Radiometry as a Tool:
Trouble-shooting Production Problems in a Kitchen Cabinet Manufacturing Plant

By Karin Efsen and Jim Raymont

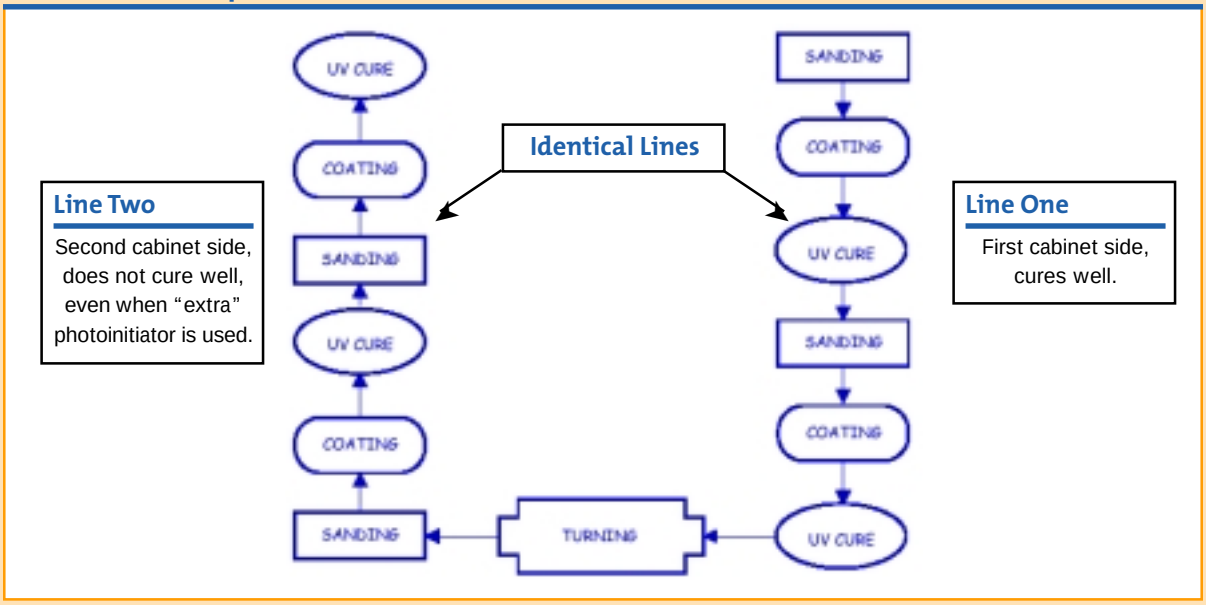
A kitchen cabinet door manufacturer was puzzled when two "identical" production lines using UV technology produced vastly different results. No matter what adjustments were made, the production lines simply did not produce curing results of equal quality. The investigative team combined two forms of data gathering —raw numerical data and radiometry picture profiles—to pinpoint the problems. The irradiance picture profile provided the visual image needed to easily determine what was causing the discrepancy. Using only numerical data, the solution would not have been obvious.

The Situation

The Danish manufacturer was using UV technology to produce kitchen cabinet doors and ran into a problem when two production lines, set up to be identical (Figure 1), started achieving critically different results.

Figure 1

Two "identical" production lines



The manufacturing plant used one production line to sand, coat and cure one side of the door, and the second production line replicated the process on the other side of the door. The results were not the same, and there was no obvious reason for the difference. The manufacturer consistently achieved good results on the first side of the cabinet door, but the topcoat on the second side did not cure well. The manufacturer resorted to adding extra photoinitiator to the coating used on the second side of the door, and still did not achieve results as good as those seen on the first side.

Investigation

A quick physical check confirmed that all UV systems were up and running—i.e. power was applied and visible light was seen from the ends of the cure stations. All lamps were set at 80 watts per centimeter (approximately 200 watts per inch), the power setting normally used for production. The production line speed was 14 meters per minute (approximately 45 feet per minute). The type and amount of UV energy could not be determined from the physical check. The last date of preventative maintenance and the number of hours on the bulbs was not known.

The topcoat curing stations for each production line were individually measured to look for any differences between the two "'identical" sides. A four-channel profiling radiometer was used to measure the UV output on the two lines. All four bandwidths (UVA 320-390 nm, UVB 280-320 nm, UVC 250-260 nm, UVV 395-445 nm) of the instrument were activated for the investigation. The sampling rate of the radiometer was set to 128 samples per second. Data collected was transferred and saved on a laptop computer for viewing, manipulation and analysis. The instrument also time/date stamps each file when it is collected.

