UV-Curable Wood Furniture Coatings Case Studies

Midwest Research Institute, in cooperative agreement with the Air Pollution Prevention and Control Division of the U.S. Environmental Protection Agency's (EPA) National Risk Management Research Laboratory, conducted a study to identify wood furniture manufacturing facilities that had converted to low-volatile organic compound (VOC)/hazardous air pollutant (HAP) wood furniture coatings and develop case studies for those facilities. The primary goals of the project were to demonstrate that low-VOC/HAP coatings can be used successfully by some wood furniture manufacturing facilities and to provide a resource to assist other wood furniture manufacturing facilities in converting to low-VOC/HAP coatings. This document is a compilation of the UV-curable coatings case studies developed under the cooperative agreement.

The table below presents the case studies completed for wood furniture manufacturing facilities using UV-curable coatings. The following areas were examined in the case studies:

- The types of products the facility manufactures;
- The types of low-VOC/HAP coatings the facility is using;
- Problems encountered in converting to low-VOC/HAP coatings;
- Equipment changes that were required;
- The costs and cost savings associated with the conversion process, including capital costs, research and development costs, operating costs, and material/labor savings;
- Emissions and waste reductions achieved;
- Advantages/disadvantages of the low-VOC/HAP coatings; and
- Customer feedback on products finished with the low-VOC/HAP coatings.

Facility	**Products**	**Low-VOC/HAP Coatings Used**
Artistic Finishes St. Paul, MN	Custom finishing	UV-curable topcoats (clear and pigmented), one UV-curable stain Waterborne topcoat
Columbia Forest Products Chatham, VA	Panels	UV-curable sealer, topcoat
Geiger Brickel Atlanta, GA	Office furniture	Waterborne urethane topcoat, stain UV-curable sealer, topcoat
Hussey Seating Co. N. Berwick, ME	Bleacher, stadium, and theater seating	Waterborne stain, sealer, topcoat UV-cured sealer, topcoat

Facility	Products	Low-VOC/HAP Coatings Used
Knoll E. Greenville, PA	Office furniture	Waterborne pigmented coatings, UV-curable sealer and topcoat, powder pigmented coatings Hot-melt adhesives
Lane Altavista, VA	Home office furniture	UV-curable sealer, topcoat
Loewenstein Pompano Beach, FL	Seating	UV-curable sealer, topcoat
Prestige, Inc. Neodesha, KS	Cabinets	UV-curable sealer, topcoat
Riverside Furniture Fort Smith, AR	Residential, home office furniture	Waterborne ink and basecoat, UV-curable filler, topcoat
States Industries Eugene, OR	Panels	UV-curable filler, sealer, topcoat

Case Study No. 2 Waterborne and UV-Cured Coatings
Artistic Finishes, Inc.
Roseville, MN

Background

Artistic Finishes is a contract custom finishing company. Products finished include furniture, cabinets, windows, doors, picture frames, hardwood flooring, molding, and exercise equipment. Many of their jobs are finished with low-VOC/HAP coatings. The company has made a commitment to use environmentally friendly finishing methods, and has engaged in various research and development projects to find high-performing, low-emitting finishes to replace solvent-borne finishes. Artistic's customers typically specify the coatings they want them to use on particular products, so many of these research projects were conducted to develop alternatives to solvent-borne coatings their customers wanted them to use. Since the specific manufacturing and coating processes vary by product, this case study will discuss projects Artistic has undertaken to switch various product lines to low-VOC/HAP coatings.

Conversion to Waterborne Coating for Interior Window and Door Components

Artistic has been finishing this particular product line since 1989. Artistic's customer wanted them to use a catalyzed, solvent-borne polyurethane coating that was very toxic. The VOC content of the coating was about 5.8 pounds per gallon and the catalyst was isocyanate-based. In 1992, Artistic decided to bring in a new coating supplier to develop a non-toxic, low- or no-VOC coating of equal performance. The research and development process for the coating took about one year, and the coating supplier was able to produce a high-solids, waterborne, single pack urethane that contained only 1 pound per gallon of VOC and 45 percent solids. Artistic has been using that coating since 1993.

Capital costs for process changes and the new equipment required to apply that coating were about $300,000, and costs involved with labor, planning, and research are estimated at about $100,000. However, the coating cost was cut in half, since the catalyst for the old coating was very expensive. The equipment maintenance required also decreased, and mixing equipment was no longer necessary with the single pack system.

Cleaning emissions also were reduced. Previously, the lines were cleaned several times per day with methyl ethyl ketone, due to color changes or clogged lines. With the new coating, operators flush the lines with water only during color changes.

Conversion to UV-Curable Coatings for Exercise Equipment Components and Other Products

Artistic was contracted to finish a line of exercise equipment components until 1996 (at which time the product line changed). When they began finishing this line, they used a solvent-borne stain, a catalyzed sealer, and a catalyzed topcoat or conversion varnish. Three coats were applied to the components, which had to be racked overnight to dry.

In 1994, Artistic began to investigate alternative coating systems for this line, including waterborne and UV-curable coatings. They initially switched to UV-curable coatings that had only 60 percent solids, but then transitioned to 100 percent solids UV-curable stains and topcoats. Artistic estimates that the time to convert to the UV-cured product was only 60 to 90 days, and they were able to increase their production rate to five times that of the solvent-borne system because the coatings cure within seconds and are applied on an automated flat line.

The transition to UV-curable coatings for the exercise equipment components allowed Artistic to bring in other business, namely hardwood floors and transitional moldings. They currently use waterborne stains and 100 percent solids UV-curable sealers and topcoats on hardwood flooring, molding, and paneling. They found that the waterborne stains provided better color consistency and color matching than the UV-curable stains. Drawer components also are finished with UV-curable acrylic urethanes.

Artistic also uses a 100 percent solids, sprayable, UV-cured coating. They use an automated spray system to apply this coating to profiled parts, such as molding. Since the UV-curable coatings cost $60 to $80 per gallon, Artistic wanted to find a way to capture and reuse the overspray from this system. Therefore, they developed an overspray reclamation system customized to their line. The implementation of the sprayable UV-cured topcoat and overspray reclamation system also resulted in a reduction in the amount of cleaning solvent used, since they flush this line less often than they would a solvent-borne spray system.

Facility personnel stated that it took time for the operators to orient themselves to the new coatings. Employees have to wear protective equipment when working with the UV-curable coatings, and they had to learn new safety and housekeeping procedures. A labor savings was experienced with the switch to UV-curable coatings, since the line is automated and no operators are required to rack parts for drying. Space also was saved, since the drying racks are no longer required.

Emissions

Artistic's operating permit allows them 100 tons per year of VOC emissions. According to Artistic, they currently are operating at 12 to 14 tons of VOCs per year, and have been able to decrease their emissions over the past several years as production has increased and the types of products coated have varied. Their high permit limit provides them with a lot of flexibility and a high production capacity.

Summary

From 1985 to 1992, Artistic mostly used solvent-based coatings. Then, they began to investigate alternative coating technologies. Today, 90 percent of their finishing is done with waterborne or UV-curable coatings. They will work with their customers to find low-emitting coatings of equal or better quality than traditional solvent-borne coatings, and have refused jobs when customers insisted on having their products finished with traditional solvent-borne lacquers.

Artistic is very satisfied with the quality of the waterborne and UV-cured finishes. Because the UV coatings cure in seconds, problems with dry time (e.g., finished pieces sticking together) have been eliminated. Artistic has had no negative feedback from their customers on products finished with the low-VOC/HAP coatings. They feel that being a contract finishing facility saves their customers the cost of complying with regulations, while providing skilled workers and extensive finishing knowledge.

Case Study No. 7   UV-Cured Coatings
Columbia Forest Products
Chatham, VA

Background

Columbia Forest Products has 18 plants throughout the United States. The Chatham plant is the only plant that coats its product. A wide variety of hardwood plywood panels are produced, with approximately 10 percent receiving a clearcoat on one or both sides. The coating process includes a UV-cured sealer and a UV-cured topcoat. The panels are either multi-ply, with a core consisting of three or more sheets of thick veneers pressed together, or three-ply, with a solid core of premanufactured particleboard or MDF. Panel thicknesses range from 5/32 to 1½ inches and panels range in size from 30 to 50 inches in width and 5 to 10 feet in length. The finished panels are sold for use in a variety of applications, including cabinetry and casegoods.

Manufacturing and Coating Operations

The first UV coating line was instituted in June 1995 due to customer request for a prefinished product, which was previously unavailable. Customer demand also played a role in choosing to use UV coatings over traditional solvent-borne products. Not only do UV coatings produce significantly less emissions, they are also more cost-effective for both Columbia Forest Products and the smaller companies they supply with finished panels. Since Columbia Forest Products produces thousands of panels per day, it is more cost-effective for them to supply prefinished panels than for each of their customers to coat the panels that they purchase, especially with the UV technology. In July 1998, a second UV line was added. The older equipment then became the topcoat application line, and the new equipment became the sealer application line. Before the addition of the second line, a panel had to pass through the finishing line twice per side, once for the sealer and once for the topcoat. The addition of the second line effectively created one single pass line. The finishing capacity was doubled, causing the plant to increase operation from five to seven days per week. There currently are two 12-hour shifts per day, with six coating employees per shift.

