The Effect on Energy Use from an Optimized Reflow Oven Recipe in Lead-Free Applications

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Abstract

Due to the higher melting point of lead-free Sn-Ag-Cu alloy, higher reflow soldering temperatures are required for lead-free PCB assembly. Consequently, reflow oven energy consumption is growing as well. This research work is focused on the potential opportunity to reduce higher energy requirements with the use of modern thermal profiling and process optimization software.

Introduction

In order to determine the energy consumption during the lead-free reflow process, a convection oven was equipped with a multifunctional energy meter. Then measurements were performed for several days, when the oven processed leaded and lead-free versions of the same product respectively.

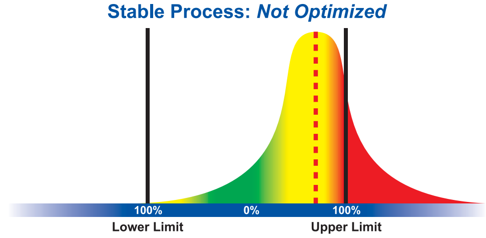
Experiment description

The experiments were conducted using a Heller 1912 EXL reflow oven manufactured in July 2005, and a SlimKIC 2000 profiler equipped with the Auto-Focus optimization software.

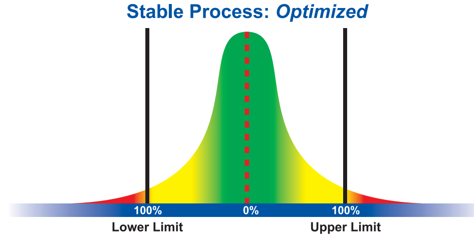
For the tests, a representative product was chosen from the telecom family group of products that were to be converted to lead-free in the near future. A comparison was performed on the same product manufactured in both technologies. The experiment consisted of four sets of measurements:

- leaded product with non-optimized reflow profile
- leaded product with optimized profile
- lead-free product with non-optimized reflow profile
- lead-free product with optimized reflow profile.

Stable Process: *Not Optimized*



Stable Process: *Optimized*



Care was taken to make sure that no optimized oven recipes used a conveyor speed slower than the slowest cycle time in the production line. In other words, the reflow oven did not become the bottleneck in the production line for any of the tests in this report.

Case A – Non-optimized leaded profile

For the non-optimized profile a recipe was chosen manually that fit the process window in terms of peak temperature. Based on the solder paste, substrate and components, the process window for peak temperature was used as the range from 205° to 225°C.

Case A Settings

Oven settings for Case A were set as follows:

Zone	1	2	3	4	5	6
Setpoint	101	117	131	155	161	161

Zone	7	8	9	10	11	12
Setpoint	171	180	199	239	239	220

Conveyor speed: 95 cm/minute (37"/minute)

The reflow process parameters for Case A:

Peak temperature [°C]:	223.5
TAL [s]:	82.0
ΔT [°C]:	11.06

Case A Results

Once the profile had been set, the hourly energy consumption at the oven was measured. As is typical, the data were fluctuating somewhat, but the average energy consumption for Case A was 10.4 kWh.

Case B – Optimized leaded profile

The optimized profile was created with the help of a profiling software system with an Auto-Focus option. This automatic prediction optimizer has the ability to pick up the lowest available peak temperature that fits into the process window. Before engaging the software, the Case A profile above was chosen as the starting point.

Case B Settings

The optimized oven settings for Case B were:

Zone	1	2	3	4	5	6
Setpoint	101	117	131	155	162	162

Zone	7	8	9	10	11	12
Setpoint	172	183	193	229	230	217

Conveyor speed: 92.3 cm/minute (36"/minute)

The reflow process parameters for Case B:

Peak temperature [°C]:	216
TAL [s]:	81.3
ΔT [°C]:	9.18

Case B Results

What can be observed at first glance is that both the peak temperature and the delta T across the board are significantly lower. Once the profile had been set, the hourly energy consumption at the oven was measured. Average energy consumption for Case B was 8.8 kWh, which is 15 percent lower than in Case A.

Case C – Non-optimized lead-free profile

The non-optimized lead-free profile was chosen in the same way as the non-optimized leaded profile (Case A). The difference is the peak temperature. The process window (in the terms of peak temperature) was defined as the temperature range from 235° to 260°C.

Case C Settings

Oven settings for Case C were set as follows:

Zone	1	2	3	4	5	6
Setpoint	120	130	150	179	190	222

Zone	7	8	9	10	11	12
Setpoint	235	235	243	263	262	222

Conveyor speed: 90 cm/minute (35"/min)

The reflow process parameters for Case C:

Peak temperature [°C]:	252.7
TAL [s]:	88.8
ΔT [°C]:	9.71

Case C Results

Once the profile had been set, the hourly energy consumption at the oven was measured. Average energy consumption for Case C was 11.5 kWh. This represents a 10.6 percent increase in energy use compared to the equivalent leaded application and a 30.7 percent increase over the optimized leaded process.

Case D – Optimized lead-free profile

As with Case B, the optimized profile was created with the help of a profiling software system with an Auto-Focus option.

Case D Settings

The optimized oven settings for Case D were:

Zone	1	2	3	4	5	6
Setpoint	116	104	140	166	193	211

Zone	7	8	9	10	11	12
Setpoint	219	231	257	247	245	208

Conveyor speed: 80.6 cm/minute (32"/minute)

The reflow process parameters for Case D:

Peak temperature [°C]:	241.4
TAL [s]:	85.0
ΔT [°C]:	4.67

Case D Results

We can observe significant delta T reduction. The average energy consumption for optimized lead-free reflow profile is 10.6 kWh. It is very similar to non-optimized leaded profile consumption (1.9 percent higher). Comparing the optimized lead-free profile to the non-optimized lead-free profile, there is a 7.8 percent improvement.

Conclusion

The table shows all average energy consumption for leaded and lead-free profiles. The lower usage of energy with optimized profiles can be seen.

	Leaded	Lead-Free
Non optimized	10.4 kWh	11.5 kWh
Optimized	8.8 kWh	10.6 kWh

The above numbers can easily be translated into the financial impact using the following formula:

Total annual cost of energy = Average kWh consumption • Cost/kWh • 24 hours • 7 days • 52 weeks

Assuming an average energy cost of **$0.076/kWh**, the following table illustrates the total annual cost of energy per oven and the total annual savings per oven as a result of optimizing the process.

	Leaded	Lead-Free
Non-optimized	$6,904.93	$7,635.26
Optimized	$5,842.64	$7,037.72
Cost Savings	**$1,062.29**	**$597.54**

This proves that using a modern thermal process optimization tool can result in production cost reduction. Further, the optimized oven recipes operate in the "sweet spot" of the process window. This improves quality and productivity in addition to reducing operating expenses.

References

M. Apell, J. Dautenhahn, T. Formella, J. Morris, "Power Consumption and Nitrogen Control in Lead-Free Reflow," *OnBoard Technology*, April 2004, pp. 24-26.