Figure 2

Measurement of line one: 8:40 a.m.

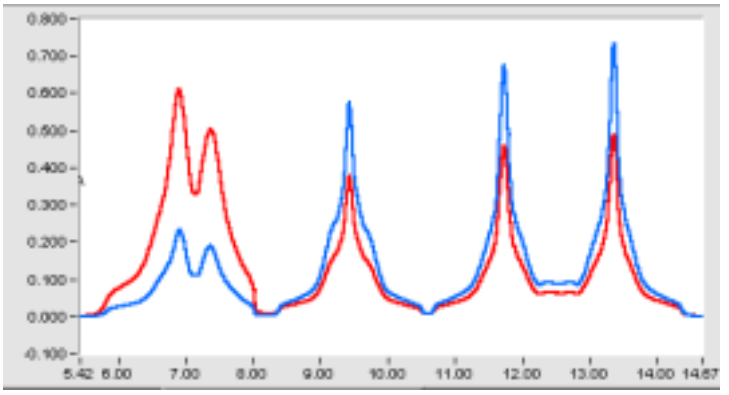
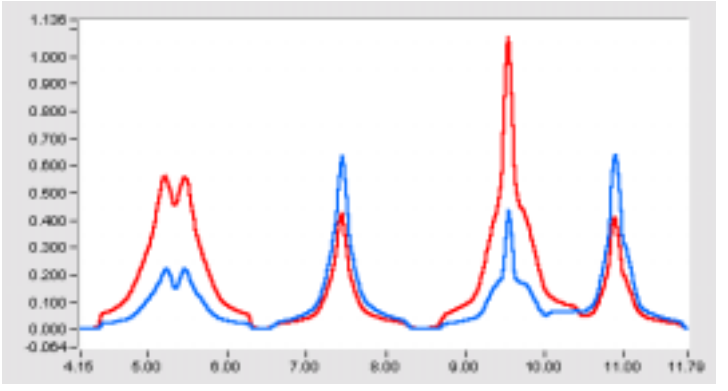


Figure 3

Measurement of line two: 8:43 a.m.



Results

The results are presented along a timeframe to illustrate and help explain the troubleshooting process. The results and discussion focus on UVA and UVV, as these are the two spectral bandwidths of most importance for the type of bulbs used. Both numbers (radiant energy density and irradiance) and the irradiance profile helped investigators see the differences between the two production lines. Line two is always compared to line one (standard) when calculating the percentage difference between the two systems. On the irradiance profiles presented, time in seconds is on the X-axis and the UV irradiance in watts/cm^2 is on the Y-axis. UVA is shown in blue, UVV in red, on Figures 2 and 3.

Comments on Line One

Line one is the side of the line that was producing good-quality cabinet doors. It consisted of four UV systems. The first system contained a mercury-gallium additive bulb that was set up out of focus. The mercury-gallium

bulb was identified by the high UVV to UVA ratio and confirmed by the plant staff. Because the system was running out of focus, the profile showed the double peaks for the first lamp. Three focused mercury bulbs followed the first UV system.

Comments on Line Two

Line two was the side of line that was not producing good-quality cabinet doors. It consisted of four UV systems. The first UV system contained a mercury-gallium additive bulb that was set up out of focus. Instead of being followed by three focused mercury bulbs, line two was followed by a mercury bulb, then a mercury gallium bulb and then a mercury bulb.

First Major Conclusion

By looking at the irradiance profiles, the first major conclusion was discovered about five minutes after starting the trouble-shooting process—a different bulb was being used in the third UV station in line two.

A comparison of the numbers in Table 1 also reveals differences, but the clear indication that there is a different bulb in the third system on line two is not as obvious as with a picture of the irradiance profile.

With a multi-band radiometer, the individual lamps could be measured one at a time and the UVA:UVB:UVC:UVV ratios compared to determine the bulb type. This process takes a little longer to confirm bulb types.