The panel materials are first matched and ordered according to customer request and then sent to the glue spreader. The bottom layer is laid face down and the core layer(s), with glue (a urea-formaldehyde resin) spread on both sides, is placed on top. The panel is completed by placing the face on top of the core. Several panels are assembled in this way and stacked together. The panels first are cold pressed and then sent to a steam-heated multi-opening press. Following this hot pressing, the panels are trimmed on all four sides and voids are filled with putty. The panels then are stacked and sent to the sander. First the edges are sanded, then the back. The panel is flipped and the front is sanded last. The panels then are considered finished product. Most are packaged for shipping, but the panels that are to be coated are sent to the UV finishing line. Approximately 2,800 panel sides are coated per day.

The UV coating line consists of two sanders, two roll coaters, and two UV ovens, connected by conveyor belts. The panels are fed by hand onto a moving conveyor belt and pass through the newer equipment to receive the sealer. The panels first pass through a multi-head sander that also cleans the panels for a smoother coating application. The sander exhaust is sent to a baghouse. The panels then pass through the roll coater where the sealer is applied. The coating is cured by UV lamps. The number of lamps and cure time vary depending on the product, however cure time is only a few seconds. The second half of the line consists of the older equipment. A conveyor transports the panels to this section of the line to receive the topcoat. Because the sander on this line does not also clean the panels, they must be sent through a separate cleaner after they are sanded. The topcoat is applied by a roll coater and cured by two UV lamps.

All coatings are received in 55-gallon drums and transferred manually to the roll coaters using 5-gallon buckets. The empty drums are sold to a barrel company for reuse.

Facility Experience with UV-Cured Coatings

The addition of the UV line went smoothly for Columbia Forest Products. The main problem with the new UV-cured coatings is the difficulty of repair or rework. Because the veneer is so thin, the panel cannot be sanded to completely remove the coating without damaging the veneer. The UV-curable coatings cannot be sprayed over a small area to repair a coating defect the way traditional solvent-borne coatings can. The difficulty of repair increases the number of rejects that must be sold as shop-grade panels.

The value of proper operator training was very clear at Columbia Forest Products. The addition of the new equipment, as well as the switch from five to seven days per week operation, added many new operators who had no experience with the UV line. Their lack of experience led to an increase in rejects and equipment maintenance, both of which declined as the personnel became familiar with the equipment.

There are several advantages to using the UV-cured coating system instead of traditional solvent-borne nitrocellulose coatings. Less paperwork is associated with the lower-emitting UV-cured coatings, a benefit enjoyed by both Columbia Forest Products and their customers. In addition, the short curing time reduces the amount of space required in the facility to house the UV line. The UV equipment also provides a highly automated coating process and requires a smaller labor force than hand spraying traditional coatings. The UV system produces a consistent, high quality finish that has resulted in high customer satisfaction. Overall, facility personnel are pleased with the quality and performance of the UV-cured coatings.

Costs

The major cost incurred as a result of the facility's decision to begin coating was the purchase of the new equipment. The capital investment for the first set of equipment was approximately $375,000; the line consisted of the sander, cleaner, roll coater, and UV curing equipment. The second line was slightly more expensive, approximately $500,000, because of an upgrade to the sander. The second line is made up of a sander with an integrated cleaner, a roll coater, and a UV curing station.

The in-plant trial period for both installations was very short. Most of the coating formulations had already been tested at the equipment manufacturer's on-site lab. The original coatings were supplied by R & D Coatings, who were very helpful in finding the proper formulation for the required finish. R & D Coatings also took two Columbia Forest Products employees to a plant that uses their UV-curable coatings to aid in operator training. After the initial training was complete, R & D Coatings maintained contact to ensure everything was going smoothly.

Columbia Forest Products tried several other coating suppliers as they were developing their coating process and is currently using both R & D Coatings and PPG Industries products. The UV-curable coatings are more expensive per gallon than traditional coatings (40 to 45 dollars per gallon), but facility personnel believe benefits like low emissions, high solids content, and customer satisfaction outweigh the cost difference.

Emissions

The majority of the facility's VOC/HAP emissions are from the plywood pressing process, due to emissions of formaldehyde and methanol from the adhesive and the wood as it is pressed. Another large source of emissions is the coating equipment cleaning process. Propylene glycol monopropyl ether is used for in-place cleaning of the roll coating equipment. However, now that the line is running continuously, it is cleaned only when a roll is replaced. This practice has reduced the amount of cleaning solvent used, and therefore cleaning emissions, but no data on the size of the reduction were available.

Surface coating is not a major source of emissions, representing only 1 percent of the total facility-wide VOC emissions. According to the facility, coating operations accounted for only 0.22 ton of VOC emissions and represented only 0.5 percent (0.08 ton) of the total facility-wide HAP emissions in 1997. Columbia Forest Products stated that the UV-curable coatings have a very high solids content and a typical VOC content of less than 1 percent. The coatings also contain small amounts of HAPs (e.g., xylene and/or ethyl benzene) that are emitted during curing, but most of the coating components combine to form the final film.

Case Study No. 11 Waterborne and UV-Cured Coatings
Geiger Brickel
Atlanta, GA

Background

Geiger Brickel began producing high-end wood office furniture in Toronto, Ontario, in 1964. The company has two manufacturing facilities in Atlanta, referred to as the Fulton facility and the Assembly to Order (ATO) facility. The Fulton facility began operation in 1978, has about 290 employees, and produces about $40 million per year. The ATO facility was completed in May 1999. Geiger anticipates the ATO facility will have approximately 78 employees and produce about $40 million per year at full production. Most of the finishing operations in the Fulton facility are manual, while only automated spray and roll coating equipment are used at the ATO facility.

The switch to low-VOC coatings at Geiger was prompted by a desire for a high-quality, more environmentally friendly coating and to stay "ahead" of EPA requirements. Geiger Brickel applied for and received a grant from EPA to investigate a waterborne urethane topcoat. They began using the new waterborne urethane in 1996. They installed a roll coating line at the Fulton facility in 1998 to apply UV-curable topcoat to certain types of flat components.

Manufacturing and Coating Processes

All raw materials are received in bulk at the Fulton facility, including particleboard, veneers, and solid wood. Both domestic and imported wood species are used, including maple, ash, cherry, oak, walnut, beech, sycamore, anigre, and sapele. After the materials are sorted, veneers are spliced together, and the particleboard and solid wood are milled into components. Veneer is applied to the particleboard using a waterborne glue and a hot press. Some components receive a wood veneer on one side and a paper backing on the other side if only one side will be visible on the finished product. Any edge banding or solid wood edging then is applied.

Casegood components receive any necessary holes or grooves and are sanded and assembled prior to finishing. Desk and table tops are sanded before finishing and are finished separately from other components.

Fulton Facility Coating Process

There are five coating lines or stations at the Fulton facility: a stain wiping station; a shade/sealer spray booth; a waterborne urethane spray booth; a solvent-borne urethane spray booth; and a flat line used to apply UV-curable topcoat. All stains at the Fulton facility are hand wiped to achieve the desired depth and clarity. An oil-based stain currently is used, but the facility plans to move to waterborne stains in the future. After stained products air dry, they move to a spray booth, where they are sprayed with additional stain to match a color control sample. This step is referred to as shading.

Both natural and stained products receive a coat of sealer in this booth. All spray guns are HVLP. The product is then racked and left to dry.

After the product has dried (usually 24 hours), a topcoat is applied. One of three topcoats is used: waterborne topcoat, solvent-borne topcoat, or UV-curable topcoat. Table and desk tops (horizontal surfaces) receive one coat of solvent-borne urethane topcoat. Most casegood frames receive two coats of waterborne urethane topcoat. The first coat is sprayed, the components are transferred to a flashoff area to stand for 20 minutes, and then enter a gas-fired oven. After cooling, the components are sanded, receive a second coat, and pass through the flashoff area and oven a second time. About 80 percent of the volume of products coated in the Fulton facility receive the waterborne topcoat.

Casegood components referred to as “storage 3,” such as shelves and drawer fronts, are sanded and receive two coats of UV-curable topcoat on a roll coater. Component edges also are finished on an edge coating machine using a UV-curable coating.

Finished parts then are sent to the assembly area. After products are fully assembled, they are blanket-wrapped and shipped.

ATO Facility Coating Process

Components to be coated come into this facility already veneered and edge banded. There are four coating lines at this facility: a reciprocating spray stain line; a roll coating line for flat components; an edge coating line; and a robotic spray line for table and desk tops.

Parts to receive stain are placed on the stain line and travel through a sander and a dust removing device. Stain is applied on the edges of the parts by hand. The parts then pass over a sensor that determines the shape of the part and the appropriate spray pattern. A waterborne stain is applied by the reciprocating sprayer and any overspray is recycled. A transfer efficiency of up to 80 percent can be achieved with this equipment. Upon exiting the spray booth, the parts are wiped by hand and then pass through a drying tunnel.

Flat parts then pass through the roll coating line twice to receive both a UV-curable sealer and topcoat (although the same material is used for both coats). These parts then go to the edge coating line to receive two coats of UV-curable topcoat for the edges.

Table and desk tops receive a UV-curable sealer and topcoat on a robotic spray line. The tops pass through a sander and receive a coat of sealer in the robotic spray booth (overspray is recycled here, also), followed by a drying oven to flash off the solvent in the coating and UV lamps to cure the coating. The tops pass through the line a second time to receive the topcoat. The sealer and topcoat are different materials on this line.

After all coating steps are complete, components pass to the sub-assembly and assembly areas. After assembly, the furniture is blanket-wrapped and shipped.

