

The Economics of “True” 100% UV Curable Solids Electronic and Graphic Inks

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The Economics of True 100% Free Radical UV Curable Solids

Electronic and Graphics Inks

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Abstract

This analysis examines the total process costs associated with the use of a true 100% UV Curable Solids graphic and electronic ink. It is illustrative of the potential economic gain associated with this new and innovative technology and industrial finishing process. While the specific example of a solvent based electronic ink screen printing line is detailed, the economic concepts are easily extrapolated to show similar benefits in the graphics inks.

There are several costs associated with a printing operation which are commonly taken into account:

- . • Material cost (paint and/or coating)
- . • Manufacturing real estate, (process footprint)
- . • Capital cost (equipment)
- . • Operating cost (energy, labor)
- . • Maintenance costs (clean-Up, spare parts)
- . • Safety /Insurance savings (Radtech/Hartford)
- . • Lost production (downtime, scrap, rework).
- . • Regulatory compliance (EPA, OSHA, VOC emission monitoring, etc...)

The information presented in this paper is derived from commercial and pilot 100% UV curable solids printing installations. It is intended to highlight the various economic elements associated with the 100% UV curable solids printing operations and provide estimates of the associated costs. Some basic assumptions were necessary for the sake of comparison.

Introduction

The use of conventional solvent based inks has added significant value to decorative printing operations for centuries. Only in the last few of decades has regulatory environmental and safety issues have placed a myriad of restrictions on where, what, how, when, and who can manufacture and apply these products.

While this is difficult for the traditional solvent based ink industry, it's a validation for UV curable printing ink technology. The Southern California Air Quality Management District, (SCAQMD) has bestowed the **Best Available Control Technology (BACT)**, a designation under the Clean Air Act of 1990. This specifically applied to UV curing technology for use in screen printing and wood coating applications. Additionally, SCAQMD also made UV technology **an exempt process** and can be installed without permitting requirements. Therefore, if a new printing line is installed or an old one is refitted, it must utilized "**UV technology**" to operate in Southern California or very cost intensive end of pipe technology must be implemented.

The early UV hybrid (thermal and UV) cationic cure systems offered promise. Alas, no single technology has been developed to address the variety of printing needs. In reality, there will probably not ever be a single technological panacea to accomplish this daunting task.

Recent advances in raw materials, product formulations, and manufacturing techniques have enabled several innovative products to develop which address most of the subject environmental and safety concerns. The most significant development is a **true 100% UV curable solids** products patented by Allied PhotoChemical, Inc.

What is “True 100% UV Curable Solids”?

100% UV curable solids paint is technically a non-Newtonian fluid, such as an emulsion or colloidal suspension. It is a fluid which consists completely of solids and reacts to polymerize upon exposure to specific spectrum of light. 100% of what is applied as an ink is cured as a print. There are no evaporative losses associated with 100% UV curable solids.

For a given 100% UV curable solids ink product the physical appearance is similar to its solvent based counterpart in terms of rheology, processing, application, as well as, the visible look. In this case of true 100% UV curable solids ink, ultraviolet light (UV) in the 320 – 400 angstrom (a.k.a. standard mercury vapor) spectrum is the predominant lamp utilized. An energy output of approximately 400 milli-Joules per square centimeter is required to fully cure 100% UV curable solids ink in one pass. Product viscosities can be custom designed in the range from 1000 cps to 300,000 cps.

The “True” 100% UV Curable Solids is differentiated by cure mechanism and Volatile Organic Component (VOC) content. APC’s free radical “100% UV curable solids” technology differs from cationic “100% UV solids” technologies.

VOC determination is based on a 120 ° Celsius bake test. Previous 100% solids systems can possess up to 5% VOC and/or solvents to aid flow and adhesion. These components are typically observed as weight loss in the subject test protocol. Recent EPA definitions also included UV technology as “superclean” averaging just 3% emissions.

