

UV Lamp Performance over Time

UV Process Supply Inc.

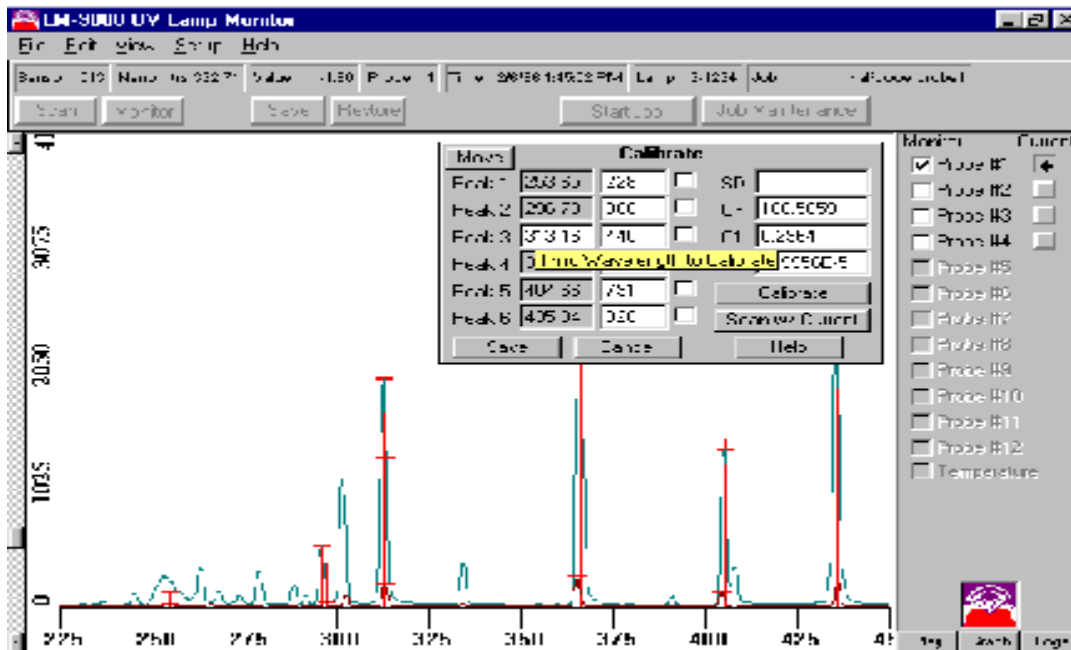
ABSTRACT

A study was performed by UV Process Supply Inc. to review the ultraviolet lamp as a variable in the UV curing process.

In this study, they investigated and displayed graphically how an individual UV lamp degrades over time, and how individual UV lamps compares to another. The results were displayed in terms of intensity at critical wavelengths. The following is a reprint of the tests with permission of UV Process Supply Inc.

TEST METHOD

The monitoring system used for the tests consisted of the LM-9000 UV Lamp Monitor from UV Process Supply, an analytical tool designed for directly measuring the output of UV lamps while on-line, operating inside the curing system. The PC-based computer hardware and software based data acquisition system worked in conjunction with an optical probe, fiber optic cabling, and an optical bench sensor unit.



The optical probe, which has a rated maximum temperature of 400°C, is mounted within the lamp reflector housing or clipped directly onto the lamp. It is connected via fiber optic to an optical bench, mounted on an internal P.C. card or in an external case (attached via serial cable). This unit splits the incoming light "signal" from the fiber optic into its various components (Wavelengths). An array of 1100 sensors then converts this wavelength information into electrical signal voltages, which the lamp monitoring software measures and manages.

The software displays the Wavelength Intensity Distribution between the 200nm and 450nm wavelengths in real-time, sampled approximately every 5 seconds. All wavelengths within the range (all 1100 data points) were examined at each sampling. Particular wavelengths were selected for special attention; such as to generate "Events" or to signal various simulated phases of actual production runs (Start, Stop, Change Power Settings, etc.).

The Life of Lamp Test (single lamp) data was collected from a 10" arc length lamp, at 750 watts per inch, over its actual life of 408 hours (18 days) continuous use before failure.

The Lamp Comparison Test data was collected from 14 lamps, all 20" arc length, at 300 watts per inch, each lamp run for 15-20 minutes, but sampled only after lamp stabilization had occurred.

Two (2) were brand new, the others were returned from production environments after 1000 hours of use. Some of these lamps were of foreign manufacture, while others were of US-origin.

BASELINE OF A LAMP

Every UV lamp produces specific wavelengths of light associated with the materials inside the lamp (i.e. mercury, metal halides, etc.). Each lamp produces its own Wavelength Intensity Distribution over its given range (usually between 200nm and 450nm) which can be viewed as its signature.

Certain frequencies within this range are important to the curing process, and the others are either unnecessary, or harmful, to that specific process. Photo initiators can respond, to greater or lesser degree, at various frequencies. Once power has been applied to a lamp, it goes through a "warm-up" period, during which time it's output levels are unstable. This makes the lamp an unreliable curing instrument until stabilization occurs.

