

Economic Considerations of “True” 100% UV Curable Solids Paints and Coatings.

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Summary

The Economics of True 100% Free Radical UV Curable Solids

Paint and Coatings

Allied PhotoChemical, Inc.

Abstract

This analysis examines the total process costs associated with the use of a true 100% UV Curable Solids inks, paints, and coatings. 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 paint line is detailed, the economic concepts are easily extrapolated to show similar benefits in the markets of graphic and electronic inks.

There are several costs associated with a finishing 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 painting installations. It is intended to highlight the various economic elements associated with the 100% UV curable solids finishing operation and provide estimates of the associated costs. Some basic assumptions were necessary for the sake of comparison. Since process elements such as part density and geometry, weight, line speed, equipment, performance requirements, and cost constraints, etc. will differ, the economics presented are estimates.

Introduction

The use of conventional solvent based paints and coatings has added

significant value to metal finishing 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.

In the year 2000, 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. upon UV curing technology for use in screen printing and wood coating applications. Therefore, if a new printing line is installed or an old one is refitted, it must utilized UV technology to operate in Southern California. Even powder coatings are coming under increased scrutiny due to particulate generation and the potential explosive hazard associated with airborne dust particles.

A plethora of alternative paint and coatings technologies have seen varying degrees of success in the industrial market. The early UV hybrid (thermal and UV) cationic cure systems offered promise. Alas, no single technology has been developed to address the variety of finishing needs. In reality, there will probably not ever be a single technology panacea to accomplish 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 a coating is cured as a coatings.

For a given 100% UV curable solids product, (i.e., ink, paint, or coating) the physical appearance is similar to its solvent based counterpart in terms of rheology, application, as well as, the visible look.

In this case of free radical 100% UV curable solids paint, ultraviolet light (UV) in the 350 – 450 angstrom (a.k.a. standard mercury vapor) spectrum is the predominant method utilized. 100% solids UV paint viscosity ranges from 500 cps to 1500 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.

This technology is the only “**True 100% UV curable solids**” **paint and coating** 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. Current technologies evolve intermediate or decomposition products such as acetaldehyde, normal vinyl pyridines, vinyl-caprolactum or Isocyanates.

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

- improved operating economy,
- improved finish quality,

- . •energy savings,
- . •environmental friendliness, and
- . •easier regulatory compliance.

Is Low Temperature coating applications counterintuitive?

Generally, true 100% solids technologies tend to demonstrate counterintuitive processing behavior. For instance, conventional wisdom calls for a temperature increase to increase adhesion or improve flow. This is not the case for true 100% solids technology. True 100% UV Curable Solids are best applied to substrates and in environments below 100 ° F.

As such, True 100% UV Curable Solids product **does not** rely on heat for adhesion, viscosity reduction, cross-linking or curing. Therefore, applications **are not** limited to only products unaffected by high temperature levels.

More recently, advances in three dimensional (3D) 100% UV solids technologies have overcome the constraints of conventional finishing. As a result, these new materials and equipment systems have opened a wide range of market opportunities for a vast number of companies.

Some of the applications and substrates include:

- . • Hard coatings for Aluminum architectural panels.
- . • Automotive underbody corrosion resistant assemblies.
- . • High thermal density materials which act as heat sinks. (large metallic parts or assemblies)
- . • Temperature-sensitive materials. (plastics, wood, composites, etc...)
- . • pre-assembled components. (welded, brazed, soldered, or joined parts)
- . • Porous materials. (metal castings, fiberboard)
- . • Sheet molding compounds.

“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 following will outline how cost savings can be realized despite a higher unit price.

Processing

The differences between a solvent paint system and a UV curable paint system

are quite obvious. Figure one shows a schematic of the general processes used for each.