We refer to the Allied PhotoChemical technology as the only “**True 100% UV solids**” **electronic and graphic ink** products due to the nature of the product which contains **zero** Volatile Organic Compounds (**VOC’s**) and **zero** Hazardous Air Pollutants (**HAP’s**), and **zero** normal vinyl Pyridines (**NVP’s**) even when tested at more stringent conditions such as a 180 ° Celsius bake test.

This includes the presence of the subject deleterious components in

raw materials, intermediate products, decomposition products, and finished products. Most hybrid UV technologies evolve intermediate or decomposition products such as acetaldehyde, normal vinyl pyridines, vinyl-caprolactum or Isocyanates at the more stringent temperatures.

Several key benefits of the free radical 100% UV solids paint inks include:

- . •improved operating economy,
- . •Reduced or eliminated corona treatment,
- . •improved print quality,
- . •energy savings,
- . •environmental friendliness, and
- . •easier regulatory compliance.

“Applied Costs vs. unit price”

Often, end-users incorrectly assume that the **unit price** of free radical 100% UV solids material is synonymous with the **total cost** of finishing. **It isn't**. When making thorough economic comparisons of finishing alternatives there are a myriad of factors to consider for each application. The calculations will detail how cost savings can be realized despite a higher unit price for the ink.

The personal safety equipment is generally similar as well. The need of solvent paint systems to require environmental remediation such as scrubbers or incinerators of the volatiles and hazardous air pollutants is a tremendous expense accounting for approximately 30% of the cost. A true 100% UV solids ink does not require these additional processes. In fact, only particle filters are required to prevent paint buildup in the air handling system. No volatiles mean no need for external stacks or ventilation systems. This leads to less permits and approvals to install a UV curing system.

Pretreatment

The first step in most polymeric printing processes is pretreatment. Pretreatment methods are generally dependent on both the substrates basic characteristics, as well as, its recent history. For example, in corrugated plastic board printing there is usually a corona or flame pretreatment step. Additionally, the treated substrates may have been stored in a dusty or area with airborne petrochemical (i.e., oils, etc...) contaminants. Also, typical corona treatment has a finite duration and must be rechecked for adhesion after a few days.

The ability of small amounts of some typical petrochemicals to migrate through the true 100% UV curable solids ink prior to cure improves the overall quality with 100% solids inks. Consequently, true 100% UV curable solids ink can potentially eliminate and generally reduce the initial step of pretreatment in the printing process.

Thermal Management and Cure Equipment

Traditionally, large scale printing involves heat and/or solvents. Heat

is used in solvent based ink to accelerate drying by driving off the solvent or water carrier. These dryers usually operate anywhere from 150°F to 400°F depending on the ink, line speed, and production requirements. Conventional wisdom also denotes that preheating is beneficial to adhesion. For free radical 100% UV solids, **NO HEAT** is needed to drive cure reactions to produce the final coating.

Intense ultraviolet light activates a catalyst for the polymerization (curing) process of the 100% UV curable solids as the final step (Figure 1). However, because UV curing is relatively instantaneous, the size of an UV oven is not a direct function of system line speed (as with the conventional process) and capacity.

For most printing operations (and occasionally the entire manufacturing process), drying or curing paint is usually the limiting factor to throughput and productivity. While other steps within the printing process can be accomplished in minutes or even seconds, curing often takes hours. Costs are significant in terms of time, as well as, in the expense of floor space for large ovens, long conveyor runs, additional tooling, more energy and other associated costs such as work-in-process.

Generally, the UV light sources tend to be the most critical and expensive component of the total system. This disadvantage is offset by the increased production robustness and flexibility and reduced cost of thermal management. It has been found that the traditional electrode based UV light equipment tends to have better throwing power than other technologies. This is very important when dealing with a demanding “real life” production operation.

Production Real Estate

Consider a line moving at a slow rate of only 10 feet per minute. One half-hour of drying time equates to 300 feet of extra conveyor winding inside a large convection oven. The problem is magnified on high-speed lines which might operate at 100 feet per minute.

