NICE^3 and Coors

UV-Curable Coatings for Aluminum Can Production

Bob Brady

Principal Environmental Scientist

Coors Brewing Company, BC395

Golden, CO 80401

ABSTRACT:

Over the last two years, the Coors Brewing Company has been conducting a pollution prevention and energy conservation project jointly with the DOE, EPA and Colorado Office of Energy Conservation, utilizing the NICE^3 (National Industrial Competitiveness through Energy, Environment, and Economics) program. The goals of the project are to investigate a can printing technology developed at Coors, and in use for 20 years, which appears to have significant environmental, energy and cost advantages. The technology utilizes ultraviolet (UV) light to cure the decorative image and its overcoat on the exterior of beverage cans instead of conventional gas fired curing. The Coors plant is currently the only aluminum can manufacturing plant in the country using the UV technology. We wish to quantify and verity the pollution prevention and energy efficiency benefits of this technology, and compare this technology to the traditional technology which is in use at all other can manufacturing facilities.

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INTRODUCTION:

The Coors Can Manufacturing Plant, located in Golden, Colorado, is the largest single aluminum can manufacturing plant in the world, producing approximately 4 billion cans a year. The Coors Brewing Company developed the country's first commercial aluminum beverage can, a two-piece aluminum can, in 1959, and was instrumental in the transfer of aluminum can production technology throughout the beverage container industry. The plant currently produces aluminum cans primarily for the beer beverage market.

Coors has worked in partnerships with several companies to develop an ultraviolet light (UV) curing technology for decorating aluminum cans. The decision to use a UV process was motivated by a desire to increase can printing speeds, to reduce energy consumption, and to lower air emissions. In 1974, Fusions Systems Corporation and Coors developed UV oven equipment which could rapidly cure UV inks. These UV ovens were installed in full scale can production in the Golden plant in 1975. Coors has worked with several chemical companies over the years in developing practical UV inks and over varnishes. These chemical vendors have included Borden, General Printing Ink, Akzo and Martinez Ink Company. The Coors plant is currently the only aluminum can plant in the country using the UV technology.

Early estimates indicated that the UV process resulted in very low air emissions. The Coors plant manufactures cans almost exclusively for its own brewery, therefore this technology has not been disseminated through the rest of the beverage can manufacturing industry. The NICE^3 program was seen as an ideal way to validate the benefits of the technology, and potentially aid in implementing this technology through the rest of the industry. Project work began early in 1994, and is scheduled for completion by mid-1995.

CAN PRINTING TECHNOLOGIES:

Past can decorating technologies trials have included the use of solvent based coatings, high solids coatings, powder coatings, electrocoat, and UV curable coatings. Among other factors, these techniques differ in the content of solvents in the coatings.

Solvent based coatings contain solvents at concentrations of approximately 70 to 75 percent by volume (1). The solvent composition is typically a mixture of aliphatic hydrocarbons, aromatics, ethers, cellosolves and acetates. As a result, this method produces significant VOC (volatile organic compound) and HAP (hazardous air pollutant) emissions. The coatings have good abrasion resistance and high quality, but the high VOC emissions have virtually eliminated their use in can plants.

High solids coatings contain less solvent than the conventional solvent based coatings (1). In water based high solids coatings, the solids content ranges from 10 to 35 percent, the water content from 45 to 72 percent, and the solvent content from 13 to 27 percent. The solvent is used to control viscosity, disperse pigments and aid in wetting. Curing is achieved with a thermal oven which requires a high operating temperature due to the high water content in the coating. Since the coating does contain solvents, VOC emissions are still present. This coating method is the one most widely used in can manufacturing plants.

UV curing of can decoration coatings is currently accomplished with either acrylate based coatings or cationic coatings. UV acrylate coatings contain photochemical initiators which form free radicals upon exposure to UV light. The free radicals initiate the cross linking of monomers and oligomers, which results in a rapid curing of the coating. A newer cationic coating forms Lewis acids after a brief exposure to UV light. Cationic initiated curing then proceeds even after UV light is removed (“dark curing”). The UV chemicals are approximately 100% solids in content, with essentially zero solvent contents. The UV coating technology is also in use in can production.

