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# Machine Optimization: Is it Artificial Intelligence?

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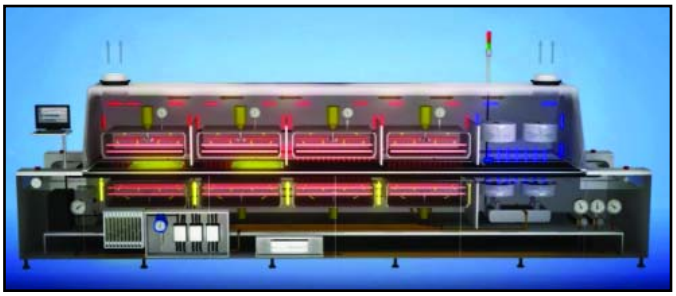
Whether we hype it and call it artificial intelligence (AI) or the more modest "machine optimization," reflow oven optimization software is a great example of a smart machine.

A reflow oven is a complex machine with PC-controlled heaters, airflow, conveyor speed, flux management, and much more. Reflow ovens serve one main purpose: to process any product in accordance with its soldering specifications.

More precisely, this is where three sets of process specifications for components, solder paste and substrate intersect. The key measurement is called a product profile, which will need to fall within the relevant process specifications, also called the process window. Therefore, we can think of a reflow oven as a "profile making machine."

### Automatic Profiling's Development

Twenty years ago, it was common for a process engineer to try different oven setups during new product introduction (NPI) until satisfied with the resulting profile on the assembly. Software was developed that allowed this "trial and error" method to be replicated on the PC. One or more temperature zone set points were changed on the PC, perhaps along with a changed conveyor speed, and the software would immediately predict what the resulting profile would be on the PCB if the oven had stabilized on that new setup.



***Today's smart reflow ovens can suggest optimal oven setups without running a single profile.***

Profiler companies then developed software algorithms that used the laws of thermodynamics to calculate the effect of a changed processing environment. With a known starting point, namely a single profile run through the oven, the mathematical model would calculate how varying temperatures and duration at each temperature would affect the profile on the assembly. A key variable was each oven's unique heat transfer rate coefficient, hence the need for an initial profile run on that specific oven.

By capturing the essential cause and effect data, it became possible to make a very accurate prediction model, based on the assumption that all PCBs in the relevant production run were identical. That was a safe bet as the product BOM obviously had to be a constant, along with a very specific solder paste volume and placement of components.

This prediction software was a big help to engineers, especially in reducing NPI time and increasing equipment utilization. With the introduction of lead-free solder, the process window tightened up and made this task more challenging. An average reflow oven is capable of billions of alternative setups when changing each zone temperature and the conveyor speed in small increments over a

wide range. This was the time when new, much faster prediction algorithms, combined with sophisticated computers made a difference. Also, the prediction results were no longer only good or bad but instead offered a quality ranking of each resulting reflow profile.

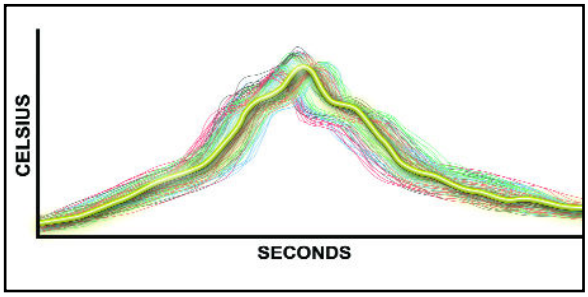
### Enter the PWI

The introduction of the process window index (PWI) was the final new invention that allowed for automated reflow oven optimization. The PWI quantifies the quality of each profile with a single number. PWI, which literally condenses hundreds of thousands of data points into a single number, is similar to the historic Richter scale. In the 1920s, there were very complex and competing methods to characterize the strength of an earthquake. Dr. Richter developed an efficient, powerful alternative to chaos by condensing the information into a single number to quantify an earthquake's force.

A PWI number of 100 percent means that 100 percent of the process window is used, which is another way of saying that the reflow profile is exactly on the edge of the process window. A PWI of less than 100 percent means that the profile is in spec. The lower the number, the more the reflow profile is located toward the center of the process window.

On the other hand, with a PWI greater than 100 percent, the profile is out of spec to larger or smaller degrees. One benefit of the PWI concept is the simplicity and speed with which a conclusion can be made. If you had ten process engineers in a room and presented each of them with the raw profile data — hundreds of thousands of data points — and asked their opinion about the quality of the reflow profile, you would likely get ten different answers. If you gave them the single PWI number, you would get the same answer from all of them, regardless of language or expertise.

Perhaps the most significant benefit of the PWI, however, was that now computers had a single number to rate the numerous profiles. With billions of alternative oven setups, the prediction software would predict the resulting profile and its match to the process window billions of times over, each with its own PWI number. Computers then had an easy task of selecting an oven setup that resulted in a profile with the lowest PWI number.




***Profile-making software churns through billions of possible setups before selecting a "golden profile."***

This could be done in just a few seconds. This capability again allowed for greater optimization. The center of the process window is a good one because it results in a stable process that allows for more of the natural drift in the process during a production run without falling out of spec.

Additional profiling optimization capabilities became popular. Search criteria, such as selecting the oven recipe that maximizes the conveyor speed while keeping a deep in-spec profile became possible. Or one could ask for the oven recipe using the least amount of electricity while still maintaining a certain minimum speed and PWI level. Or the engineer could request the fastest oven changeover by fixing the zone temperatures and only varying the speed. The equation had changed from "Tell me what happens if I do this?" to "This is the result I want to see. Make it happen, fast!"

### Real or Fake AI?

Whether we name it AI or machine optimization, the smart reflow oven shows the potential of using massive amounts of data to create insight, to deliver actionable information, or simply to communicate machine-to-machine for automatic decisions or adjustments within process criteria. The above-referenced technology, which may seem impressive to some and child's play to others, actually was developed and launched last century. It does, however, give a hint of the power and benefits to manufacturers that can be created this century.

As an example, Vitronics Soltec, a reflow oven manufacturer, has been shipping their ovens with a similar oven setup software that goes one step further. The reflow oven software includes an intelligent database that contains a rich library of these "cause and effect" observations. A user can simply enter the length, width and weight on the new PCB and the software will suggest the optimum oven setup without the need to run a single profile.

With Industry 4.0 and the smart factory trend ramping up, we are entering an exciting new world of running machines and factories vastly more effectively, with lower cost and consistent quality. This is done while adding process transparency and traceability, machine learning, system interconnections, and much more.

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