The following comparison shows how dramatically curing time can be reduced by moving from convection to infrared and finally to UV curing for a free radical 100% UV solids operation. In one particular

analysis, the cost reduction from converting from 100% heating to 100% UV solids resulted in a savings of over \$250,000 per year on electric energy.

Additionally, the prospect of having to expand puts even more beneficial cost savings on the side of 100% UV solids. Such opportunity savings must be considered to realistically make practical decisions about any finishing process change.

The Economies of Speed

Conveying equipment is selected based on length, weight and line-speed requirements. Even the simplest monorail conveyor can cost approximately \$150 per foot (without tooling). UV can greatly reduce conveyor costs by providing compact curing equipment and simplifying thermal management. For example, a 30-minute reduction in both heat-up and cool-down times on a 20 FPM line would save \$180,000 in conveyor costs.

This savings is even more significant on specialty and custom engineered conveyors. By contrast, the average cost of power-and-free conveying is around \$450 per foot.

Operating Environment

A final area of consideration to installing any paint line is the operating environment. An environmental room is commonly needed to maintain a dust-free atmosphere to avoid contamination.

Solvent paints also generally need an environmentally controlled room maintained at 45 to 55 percent relative humidity and 70 to 80 F temperatures. Compressed air needed to run the solvent paint system and should be maintained at a dew point of 38 degrees or less. These are the general operating conditions required for optimal material handling of liquid based paints.

No such special temperature and humidity controls are necessary for 100% UV curable solids products. Additionally, the typical shelf life of 100% UV curable solids is in excess of one year in unopened

containers with storage temperatures under 100 ° F.

Cooling

Operators cannot handle or package parts at temperatures above 120°F. Hot parts exiting an oven must first be cooled. This is sometimes accomplished by simply conveying parts through ambient plant air. Oftentimes, however, some additional accelerated cooling method using cooled or even chilled air is required. Cooling typically increases the work in process inventory.

In many instances, the time required to remove heat from a part can be as long as or longer than the heating process itself. The same expenses paid in floor space, energy, conveyor, tooling and cooling tunnel costs are generally eliminated with respect to True 100% UV Curable Solids technology.

Material Cost

The cost per pound of UV Free Radical 100% UV solids is another important factor. Finishers already familiar with conventional solvent based paints for metal have been accustomed to prices in the \$20-50 per gallon range at 10% solids. UV Free Radical 100% UV solids have is selling competitively in existing markets at an excess of \$100/gallon. Due to the nature of being *true* 100% solids, free radical 100% UV solids can usually coat 20-30% more surface area per gallon. Also, film thickness of free radical 100% UV solids can usually be reduced to affect the same performance as solvent paints.

While UV Free Radical 100% UV solids are more costly than their solvent counterparts, total process cost savings can offset the higher cost of UV Free Radical 100% UV solids. Over time, economies of scale will drive down prices to end-users as producers are able to lower their cost of production and investment recovery time.

Figure 3 shows the cost per square foot of 100% UV curable solids expressed in cents per thousandth (i.e., per mil) of an inch of coating using the following variables:

- . •100% UV curable solids
- . •High density: 9-11 lbs. per gallon
- . •98% material utilization efficiency*

*Note: This parameter is affected by first-pass transfer efficiency of the application equipment, part racking, and degree of automation and reclaim efficiency.

In contrast, the cost of liquid coatings can vary not only by the cost per gallon but also by the percentage of solids in the coating. The percentage of solid material per gallon typically varies with the cost of material. A first pass transfer efficiency of 75% was used for the 100% UV solids costs (Figure 3) in these cost calculations.

Each step of the finishing process can result in a wide range of cost per square foot of product. Table 1 summarizes costs of an existing commercial installation involving conversion from solvent based liquid paint to UV Free Radical 100% UV curable solids paint on a heat-sensitive metal product. Volumes and line speeds were equalized to make the comparison more competitive. Cost of pretreatment was not factored into the comparison since it was the same within each process. In fact, 100% UV curable solids offers the potential for reducing precleaning treatments required to assure adhesion.