A review of feasible technologies has indicated that only the high solids water based coating technology and the UV coating technology are currently practical for can manufacturing.

UV TECHNOLOGY PROCESS DESCRIPTION:

Aluminum cans are made from large coils of aluminum sheet stock by punching aluminum disks into cups, and sequential drawing and ironing to form the can body. The can body is trimmed, washed, dried and transferred to the printer, where the decorative ink and clear protective overvarnish is applied. The ink and overvarnish are cured by either UV light, or in the conventional method, by heating in a natural gas fired oven. An internal coating is next sprayed in the interior of the can, and the internal coating is cured through an additional thermal oven. The can necks are reduced in size and flanged so as to accept the can end during filling with product.

In the can printing process (Figure 1), separate UV ink fountains supply the ink to rollers, which coat individual printer plates. The plates, one for each color, are raised positive images of the graphic design which will be printed on the cans. The printer plates contact, in registration, a rubberized blanket on a rotating wheel, resulting in the formation of a complete negative color image on the blanket. Clean cans are fed into the printer and are placed on a steel mandrel. The spinning mandrel then rotates the can body against the rotating blanket, resulting in the transfer of the final graphic image onto the can body. The rotating mandrel wheel then immediately carries the can to an over varnish wheel, and the UV over varnish is directly coated over the wet ink on the can body.

The overvarnish application directly on top of colored inks is termed a “wet on wet” coating application. The inks and overvarnish chemicals, however, are pastes with only a trace amount of water and essentially no solvents at all. The overvarnish and ink chemistries are matched to allow the curing of a wide variety of ink colors without requiring photo-initiator additions to the inks. The product viscosities are also matched in order to provide a clear, non-smearing application of overcoat on top of the inks.

The cans are carried on short chains from the printer to vacuum belts, where they are transported to and through the UV oven (Figure 2). The vacuum belts stabilize and support the cans in an optimal geometry for UV light exposure. The UV ovens in use at Coors are designed by Fusions Systems (Rockville Maryland).

One UV oven is typically paired to one printer. The UV ovens are approximately 9 feet long, 5 feet wide and 5 feet high. The ovens operate at about 110 F, warmed slightly above ambient temperature due to the heat evolution from the UV lamps. The UV oven contains between six and eight 10 inch, 300 watt/inch, microwave energized mercury lamps. The lamps are positioned with parabolic reflectors in a geometry to focus maximum illumination on the exterior surface of the aluminum cans. The interior surface of the can is also exposed to UV light in order to ensure complete curing of all ink residues. The entire UV can decorating process is very rapid: printing speeds are approximately 1600 to 1800 cans per minute, and the oven cure time is approximately 0.7 seconds.

Internal coating is next sprayed into the interior surface of the cans, followed by thermal curing in natural gas fired ovens.

PROCESS EFFICIENCY:

The Coors Can Manufacturing Plant has, in the past, utilized a thermal technology can line side by side with the main UV technology can lines. As a result, production operators have had the opportunity to evaluate practical operations of the UV technology in comparison to the conventional technology.

The conventional thermal technology utilizes natural gas fired ovens to thermally cure the inks and over varnishes. The thermal curing ovens are operated at 350 F or higher in order to achieve the ink and over varnish curing. Thermal ovens are approximately 60 to 80 feet long, 8 feet wide and 25 feet high. A long pin chain, approximately 400 feet long, is used the transport the cans through the oven. The large dimensions of the thermal oven, and the long transport chain, are required to provide the thermal contact time and still achieve production rates of 1500 cans per minute or higher (2).

The UV ovens can be started up much faster that thermal ovens (only a 5 minute start up time is required). The controls for the UV ovens are simpler. The newer UV ovens utilize vacuum can conveyance belts, which are simpler, more reliable, and easier to maintain than the long 400 foot pin chains which transport cans through hot thermal ovens. The low operating temperature of the UV oven is also beneficial for front line production operation and maintenance.