Conversion to Waterborne and UV-Curable Coatings

Geiger Brickel worked with their coating supplier for 2½ years to develop the waterborne urethane topcoat used at the Fulton facility. Facility personnel stated that changing over to the waterborne topcoat was easy, because all the performance issues were resolved in the research and development phase. They worked very closely with their coating supplier to develop a waterborne coating that met their performance expectations. The waterborne urethane topcoat actually is harder than the solvent-borne urethane topcoat. Geiger has received no negative feedback from their customers or salespeople since implementing the waterborne topcoat.

One issue that Geiger overcame was an increase in drying time with the waterborne coating. In order to accommodate the desired production rate, a drying oven was necessary. Geiger did not have to purchase a new drying oven because they had one that had been in use for an old product line. Another issue was the appearance of the coating if too much was applied at one time. Geiger switched from applying one coat of topcoat to two light coats because the waterborne topcoat appears cloudy if too much is applied at once. Running on the vertical surfaces also was a concern if too much of the coating was applied.

Geiger Brickel chose not to implement the new coating on desk and table tops because of the cost related to the purchase of an automated line with a drying system. They plan to make the switch to the waterborne urethane or the UV-curable topcoat used in the ATO facility on the desk and table tops in the near future. If they choose to switch to the waterborne coating, they will have to install a drying oven on that coating line, and probably will install a robotic spray system, as well, to improve transfer efficiency and finish consistency.

Implementation of the roll coating line involved only a slight learning curve because, again, Geiger was able to resolve most issues during the research and development phase. They also began using the line in production slowly. The finish quality was acceptable in the beginning, but Geiger improved the quality to the level at which they currently operate in about 6 months and surpassed their previous quality level.

Geiger anticipates a total conversion to automatic spray and roll coating at the Fulton facility over the next few years. Use of urethane-based coatings requires that the spray booth operators wear supplied-air respirators. Although the waterborne urethane topcoat does have less VOCs and HAPs, the main safety issue becomes the detection of the coating, since there is no smell associated with it.

Cleaning Operations

Equipment used to apply waterborne coating is cleaned with a very dilute mixture (mostly water) purchased from the coating supplier. In order to reduce cleaning material usage and coating waste, Geiger purchased a new system that mixes the waterborne urethane and catalyst right before it is applied, instead of mixing a whole batch of coating and catalyst and discarding the unused coating at the end of the day. Equipment used to apply UV-curable coatings is cleaned with a mixture of chemicals Geiger purchases from their coating supplier.

Cleaning emissions consist mainly of acetone, butyl acetate, isopropyl alcohol, and mineral spirits. Implementation of the waterborne system greatly decreased the amount of organic solvent used for cleaning each month and the associated VOC emissions.

Costs

The waterborne urethane topcoat costs about 45 percent more per gallon than the solvent-borne topcoat. However, Geiger uses less of the waterborne topcoat per piece, so the coating cost per piece actually is lower. One significant cost of the conversion to the waterborne urethane was the purchase and installation of stainless steel lines and equipment. A new gun mechanism also was purchased and installed at the waterborne topcoat line to mix the catalyst and coating just prior to application (facility personnel estimated the cost to purchase and install that piece of equipment was $20,000 to $30,000). Other costs include the research and development costs, rework due to early test failures, and the additional energy required to run the drying oven.

The equipment required to apply UV-curable coatings is significantly more expensive than that required for the waterborne or solvent-borne coatings. Facility personnel estimated costs at about $200,000 for each edge coating machine, $500,000 for a robotic spray line, $200,000 for each sander, and about $200,000 for a roll coating line. The UV-curable coatings also are much more expensive per gallon than the solvent-borne and waterborne topcoats, but the solids content is much higher and less of this coating is lost to overspray or waste because of the manner in which it is applied. There are cost savings associated with the reduced labor required to run the automatic spray and roll coating lines and with the reduced amount of coating waste.

Emissions

Since Atlanta is a VOC nonattainment area and the facility is subject to the wood furniture NESHAP, Geiger Brickel faces both VOC and HAP limits. Although Geiger still uses more gallons of solvent-borne topcoat than waterborne, facility personnel stated that the switch to waterborne urethane on vertical surfaces reduced mass emissions of VOCs by over 30 percent at a time when production simultaneously increased by about 40 percent. They also noted that the implementation of the UV-cured topcoats reduced emissions by another 14 percent at the Fulton facility. The table below compares the VOC and HAP contents of the solvent-borne urethane, waterborne urethane, and UV-curable topcoats, based on data provided by the facility. The VOC and HAP contents of the waterborne and UV-curable topcoats are considerably less than those of the solvent-borne topcoat.

Coating	Average VOC content, lb/gal (lb/lb solids)	Average HAP content, lb/gal (lb/lb solids)
Solvent-borne urethane topcoat	6.0 (3.4)	0.85 (0.62)
Waterborne urethane topcoat	0.31 (0.13)	0.01 (<0.01)
UV-curable topcoat	0.067	0.0090

The VOC emissions at the Fulton facility were about 70 tons in 1998. When Geiger begins using the waterborne urethane topcoat on horizontal surfaces at the Fulton facility (projected mid-year 2000), VOC and HAP emissions will be further reduced. Geiger estimates VOC emissions at the ATO facility will be about 15 tons per year at full production.

Case Study No. 12 Waterborne and UV-Cured Coatings
Hussey Seating Company
North Berwick, ME

Background

Hussey Seating Company (Hussey) is a major manufacturer of roll-out bleachers, stadium, and theater seating. Hussey's North Berwick facility is located in southern Maine, close to the border with New Hampshire. The plant employs approximately 600 people, making it a major employer in southern Maine. All wood components are finished at the North Berwick facility. The bleacher seating is constructed of wood and plastic. The stadium and theater seating has wood arm rests, wood seats, and/or wood backs. North Berwick also fabricates and finishes metal frame retractable bleachers. All seating, regardless of substrate, is assembled at the North Berwick facility.

In an effort to improve the work environment at the plant, and to prevent becoming subject to the Wood Furniture NESHAP, Hussey decided to make changes to dramatically reduce the air emissions from their wood finishing operations. Hussey implemented two major pollution prevention projects: switching to an automated UV-cured coating system for the bleacher seating, and switching to waterborne coatings for finishing the wood components of the stadium and theater seating. Through these pollution prevention efforts, Hussey has reduced total VOC and HAP emissions to levels at which they are no longer considered a major source of VOCs or HAPs. Hussey is not subject to the Wood Furniture NESHAP.

Manufacturing and Coating Operations

UV-Cured Bleacher Seating

The new UV-curable coatings are applied on an automated flat line. At the front of the line, the boards are placed on a conveyor. The first step is the application of the sealer by a roll coater machine. One coat of sealer is applied to each side of the board. The boards then are cured by exposure to UV light in a UV oven. After the UV oven, one coat of topcoat is applied to each side using a vacuum coater. The topcoat also is cured by exposure to UV light. The entire UV process occurs within a protective enclosure.

Waterborne Coatings for Stadium and Theater Seating

Hussey uses a three-coat finishing process on the wood stadium and theater seating components: stain, sealer, and topcoat. All three coatings are waterborne. The coatings all are sprayed manually using HVLP guns.

Conversion to UV-Curable and Waterborne Coatings

Air emissions from Hussey primarily are from the wood and metal finishing processes. Hussey implemented two major pollution prevention projects: switching to an automated UV-cured coating system for the bleacher seating, and switching to waterborne coatings for finishing the wood components of the stadium and theater seating. In addition, Hussey has implemented several other pollution prevention projects not directly related to wood finishing, including switching to waterborne adhesives for seating upholstery, switching to high-solids and powder coatings for metal finishing, and implementing various employee involvement programs. All of these pollution prevention projects are discussed in the following sections.

UV-Cured Coatings for Bleacher Seating

Bleacher seating consists mainly of flat, long, relatively narrow boards. In the past, these boards were finished with two coats of polyurethane varnish brushed on each side by hand. In 1993, at the suggestion of an employee, Hussey began investigating the applicability of UV-curable coatings. After analyses and pilot studies, Hussey switched to an automated UV coating system in 1994. There are important benefits of the new system and a few challenges as described below.

To Hussey, the primary benefit has been increased productivity and improved on-time delivery to customers. In the past, boards that were finished had to be placed on racks to dry. These drying boards required a significant amount of space, approximately 800 square feet. In order to expand production to meet increased demand, Hussey would have had to construct additional storage space just to accommodate the drying boards. With the UV-cured coating system, the boards exit the second UV light exposure completely cured and ready for immediate stacking. This has allowed Hussey to meet or beat delivery deadlines, an important improvement over their previous system and an important advantage over their competition.

Another major benefit is that there are very low emissions from the UV-cured coating system and the facility is not subject to the Wood Furniture NESHAP. Their VOC and HAP emissions were reduced from nearly 50 tons per year to only 219 pounds per year. This reduction occurred as production increased by over 55 percent, from 9,000 units per week to over 14,000.

The labor requirements also have been reduced. The old system required eight employees to finish 9,000 units each week. The new finishing system is automated, and only four employees are needed at the finishing operations, despite the increase in production to 14,000 units each week. Assuming that increasing production of 55 percent using the old finishing system would have required a 50 percent increase in labor, or 12 employees total, the new system represents a 67 percent reduction in labor requirements.