Synchronizing Line One and Line Two

The computer software with the profiling radiometer allows two files to be viewed at the same time. It also allows the files to be synchronized and placed on top of each other. When this is done, it leads to another very important observation about the two production lines. In Figure 4, only the UVV profiles are shown for clarity. Line one (good curing) is shown in black and line two (poor curing) is shown in green. It takes the radiometer longer to pass through line one than it does to pass though line two. There is an absolute difference of 1.25 seconds or 14.5%. On radiometers that report only numbers, the difference in the speeds of the two production

Table 1

Comparison of numbers

Bandwidth	Radiant Energy Density (mJ/cm2) Total for all four lamps		% Difference	Peak Irradiance (mW/cm2) Highest value reported		% Difference
	Line One	Line Two		Line One	Line Two	
UVA	1141	793	-30.6%	733	637	-13.0%
UVV	1230	1212	-1.4%	608	1070	76%

Figure 4

Speed measurement of the two production lines

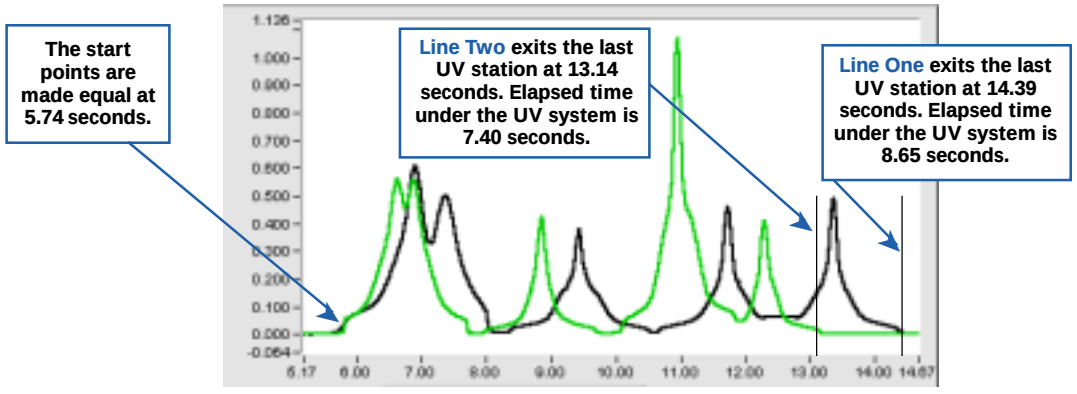
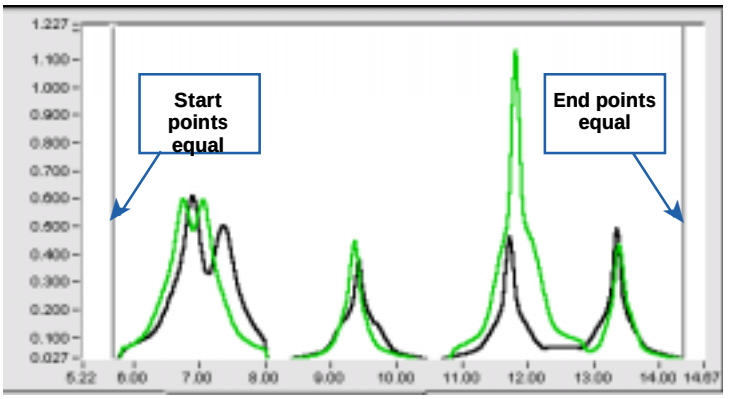


Figure 5

Adjustment of the process speed on line two and measurement again: 9:00 a.m.



lines would have been harder to uncover. It may be helpful to monitor process speed with an independent tachometer or stopwatch.

Second Major Conclusion

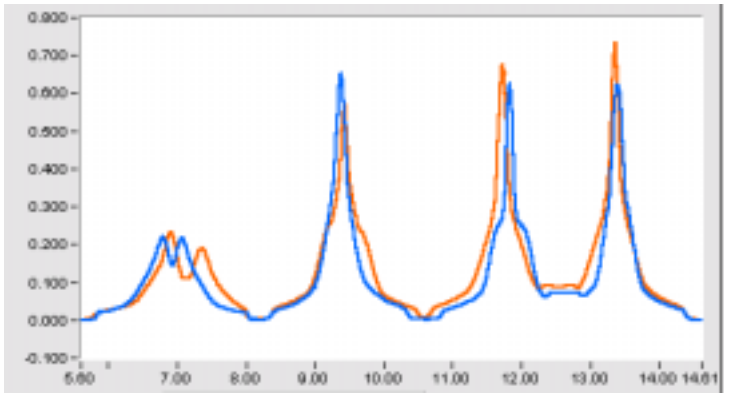
By looking at the irradiance profiles, the second major conclusion was discovered about 20 minutes after starting the trouble-shooting process—line two is running approximately 14% faster than line one.

In a very short time, we were able to confirm:

- A different bulb is being used in the third UV station in line two. No one in the plant knew how the mercury-gallium bulb was installed into station three.
- Line two is running approximately 14% faster than line one. No one in the plant knew how long it had been running "fast."

Figure 6

Comparison of line one and line two (UVA)—changing of the bulb and measurement at the same process speed of the line: 9:48 a.m.



