



Pilot line or production line trials enable actual production parts or films to be run at speed, cure width, and the desired working distance.

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## Manufacturing Conversion: Transitioning from Conventional UV to LED Curing

While the process steps in a UV LED manufacturing conversion are slightly more involved than a direct-swap mercury replacement, the benefits are often significant and well worth the time and effort.

In product replacement, two personality extremes typically drive how and when consumption occurs. Some of us might squeeze every ounce of useful life out of an item before reluctantly seeking an alternative, while others routinely upgrade to the latest versions without hesitation or need. Both extremes can result in rushed and poorly executed purchasing decisions, with the former driven by an urgency to quickly return to status quo and the latter solely by a desire to be first. In practice, most consumers typically fall somewhere in between these extremes, taking the necessary time to apply their style of product evaluation and decision-making criteria before moving forward.

In industrial manufacturing, companies often push the life of capital equipment in the hope of optimizing operational costs by utilizing assets that have long since been paid off. However, when the line goes down and failure ultimately occurs, companies can be left scrambling to secure the necessary replacements to resume production. When direct replacements and spare parts are standard and readily available, this practice is justifiable and cost effective. In cases where replacement items have long lead times or have become obsolete and replaced by technology that is not a drop-in solution, waiting until failure can be disastrous to a company's bottom line.

## Deciding to Make the Change

For long-running manufacturing processes that use mercury UV systems to cure inks, coatings, and adhesives, it is common for the initial UV qualification and production setup to have occurred 10, 20, or even 30 years ago. In fact, some of these lines still have the original curing systems in place. While lifetimes vary by manufacturer, product model, operating environment, preventative maintenance schedule, and reactivity of the formulations being cured, conventional UV curing systems generally last around 10-15 years.

Within the useful lifetime, lamps, reflectors, windows, shutters, magnetrons, screens, power supplies, cables, and exhaust blowers are cleaned, repaired, and replaced as needed. At some point, an increasing degree of labor, maintenance, and downtime occurs—leading to an overall reduction in curing performance and reliability, as well as an indication that the time to replace the entire system may be approaching.

In cases where the staff who conducted the initial UV qualification are no longer available, the original system supplier is no longer in business or has been acquired by another company, or the manufacturer has discontinued the UV system, it can be difficult to know where to start. UV replacement options have historically been limited to broadband mercury arc and microwave lamps, but today more efficient UV LED curing systems are increasingly being evaluated and selected as viable substitutes. When a conventional mercury UV curing system on an existing production line is replaced with a UV LED curing system, the process is known as a *manufacturing conversion*.

## Optimizing the Conversion Process

While the process steps in a UV LED manufacturing conversion are slightly more involved than a direct-swap mercury replacement, the benefits are often significant and well worth the time and effort. Both conventional mercury and UV LED curing systems emit ultraviolet energy; however, the manner of UV output is very different. These differences influence the chemistry, LED system form factor, and integration. All three of these factors need to be properly evaluated so that the UV LED curing system can be confidently and successfully matched to the formulation and material handling needs of the existing production process, as well as the application needs of the final product being manufactured.

The general process for executing a manufacturing conversion is outlined in the following steps. Some of these steps are sequential, while others can be executed in parallel. A successful conversion is often an iterative process, and it is common for some stages to be repeated a number of times. Since there is no set path for a manufacturing conversion, it is important to work closely with all critical suppliers involved in the process.

### Engage with Formulators

It is important to remember that existing formulations for mercury and microwave lamps will unlikely be LED compatible. While many who are new to UV LED curing assume that a direct hardware/technology replacement will work, the extremely different spectral output of LEDs makes it essential to use an ink, adhesive, or coating that is specifically formulated for UV LED curing.

Always start with the existing formulator. A growing number of UV formulators already offer dedicated UV LED-curable products or dual-cure variations that are designed to cure with both LED and mercury lamps. If they do not provide a UV LED variation for the current material, engage with them to collaborate and justify the business case for development. Many products that are not yet suitable for UV LED sources can be reformulated in a few days or weeks, while other more functional products may require months, a year, or even more for complete development.

### Work with a UV LED System Supplier

Manufacturing conversion requires assistance from the UV LED system manufacturer or their distributor throughout the development of the application. Solution suppliers typically have a range of products with varying performance tiers and features to suit different applications and process speeds. As a result, it is important to understand the available UV LED curing options, system configuration, operator interface, and output of the UV LED curing system to best suit the process requirements. This information and its impact on both process and operation are critical for all involved.

