UV screen inks were developed in the late 1970s and have revolutionized the screen-printing industry. This technology introduced the use of UV radiation to cure a printed ink to an almost 100% solids film, all but eliminating the release of VOCs into the air versus its solvent ink counterpart.

Most ink manufacturers today formulate UV ink with several environmental and health and safety advantages in mind over solvent based inks: elimination of heavy metals, less VOC emissions, less harmful solvent vapor exposure to the printer, less harsh cleaners required during the print process and in cleaning/reclaiming screens, more efficient curing of the ink, less energy use by the curing unit as compared to thermal dryers used with solvent and water-based inks, use with multi-color printing presses, and the elimination of NVP or V-Pyro. As early adopters of UV technologies, screen printers have seen environmental, worker safety, and economical benefits for years, and today’s UV graphics inks have kept up with the ever increasing demands of screen printers in these areas.

What is a UV ink?
A UV ink is formulated to contain oligomers, monomers, pigments, photo initiators, and various additives to enhance performance. Most UV inks used today are based on free radical cure of acrylated pre-polymers.

UV screens inks are formulated to adhere to a wide range of materials for graphics, decal, poster, container, CD, banner, metal-decorating, nameplate, automotive, fleet graphic, and industrial applications. Inks are tailored to each market’s requirements for outdoor durability, chemical resistance, cold/heat resistance, water resistance, flexibility for processing and mounting graphics, etc.

Use in the graphics market
The US screen-printing industry was early to adopt UV ink technology. UV ink has continued to grow in the USA to make up 60-65% of ink sales in comparison to solvent- and water-based inks. The growth rate of UV ink is approximately 4% per year. By far, the USA is the most active user of UV screen inks.

In contrast, Europe was an early adopter of UV screen inks but was hesitant to convert quickly due to potential irritation issues. In an article addressing the elimination of air pollution through the use of UV, RadTech states, “Although early in its history, UV/EB (ultraviolet/electron beam) used volatile monomers that caused irritation of the eyes and skin; the monomers now used are non-volatile and airborne irritation has been eliminated. Contact with the liquid products can still cause irritation to some susceptible individuals; however, the normal health and safety rules involving aprons, gloves, and eye protection constitute a safe milieu for the workers.”

With the continued advances of UV ink technology, Europe is embracing UV screen inks at higher rates every year due to the positive environmental, worker safety, and economical impacts. Europe today uses approximately 45-40% UV ink with the remaining 55-60% of shops using solvent- or water-based inks. In Latin American, Central America, and Asia, solvent inks are used more than 60% of the time. Due to lower cost per gallon, lower labor costs, and lower environmental controls for smaller users, the wide spread use of UV inks is limited in these areas.

Past use of UV inks
It is easy to see that converting to UV inks from solvent-based inks has tremendous impact on the reduction of harmful VOCs being emitted into the air and the safety of the printer. In relation to today’s environmental concerns, screen printers who have adopted UV ink technology have lead the way in positively impacting the environment and should not go unrecognized. Both the offset and flexographic industries have been much slower in adopting UV ink technology.

Today’s inks
One of the advantages of UV ink over solvent- or water-based inks is the elimination of the need for oven-type dryers to evaporate the water or solvent in the ink. Additional advantages include the following:
The Environmental Aspects of UV Screen Inks: Past, Present, and Future

- fewer emissions of solvents and air pollutants (less toxic to the environment and the press operator)
- less energy needed to dry each color
- less energy needed to keep the overall workspace cooler
- less floor space required for equipment
- faster overall processing, resulting in cost reductions

Formulation of UV inks has improved over the last 30+ years. The biggest contributing factors have been the improvements in raw materials, printing machines, UV-curing units, and the print process. Today’s UV graphics inks provide faster curing, denser colors, multipurpose functionality, more stable printing, and lower ink deposit/higher ink coverage.

**Faster curing** has been continuously pushed with regard to printing more product in a shorter period of time with less waste and lower cure output on the UV cure units. The UV inks for graphics screen printing are considered high performance and cure at 80-100 millijoules (mJ)—a measure of UV irradiance—and 600+ milliwatts (mW)—a measure of UV dose—for most colors. Older UV inks or specialty inks may require up to 150-180 mJ and 600 mW or more. An ink that requires more UV output to cure can bring the following disadvantages:

- requires a decrease in belt speed (may not be an option due to heat sensitivity of the substrate), resulting in slower printing
- requires an increase of the wattage, leading to more energy usage
- requires the use of two lamps instead of one lamp in an attempt to increase UV output
- may carry a higher potential of undercuring issues, resulting in potential waste of finished materials and reprinting of the job

See the sidebar “Energy Savings & CO₂ Emissions Reduction with Faster Curing UV Screen Inks,” on page 36 for a comparison of the energy used for various UV-curing station settings. The setting required is based on the level of output needed to properly cure the ink deposit. Using today’s faster curing UV inks on properly maintained UV curing stations, a cure level of 80-100 mJ and 600+ mW can often be achieved with a 200-watt setting.