The UV coating line is fully automated, and all coating that does not adhere to the boards is collected and filtered for reuse, resulting in a transfer efficiency of nearly 100 percent. The cost of the UV-curable coatings is approximately 8 percent higher than the polyurethane coatings. However, because the UV-curable coatings are 100 percent solids, there has been a 23 percent reduction in the volume of material needed to coat each item. Therefore, the coating material costs per unit have decreased by approximately 17 percent.

The UV-curable coatings remain liquid until they are exposed to UV light. Therefore, as long as coating reservoirs are protected from incident light, little equipment cleanup is necessary. Coatings can be left in the system at the end of one day and used as-is the next day. This practice is a substantial improvement over the cleaning requirements of the previous finishing process. Under the old system, significant air emissions occurred because solvents were used on a daily basis to clean brushes and spills.

Finally, the last major benefit enjoyed by Hussey is that UV-cured coatings are more durable than solvent-borne coatings. This increase in durability is most noticeable under exposure to sunlight, heavy use, and/or water, attributes particularly important for outdoor seating. This improvement should enhance long-term customer satisfaction.

There also are several disadvantages to using UV-curable coatings. There are some potential adverse human health effects associated with the use of UV-curable coatings. Exposure to the UV lights can cause damage similar to exposure to the sun. To protect workers, the process is fully enclosed and cannot be inadvertently opened while the UV lamps are activated. The UV-curable coatings also can contain hazardous compounds and unreacted UV-curable coatings are associated with potentially severe skin irritation. Once cured, the coatings are nonhazardous, and there is no skin irritation. Empty coating containers and rags containing coating are sent through the system so they are exposed to the UV light and the coating residue cures. The resulting materials are considered a solid waste. There has been no increase in solid waste generation associated with the new UV system.

Worker training is essential to prevent direct exposure to the uncured coatings and the UV light. Therefore, Hussey had to initiate a new worker safety training program. In addition, the new automated system is much different from the previous manual application system, requiring extensive retraining of the finishing room employees.

Waterborne Coatings for Chair Arms and Backs

Hussey replaced the nitrocellulose solvent-based coatings used on wood chair arms and backs with waterborne polyester coatings. Hussey uses a three-coat finishing process on the wood components: stain, sealer, and topcoat. All three coatings were reformulated as waterborne. Hussey used HVLP guns for the nitrocellulose coating application, and they did not require any new equipment to switch to the waterborne coatings. There was no change in the number of operators required to apply the new coatings.

The main benefit associated with the switch to waterborne coatings is that the VOC emissions now are less than 2 pounds per gallon, in contrast to the 6 pounds per gallon with the nitrocellulose coatings. This represents an emissions reduction of over 65 percent. Another benefit is that the waterborne coatings do not require solvents for clean-up. Therefore, Hussey has reduced hazardous waste generation from wood component finishing from 165 gallons per year to zero.

In addition, the work environment for the spray gun operators has improved substantially, and they have not had problems adjusting to the new coatings. The quantity of coating used is the same with the waterborne coatings as it was with the nitrocellulose coatings.

The waterborne coatings cost approximately 10 percent more than the nitrocellulose coatings on a per gallon basis, but Hussey believes that the worker health and safety and environmental benefits are worth this extra cost. The only other additional start-up costs were to conduct performance tests to evaluate and select the waterborne coatings and to retrain the operators to adjust to the characteristics of the new coatings.

Other Pollution Prevention and Recycling Efforts

Waterborne Adhesives

Hussey uses adhesives to attach fabric to chair seats and backs during the upholstery operation. Hussey also makes all of the wooden seats and backs at the North Berwick facility in a process that includes gluing several thin pieces of wood together. These processes contributed to Hussey's VOC and HAP emissions as well as potential air quality problems within the plant. In 1995, Hussey switched all of the adhesives used at the plant to waterborne glues similar to Elmer's™ glue. There are no air emission or safety concerns associated with the new adhesives. In addition, the glue manufacturer takes back all of the waste glue and clean-up rinse water to use in their production process. Therefore, Hussey no longer has any glue or rinse wastewater disposal issues or costs.

High-Solids and Powder Coatings for Metal Finishing

Hussey was able to reduce VOC and HAP emissions from their metal coating operations by 50 percent by implementing two changes. To coat metal components that will remain in an indoor environment, Hussey has installed an electrostatic liquid paint distribution system and switched to higher-solids paints. For metal components that will be installed outdoors, Hussey replaced a two-coat nitrocellulose coating system with a one-coat powder coating system. In addition to reducing emissions, the new system has reduced color change times and coating waste as well as improved product quality.

Employee Involvement Programs

Hussey is progressive in efforts to involve their employees in environmental initiatives. In November of 1994, Hussey employees began an effort to reduce, reuse, and recycle the facility's various waste streams. Voluntary employee committees for waste and for safety were established. These committees provided a forum for all employees to voice their concerns and present their ideas for improvements. The company's weekly newsletter often highlights waste committee initiatives. In addition, Hussey has structured their employee incentive pay programs to reward involvement in the waste reduction and productivity improvement efforts, such as presenting ideas to reduce waste and air emissions and cooperating with waste reduction initiatives.

As a result of the waste committee initiative, scrap metal sales have doubled, increasing income by over $50,000 in 1995. Recycling of office paper also has doubled in response to waste committee efforts. In the past, corrugated cardboard was discarded as trash. Now, over 60 tons of corrugated cardboard is recycled each year. Although the market and price for corrugated cardboard scrap fluctuates, Hussey still realizes savings by avoiding solid waste disposal fees. Hussey also generates a significant quantity of waste fabric that is now recycled. Previously, Hussey had to pay to dispose of this waste. Finally, Hussey makes its scrap wood available to a local hobbyist and to its employees for their personal use, eliminating the need for scrap wood management.

Costs

The following table shows the cost information for Hussey's conversion to UV-cured sealers and topcoats.

Item	Savings or (Cost)
Labor	$280,000 per year
Materials	$55,000 per year
Capital costs	($320,000)
Avoided construction cost	$200,000
Payback period	4½ months

Labor

Elimination of the need for eight finishing room workers (taking into account the increased production) results in an estimated annual savings of approximately $280,000.

Material

At current production levels (14,000 units per week), the savings in coating material is approximately $55,000 per year. Hussey has not determined the effect on electricity costs due to operation of the UV coating system. However, due to decreased ventilation and health requirements, Hussey believes the increase may not be substantial.

Capital Costs

The initial capital cost of the automated UV-curable coating application system was $190,000. Hussey estimates the labor cost to investigate and install the new system, and retrain workers was approximately $100,000. Other capital costs included $30,000 for an air handling system. Hussey was able to avoid the cost of constructing the additional storage space that would have been needed if the old finishing process had been continued. Hussey estimates the storage space construction would have required a $200,000 investment.

Emissions
In 1993, Hussey's total VOC emissions from the wood finishing operations were approximately 50 tons per year. Total HAP emissions from the wood finishing operations were approximately 10 tons per year. By 1995, combined VOC and HAP emissions were less than 1 ton per year, reductions of 98 and 90 percent, respectively. Hussey is a growing company and was able to achieve these emission reductions while expanding production by 55 percent.

Acknowledgment
This case study was based on a study prepared by the Northeast Waste Management Officials Association (NEWMOA) and the Northeast States for Coordinated Air Use Management (NESCAUM) under an Environmental Technology Initiative (ETI) grant from the U. S. Environmental Protection Agency. The purpose of this ETI project was to promote pollution prevention approaches to comply with the hazardous air pollution control requirements of the 1990 Clean Air Act Amendments. NESCAUM and NEWMOA are nonprofit, nonpartisan interstate associations established to address regional pollution issues: NEWMOA focuses on waste and pollution prevention, and NESCAUM on air pollution. For more information about NEWMOA, NESCAUM, the ETI project, or other pollution prevention opportunities for the wood furniture industry, please contact Jennifer Griffith at NEWMOA at (617) 367-8558, ext. 303.

Case Study No. 13 Waterborne, UV-Cured, and Powder Coatings
Knoll
East Greenville, PA

Background

The Knoll facility located in East Greenville, Pennsylvania, is a part of Knoll, Inc., one of the top manufacturers in the office furniture industry today. Knoll produces a range of products including systems furniture, casegoods, seating, upholstery, fabrics, leather, and office accessories. The East Greenville facility manufactures both metal and wood office furniture. There are approximately 1,300 employees at the East Greenville facility; more than 800 of those are manufacturing employees. The facility also serves as the corporate headquarters for Knoll, Inc.

Knoll is well known within the industry for its commitment to the environment. Knoll made the decision to focus on clean technologies in the early 1980s. Because of this focus, Knoll's East Greenville facility has reduced VOC emissions by more than six-fold since 1983 while simultaneously improving product quality. In 1994, the East Greenville facility was awarded the Governor's Waste Minimization Award, which is given annually by Pennsylvania's Department of Environmental Protection. In 1998, the company was awarded the "Clean Corporate Citizen" award from the State of Michigan.

Knoll management is committed to using clean technology wherever and whenever reasonably possible. Knoll's East Greenville facility is ISO 9000 certified and has started gathering the prerequisite information for becoming ISO 14000 certified. Knoll currently is ISO 9000 certified for health and safety and is working towards the environmental certification being completed by the year 2000.

Knoll's East Greenville facility has reduced emissions in all areas of operation, including finishing, gluing, and cleaning operations. In addition to these significant emission reduction efforts, Knoll has developed a new coating process to apply powder coating on wood components. Full implementation of this process is expected to further reduce facility-wide VOC emissions. The following is a summary of the pollution prevention alternatives employed in Knoll's wood finishing operations.