Adjustments Made

Adjustments were made to the speed on line two until it was similar to the speed of line one. The results are displayed in Figure 5. Again, only the UVV profiles are shown for clarity. Line one (good curing) is shown in black and line two (poor curing) is shown in green.

With the change and equalization in speed on line two, there was a closing of the gap in the number of joules. For a true comparison and equalization between line one and line two, the third bulb in line two needed to be changed to a mercury bulb instead of a mercury-gallium bulb.

Line two was shut down, allowed to cool, and the third bulb was changed to a mercury bulb. The system was restarted and allowed to warm up.

When both the speed and third bulb in line two were changed, the traces matched up much better. Figure 6 (on previous page) compares UVA with line one in orange and line two in blue.

Figure 7 compares UVV with line one in black and line two in red.

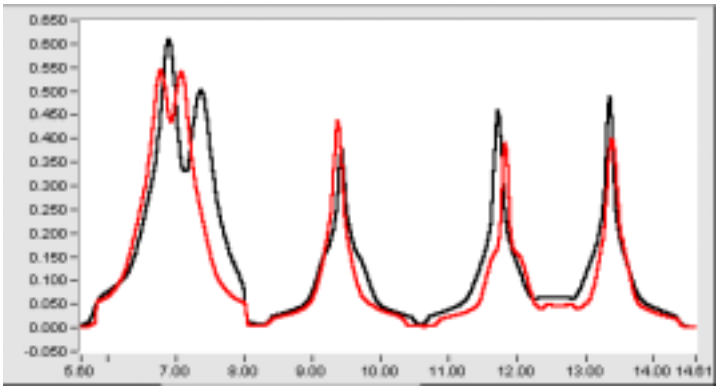
Tables 2 and 3 present the radiant energy density and irradiance data for UVA and UVV. The data is presented for line one; line two as found; and line two after speed and the bulb change were made.

Conclusion

Numbers do not always tell the whole picture—a profile helps. A multi-channel profiling radiometer was able to quickly identify the differences between the two production lines. The curing on the second side of the cabinet door (line two) was as good as the curing on the first side of the door (line one) after the bulb was changed and the speed adjusted on line two. The customer eliminated the need to add 'extra' photoinitiator for line two and increased throughput.

Figure 7

Comparison of UVV



Facilities may want to establish controls to check and confirm process speed and bulb type for each line and UV system. ◗

—Karin Efsen is a director at Efsen Engineering A/S, in Vedbaek, Denmark. Jim Raymont is the director of Instrument Markets, EIT Instrument Markets, Sterling, Va.

Table 2

Irradiance data for UVA and UVV

Bandwidth	Peak Irradiance (mW/cm^2) Highest value reported			% Difference between Line One and Line Two with speed and bulb change. Line One used as the reference.
	Line One	Line Two	Line Two after both speed and bulb change	
UVA	733	637	651	-11.2
UVV	608	1070	544	-10.5

Table 3

Radiant energy density

Bandwidth	Energy Density (mJ/cm^2) Total for all four lamps			% Difference between Line One and Line Two with speed and bulb change. Line One used as the reference.
	Line One	Line Two (as found)	Line Two after both speed and bulb change	
UVA	1141	793	1002	-12.2
UVV	1230	1212	1043	-15.1

UV PRAYER

Dear UV angel in the sky
Please let my UV coatings dry.
Give me the Joules, I'm tied in knots.
I'm also in the dark on Watts.
All I've done with "trial and guess"
Is make a lot of scrap pile mess.
My line is down, the job is late.
I need help now, the boss won't wait.
I promise if you'll hear my plea
Tomorrow I'll call EIT.

If this is your idea of UV process control, it's time to call EIT. We have the products, the experience, and staff—both in the field and in-house—to help you document, achieve and maintain control of your UV process.

ANSWER TO A UV PRAYER

I learned the error of my ways.
Wow, a job log really pays!
Keeping track of Joules and Watts
Can really help my process lots.
I've reduced scrap and life is good.
My stuff is curing like it should.
Start or stop? Relamp or not?
These are things I now can spot.
My instruments from EIT
Tell me where I need to be.

If process control is your goal, it's time to call EIT. We have the products, the experience, and staff—both in the field and in-house—to help you document, achieve and maintain control of your UV process.

Anything less than EIT would be a guess!

EIT
108 Carpenter Drive
Sterling, VA 20164 USA

Tel 703-707-9067
Fax 703-478-0815
www.eitinc.com
uv@eitinc.com