It was observed that this warm-up period is different for every lamp and power supply combination, lasting for between 5 and 15 minutes, during which intensity of the various wavelengths fluctuate wildly. Some wavelengths can reach 150% of their operating maximum before settling down, while others do not approach 100% until lamp temperature reaches some critical point.

Once the lamp has reached this stabilized state, all associated values were recorded to form the "lamp baseline". By saving the signature of the lamp when it is "new" or newly installed into the curing system, a permanent set of baseline values were established to use for comparison at any time in the future.

ENERGY OUTPUT EVENT

From lamp start, when energy output of all wavelengths was "zero", through the warm-up period, to the time when output characteristics appear to stabilize, the particular wavelengths showing the highest intensities (or peaks) changes as the lamp proceeds to its operating state. Radiometers give readings showing total energy output (in mJ/cm²) on a narrow range of wavelengths, presumably some of those same high-intensity peaks, sampled at a given rate, such as 40 samples per second. Such devices may show the same reading even though the actual wavelengths of light being output is rising or falling within the range.

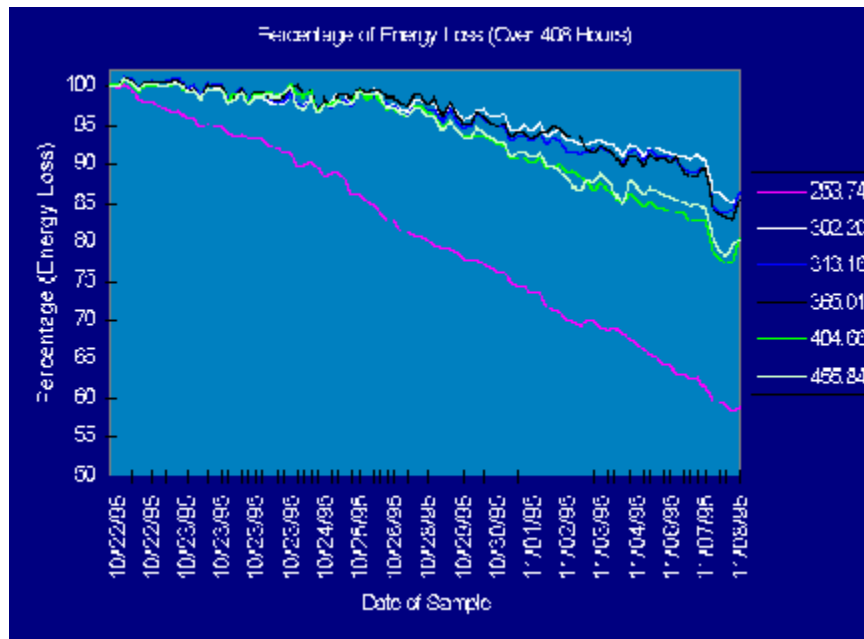
As an example, from lamp start until three minutes had elapsed, one lamp displayed peaks at 350nm, which after four minutes became two lower peaks both above and below 350nm. Total energy of the individual 350nm peak was about the same as the two lower adjacent peaks. This type of behavior would not be differentiated by the "snapshot" method of a radiometer: both would have given similar results even though the actual output frequencies were different. Total energy of the individual 350nm peak was about the same as the two lower adjacent peaks. This type of behavior would not be differentiated by the "snapshot" method of a radiometer: both would have given similar results even though the actual output frequencies were different.

By using the baseline of a lamp obtained previously, and comparing it to the present state of that lamp (which was just started), a real-time display of percentages at the six selected wavelengths allowed us to see when the lamp stabilized. This stabilized state was defined by viewing this percentage display and noting when the intensity values no longer increased.

Once the intensity levels of the various wavelengths had stabilized, the warm-up phase ended and the simulated job start would begin, as in a production environment. The instrument was set up to save a job baseline of all wavelengths, the simulated job would then proceed with subsequent samplings occurring at regular (under 5 seconds) intervals.

This regularly sampled data could be saved at either regular intervals or saved only upon an "Event", such as when any monitored wavelength's intensity level fell below 25% or 50% of it's baseline value.