Wood Finishing Operations

Knoll has switched the majority of its wood finishing operations in East Greenville from solvent-borne coating systems to waterborne and UV-cured coating systems. Knoll has installed a powder coating line to replace much of its waterborne coating usage. The following paragraphs describe each coating system and the facility's experiences while converting from solvent-borne coatings.

Waterborne Coating Line

Approximately 70 percent of the facility's products receive pigmented coatings. Pigmented finishes are applied primarily on particleboard components. Pigmented waterborne coatings are applied using HVLP spray guns. The waterborne coating line is a conveyorized hanging line. The line moves at 6.5 feet per minute, and parts take 1 hour and 45 minutes to travel the length of the line. Thirteen to fifteen coating operators work at this line.

The operators apply the coating to the front of each piece, and then turn it around to coat the back. A primer is applied first, and then cured in a conventional oven. A basecoat is applied, which also is cured in a conventional oven. The final coating, used to give the piece a textured appearance, is cured in an IR oven. Knoll expects to replace this line with the powder coating line, with the exception of a few specialty colors.

UV-Cured Coating Line

Knoll installed a UV-cured coating line for applying clearcoats to flat panels in 1995. This line accounts for approximately 30 percent of the production at the facility, primarily finishing veneered products, from 5,000 to 10,000 square feet of panel per day. The finishing line, a Cefla Ecolight™ UV flatline system, can be used to apply up to four coats. The finishing process is relatively automatic. Parts are hand fed onto the conveyor line. The panels are brushed and cleaned before a waterborne washcoat is applied with a roll coater. The panels are dried in an IR oven, then two coats of sealer are applied. The panel is partially cured by UV lamps using a low intensity and short cure time after the first coat of sealer is applied. After the second sealer application, the sealer is completely cured by a set of UV lamps. The panels then are sanded, brushed, and the final topcoat is applied. Final curing is accomplished by the last set of UV lamps, and the panels are allowed to cool. Knoll tracks the amount of coating applied to each piece closely, and operators know how many grams of coating should be applied to a particular panel.

Before moving to a UV-curable coating system at the East Greenville facility, Knoll started using a UV system at its Toronto, Canada, facility. Most of the early parts that were finished with the UV system at the Toronto plant had a closed pore or plastic appearance. Knoll worked extensively with the system at Toronto so that it could achieve the wood grain appearance that they wanted before installing the system in East Greenville. The company spent approximately $2 million at the Toronto plant and another $1.5 million on the system at the East Greenville facility. The system is expected to pay for itself within 4 to 5 years.

The facility experienced only minimal downtime in switching to the UV system. The facility hired outside engineers in the planning stages to help facilitate the transition. These engineers were responsible for training the employees before the system was installed so that operation of the line would not be delayed by employee training.

Powder Coating Line
Knoll spent four years and more than $2 million developing a powder-on-wood technology to use on the MDF components of many of its products. The powder-on-wood process will replace much of the current waterborne technology and further reduce the East Greenville facility's VOC emissions. The powder coating is durable and has excellent color consistency and reproducibility.

Knoll ran hundreds of tests, working with the equipment and coating suppliers, in developing the process. The process that was developed is computerized and the production line requires seven operators. Two operators load parts onto the line, two operators run the line, two operators take parts off the line, and one operator performs material handling duties. The parts are bar coded prior to the coating process. Once the parts are loaded onto the line, they are scanned and the computer responds with the appropriate process adjustments for that part. The system is capable of distinguishing between small and large pieces and can adjust the number of spray guns used to coat the parts and configure the curing ovens accordingly. This minimizes overspray and energy usage for the curing ovens.

The parts pass through the coating booth on a hanging line. In the powder coating process there is no presanding step; the wood operators must carefully inspect the quality of the parts prior to the coating operation. The first two pieces on the line are "dummy" boards that signal the ovens to come online when they pass an electric eye (the ovens run at idle when there are no parts passing through them). The line moves at about 10 feet per minute, and the ovens take about one minute to heat up. The pieces first pass through a preheating oven. They then enter the spray chamber, where a series of guns moves up and down to coat the piece with 3 to 5 mils of powder. There are two arms on each side of the spray chamber that move up and down, with four guns per arm. Electric eyes sense how large the piece is and the appropriate number of guns are used. The pieces then pass through a 60-foot long, gas-fired IR oven and a subsequent cooling chamber. The curing time is approximately one minute. The cooling chamber is 150 feet long and reduces the temperature of the parts down to 95°F. Any pieces with coating defects are sanded and recoated.

A color change in the powder coating process takes approximately 45 minutes to complete. The actual down time for the production coating line is only 5 to 10 minutes and the design of the line minimizes labor time and equipment moving. There are two spray chambers that may be used interchangeably, so when a color change occurs, one is being cleaned while the other is being used. There are dedicated pots and transfer lines for each color; Knoll makes four color changes each operating shift with their current mix of products.

The payback for the investment in the powder-on-wood process is projected to be 2.3 years and will come from saved coating material costs and labor efficiency in operating the line. Full implementation of this new process is expected to increase the facility's capacity.

In developing the powder-on-wood process, Knoll evaluated three different types of spray guns from three different companies. The equipment, even though dedicated to the powder line, could be used on the wet (waterborne) line with only minor modifications if needed. The total line is 550 feet long and considered compact in comparison with most wet coating lines. The powder line typically will run at 10 feet per minute compared to 6.5 feet per minute for the waterborne coating line.

The coating line was designed with continuous flexibility. The line can handle seven different colors and three different board thicknesses, and there are plans to add the capability to coat some plastic components, such as drawer fronts. The line can coat components with dimensions up to 4 feet by 10 feet. Some of the components had to have minor design modifications to accommodate the powder coating process. For example, areas that have been milled out for hinges may be too thin to retain enough heat from the preheating oven for the coating to stick.

The spray chamber is equipped with a cyclone powder recovery system. Knoll estimates that the cyclone recovery system will capture almost all of the powder overspray and the spray guns will have at least 90 percent transfer efficiency (as opposed to an estimate of 40 percent transfer efficiency for the wet coating processes). The powder overspray is directed via airflow into the cyclones, collects at the bottom in the hopper, and is mixed back in with virgin material fed to the spray guns. On very small specialty jobs, the powder overspray will not be reclaimed/recycled, but will be collected as waste.

The powder coatings are shipped from the supplier to Knoll in small bags inside of cardboard boxes and stored in an adjacent room with a controlled environment. The temperature is maintained between 72° and 78°F and between 40 and 50 percent relative humidity. The coating storage room is designed to hold up to 23,000 pounds of coating. The powder coatings cost about $7.50 per pound compared to the previous waterborne products which ranged from $25 to $40 per gallon with 40 to 45 percent solids. From a material cost perspective, the waterborne coatings cost $0.48 per square foot of surface coated and the powder coatings cost $0.17 per square foot of surface coated.

The moisture content of the types of components being run on Knoll's powder line is very consistent, usually 6 to 8 percent. Facility personnel commented that they sometimes see problems with boards splitting in the curing oven if the moisture drops down to 3 percent or below. Knoll typically keeps a 10-day supply of components at their facility. Facility personnel noted that the board suppliers do a good job of rotating their stock and consistency problems involving moisture content are rare. The core temperature and surface temperature of the material being coated are critical parameters and as such, are measured and monitored closely. If the core temperature is too high, there can be problems with the substrate splitting and off-gassing. If the surface temperature is not high enough, the powder will not stick to the board.

One of the current issues involves the coating uniformity around the area of where the hook (used for attaching the component to the transfer hoist/conveyor) is attached to the actual component. Knoll is currently looking at different ways to redesign the hook and/or the spray pattern from the top set of spray guns to overcome this issue.

As part of the final qualification of the powder process line, numerous tests and comparisons have been conducted. Mock-ups have been run through the new process and sent out into the field for real-world testing and evaluation. Knoll began to integrate the powder-on-wood products into their manufacturing operations in early 2000.

Gluing Operations

Contact adhesives have traditionally been used by the furniture industry for upholstery operations. Foam is glued to foam and to fabric during the manufacturing of upholstered office chairs. Traditionally, these adhesives have been solvent-borne products with 1,1,1-trichloroethane (also known as methyl chloroform), a HAP and ozone depleting compound, as the primary solvent. In 1994, Knoll switched to hot melt adhesives for the upholstery operations, thereby eliminating methyl chloroform emissions from the process. The hot melt adhesives are 100 percent solids adhesives. Because excess glue residue can be reheated and reused, no adhesive is wasted with the hot melt adhesives. Because there are no emissions from the hot melt adhesives, the facility was able to rework the adhesive application area. Spray booths that were needed when the facility was using solvent-borne adhesives were eliminated. The work area was redesigned so that it has a better work environment that is more comfortable for the operators.

Cleaning Operations

Some of the metal and wood finishing lines at Knoll are hanging lines where parts are hung from metal hooks. These metal hooks collect overspray and they must be cleaned from time-to-time. Previously, Knoll cleaned the hooks using chemical strippers. These strippers not only generated emissions, they also generated liquid waste that had to be treated. In 1994, Knoll purchased a fluidized bed system that uses sand heated to about 1,000°F to clean the hooks. The high temperatures volatilize the dried paint. Eventually, the sand has to be removed and replaced, but the sand that is removed is clean enough that it does not require special or costly disposal. In addition to a significant reduction in emissions and waste, this system has the added benefit of extending the life of the hooks. Knoll estimates that the return on investment for this system was less than one year.