ECONOMIC ANALYSIS:

A cost analysis has been conducted to compare the UV and conventional thermal can printing technologies. The cost analysis rated according to billion cans produced, and UV is compared to both thermal curing and the thermal technology with incinerator air emission controls applied (Table 1). Electrical costs are similar for UV and conventional thermal curing. Chemical costs are currently approximately 5% higher for UV inks and over varnishes. Natural gas is not required for UV ovens, therefore the UV technology provides an estimated savings of $170,000 to $420,000 per billion cans produced. As previously mentioned, thermal ovens require more maintenance. Overall, approximately $20,000 per billion cans savings is provided with UV technology in comparison to thermal with no emissions controls, however the savings grows to approximately $450,000 compared to thermal curing ovens with stack controls.

ENERGY EFFICIENCY:

The total energy consumption requirements have been compared for the UV and thermal technologies (Table 2). The analysis is indexed in units of millions of BTUs per billion cans produced, and UV is compared to both thermal curing and the thermal technology with incinerator air emission controls applied. Both types of ovens require similar levels of electrical power. Electrical power consumption is slightly higher for UV than for thermal, due to the energy demands of the UV lamps, however the thermal ovens also require comparable electrical power to run blowers and can chain conveyors. The net energy savings with UV technology is approximately be 14,000 million BTUs in comparison to thermal curing alone, and 50,000 million BTUs per billion cans produced in comparison to thermal curing with air emissions control.

PRODUCT QUALITY:

The print quality of the UV technology process is an important consideration. All cans produced at the Coors Can Manufacturing Plant are now made with the UV process, and print quality is comparable to that obtained with thermal curing (Table 3). Similarly, color and gloss is equivalent to that obtained from the thermal process. The over varnish is applied in order to provide a protective coating over the decorative label; currently the abrasion resistance of the over varnish is dependent on the film thickness of the over varnish. For a fully commercial can market, with markets including all beverage categories in addition to the beer beverage, more technical development is needed to formulate a higher abrasion resistance. This should be achievable with newer formulations of cationic UV overvarnish (3).

ENVIRONMENTAL IMPACT:

Over the past two years, several studies have been conducted at the Can Manufacturing Plant to estimate the environmental impact of the UV printing technology. The procedures ranged from the laboratory analysis of ink and over varnish to full EPA protocol stack testing. This analysis has provided a comparison of the UV to the thermal conventional technology.

The comparison off the UV process to the uncontrolled and incinerator controlled thermal technologies shows that the UV process has a significantly lower environmental impact (Table 4). This analysis includes not only the air emissions from the direct oven source, but also the air emissions from the power utility generating electricity for the UV or thermal ovens. Volatile organic compound emissions have been validated to be extremely low, approximately 0.3 tons per billion cans. This emission factor is lower than that estimated for a thermal oven with incinerator controls, and much lower than the approximately 100 times lower than that of a thermal oven with no control devices. Particulate and sulfur oxide emissions between UV and thermal are similar, again due to the gyration of electricity at power plants which is then used to power the UV or thermal ovens. Another large difference is observed for CO, emissions. The UV process does result in CO, emissions at the power plant, however levels are much lower than those for the thermal processes as no natural gas is consumed. Significantly more CO, is generated when incinerator control devices are used for the thermal process. Data from protocol stack testing has also indicated that only trace amounts of HAPs are emitted in the UV process. The UV technology is therefore essentially a zero HAP process in addition to being a ultra low VOC process..

The Coors Can Manufacturing Plant implemented the UV printing technology in 1975, and the plant is the only can manufacturing plant using this technology. If the conversion had not taken place in 1975, significant emissions of VOCs and HAPs would have occurred. The implementation of the UV operation has thus had a very significant pollution prevention effect. The magnitude of this is depicted in Figure 3. The upper part of the chart depicts the potential emissions from a current thermal process; the small lower area of the chart depicts the worst case estimate for UV technology emissions.

Approximately 80 to 100 tons of VOCs would have been emitted each year since 1975. The sum of these savings in potential emissions is 1,740 tons of VOCs. This comparison is conservative, since it is based on VOC contents of current UV and current thermal coatings, and earlier thermal coatings were much higher in solvent content.