LIFE OF LAMP TEST



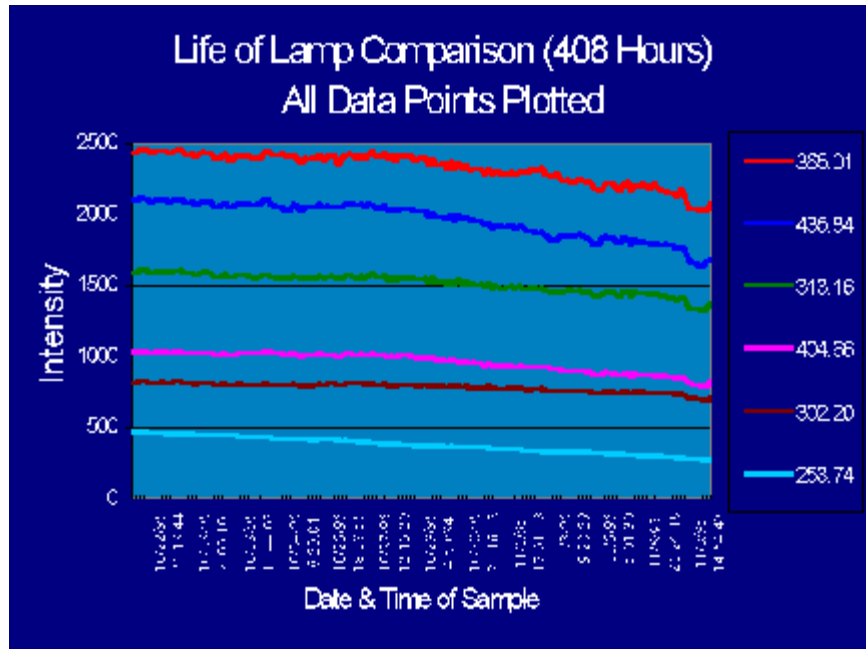
During the test a single lamp was monitored (750 watts per inch) running continuously for 18 days (408 hours) until its failure, in order to determine an individual lamp's performance characteristics. As a lamp experiences continuous use, we expected to find that lamp intensity in general degrades over time. As the contents within a lamp experience changes in pressure, as the electrodes inside the lamp decays and deposits material on the interior quartz, and possibly as the quartz itself changes with temperature, the lamp's overall output degrades. It was observed, however, is that certain wavelengths exhibit straight line decline in intensity while others show oscillating declines, with peaks, valleys, plateaus and dips having a generalized trend downward. Those wavelengths with greatest intensity tend to exhibit this agitated decline while wavelengths of lower intensity tend to exhibit more straight-line behavior.

The most startling discovery to date is that there does not appear to be any uniformity, or even any simple trend, to this degradation. Different wavelengths degrade at different rates.

The percentage of energy loss over the life of the lamp shows clearly that 254nm suffered the steepest decline in intensity while 365nm held up the best over time. Again, it was observed that subtle variances in power supplied to a lamp affect its output. When a factory up the street starts up or shuts down, an "Event" would be triggered, alerting that lamp behavior had changed.

Similarly, changes in ventilation, as well as the individual operating temperature of the lamp, had profound effects on the intensity distribution of that lamp. If ventilation air is blown across a lamp, the air temperature may cause the intensity of specific wavelengths to drop significantly from the lamp's baseline. Natural convection was chosen for these tests to help eliminate this variable from our results.

LAMP COMPERISON TEST



In order to perform a broader examination of lamp characteristics, a group of 14 lamps of the same specification: 20" arc length, 300 watts per inch were monitored. Some were new, some had over 1000 hours of service, some were made in the United States, while others were of foreign manufacture.

All lamps were installed into the same testing enclosure, provided with the same line current and power supply, and run under the same conditions. The same testing instrument was used to obtain all the results.

The intensity levels of a range of similar lamps at a particular wavelength varies. When looking at the six different wavelengths we were paying special attention to each lamp in the series displayed distinct intensity levels at each wavelength, though they do tend to congregate around a certain level. Output measured at 254nm tends to congregate around an intensity index value of 250 whereas output measured at 365nm tends toward an intensity index value of 3000.

The degree of separation lamp-to-lamp, between index values of individual lamp intensities at these pre-selected wavelengths can also vary widely. Some of the selected wavelengths held tightly together, with less than 5% variation lamp-to-lamp, while others changed considerably.

Further, some "used" lamps (with over 1000 hours in service) produced higher intensity levels at critical frequencies than did comparable "new" lamps, or used lamps with higher or lower hours. However, this may be due to variances in internal lamp conditions, where a particular lamp's electrodes have decayed or changed conductance.

It was observed that with any given lamp, the individual wavelengths degrade at individual rates, some displaying marked fall off (40% or more from baseline) while other wavelengths remain strong (within 15% - 20% of baseline).

Some uniformity in degradation of lamp performance between similar lamps would be expected, given general entropy effects and the observed variances in specific wavelength output.

However, no true pattern of decay between similar lamps manufactured by the same company, much less by similar lamps produced by different lamp manufacturers. Lamps produced on the same day, to the same specifications, by the same manufacturer exhibit different operating characteristics over time, even within the same curing system.

At different power supply settings on the same lamp, the monitored data showed non-linear variances in intensity within the selected wavelengths, the same group of lamps was tested at high and medium power settings, 300 watts per inch and 200 watts per inch respectively. The notion that decreasing the power level decreases the intensity of all the individual wavelengths within a lamp proportionately, would produce a set of graphs that look identical, except for the intensity level (i.e.: the height of each bar in the bar graph, or the starting point of the line graph).

While the graphs are similar, they are not quite proportional, with some lamps exhibiting a noticeable difference in output wavelength intensity when compared to others, which did perform more proportionately. Again, new lamps did not distinguish themselves from used lamps in these regards; they were not any more linear in behavior than the lamps with 1000 hours of use.