Emissions

The net effect of the clean technology program at Knoll has been significant. Emissions of methyl chloroform have fallen from 54 tons to 0 tons per year due to the implementation of hot melt glues. The VOC content of the solvent-borne wood coatings used previously was 5.9 pounds per gallon. The VOC content of the waterborne wood coatings is only 1.0 pound per gallon. The UV-cured coatings and powder coatings have minimal to no VOC emissions associated with their use. No hazardous materials or cleaning emissions are associated with the powder coating line. According to Knoll personnel, total VOC emissions at the facility have decreased from 200 to 25 tons per year, and will continue to decrease with full implementation of the powder coating line.

Although the emissions reductions have come at considerable cost, approximately $5 million, the costs have been recovered to date with labor efficiencies, material savings, and increased capacity. Additional savings will be realized in the next few years as the powder-on-wood process is implemented in full.

The clean technology program has and will continue to have a positive environmental effect, reducing or eliminating air emissions, solid waste generation, and water pollution.

Case Study No. 14 UV-Cured Coatings
The Lane Company
Altavista, VA

Background

The Lane Company's Altavista facility has two main finishing areas, designated as Plants 2 and 4. Plant 2 has a finishing line for cedar chests and a finishing line for tables, and Plant 4 has a flatline finishing area for home office furniture components and casegoods. The cedar chests and tables are finished manually with low-VOC/HAP, high-solids coatings, while the office furniture and casegood components are finished on an automated flat line using UV-curable or waterborne coatings. Plant 2 operates 5 days per week, two shifts per day, and Plant 4 operates 4 to 5 days per week, one shift per day. There are approximately 650 employees who work in Plant 2 and 90 employees who work in Plant 4 (4 to 5 of those employees work in the finishing area). Lane implemented its UV-curable coating system in Plant 4 as part of the development of the home office furniture line. In the future, Lane hopes to expand its Plant 4 product line into areas such as hotel furniture.

Manufacturing and Coating Processes

In Plant 4, flat office furniture and casegood components are milled, finished, and assembled. A few non-flat components that are used in the office furniture (e.g., table legs) are finished conventionally in Plant 2. Sheet stock is received at Plant 4, and then cut to size. Most of the home office furniture components have MDF or particleboard cores with cherry, maple, oak, or ash veneer. A router is used for any necessary contouring, and the edges may receive a veneer, thermofoil, or PVC edge-band, since the flat line does not apply coating to the edges of the components. Any holes necessary for hinges, cams, or shelf supports are bored. Waste wood and sawdust are used to make particleboard or sent to a local co-generation facility as fuel. The components then go to the finishing area on the second floor of the building.

The finishing area is kept at 45 percent relative humidity and has two sets of doors at each entrance to keep dust down. The first flat line has a series of roll coaters used to apply stains and inks. The flat components are placed on a conveyor, and pass through a sander and then a cleaner to remove the dust. The sander and cleaner are exhausted to a dust collector. The first roll coater is used to apply stain. Most of the stains used are waterborne, but some are solvent-borne. A hard roller is used for closed-pore woods, such as maple, and a more spongy roller and a subsequent brush roller are used for open-pore woods. Each roll coater can move into and out of the line for easy cleaning. The second roll coater applies another coat of stain, and may be followed by brushes, depending on the desired appearance. There is then a length of line to allow time for flashoff or hand highlighting. The panels then pass through an oven to dry the stain. The oven uses both hot air and infrared (IR) light. The panel may then be printed with an ink using a rotogravure cylinder to give the panel the desired appearance. A convection oven is used to dry the ink.

The second roll coating line is used to apply a tie coat and the UV-curable sealer and topcoat. First, the panels receive a catalyzed tie coat to provide a layer of coating between the solvent- or waterborne stains and inks and the UV-curable sealer and aid in the adhesion of the seal coat. The tie coat is applied using a roll coater and the panels pass through a convection oven to dry the coating. The UV-curable sealer then is applied to the panels using a direct roll coater, and the panels pass under a series of UV lamps. A second coat of sealer is applied using another direct roll coater and cured by UV lamps. The panels then pass through a wide belt sander and a panel cleaner that exhaust to a dust collector. The panels have the UV-curable topcoat applied by a differential roll coater, then pass under a series of UV lamps to cure the coating, and are taken off the line for inspection. Any pieces with finish defects are sanded to bare wood and recoated.

The second half of the finishing area contains a robotic spray booth and a curtain coater for components that require a high-build finish or color coat. The parts pass through the roll coating line first to receive the UV-curable sealer. About 30 percent of the total parts produced pass through either the curtain coater or robotic spray booth. The curtain coater applies a clear or pigmented UV-curable coating, and is followed by a series of several UV lamps and reflectors to completely cure the coating.

Parts to be sprayed are placed on a Mylar™ belt and travel into the spray booth where an automated spray arm applies a UV-curable coating. This coating is only 40 to 60 percent solids, as opposed to the coatings which are applied with the roll coaters, which are 100 percent solids. Overspray is captured and recycled. The parts pass through an oven to allow the solvent in the coating to flash, and then pass through the UV curing tunnel that follows the curtain coater.

About 25 percent of the flat components are finished on both sides. Components such as drawer fronts are finished only on one side. Components that receive the high-build finish usually receive only a sealer on the back of the piece to prevent warping or moisture damage. After the parts are finished, they are sent to the assembly area. Lane assembles most of their office furniture components with metal cams in addition to dowels and glue.

Some high-solids coatings are used in the conventional finishing areas in Plant 2 for coating chests and tables. Between 800 and 1,000 chests per day are coated on a hanging line, and tables are coated on a conveyor line. The finishing process for both chests and tables consists of as many as 30 steps, and is labor-intensive. The tables and chests receive several coats of stain, filler, highlight, sealer, and lacquer, and are hand rubbed to produce the desired final appearance. The finishes are sprayed with airless or HVLP guns. Coats such as stains and glazes are hand wiped.

Cleaning Operations
The Plant 4 roll coating equipment is cleaned often. The roll coaters used to apply stains are cleaned daily. The rolls used to apply waterborne stains undergo four water

rinses and three acetone rinses. When solvent-borne stains are applied, the rolls undergo four acetone rinses. The brushes undergo three acetone rinses. The roll coaters applying the UV-curable coatings are cleaned weekly with acetone. The equipment is drained and covered daily. The robotic spray booth is cleaned after use with water and acetone.

Conversion to UV-Curable Coatings

From 1960 to 1993, furniture was finished in Plant 4 using conventional spray techniques. Lane then decided to convert the entire finishing area to an automated system for applying UV-curable coatings and introduce a new line of home office furniture. The retrofit took approximately 8 months to complete. Lane has spent the last 4 years building up a product base for the new line. Both Lilly and Chemcraft Coatings supply the coatings used in Plant 4.

Start-up of the new line was slow. Facility personnel relied heavily on the coating suppliers for information on the new coatings and equipment and the best way to operate the new line and adjust the equipment to achieve the desired quality. Properties of the wood and the viscosity of the coating also affect the finish. The operators have found that this type of system is completely different than a conventional finishing system. As they gained experience, they learned how to adjust the equipment so it applies the material well and doesn't produce ripples in the finish. Their experience has given the coating suppliers knowledge of how their coatings perform in a manufacturing environment. Lane also found that they had to install filters in the coating supply lines so any particles in the coating would not cause finishing defects.

Lane generally is satisfied with the product they are producing with their flatline finishing system. The UV-curable coatings provide better coverage per gallon, the flatline system eliminates coating waste due to overspray, the emissions are very low, and the process is not labor-intensive. Customer feedback has been positive overall, but Lane sometimes is frustrated by the design limitations imposed by the flatline system and UV-curable coatings, such as the inability to finish the edges of pieces on the roll coating line.

Lane had to experiment with different lamp configurations, intensities, and reflector positions to ensure that the UV coating cures properly, especially with contoured edges and when multiple coats are applied to achieve a high-build finish. In addition, although the UV-cured coatings produce a durable finish, the only way to repair or rework a piece is to sand it and refinish it. Lane had to train their distributors on the characteristics of the new finish, since most of them were used to working with solvent-borne coatings that are repaired easily. They advise their distributors to use glass cleaner to clean their products finished with UV-cured coatings. Lane does not market their home office furniture line as finished with environmentally friendly coatings, but they do market the finish as more durable than a traditional solvent-borne finish.

Costs
Plant 4 underwent an extensive retrofit to accommodate the flatline finishing system and robotic spray booth. The whole project cost about $7 million and took about 8 months. The changes to the finishing room accounted for $2 to $2.5 million of the total cost. The UV lamps cost $200 to $400 apiece and last about 800 hours. Facility personnel stated that they spent extra money in order to build flexibility into the line and be able to accommodate the widest variety of products. Although the equipment was expensive, a savings in labor is experienced since the line is automated. Fewer finishing employees are needed in Plant 4 than in Plant 2.

The coatings used in the flatline system cost more per gallon but, because the UV-curable coatings have up to 100 percent solids and there is no lost overspray, Lane has experienced a cost savings in terms of the cost to coat each square foot of product. The stain used on the roll coating machines is 72 percent more expensive per gallon than the average conventional stains. However, the rollcoat stain's coverage is 75 percent higher than that of the average conventional stain. The increased coverage results in a cost reduction of 3 cents per square foot finished.

