There's a lot of aspects to what happens through the wave. How long each section of the board is going through the wave—and getting that good solder joint—is directly correlated to the dwell time.

Johnson: Not to sound like an old timer, but back in the day this was generally a static process, the sort of thing that you would need time to set up. You would have to run through test boards, figure out what the appropriate settings were for all of the conditions through the three stages, do a thorough profile, inspect the test boards, and refine the process until that one particular board was dialed in. Then, you stuck with those settings, and you had to check the finished product regularly; it was a static process.

With the move to factory automation as a general trend, is the WPI doing real-time checking?

Moreau: Effectively that's what it's like, it's like running that fixture check through for every production board. The challenge on the wave is doing static vs. dynamic, or more real time. In a reflow oven you are managing based on the control of the zone and what external forces can impact the profile or how it changes. With the solder pot, it's extremely dynamic and somewhat unpredictable, even if you fine tune all of the mechanical settings and manage the height, how you're collecting off the dross, the pump, the temperature of the solder.

It's very dynamic so the more frequently you can do that check during production, then you're going to reduce the opportunities for defects. Now what you do is, why not take that to continuous? Let's do that for every single production board, so that if there is some change, we can put a tolerance around what's acceptable. Then if it goes beyond that, we can alarm and prevent other boards from going through when the setup is no longer good.

Johnson: That used to be a tactic, right? Especially in wave solder, you would create a tolerance window, and it would be pretty large, and you would have to make sure that you stayed within that window. Does this give you the opportunity to tighten the tolerance windows? And what is the benefit there to the customer or the OEM?

Moreau: Like you described before, you do all these tests, you run profile after profile, and then you come up with the tolerances, but that's just based on these static measurements. Now imagine I can run for two hours and get the data that took me two to three days to collect before. Then I make the necessary adjustments and can have continuous improvement on the fly, with real-time feedback from WPI. No more time-consuming manual processes; you're getting the real-time feedback so then you can tweak your tolerances as you go start to improve the process and really tighten it down. It not only gives you the value of, yes, I'm getting this data to make sure that my customers' product is being built correctly, but I have real-time feedback now where I can actually fine tune and improve this process.

Johnson: Does being able to fine tune and get more precise benefit the OEM?

Moreau: Yes, they have the assurance that the product being built is in a much better controlled process, so it's going to reduce the defects, the quality is going to improve, and then you have the traceability. They have the information that, "Here's what happened in the wave;" not saying at the beginning of the shift, "I checked the machine, and everything was okay," but, "As every one of my boards went through, I know what happened."

Johnson: Right, and there's a value there as well, isn't there?

Moreau: Yes, and that gives them full traceability.

Johnson: As customer tolerances get tighter, and speeds get higher, then managing all of the design constraints—crosstalk, RF issues, shielding, environmental resilience, wider temperature ranges and humidity issues—at some point this boils down to specifications that the soldering process needs to accomplish. How does the WPI receive its incoming setup data for a particular job?

Moreau: Most of that drives around the materials used, the assembly design, and the type of equipment you have. If the customers do have particular materials to run, the chemistries and components are going to drive what their selections are in relation to the product itself. And if they want to get better control and results, they need something to go on. Repeatability of the process will influence those types of things especially when you get to dwell time; that's going to impact how well that solder joint is completed going through the wave.

Johnson: There are people in the industry who are of the opinion that slowly, steadily, the wave soldering machines are on their way out. But this addition seems like it might breathe new life, new usefulness, to wave soldering. Is that how KIC sees it?

Moreau: I believe it was Mark Twain who said, "Rumors of my death have been greatly exaggerated." I think that's true for wave. It's been rumored year after year, "This will be completely replaced by surface mount or some other insertion method or something," and nothing has been provided that has reached that goal. We see that the machines have improvements on them now so they can have much tighter control. It's not as much a "voodoo art" of setting up the wave solder machine; it's a little more scientific, and the machines have more control parameters that they can accomplish.

We saw this as an opportunity; this is actually the path of wave solder, especially in the high-volume factories, that there is a need and it's not going to go away. They need this information to do the high-volume production. When you look at wave vs. selective, wave is a much more value-added process on the high volume, or there are a lot more parts on the board that need to be through-hole. We saw that this is the type of data they need on this process, so it seemed like a good fit and a good opportunity; not just a short-term solution but something that will continue.