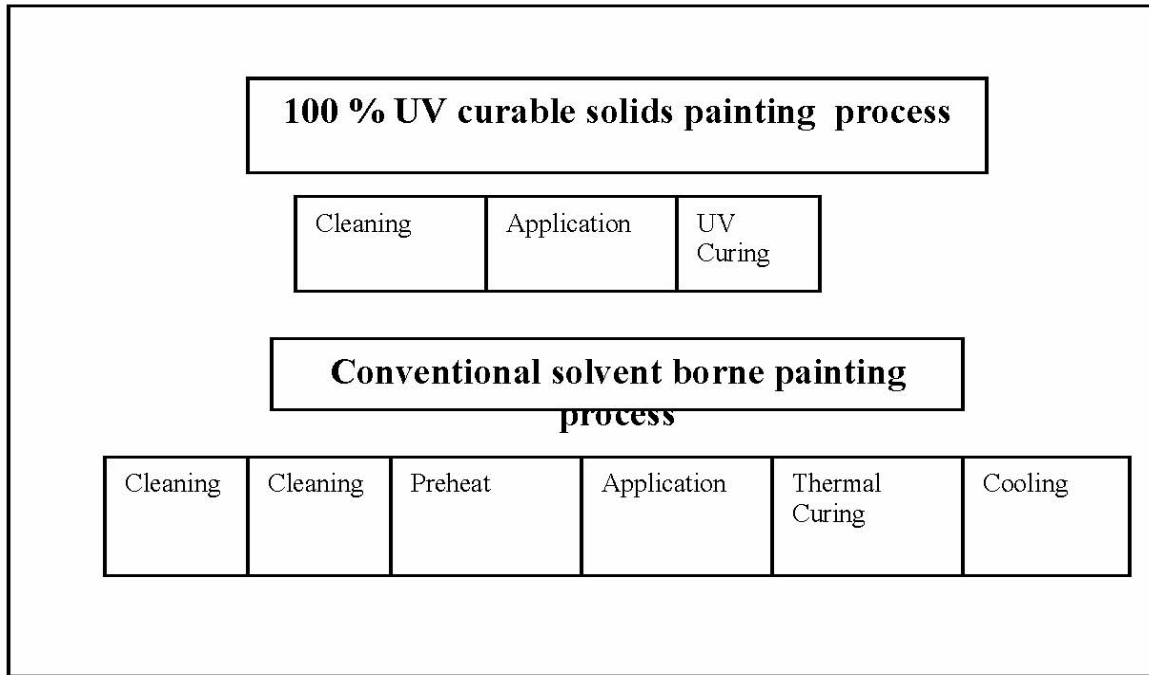


Figure 1

A standard paint line is actually a combination of a few sequential processes; cleaning, pretreatment, preheating, paint application, thermal curing, and cooling.

The major differences between a conventional solvent paint line and the 100% UV curable solids line lies in the, pretreatment, preheating, cure process, cool-down process. These thermal management issues alone account for a large portion (approx. 60%) of the processing time and floor space required (40%) of conventional paint lines.

The paint booth itself is generally no different than a conventional paint line. In fact, commercially available HVLP guns can be used for both. 100% UV curable solids paint can also be applied with automated bell sprayers, HVLP guns, roller coaters, vacuum painting, curtain coating or electrostatic hand-gun application.

Large scale paint systems typically employ downdraft or side draft paint booths to control any airborne paint. Conventional solvent paints tend to accumulate slowly on the grating used a part of the downdraft flooring system

and requires high pressure washing for clean up. The True 100% UV Curable Solids paints will remain in a liquid state until cured with UV light, making clean up and waste management a much simpler task.

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 paint 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.

Pretreatment

The first step in most finishing processes is pretreatment. Pretreatment methods are generally dependent on both the substrate and the solids to be removed. For example, in metal finishing there is usually a cleaning or degreasing operation followed by a dry-off oven.

Oftentimes, a multi-stage power washer using a series of washes and rinses is required. Due to the free radical nature of the true 100% UV solids paints, pretreatment can generally be minimized and possibly even eliminated depending on the specific application requirements.

The hydrophobic nature of true 100% solids materials provides additional benefits, as does the ability of petrochemicals to migrate through the paint prior to cure. Consequently, Free Radical 100% UV solids can potentially eliminate and generally reduce the initial step of pretreatment in the finishing process.

Some of the typical pretreatment processes required by solvent paint are outlined below.

<u>Substrate</u>	<u>Pretreatment</u>
Metal	
Wood (MDF)	
Wood (MDF)	
Plastic (conductive)	
Plastic (non-conductive)	
Clean	✂ Rinse ✂ Dry Sand ✂ Air-wash ✂ Pre-heat Sand ✂ Air-wash ✂

Prep-coat Wash ✂ Dry Wash ✂ Prep-Coat, (or plasma, flame treat) ✂ Dry

Application Equipment

Free radical 100% UV solids is a versatile technology and can be applied in a variety of methods including HVLP, electrostatic spray, curtain coatings, roll coatings, vacuum painting are all possible.