**Comparative Cost Summary
(Conventional liquid versus UV Free Radical 100% UV solids)**

<u>Raw Material Cost</u>	<u>Conventional Solvent Ink</u>	<u>True 100% curable solids ink</u>
Price per lb.	\$2.50	\$9.50
Square feet/ gallon	1200	3,300
Square feet per pound	139	330
Material Cost (\$/sq. ft.)	\$0.0179	
VOC by Volume	30%	.0288
% solids	70%	
Density (lbs./gallon)	8.60%	0%
Material utilization	30%	
Average film thickness (mils)	0.3	
Applied Material Cost (\$ / ft. sq.)	0.0537	
Savings per square foot printed		\$0.0249 (46%)

Process Costs

<u>Cure Speed (Seconds) :</u>	1800	6
Pretreatment (Corona) : (\$/ft ²)	0.030	0.000
Solvent Incineration (Gas) : (\$/ft ²)	0.035	0.000
Gas Convection Heat : (\$/ft ²)	0.000	0.000
I /R Heat (Electric) : (\$/ft ²)	0.000	0.000
<u>UV Dryer: (\$/ft²)</u>	0.000	0.0039

- Electric Rate = \$0.07 per KWhr
- Basis: one (1) 300 WPI lamp at 30fpm x 3' wide to deliver 0.35 J/cm²
- Production Capacity: 43,200 ft per 8 hourshift

Labor & Maintenance

Labor Cost: (\$/ft ²)	0.050	0.0250
# employees	6	3
Maintenance Cost : (\$/ft ²)	.020	.010

<u>Waste Disposal Cost (\$/ft²)</u>	0.035	0.010
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Summary

Processing Cost / Square Foot	0.0537	0.0489 (8.94%)
Raw Material Cost/Square Foot	0.1700	0.0288 (46%)
Total Cost/Square Foot	0.2237	0.0777
Total Cost Reduction per Square Foot		0.1460 (65.3%)

For this analysis, equipment amortization is considered a non-cash expense. Therefore, on a pre-tax basis, total cost per square foot of 100% UV curable solids paint is **7.77 cents versus 22.37 cents** for solvent based liquid paint. This represents a 14.6 cents per square foot savings.

Taken annually over 250,000 square feet of surface area printed is estimated at approximately \$36,500 savings annually. Moreover, this equates to an approximate payback on equipment of less than one year. The specific payback period will vary with the scale and complexity of the given paint line. A standard UV curing flat line can range from \$15,000 to \$25,000 depending on this size and curing requirements.

Other considerations impacting economics that have not been quantifiably factored into this analysis includes:

- . •Health and safety improvement
- . •5% discount insurance costs from Hartford Insurance,
- . •Faster line speed,
- . •better quality,
- . •lower inventory,
- . •increased production capacity,
- . •Space savings,

Summary

There are several significant areas to evaluate when considering a move to free radical 100% UV solids printing. Actual printing operations using this technology are growing by double digit rates annually. Therefore calculations submitted herein will vary depending on each Printers specific situation.

Hopefully, the ***total process considerations*** outlined in this document offers an example of how the total economic considerations can lead to financially supported decision when evaluated beyond the price of material.

The printing industry is indeed concerned about the environment and the ever increasing regulatory restrictions on conventional inks as first reason to consider UV technology. The increased production speed and lower costs are strong drivers also. In our experience, it usually comes down to costs and investment payback as the final decision making criterion.

In the very near future, as the volume of 100% UV curable solids production continues to increase and scale economies allow for a reduction in material and manufacturing costs, will provide an even more compelling reason to make the switch to 100% UV curable solids and away from conventional ink usage.

Still most end users are likely to look at only the “**per unit ink prices**” as the single comparative basis. Don't make this mistake. This would be significantly short sighted and generally a poor business practice. Only through continued emphasis of the total printing process cost detail will a company realize the best available technology is 100% UV curable solids inks for cost, control, quality, and growth.