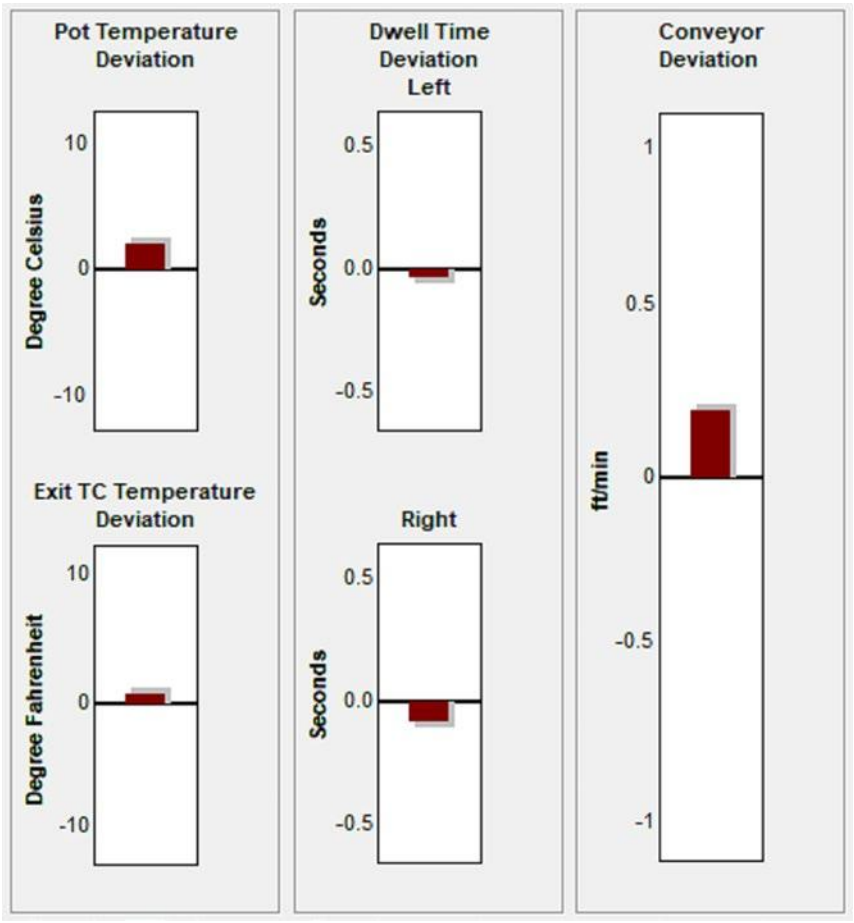
Johnson: KIC has done a lot of work with Industry 4.0 and protocols like the CFX protocol, bringing process monitoring, process control, and inter-process communication into the whole flow. How much work is going on in the industry to include wave solder in Industry 4.0? Are you unique in doing this?

Moreau: With regard to the type of data we collect and the type of solution we have, as far as I know, this is the first solution that accomplishes that. We have had a solution, and even that has been unique on the preheat side. We could monitor the preheat profile of the wave process. We're taking WPI to the next level, and it's the only solution available where you get complete process information: "Here's the temperature profile of that board even going through the wave, and here's some key process indicators, dwell time, and parallelism on the wave itself in real time." It fits into that flow: "If I have this type of data on the wave machine, how can I relate that to my factory as a whole, and all the processes leading up to that?"

It's a unique solution that fits the market well and is something our customers are saying they need.

Johnson: This is something that could be retrofitted to existing wave soldering machinery?

Moreau: Correct. It's definitely retrofittable, though there are some limitations depending on the type of machine. With our reflow solu-



Wave process deviation tracking.

tions, reflow ovens are very similar—it doesn't matter about the make or model, you have very similar attributes as far as the physical oven and the mechanics. There is a lot of variety in the way the wave machine operates, so that made it a little more challenging. Our initial release is focused on certain configurations, so we have had that conversation with our early customers who have already implemented this.

Our process looks like this: "Okay, what's the setup of your machine? How is it configured? What type of heat source are you using? How is your wave configured?" Then, we see if we have a match for the WPI. As the product and our solutions mature, we'll make it more adaptable to all the configurations out there.

Johnson: There are multiple protocols out there—CFX is a leading one, of course—yet there are protocols now being used in PCB with roots in semiconductor. How multilingual do you have to be?