All paint application equipment costs are influenced by spray booth size, number of spray guns, level of automation, number of colors being reclaimed, and color-change requirements.

Thermal Management and Cure Equipment

Traditionally, industrial painting involves heat. Heat is used in liquid spray painting to accelerate drying by driving off the solvent or water carrier. These bake ovens usually operate anywhere from 150°F to 400°F depending on the paint, drying time 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.

The cost of ovens is primarily dependent on:

- . • Number of ovens in the process
- . • Heating method used (e.g., gas/electric convection, I/R, or combination convection I/R)
- . • Oven size (volume)
- . • Load (product load, conveyor, air exchanges, etc.)
- . • Cost of energy (gas, electric)
- . • Pre-heating requirements (associated with certain substrates like engineered woods).

Required line speed can influence the size of the ovens, as well as type of conveying system selected.

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 painting 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 finishing 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 is usually based on 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)

Basic Assumption:

1,00,000 ft² Coated Annually

Raw Material Cost Conventional Free Radical Solvent Paint 100% UV solids

- . •Price per gallon \$42 \$100
- . •Square feet/ gallon 171 1,100
- . •Material Cost (\$/sq. ft.) \$0.2456 \$0.091
- . •% solids 42% 100%
- . •Viscosity (lbs./gallon) 1.4 10
- . •Cost per gallon/pound \$28.51 \$10.00
- . •Material utilization 33% 98%
- . •Average film thickness (mils) 1.0 1.0
- . •Applied Material Cost (\$ per ft. sq.) 0.7443 0.0928

Basic Assumption: Energy Costs = \$0.035/btu

Solvent Incineration (Gas) -(\$/ft²) 0.035 0.00

Gas Convection Heat -(\$/ft²) 0.00 0.00

I/R Heat (Electric)

-(\$/ft²) 0.015 0.00

UV Curing Oven -(\$/ft²) 0.00 0.0071

Basic Assumption:

Labor & Maintenance -Labor Cost: (\$/ft²) 0.050 0.007

-# employees 6 3

-Maintenance Cost (\$/ft²)

Waste Disposal Cost(\$/ft²) **0.035 0.000**

-Scrap/Rework(\$/ft²) **0.011 0.007**

-Assumed 2.5% rate

-

Equipment Amortization(\$/ft²) **0.021 0.001**

-
-Capital investment (\$000's) 475 250

Non-Material Cost / Square Foot .1670 .0221

Raw Material Cost/Square Foot **.7443 .0928**

Total Cost/Square Foot **\$0.9113 \$0.1149**

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 **11.5 cents versus 91.1 cents** for solvent based liquid paint. This represents a 79.6 cents per square foot savings over 1.0 million square feet of coating or **\$796,000** annually. Moreover, this equates to an approximate payback of less than four (4) months. The specific payback period will vary with the scale and complexity of the given paint line. Annual cost savings will fluctuate approximately \$35,000 for each \$1.00 change in the cost per pound of free radical 100% UV solids.

A similar conversion from powder coating to 100% solids also had a payback of less than 4 months on an approximately 22 million square foot annual basis on a \$700,000 equipment cost.

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

- . •Environmental remediation,
- . •Health and safety improvement/insurance costs,
- . •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 finishing. Actual installations at this time are few and therefore limit the amount of reference data.

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

Currently, most 100% UV curable solids applications and developments involve those where the technology provides the means to use 100% UV solids to coat a part which was not possible without UV coatings. Quality, environment, speed and energy consumption are not strong drivers for most early market entrants. It usually comes down to the cost and investment payback as the driving criterion.

Still most end users are likely to only look at unit prices as the sole comparative basis. This would be significantly short sighted and poor business practice. Only through continued emphasis of total painting process cost detail will a company realize the best available technology is free radical 100% UV curable solids paints, coatings and inks for cost, control, quality, and growth.

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 cost and manufacturing costs, an even more positive benefit will be realized when comparing 100% UV curable solids to alternative coating methods.