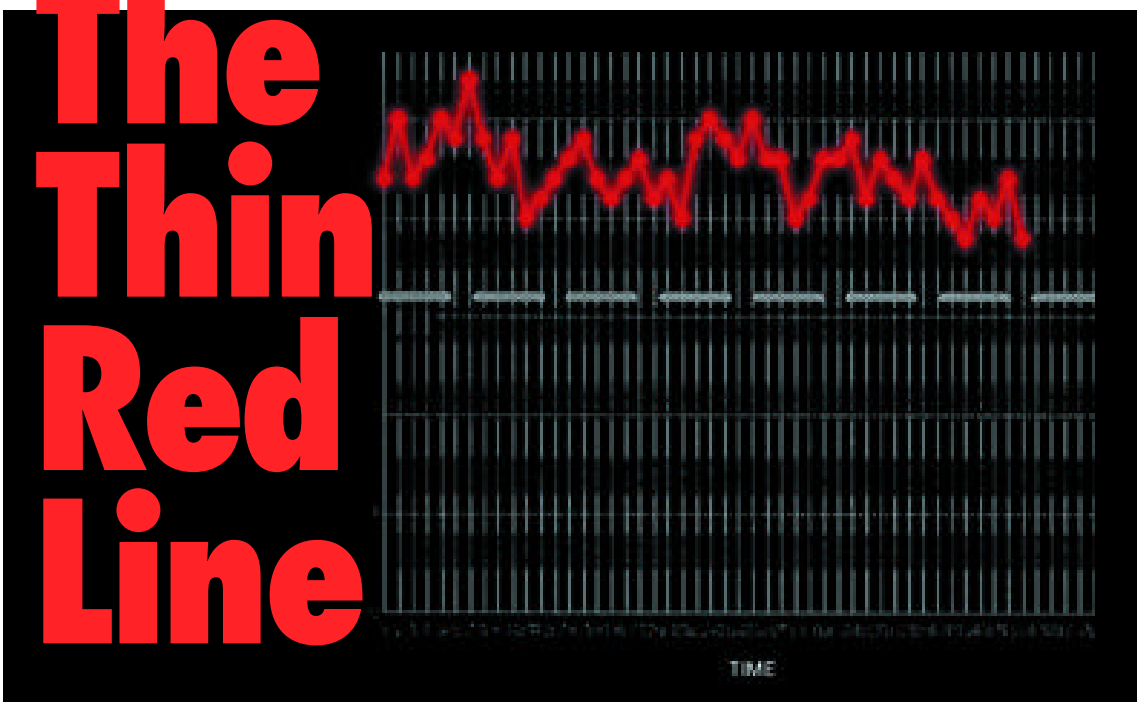
The Thin Red Line



When it comes to process control, it's not only a question of what to buy, but also a question of what to measure.

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The variety of radiometers available today makes it difficult to determine which kind of instrument to select to measure a UV process. It's even more difficult to identify exactly what to measure. Ideally, if we had a measurement that can tell when a process is about to go out of control, or fall below the "red line," that would be an invaluable management tool.

A radiometric monitoring method is valuable only if the measurements can be related to the operating limits of the process, or the "process window". The most important limit is the point at which the end product will not pass its performance requirement. This is the "red line." Because changes and deterioration in any part of the system can result in process failure, knowing in advance that the process is nearing "red line" can indicate the need for maintenance or replacement of equipment.

When it comes to selecting instruments and methods, there are three conflicting temptations facing the user, and a desire to:

- find something simple, inexpensive, universal and quick
- use sophisticated, expensive instruments that have a high content of "science" in them; and
- find a valid Quality Control tool to use in production.

Are these compatible?

First, let's distinguish process design from process monitoring. In the design of any UV application, it is essential to know the UV exposure conditions -- irradiance, energy, range and infrared energy -- which result in a successful UV-cured product. Relating the key end-properties to these conditions requires the ability to measure and quantify both. In a good design, optimization of these factors yields a more effective cure with reduced cost and less heat. This will usually involve the more complex, sophisticated, and expensive instruments.

Once a process is designed and set, process monitoring seeks to maintain the "process window." The primary purpose is to know when something has changed before it threatens the process. However, the measurements must be of key exposure conditions as determined in the design process. If the data collected doesn't relate to the key factors affecting the cure, it doesn't mean much.

If you are currently using a UV process, and the key exposure factors have not been identified (or communicated), or the instruments used to establish them are not known, you should find out now. This information allows you to determine the factors to monitor in your process and the methods you should use.

- If depth of cure and adhesion are important, then the long UV wavelengths should be monitored;
- If surface properties such as tack, stain, chemical or scratch resistance are important, then the short UV wavelengths should be monitored;

- If the relative irradiance of short and long wavelengths is important, then a periodic check of the ratio of the two will be useful;
- If the photoinitiator wavelength response range is known, it will identify an important range to monitor;
- Since the irradiance profile and peak are a function of lamp optics, specified in the design, then it's not necessary to monitor these – measurement of energy is more useful.

Because process monitoring is based on tracking changes in key exposure factors, the instrumentation used can be simpler and less expensive. If simple measurements are made, then those measurements must be correlated to the end result.

A Quick Method of Determining the "Red Line"

Determining the "red line" involves intentionally varying the process until failure is detected, while measuring and recording the associated conditions. The easy way to do this is a technique called a "cure ladder," using samples of production ink, coating, or adhesive, and samples of the actual production substrate:

- Incrementally increase the speed at which samples pass under the lamps, and
- Measure or calculate the energy in the important wavelength range(s) at successive speeds, until the process fails to meet requirements.
- The energy at which failure occurs is the "red line."
- Record this "red line" on the same data graphs on which periodic QC measurements are recorded.

Measurements can be mis-used. We regularly hear of UV production stopped because the measurements hit the "red line" – only to learn that the "red line" limit was based on a measurement that had little to do with the end result. Worse yet is a process that has become marginal but the radiometric measure provided no clue, because it was measuring the wrong wavelength band! A favorite bugaboo is a process measurement of energy ("dose") only, with complete disregard for irradiance or exposure profile as a key factor, or for the key wavelengths critical to the process. Remember, process monitoring assumes that the key interactions between lamps and chemistries have been established. This may be one of the worst assumptions in the technology. Many problems in radiometry arise from a lack of definition of the key exposure factors to be measured.

Successful implementation of a regular measurement program of meaningful exposure factors, and periodic benchmarking against a properly set "red line" can go a long way toward eliminating unnecessary "art" and "guesswork" from Process Control.

For more information on Radiometry, see *Radiometry and Methods in UV Processing*, by R.W. Stowe, Proceedings, RadTech North America 2000, April, 2000.