Moreau: It's funny, because at a certain point in the maturity of our solutions, we were adding more features to be able to track barcode or display certain things on the screen, how you alarm, or talk to the in-feeder to stop the board. Then it reached a level where we asked, "Now what do we do with that data and who do we need to connect it to?" It has become more interesting in this last decade, especially with the reflow and wave processes. We had progressed to having data as a simple format of text, CSV, or XML files that we could pass to any factory system; then it went to this factory level software that wanted it to—kind of like the semiconductor side—interact with the machines almost in real time, or at least during changeovers.

We started to integrate our KIC solutions with customers who had those requirements. But that became very customized when every customer had something a little different. Now with the IPC-CFX 2591 for PCB assembly and SECS/GEM on the semiconductor side, it provides some consistency. We've partnered with some of the major third-party MES software as well, such as Aegis, Mentor, Cogiscan, and iTAC. But that still leaves a large part of the market who have their own MES system that they've built. So, how do you do all these flavors, all these formats?

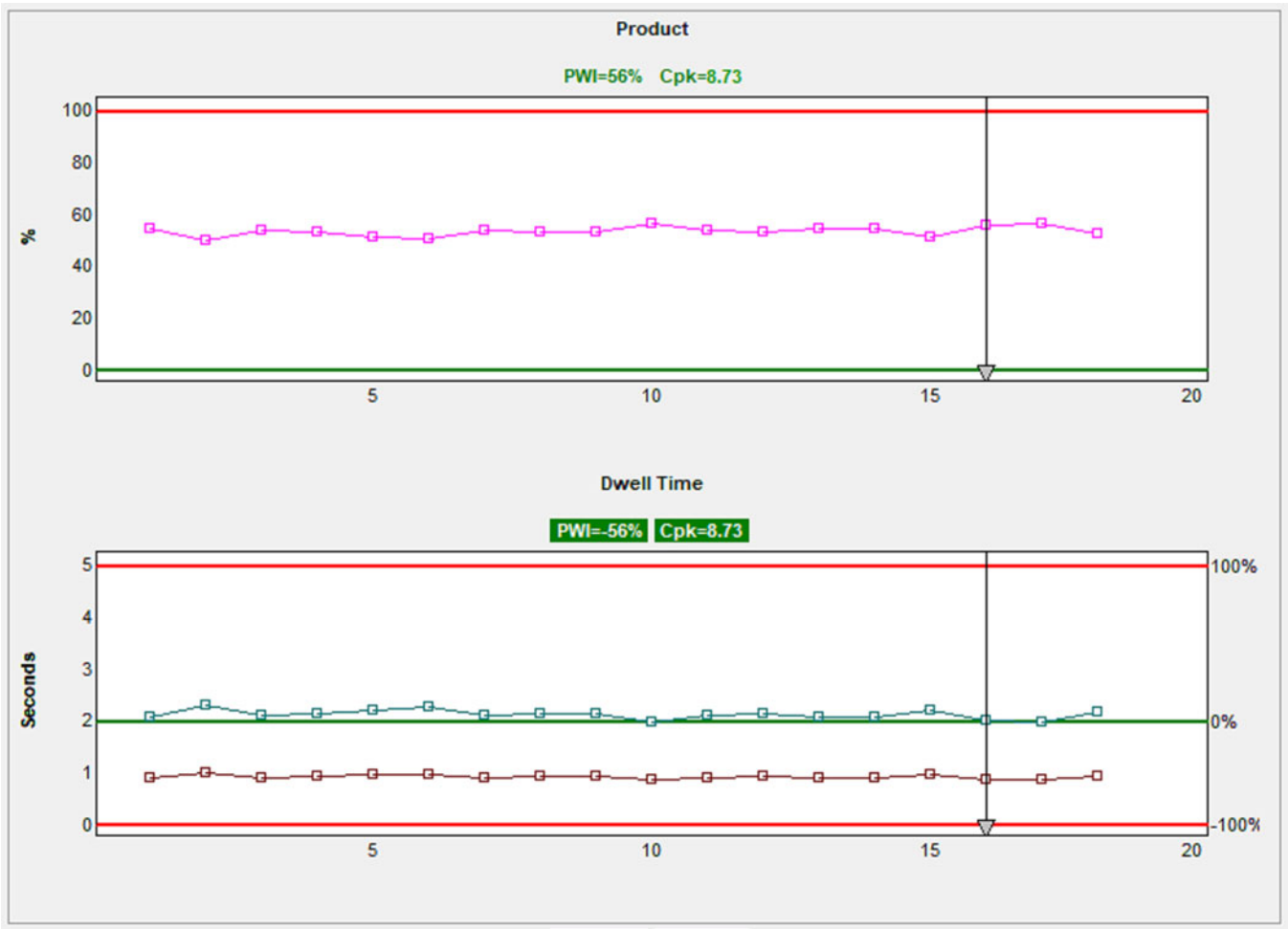
Those can be accomplished with industry standards because you aren't continually doing customized work. For example, with CFX, KIC has been involved with the CFX committee from the beginning and we were one of the first to get the IPC certification for CFX. They have a test bed that tests your system against