NATIONAL IMPACT:

If the UV technology were transferred industry wide, there would be subsequent notable pollution prevention impacts. The can manufacturing industry is large, with approximately 130 billion cans produced each year. The vast majority of these cans are aluminum cans, approximately 100 billion per year (4). Estimates for a national technology impact have been calculated by comparing the annual production of approximately 4 billion cans/year at the Coors Can Manufacturing Plant to the national production rate.

Pollution prevention estimates of 3,000 tons/year of VOCs and 130,000 tons/year of CO_2 emissions have been calculated. These impacts are even more substantial taking into account the regional clustering of can manufacturing plants in several states. The implementation of UV technology could therefore have a significant regional pollution prevention impact.

INDUSTRY ACCEPTANCE:

Barriers have existed which prevented the acceptance of the UV technology by the rest of the can manufacturing industry. These concerns have included the abrasion resistance level of UV coatings, color quality, higher current costs for UV chemicals, and reports of worker skin sensitization to early generations of acrylate coatings.

Current UV acrylate coatings in use at Coors have sufficient abrasion resistance for the beer beverage market. Newer cationic coatings are currently being developed which have the potential to fully resolve abrasion resistance concerns (3).

A full spectrum of ink colors are in continual use at Coors to satisfy marketing requirements and continually changing graphics designs. Fine color matches to thermal colors may require some additional research and process control work.

Chemical costs for UV coatings are estimated to be between 5 and 17% more expensive than conventional coatings (5). The higher cost is likely due to the more limited market which currently exists for UV chemicals. With expansion of the UV technology, these chemical costs should become more competitive with the conventional chemical costs.

Early formulations of acrylate coatings did cause skin sensitization in some workers. The generation of UV chemicals now in use at Coors has greatly reduced this effect. In addition, with proper work practices and the use of protective gloves, skin now no longer a problem. The use of conventional coatings with even low to moderate solvent compositions is likely to result in greater health effects than the current system at Coors. The cationic coatings also have demonstrated improvements in health and safety (3).

SUMMARY:

The UV curing technology in use at the Coors Can Manufacturing Plant has been a proven technology for the past 20 years. Very substantial benefits are evident with this technology in very low, or zero, VOC and HAP emissions, and much lower CO, emissions as compared to the alternative thermal curing technology. Estimates also indicate that the UV technology consumes less energy than the thermal technology, and that the UV technology is operationally more cost effective than the alternative technology. The UV technology at the Coors plant is currently dedicated to a beer beverage market, and can product quality is fully acceptable for this market. A higher abrasion resistance can coating is currently desired for other beverage markets. Therefore newer generation UV over varnishes with higher abrasion resistance ratings will have to be investigated or implemented in order to fully convert this technology.

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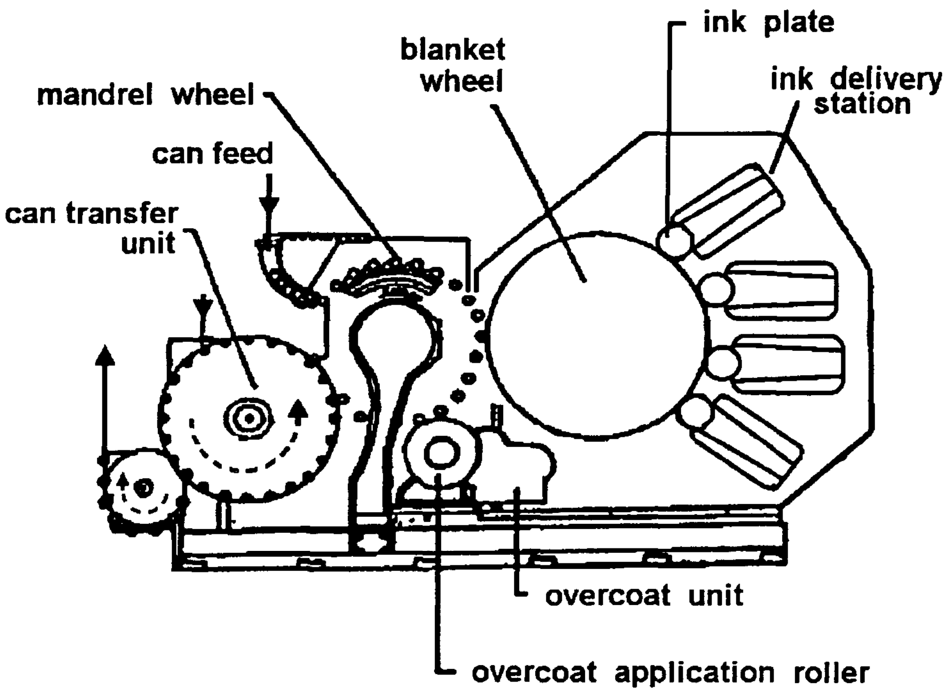