Keep in mind that UV curing units can vary greatly from shop to shop and within a shop in terms of performance. The amount of irradiance and dose from each UV cure unit needs to be measured. The mJ and mW values mentioned are representative of measurements of the UVA bandwidth (320-390 nm) taken with a standard radiometer.

Most UV inks require only one lamp to cure when the lamp provides sufficient output. Many printers use a second lamp to overcome deficiencies in the UV output of one lamp. Only in specialized applications will a second lamp benefit the printer and then only marginally. By using a faster curing ink and maintaining the UV cure station’s bulb and reflector, a shop should be able to achieve the proper amount of cure with a single lamp. This not only saves significant energy, but also provides hidden savings. A printer not only saves in energy consumption (reducing emissions), but also reduces the number of mercury-vapor bulbs that will need replacement over time.

**Denser halftone colors** in a UV ink have allowed screen printing to provide saturated color reproduction, even when printing a low ink deposit. Dense colors also provide, in essence, concentrated colors. Printers can purchase dense colors and use a base to reduce density on site. With a computer-controlled color-mixing system, matching density required per print job can be achieved very quickly; in addition, waste ink can be input back into inventory and reused on future jobs.

A color-mixing system paired with an automatic dispensing system and shaker can allow printers to mix up enough ink to start a print job and hit the appropriate color. With production ready to go, the ink mixer can quickly produce just enough ink for the job to be run. A mix-on-demand system with very little waste ink at the end of a job increases efficiency by reducing issues surrounding inventory, such as aging excess ink.

### Table 1: Comparison of Ink Thickness to Total Thickness of Printed Graphic Substrate

<table>
<thead>
<tr>
<th>Substrate thickness (mils)</th>
<th>Ink thickness (mils)</th>
<th>Total graphic thickness (mils)</th>
<th>% of total thickness represented by ink</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.00</td>
<td>6.00</td>
<td>17%</td>
</tr>
<tr>
<td>5</td>
<td>0.50</td>
<td>5.50</td>
<td>9%</td>
</tr>
<tr>
<td>10</td>
<td>1.00</td>
<td>11.00</td>
<td>9%</td>
</tr>
<tr>
<td>10</td>
<td>0.50</td>
<td>10.50</td>
<td>5%</td>
</tr>
<tr>
<td>10</td>
<td>0.25</td>
<td>10.25</td>
<td>2%</td>
</tr>
<tr>
<td>15</td>
<td>1.00</td>
<td>16.00</td>
<td>6%</td>
</tr>
<tr>
<td>15</td>
<td>0.50</td>
<td>15.50</td>
<td>3%</td>
</tr>
<tr>
<td>15</td>
<td>0.25</td>
<td>15.25</td>
<td>2%</td>
</tr>
<tr>
<td>20</td>
<td>1.00</td>
<td>21.00</td>
<td>5%</td>
</tr>
<tr>
<td>20</td>
<td>0.50</td>
<td>20.50</td>
<td>2%</td>
</tr>
<tr>
<td>20</td>
<td>0.25</td>
<td>20.25</td>
<td>1%</td>
</tr>
</tbody>
</table>
Energy Savings & CO₂ Emissions Reduction with Faster Curing UV Screen Inks

The following is an example comparison of energy required to power one or two 60-in. mercury-vapor lamps where the cost per kilowatt hour is $0.054. Cost varies depending on the location of a printing plant, but the same percent in savings should apply.

Note: Each printing press outputs varying degrees of mJ and mW. Each UV cure station on a multicolor press should be measured and compared to the recommended cure levels of inks used. UV cure settings should be fine tuned to produce the desired level of cure before calculating the savings.

1 lamp x 200 W x 60 in. = 12 kWh x 8 hours x 20 days = 1920 kWh / month
1 lamp x 300 W x 60 in. = 18 kWh x 8 hours x 20 days = 2880 kWh / month
2 lamps x 200 W x 60 in. = 24 kWh x 8 hours x 20 days = 3840 kWh / month
2 lamps x 300 W x 60 in. = 36 kWh x 8 hours x 20 days = 5760 kWh / month

Significant savings will be realized if you can switch from one 300-watt bulb to one 200-watt bulb or if you can switch from two 200-watt bulbs to one 200-watt bulb. Making changes in belt speeds will not impact electrical use significantly. Also, use the above calculated information to determine the energy cost per your area.