what the standard is and certifies the equipment as an IPC_CFX qualified product. The KIC RPI (Reflow Process Inspection) is the only automatic profiling system qualified at this point.

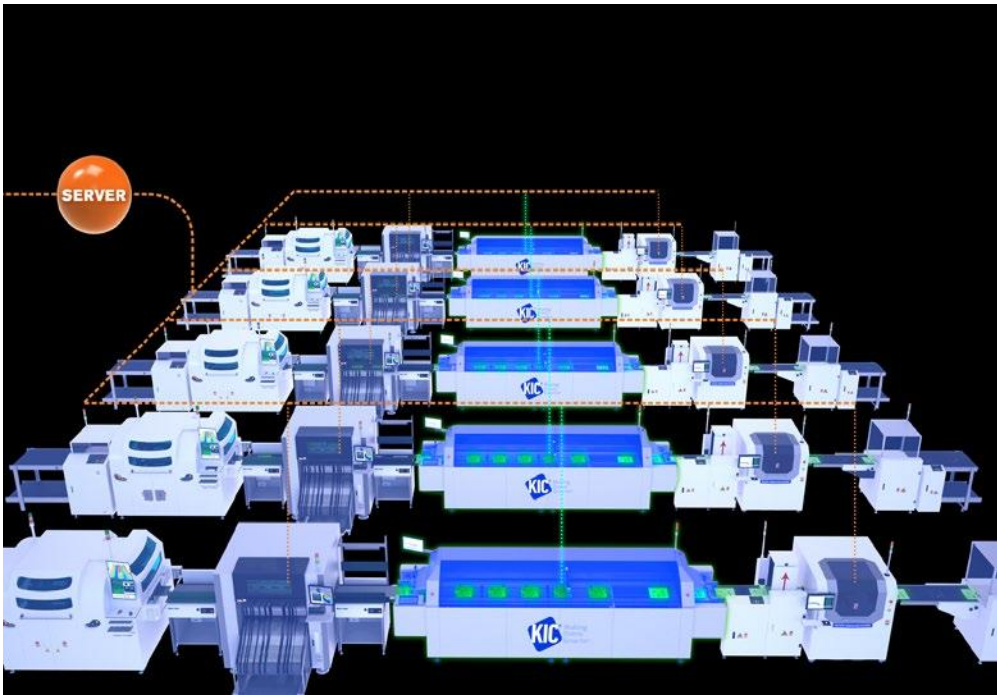
It makes it easy for the customer, who then can say, "Here is all this equipment that is CFX compliant, now I can make my CFX broker system and MES from that standard." I think our solutions around wave and reflow and being able to link to those types of factory systems, really play well into companies creating the smart factory. And coming up shortly we are releasing our own KIC API and SDK.

We have a software development kit for customers who don't want to necessarily have KIC customize everything for them; we can hand them the kit with an API and say, "Use this kit, it will show you how to connect to our system. You can pick and choose what data you want to go to your MES or factory system." It's a really good, robust way of handing off the data because the customer can pick and choose how they want to do it. It's those types of things—the standards, having an SDK—that allows our system to be a really flexible solution for the customer, not just with all the value that it brings as being a real-time system on the line, but now it's very flexible on how they want to bring it to that smart factory level.

Johnson: Is the implication that a customer can take baby steps as they work toward a final solution of an integrated digital factory? Maybe they're not ready for all the industry standard protocols because they have a homegrown system that they're working with or phasing out. By plugging into the SDK, are they still able to take what they already have and start to move that direction with KIC?



WPI with real-time production dwell time.



Inline reflow process inspection. Click here to learn more.