### Define the Cure Surface and Final Use Requirements

Is the cure surface a web, a sheet, or a 3D part? What is the material nature of the cure surface (e.g., plastic, metal, wood, or paper)? What are the post-cure manufacturing steps? How will the final product be used? How long is the product expected to last, and under what environmental conditions? Is the manufactured good used in food, pet, or children's products? Are the desired final cure properties aesthetic or functional, and what degree of scratch, mar, or chemical resistance is required? All of these factors should be considered and communicated to the formulator and UV LED supplier.

### Define the Integration Constraints

Existing manufacturing lines have built-in limitations regarding available mounting space, working distance between the cure surface and the UV LED lamp head, available clearance gaps for air-cooled LED heads, material handling, temperature and humidity, air cleanliness, accessibility, line speed or cycle time, and more. Engage with the UV LED system supplier and integrator to clearly define and communicate these requirements. By proactively working with the UV supplier early in the process, it is possible to alleviate some implementation issues that may otherwise arise later.

### Confirm the UV LED Formulation Can Be Cured

Most development or qualification projects typically start in a formulator's lab or customer demo facility. It is important to confirm that the formulation can be cured on the exact part or substrate, with the desired UV LED system operating under precisely defined conditions (e.g., the intended working distance and line speed or cycle time). Whenever possible, the desired conditions should be replicated in the lab. If this is not possible, the formulator and UV LED supplier can manipulate the lab setup to simulate or scale the results to satisfy the production conditions.

The development of a suitable UV LED formulation is an iterative process and may require a series of lab tests spread across

days, weeks, months, or even years, depending on the complexity. Based on the lab or demo room tests, confirm the optimal UV LED wavelength, as well as the irradiance (Watts/cm<sup>2</sup>), energy density (Joules/cm<sup>2</sup>), and working distance (mm) process windows. Samples should be created in the lab and subjected to any post-cure manufacturing or application conditions to confirm suitability, migration, and aging.

#### ***Conduct a Pilot or Production Line Trial***

Once successful samples have been created in a lab and subjected to further processing, it is sometimes desirable to conduct a pilot line or production line trial. Doing so enables actual production parts or films to be run at speed, cure width, and the desired working distance. While this step may not mimic the production conditions exactly, it is generally much closer than testing done in a formulator's lab and will help ensure that a manufacturing conversion can be successfully implemented.

#### ***Finalize the UV LED Model or Configuration***

Once the testing and qualification process in the lab and plant are complete, it is then possible to finalize the necessary UV LED system specification. At the minimum, this should reflect the desired wavelength, irradiance, and energy density at the cure surface for the production line working distance and process speed needed to achieve the desired final cure properties. The curing system must also be capable of spanning the entire cure surface width or area.

The UV LED system supplier can help make the final UV LED product recommendation based on the established specifications. They also have valuable applications experience and can act as a guide throughout the process.

#### ***Design and Coordinate System Integration***

While press integration is discussed and brainstormed throughout the development process, it is time to finalize the design and operator requirements; engineer any ancillary equipment, including mounting brackets, nitrogen inertion, shielding, and exhaust; and confirm power and control cabinet designs, cable lengths, operator interface, and main AC power requirements, among others. Integration can be handled by the UV LED system supplier, a distributor, a press OEM, a third-party integrator, or the end user.

#### ***Define the Process Window***

Once the UV LED system is installed and operating on the production line, it is important to document and clearly communicate the operating process window conditions to operators, maintenance staff, and any engineering or management involved in running the line. A process window includes all the variables that can be controlled during setup and operation and allows the system to be quickly corrected if it is adjusted to the point of being out of control. This should clearly state the irradiance required, the measurement device, and calibration interval.

#### ***Establish Quality Inspection Protocols***

It is also important to define and document the necessary quality inspections, procedures, and frequency with which inspections

should be conducted. Quality checks are necessary to confirm that an acceptable cure is consistently being achieved.

#### **Planning for the Future**

UV LED curing is gaining traction across many markets that have used conventional UV curing for decades. If companies are not investigating or pursuing a conversion in advance of a major conventional UV system failure, it will often be difficult to convert to UV LED in a time period that avoids long periods of downtime. As a result, these companies will be driven to find as close a direct replacement as possible, which will likely commit them to using conventional mercury lamps for another 10-15 years.

When initiating a UV LED manufacturing conversion, it is important to partner with a UV LED system supplier and/or distributor that can provide assistance throughout the conversion process—from advice on available UV LED curing options that meet process requirements to guidance with system configuration, operator interface, and output of the UV LED curing system. The benefits of an informed, proactive UV LED manufacturing conversion for a conventional UV curing line can deliver significant time and cost savings for the future. **ASI**

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