Facility personnel stated that the research and development costs when developing a new product line using the flatline system are higher than those for a conventional finishing system. To develop a new product, it is necessary to adjust the entire coating process, not one individual step. They estimated that it takes about 5 days of laboratory and manufacturing trials to develop a new coating system for a new product, which in their experience is much more than the development time required with a conventional solvent-borne finishing system.

Emissions
Lane is subject to the Wood Furniture NESHAP and has a plant-wide VOC emissions limit in their operating permit. From January through November 1998, their VOC emissions were approximately 16 tons, while HAP emissions were less than 2 tons (includes both Plant 2 and Plant 4). Coating usage exceeded 18,000 gallons during that time. Average coating HAP content was 0.12 pound of HAP per pound of solids, well below the NESHAP limits.

The waterborne rollcoat stains contain almost no HAPs and little VOCs; the solvent-borne rollcoat stains contain almost no HAPs, but tend to have a higher VOC content and a much lower solids content than the waterborne stains. The UV-curable sealer and topcoat applied by the roll coaters have no HAPs or VOCs and essentially are 100 percent solids. The coatings applied by the robotic spray booth are 60 to 80 percent solids and contain less than 0.2 pound of HAP per pound solids and less than 0.6 pound of VOC per pound solids. The coatings applied by the curtain coater are 60 to 75 percent solids and have from 0 to 0.7 pound of HAP per pound of solids and less than 0.7 pound of VOC per pound of solids. In Plant 2, Lane has reduced or eliminated the HAP content of the coatings, lowered the VOC content (in some cases by substituting acetone), and increased the solids content of the coatings.

Case Study No. 15 UV-Cured Coatings
Loewenstein, Inc.
Pompano Beach, FL

Background

Loewenstein, located in Pompano Beach, Florida, is a contract seating manufacturer using state-of-the-art manufacturing techniques. The company was founded in 1966 and became an important supplier to the hospitality industry. Loewenstein produces a wide range of chairs, stools, and benches, allowing customers to choose from more than 250 models in 16 standard wood finishes and over 3,000 custom finishes. They import fully machined and sanded European beech components and manufacture wood products in their plants in North Carolina and Tennessee. The Pompano Beach facility manufactures both wood and metal chairs, but does not finish any of the metal components. The facility has approximately 250 employees, and more than 200 of those are manufacturing employees.

The Pompano Beach facility has reduced emissions in both their finishing and gluing operations. In mid-1984, Loewenstein began investigating the use of UV-curable coatings in an attempt to increase finish quality and speed the required curing time. By 1987, different technologies were being tested at an equipment supplier's laboratories. By 1988, a temporary UV curing oven was installed, allowing Loewenstein to continue testing without shutting down their main production line. The UV-curable system was in full production by November 1988. This case study provides an overview of Loewenstein's efforts to reduce VOC emissions by reformulating their stains and switching to UV-curable sealers and topcoats.

Wood Finishing Operations

Loewenstein uses automated electrostatic disk booths to finish chairs. The small quantities of benches that are manufactured are batch finished with electrostatic spray guns and UV-curable topcoat. Each disk booth has a ceiling-mounted, vertically reciprocating disk that is 9 inches in diameter. The stroke is adjustable and is varied according to the length of the parts being coated. The parts are conveyed around the disk about 18 inches away from the disk edge.

The configuration of each disk resembles a soup bowl with a "sink strainer" resting in the bottom of the bowl. The "bowl" is mounted upside down on the reciprocator. The edge of the disk is serrated to help with the paint atomization, and the angle of the disk to the horizontal is about 15 degrees. The disk is connected to a shaft equipped with an air turbine. Variable air pressure ranging to 40 psi drives the turbine and disk.

Paint is metered into the perforated center, and centrifugal force hurls it out the holes to the inner surface of the disk and to the serrated edge where the paint is atomized. The disk is charged positively to between 75 and 100 kV, which gives an electrostatic charge to each atomized paint particle. The charged particles then are attracted to the closest ground, which should be the part to be coated. Makeup air is drawn into the top of the booth and exhausts through dry filters around the base. The downdraft air is necessarily gentle for minimal distortion of the path of the atomized paint particles from the disk to the parts to be painted.

A touchup booth is required after each disk booth because of the 250 varieties of chairs, stools and benches that are coated. Although the disk coverage is extremely efficient, the touchup booths serve to ensure total part coverage. Each manual touchup booth is a side-draft, dry-filter type. Makeup air enters the booth behind the spray operator's back and proceeds past the parts being conveyed laterally through the booth and to the particulate filters at the back of the booth. The operators in the stain touchup booth are equipped with non-electrostatic HVLP spray guns, while the touchup operators in the sealer and topcoat touchup booths are equipped with electrostatic spray equipment.

The first spray booth is used to apply the stains and opaque lacquer finishes. The booth consists of an Aerobel™ spray system and non-electrostatic HVLP manual spray guns for touchup. The sprayable, solvent-borne stains Loewenstein was using had high VOC contents. These stains were replaced with UV-compatible wood stains, aniline-based color stains, and opaque lacquer finishes. All stains and color coated parts are conveyed through a gas-fired oven to thoroughly dry the coating prior to sealer application.

The UV-curable sealer is applied in the first set of disk and touchup booths. The sealer is used to wet all surface areas and thereby lift sawdust particles and raise unsanded attached fibers. Flash time is allowed after the sealer is applied to give the coating adequate time to wet all surfaces and to allow evaporation of the solvents prior to the UV cure. The UV oven is equipped with six 48-inch UV lamps rated at 200 Watts per inch. The actual required UV-cure time is about 15 seconds. Because eye-protective shielding devices had to be added around the UV lamps, the total conveyor time through the units is about 20 seconds. After the UV cure, the sealer coat is hand sanded to provide an ultra-smooth surface for the topcoat. The hand sanding tends to be the limiting factor in the line's conveyor speed, which can be varied from 4 to 20 feet per minute.

The UV-curable topcoat disk and touchup booths are located within a clean room. The room has its own filtered air supply to minimize dust and lint collection to help ensure a dirt-free finish. Flash time again is allowed to ensure adequate dispersion of the coating before entering the UV oven. The cure time and curing equipment for the topcoat are identical to those of the sealer.

Spray booth filters are changed daily. Filters with trapped UV-curable coatings are run through the UV ovens to dry the coatings and facilitate waste disposal.

Gluing Operations
The furniture industry traditionally has used contact adhesives for upholstery operations. Foam is glued to foam and to fabric during the manufacturing of upholstered office chairs. Traditionally, these adhesives have been solvent-borne products with 1,1,1-trichloroethane (also known as methyl chloroform), a HAP and ozone depleting chemical, as the primary solvent. In 1997, Loewenstein switched to a waterborne contact adhesive for their upholstery operations, thereby eliminating methyl chloroform emissions from gluing operations. The waterborne adhesive is 47 percent solids and dries quickly without drying equipment. The hand held applicator co-sprays adhesive and activator through a unique detachable twin nozzle spray tip. A single pressure control adjusts the output. The parts can be used within 5 to 15 seconds after application. A water/detergent solution is used for cleanup.

Conversion to UV-Cured Coatings
As an initial means of reducing emissions, Loewenstein analyzed existing coating application methods, searching for ways to improve efficiency and economize on coatings use. This analysis included additional operator training to ensure sprayers were using the minimum amount of coating necessary. The resulting process changes enabled them to reduce VOC emissions by 50,000 pounds.

Before Loewenstein could switch to UV-cured coatings, they had to determine if UV-cured coatings could be formulated to match the coatings they currently were using (Loewenstein had not used nitrocellulose coatings since 1982). In initially researching the possibility of using UV-cured coatings, Loewenstein began UV-cured coating tests on their products. Numerous chairs were finished with UV-cured coatings at supplier test labs. Some UV-cured coatings appeared satisfactory, while others did not. After studying the test results, Loewenstein wanted to see how UV-cured coatings could be applied under production conditions. They arranged for a portable UV oven to be installed on the finishing line for a weekend of production testing. Four suppliers brought UV-cured coatings for the testing.

On the basis of the production testing, Loewenstein installed a temporary curing oven on their finishing line to allow switching back and forth from UV-cured coatings and UV curing to conventional coatings and gas-fired oven curing. This enabled Loewenstein to focus on the development of UV-cured coatings to meet their requirements while continuing regular production.

Loewenstein's decision to permanently install UV equipment and a new finishing system marked the end of a two-year testing period. The new finishing line consists of an Aerobel™ spray system, two disk booths, three touchup booths, and two UV ovens. In addition, three repair booths are located off-line.

Several problems were encountered with the original UV-cured coating system that was used. The finish had a poor build, and the stains appeared fuzzy. The high-gloss black lacquer chairs had an "orange peel" finish. Some of the colors had poor adhesion and the white finishes appeared slightly yellow after the curing process. Finally, the UV-cured sealer did not have sufficient sanding properties. All of these problems were worked through with various coating reformulations and coating supplier changes.

There also were initial concerns about curing problems, since the product being coated is 3-dimensional. Early efforts caused the coating to burn. However, Loewenstein was able to work with the equipment and coating suppliers to perfect their 3-dimensional curing system. It is necessary to configure the system for each model to pass through the drying and curing process. Each part of the chair must be exposed to the UV lamps for the entire cure time.

Another potential problem was achieving good electrostatic attraction. Normally, wood receives a conductive prep coat before undergoing electrostatic painting. The prep coat provides a conductive coating to aid in attracting the electrostatically charged paint particles. Loewenstein does not apply a prep coat and is getting excellent electrostatic attraction. They believe that transporting the wood across the ocean in a ship adds salt water moisture to the wood surface. In addition, South Florida's high humidity provides a continuous surface moisture. The result is a conductive, moist wood surface that gives excellent electrostatic attraction.