Figure 1. UV Printer

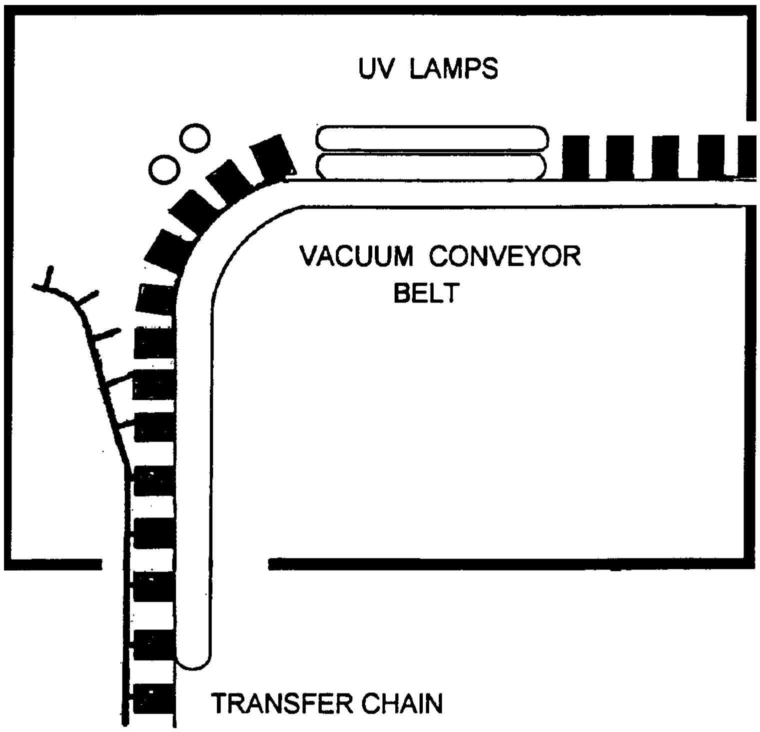

Figure 2. UV Oven

Table 1. Economic Analysis

($ / billion cans)

	Thermal	**Thermal,**	**UV**
Electricity	$ 171,000	$207,000	$170,000
Natural Gas	$ 170,500	$420,000	$0
Chemicals	$ 1,010,000	$ 1,010,000	$ 1,180,000
O & M	$41,600	$ 192,000	$21,200
Total Costs	**$ 1,393,100**	**$ 1,829,200**	**$1,371,200**

Table 2. Energy Efficiencies

(MMBtu / billion cans)

	Thermal	**Thermal,**	**UV**
Electricity	5,600	6,400	**15,900**
Natural Gas	23,900	60,100	0
Total Energy	**29,500**	66,500	**15,900**

Table 3. Product Quality

(UV vs. Thermal)

Print Quality	Equivalent
Color Match	Equivalent
Gloss	Equivalent
Abrasion Resistance	Application Dependent

Table 4. Environmental Impact Including Energy Source

(tons emissions / billion cans)

	Thermal	Thermal,	UV
VOCs	31	0.6	0.3
Particulates	27	32	26
Sulfur Oxides	20	26	20
CO_2	3,200	5,700	1,900

Figure 3. Cumulative VOC Emissions Comparison