UV curing of coatings is a proven technology and offers a practical and profitable alternative to traditional curing.

High-power UV lamps are the source of curing-light energy, and arc or medium-pressure lamps dominate the market. Within the past five years, lamp manufacturers have developed and are producing UV light-emitting diode (LED) lamps with higher UV-energy output. These are replacing arc and medium-pressure lamps, with some specified for use in new finishing systems.

Graph 1: Part Cycle Time Analysis
Thermal Cure Coating Systems (Powder and Liquid) vs. UV Powder Coatings

UV-curable liquids and powder coatings are photopolymerized materials with a chemical photoinitiator that instantly respond to UV-light energy, starting the reaction leading to cure. To cure a UV-powder coating, a separate melt stage precedes the cure stage, which typically takes 1-2 minutes or longer, depending on the substrate. UV curing is almost instantaneous. When considering UV-cured coatings for liquid or powder, it is necessary to balance the operating parameters of the coating system, process speed and the coating material with the spectral range of the UV bulb and lamp system energy output. If the bulb’s spectral output does not match the absorption range of the photoinitiator or if the lamp system is underpowered, the coating may not completely cure.

Regulatory and Environmental Constraints
Consumer interest in environmentally friendly materials (as well as health and safety regulations eliminating or reducing the amount of hazardous materials) are changing how coatings are made and how chemicals are used and applied. The user’s alternate choices are waterborne; no/low-solvent and UV-cured liquid coatings; and thermoset and UV-cured powder coatings.

Waterborne coating is the fastest growing sector of the coatings industry. Water is replacing solvents in paints and coatings. Besides being challenged to be a 1-to-1 quality and performance replacement for solvent coatings, waterborne coatings have economic, social and environmental costs that have yet to be fully measured. Water is a scarce and unequally distributed natural resource.

UV-cured powder coatings have many operational benefits—they lower energy consumption and the total application system has a smaller plant footprint, increases productivity, reduces material usage and produces higher profits per hour. In addition to these operational benefits, UV-cured powder coatings have health, safety and regulatory benefits. As they are 100 percent solid, they are solvent and water free. They don’t have hazardous or regulated chemicals and don’t require permits to make or use. When factored into a total applied cost model, these benefits make UV-cured powder coatings a sound investment. Graph 1 captures the productivity benefit of UV-cured powder coating compared to thermoset powder and liquid coatings. Each bar is the sum of time needed to complete application-to-cure.

UV-cured powder coatings and thermal powder coating are made the same. The difference is the UV resin, which is specifically designed to be cured with UV light. Typical resin types are polyesters, epoxies and urethanes. Additives and pigments
UV-Light Curing Technology

UV lamp output is described as irradiance (intensity), and lamp power is measured at a specific distance, with the notation as mW/cm². As distance changes, irradiance changes. The second descriptor is energy density, the amount of the lamp’s power reaching the surface of the object being cured as it moves though the lamp’s light field—the notation is mJ/cm². As line speed varies, exposure changes. It is important to understand how curing conditions change as lamp power, distance and time change.

Table 1 shows the results from four measurements of three lamp types: 300-watt and 600-watt medium-pressure mercury lamps and a 395 Nm LED, with power output at 50 percent and 100 percent. The third condition shows where the measurement on the UV spectrum was made (either UBV and UVA2). The two constants for all tests are a distance of 4 inches and a speed of 5 feet per minute.

UV-light spectrum has three bands between 100 Nm to 400 Nm. Depending upon the type of lamp, the energy irradiance and exposure will vary across the spectrum. Photoinitiators absorb UV light at different wavelengths. The UV light’s emission wavelengths must match the absorbing wavelengths of the photoinitiator to start and complete the cure response in the coating.

Table 1: Results at 5 ft./min. at 4” Distance

<table>
<thead>
<tr>
<th>LAMP TYPE</th>
<th>POWER SPECTRUM</th>
<th>EXPOSURE mJ/cm²</th>
<th>IRRADIANCE mW/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>300W Medium Pressure at 100% UV</td>
<td>2,811</td>
<td>1,088</td>
<td></td>
</tr>
<tr>
<td>600W Medium Pressure at 100% UV</td>
<td>10,000</td>
<td>2,232</td>
<td></td>
</tr>
<tr>
<td>600W Medium Pressure at 50% UV</td>
<td>5,622</td>
<td>1,244</td>
<td></td>
</tr>
<tr>
<td>395 Nm LED at 100% 8W UVA2</td>
<td>12,312</td>
<td>2,711</td>
<td></td>
</tr>
</tbody>
</table>

To cure a UV-powder coating, a separate melt stage precedes the cure stage that typically takes 1-2 minutes or longer depending on the substrate.

UV curing of coatings is a proven technology and offers significant operational, health, safety and regulatory benefits—making UV curing a practical and profitable alternative to traditional curing. Ongoing developments in UV-LED technology are increasing the market for UV-cured materials, specifically UV-cured powder coatings. Improvements in UV-LED equipment and concurrent UV-cured powder coating chemistry developments have made the combination of UV-LED and UV-cured powder coatings an enabling finishing technology—not only for replacing solvent coatings, but also for many new materials and product markets.