The kWh can be used to calculate the CO₂ emissions. An estimated value of 1.55 lbs of CO₂ per kWh when the electricity is derived from combustion of coal was used for the example. (Calculation from www.energystar.gov.)

1 lamp x 200 W x 60 in. = 1920 kWh x 1.55 lbs CO₂ per kWh = 2976 lbs CO₂/mo (35,712 lbs CO₂/yr)
1 lamp x 300 W x 60 in. = 2880 kWh x 1.55 lbs CO₂ per kWh = 4464 lbs CO₂/mo (53,568 lbs CO₂/yr)
2 lamps x 200 W x 60 in. = 3840 kWh x 1.55 lbs CO₂ per kWh = 5952 lbs CO₂/mo (71,424 lbs CO₂/yr)
2 lamps x 300 W x 60 in. = 5760 kWh x 1.55 lbs CO₂ per kWh = 8928 lbs CO₂/mo (107,136 lbs CO₂/yr)

The amount of lbs of CO₂ emissions has been further calculated for a 12-month period and converted to CO₂ tons; the savings per setting is outlined below. This savings is represented per UV cure station. A typical inline screen-printing machine will have five to six cure stations. The use of a fast curing UV screen ink on a properly maintained inline printing press allows most shops to use a 200-watt setting with only one bulb.

<table>
<thead>
<tr>
<th># of lights</th>
<th>Wattage</th>
<th>Amount of kW per month</th>
<th>Reduction in CO₂ (lbs) over 12 mo per UV-curing station</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>1 lamp</td>
<td>200 W</td>
<td>300 W</td>
<td>1 lamp x 200 W x 60 in. = 12 kWh x 8 hours x 20 days = 1920 kWh / month</td>
</tr>
<tr>
<td>1 lamp</td>
<td>300 W</td>
<td>300 W</td>
<td>1 lamp x 300 W x 60 in. = 18 kWh x 8 hours x 20 days = 2880 kWh / month</td>
</tr>
<tr>
<td>2 lamps</td>
<td>200 W</td>
<td>200 W</td>
<td>2 lamps x 200 W x 60 in. = 24 kWh x 8 hours x 20 days = 3840 kWh / month</td>
</tr>
<tr>
<td>2 lamps</td>
<td>300 W</td>
<td>300 W</td>
<td>2 lamps x 300 W x 60 in. = 36 kWh x 8 hours x 20 days = 5760 kWh / month</td>
</tr>
</tbody>
</table>

When changing from two lamps to one lamp, you can also figure the environmental impact of replacing only one lamp. 1000 hours as an average lamp life.

To calculate your own settings, use the following factors and equations:

\[ \text{C kWh} = \text{average kWh per lamp at current settings} \]
\[ \text{N kWh} = \text{average kWh per lamp at new settings} \]
\[ \text{C lamps} = \text{number of lamps per UV-curing station for current settings} \]
\[ \text{N lamps} = \text{number of lamps per UV cure station for new settings} \]
\[ \text{UV stations} = \text{number of UV cure stations} \]
\[ \text{hrs/day} = \text{number of hours running the machine} \]
\[ \text{day/mo} = \text{number of days running the machine} \]
\[ \text{kWh cost} = \text{cost of energy for location per kWh} \]
\[ \text{lbs CO₂/kWh} = \text{estimated lbs CO₂ per kWh} \]

Calculations

- Energy user per printing press (current and new UV-cure settings):
  \[ \text{C kWh x C lamps x UV stations x hrs/day x day/mo = Current kWh/mo} \]
  \[ \text{N kWh x N lamps x UV stations x hrs/day x day/mo = New kWh/mo} \]

- Energy cost and lbs CO₂ comparison
  \[ \text{Current kWh/mo – New kWh/mo = Energy savings/mo} \]
  \[ \text{Energy savings/mo x kWh cost = $ savings/mo x 12 mo = $ savings/yr} \]
  \[ \text{Energy savings/mo x lbs CO₂/kWh = lbs CO₂/kWh savings/mo x 12 mo = lbs CO₂/kWh savings/yr} \]

**Multipurpose inks** allow for a minimal number of ink series to be used on a wide range of substrates. The first savings is related again to inventory issues. Each ink series typically needs to have inventoried halftones colors (extender base, cyan, magenta, yellow, and black) along with mixing colors (used to match specialized colors) and some additional, high-volume colors such as white, black, red, etc., for about 25 colors per ink line. The use of multipurpose inks can cut down on the amount of gallons in inventory. There are additional benefits to multipurpose inks:

- less waste due to the same ink being used on multiple jobs
- less potential mistakes of putting the wrong ink on the wrong substrate, reducing scrap and reprinting

Many manufacturers develop all their multipurpose ink lines so that colors are made to the same specifications for each line. Customers using more than one multipurpose UV-ink line from the same manufacturer will find that color reproduction is much more predictable. Settings from the art department through printing need much less adjustments since the inks are printing the same. Predictable results lead to more efficient printing.