Moreau: Exactly. It gives the customer some flexibility. Rather than having to set up a structure, they can say, "We can grab some data off of here, we can grab some flat files, we can use their SDK and integrate their system directly with ours," even though ours isn't some standard.

Johnson: Interestingly enough, that very theme showed up in one of the keynotes for IPC APEX EXPO 2021. I don't know if you caught Travis Hessman's keynote presentation, but he was talking about how to migrate well into a digital factory environment; he talked about nibbling at the edges where you're solving a problem, not creating a new factory.

Moreau: Over the past couple of years, we've even promoted a smart factory starter kit. Why not start? As far as an inspection system, say for example the RPI reflow process inspection; it's a very low cost compared to AOI or SPI. You put in those embedded sensors, get that system working on your reflow process, and now use the tools it has to automate, inspect, and capture that data; it's your test bed for smart factory and at a low investment.

Now you've tested it and worked out how to accomplish it and who needs to be involved, then it's as you said—you start eating away at the other edges and combine them. We say, start with reflow because it's a pretty straightforward process. What's the key process thing on an oven? It's not necessarily the recipe, it's the temperature profile. If you have a system that's capturing the temperature profile of your production boards, now you can use that as the base and then extend that into your smart factory. You will have learned all your lessons and now you can start spreading it to other processes.

Johnson: KIC recently completed a first dual lane vacuum reflow RPI system with SMT, the German oven company, as your partner. Tell me about that?

Moreau: The vacuum reflow oven, it's a bit of a different animal. It has some challenges because smack in the middle of the reflow oven, you're stopping the product, putting it inside a chamber, and drawing down a vacuum to reduce voids. That's the key for those manufacturers and their end customer; it's driven by their end customer saying, "This is the maximum size void that you can have in our products when you build them. You need to be down at a very, very small level of voids." There are ways of mitigating that through the materials itself, through the solder and the solder paste, but another solution is vacuum ovens.

Our typical solution on reflow is an array of thermocouples down the tunnel mounted on the rails. Now you're putting a chamber and it's a stop/start process, so that creates some challenges. About a year and a half ago, we released an RPI for vacuum reflow ovens with Rehm, and now we have a couple of partners we've released that product with. We're able to capture the vacuum cycle time along with the reflow profile data; customers wanted to see that consistency and repeatability added to the typical profile data, and that ensures that their process is under control.

This past year, it's just a more challenging process because of that vacuum chamber. We've worked with SMT and come out with a solution on the dual lane, because as opposed to a typical RPI system on a dual lane oven and typical production where boards can go on either lane, with the vacuum chamber, the boards have to be aligned; it's about the timing and the way the boards move. When they go in the chamber, they have to go in at the same time, so there's a bit more logic and mechanical challenges around a vacuum reflow oven integrating the KIC RPI system, but a dual lane adds to that complexity. We were able to, with a common customer, come out with a dual lane RPI system for vacuum reflow with SMT. They are a good partner to work with.

Johnson: Great. What sort of ROI is the customer seeing?

Moreau: For the most part, the key customers using our system for the vacuum reflow process are automotive and medical. Those are high reliability products that they're building and there's a high level of traceability requirements that have to be met. To even get the contracts to build those products, they have to have a high level of traceability, they have to save the production data for a number of years.

Johnson: Ah, so it's not so much ROI as it is accountability.

Moreau: Yes, there is a certain value-add to have this real-time inspection, just like on a regular reflow process, but now you're trying to mitigate voiding, and because the customer requirement is you can have void sizes no larger than a certain amount on my products, how do you ensure that the temperature profile and the vacuum are done consistently? The value is added when it gives that data, which then can be handed off to their customer; it automates that.

It goes to continuous improvement in automation, rather than the customer saying, "Well, you're going to have to do more frequency of profiles; if you're going to do our product, then we want you to run a profile maybe twice a shift." Now they have to stop and run that profile through. Now that's your direct ROI saying, "I either have to run profiles pretty frequently and disrupt my production, or I can put this automated inspection system that gets me the traceability that my customer needs."

Johnson: The reason to implement traceability is so that, if something goes terribly wrong in the field, you can search back through the data to find the root cause.

Moreau: Correct, exactly.

Johnson: Miles, this has been most informative. Thanks for taking the time to talk!

Moreau: Excellent. Let's talk again soon. SMT007

Miles Moreau is general manager of KIC EMEA, Americas, Australia.