**More stable printing** refers to the ability of the ink to achieve consistent color reproduction from print to print both initially and throughout the print run. As solvent inks are printed, the solvent evaporates and the ink viscosity thickens, resulting in color changes on press. The printer will add additional thinner to the ink, again changing the color on press. The color reproduction of UV inks stays much more consistent on press because there is no solvent to evaporate. Printers using UV graphics
To calculate your own settings, use the following factors and equations:

\[ \text{lbs CO} = \text{Energy savings/mo} \times \text{kWh cost} = \text{$ savings/mo} \times 12 \text{mo} = \text{$ savings/yr} \]

\[ \text{Current kWh/mo} - \text{New kWh/mo} = \text{Energy savings/mo} \]

\[ \text{N kWh} \times \text{N lamps} \times \text{UV stations} \times \text{hrs/day} \times \text{day/mo} = \text{New kWh/mo} \]

\[ \text{C kWh} \times \text{C lamps} \times \text{UV stations} \times \text{hrs/day} \times \text{day/mo} = \text{Current kWh/mo} \]

Calculations

\[ \frac{2}{kWh} \times \text{savings/yr} \]

\[ \frac{2}{kWh} = \text{lbs CO} \]

\[ \text{Energy savings/mo} \times 12 \text{mo} = \text{37 into the paper, which makes it possible} \]

Ink manufacturers continuously evaluate new raw materials becoming available. The few that do exist do not enhance the use of renewable resources. In developing tomorrow’s greener UV inks, manufacturers are looking at the overall scope or footprint of the screen-printing process and ways to make it more sustainable with regard to environmental issues. The main concerns relate to renewable resources and recycling.

Renewable resource

Replacing petroleum-based raw materials is the first area to evaluate. At this time there are very few acrylate-based UV raw materials that are based on renewable resources. The few that do exist do not enhance the performance of UV-curable inks. Small amounts could be safely added to existing formulations, but how much would be gained?

When considering the ink and substrate combined, the renewable raw material represented by the ink film would be less than 1% of the total material (ink + substrate) that the final graphic comprises. However, this could change as newer raw materials become available. Ink manufacturers continuously evaluate the use of renewable resources.

Water could also be used in UV inks. This is not new technology and is found widely in Europe. The downside is that this hybrid ink is limited in use to paper and a few plastics. The paper or porous material allows the water to be pulled into the paper, which makes it possible for the UV materials to cure properly. On non-porous materials, water-based UV inks would first need to be heat dried to remove the water and then UV cured. If the water is not removed first, the UV reaction is retarded, which results in poor ink adhesion.

This type of hybrid ink not only slows down production, but also consumes more energy in the drying process. In addition, water-based UV inks require very careful processing and good environmental controls related to humidity. When humidity is not controlled, print and curing properties will vary as the water evaporates from the ink during a print run.

A healthy future for UV screen printing

As an early adopter of UV inks, the screen-printing industry has already made great strides in being both environmentally aware and worker-safety conscious, as well as economically efficient. In summary, the UV inks currently available for screen shops provide the following characteristics:

- are 100% solids and non-toxic once cured
- emit almost no VOCs
- use less energy compared to solvent-based inks to cure
- are optimized to cure at low UV output, significantly reducing energy use and decreasing the number of mercury vapor bulbs needed
- are optimized to print on faster printing presses and to reduce ink deposit and increase ink mileage
- provide stable printing to allow screen shops to reach suitable color reproduction faster and more consistently
- provide a reduction in inventory, waste ink, and waste printed materials due to mistakes, while leading to more predictable and efficient printing with multi-purpose inks
- have been successfully recycled in some locations when certain substrates are used

Moving towards an even more environmentally friendly UV ink remains a high priority among ink manufacturers for all printing industries, but not at the cost of creating detrimental effects on the print-production process. Ink is a small part of the overall, finished print. More is gained by using substrate alternatives that are recyclable, reusable, renewable, or quickly biodegradable. The biggest environmental benefit will be getting a safer, more efficient process that uses less energy.

Laura Maybaum

Laura Maybaum is the point-of-purchase market segment manager for Nazdar. Involved in the industry for more than a decade, she has served in screen-printing technical and marketing positions with Nazdar, KIWO, and Sefar America. Maybaum holds a degree from Bowling Green State University.