Currently, the UV-cured coating system is performing well, and Loewenstein is happy with the quality of the finish. The UV-cured coating system brought many other advantages, the most noticeable being a sharp reduction in VOC emissions. Other advantages of the UV-curable coating system include:

- Improved coating quality; excellent film properties and appearance.
- Improved atomization and increased transfer efficiency at production speeds due to low coating viscosity. The transfer efficiency of the electrostatic disks is between 80 and 90 percent, and that of the electrostatic manual guns is 70 to 80 percent.
- Higher solids content, resulting in a coating material savings per piece.
- A harder sealer film that allows extensive sanding without wearing through the coating.
- A reduction in necessary floor space of 40 percent, allowing expansion without purchasing an additional building.
- A reduction in cure time from 45 minutes (in conventional gas-fired ovens) to 20 seconds (in the UV ovens) that resulted in a dramatic increase in production capacity and shortened turn-around times.

Costs

Loewenstein spent about $2 million and nearly 2 years developing their new finishing system. As a result, they have experienced cost savings in several areas. The number of rejects decreased as a result of the changes in application methods. Although the UV-curable coatings cost more per gallon than traditional solvent-borne coatings, the solids content of the UV-curable coatings is much higher. A sealer coat application and a topcoat application were eliminated from all finishes resulting in a material savings. Two sealer coats and two topcoats formerly had to be applied with the original finishes. The relatively high solids content of the sealer and topcoat allows total film thickness (3 to 4 mils) to be reached with fewer applications than before. Energy costs have been reduced due to the elimination of several spray booths and labor costs have been reduced due to the level of automation of the new coating line and the elimination of the wiping stains. Because of the extremely short curing time of the UV-curable sealer and topcoat, shipping time was cut dramatically and Loewenstein was able to increase production.

Emissions

The net effect of the emissions reduction program at Loewenstein has been significant. Emissions of methyl chloroform have been eliminated due to the implementation of the waterborne contact adhesive. Loewenstein also has eliminated all phenolic resins and chlorofluorocarbons from the foam used in their upholstered products.

According to data provided by the facility, the solvent-borne wood coatings used previously were 16 percent solids, with a VOC content of 5.9 pounds per gallon. The current UV-curable sealer and topcoat have around 40 percent solids and less than 5 pounds of VOCs per gallon. The UV-compatible stains have VOC contents that range from 1 to 7 pounds of VOCs per gallon. Total VOC emissions at the facility have decreased from 145 tons per year in 1987 to 37 tons per year in 1997, with a large production increase during this same time period.

Loewenstein is subject to the Wood Furniture NESHAP. The average HAP content of all the wood coatings used currently is between 0.5 and 0.6 pound of HAP per pound of solids. The HAP content of the UV-curable sealer is 0.2 pound of HAP per pound of solids, and several of the stains contain no HAPs. Loewenstein currently is working with their primary coating supplier to reformulate their conventional coatings with non-HAP components and further reduce emissions.

Case Study No. 18 UV-Cured Coatings
Prestige
Neodesha, KS

Background

Prestige was founded in 1967 and produces all-wood, semi-custom cabinetry. Oak, maple, cherry, and hickory are the primary wood species and are finished with eight different stain colors. While some plywood veneers are used, there is no particleboard in any of Prestige's products. Prestige operates one shift, five days per week. There are 240 employees, including sales staff and drivers; 170 of these employees are hourly employees on the manufacturing line. The finishing line has 29 employees: 18 on the spray line, 6 on the flat line, 4 to clean the finishing room at night, and 1 maintenance employee specifically for the finishing operations. Prestige has an annual production of 117,000 units, but anticipates this number will rise in 1999. The change to UV-curable coatings began in 1992, as a the result of Prestige's search for a higher-quality finish.

Manufacturing and Coating Operations

On average, it takes seven days to mill, finish, and assemble an order. Prestige receives raw lumber and planes it to size. The lumber is sanded, ripped, and cut to length. At this point, the pieces are sorted into four classes to provide a better color consistency in the final product. Three of the classes are purely color classes: light, medium, and dark. The other class is for a product that showcases the knots in the wood to create a more "rustic" appearance. As a result of utilizing the knotty material, Prestige has reduced their wood waste. After sorting, the pieces are glued together and cut to size. Cabinet components are finished prior to assembly.

Prestige operates two automated finishing lines: a flat line and a spray line. There also are two small spray booths, one for touch-up and repair and one to apply coating to parts that cannot be finished on the automated lines. The pieces that cannot be finished by the automated lines make up a small percentage of production and include items such as shelf edges and Queen Anne legs. The coatings in both spray booths are solvent-borne and are applied using HVLP guns.

The flat line is a horseshoe-shaped roll coating line, used mainly for flat components such as cabinet box parts. The conveyor operates at 40 feet per minute. Pieces first go through a dual-sponge roll coater that applies solvent-borne stains or whitewash. One roll is used for all stains, but the white coatings require a separate roll because it is too difficult to clean the white coatings completely from the roll. A reclamation system is in place to catch all excess coating and funnel it back into the coating reservoir. The pieces then are conveyed through a series of three brushes that eliminate the hand wiping step. The stain then is sanded by an automated brush-sander and conveyed to a roll coater. These rollers are a combination of rubber and steel that apply the 100 percent solids UV-curable sealer. The line then moves under two UV lamps to cure the seal coat. A second coat of sealer is applied and cured, and the piece is brush-sanded. Two coats of UV-curable topcoat are applied; the first is cured using two UV lamps and the second is cured using four UV lamps. Pieces then pass through the line again to be finished on the opposite side.

The automated spray line is a circular line, with a cycle time of 15 minutes. The entire finishing process consists of three passes through the line and takes about 45 minutes. The spray line is used for pieces that are not entirely flat, such as doors, drawer fronts, face frames, and moldings. After the pieces are loaded onto the conveyor, they are hand sanded. A solvent-borne stain then is applied by the automated spray system. The system has electronic eyes that sense when product is passing through the booth, and spray coating only when product is present, which helps to reduce overspray. The spraying mechanism contains six chambers: two for stains, two for sealer/topcoat, and two that are empty. The coatings are directly pumped from 55-gallon drums located in the paint kitchen. There are four arms with two guns each that move in a circular pattern and are aligned to ensure coating is applied to the front or back and all four sides of a piece. All of the guns on the automated spray line are air-assisted airless, and have transfer efficiencies of 50 to 60 percent.

After the stain is applied, the pieces go through a stain wiping machine and the edges are hand wiped. Components then are conveyed through a gas-fired oven to flash off the solvent in the stain and pass under three sets of UV lamps for curing. The pieces continue on the conveyor and pass through the second automated spray booth where the first coat of UV-curable sealer/topcoat is applied, then through a gas-fired oven where coating solvent flashes off and under another set of three UV lamps for curing. The pieces then are sealer-sanded, turned over, and go around the line a second time for stain, sealer, and topcoat. The pieces go around the line for a third and final time, and UV sealer/topcoat is applied first to one side, then the other (no stain is applied on the third pass). The pieces then are taken off the finishing line and are ready for the assembly line.

Gluing Operations
Prestige previously was using a two-part formaldehyde glue that had to be mixed before application. In 1992, they began using all waterborne or hot melt adhesives. The quality of these glues is equivalent to the previous glue system, and the associated formaldehyde emissions have been eliminated.

Cleaning Operations
Neither of Prestige’s finishing lines requires extensive cleaning. The flat line requires little cleaning; the brushes and sponge rollers are cleaned with a no-HAP cleaning solution. However, Prestige still uses acetone on the automated spray lines because an alternative cleaning solution has not been found that can do an adequate job. The automated spray line has four different dedicated coating lines fed into it, which reduces cleaning due to color changes.

Conversion to UV-Cured Coatings
Prestige previously had an overhead and cart line and was finishing with air-assisted airless and conventional spray guns. Their coatings were traditional solvent-borne stains, sealers, and topcoats. In 1992, while investigating higher-quality finishing systems, Prestige decided to switch to a waterborne UV-curable finishing system. From July 1992 to March of 1993, Prestige used a waterborne UV-curable sealer and topcoat on their automated spray line. The quality of the coatings they were using was poor, with an assortment of problems. The finish was very durable, but the appearance was not acceptable. Prestige had to replace thousands of dollars of product because of bad finishes. In March of 1993, Prestige switched to a solvent-borne UV-curable sealer and topcoat in the automated spray line. This system is still in use today.

Prestige was very disappointed with the waterborne UV-curable coatings. They had visited the supplier's lab to see the finish quality before installing the system, but never achieved results similar to what they had seen. Prestige is happy with the finish they are producing currently, using the solvent-borne UV-curable materials. The finish is durable and of comparable quality to their previous finishing system.

One of the main problems Prestige encountered with the solvent-borne UV-curable system was maintenance. The UV-curable coatings are very sticky and difficult to clean from the equipment, especially on the spray line. The only product that Prestige has found that does a good job is acetone. The flat line is easier to clean and Prestige has found a no-HAP cleaner that does a good job.

Another problem with the UV finishing system is repair. The UV-curable material cannot be spot repaired like the traditional solvent-borne coatings. When an entire piece needed to be refinished with the old system, the piece was placed in a wash-off tank filled with acetone to strip the damaged coating. However, the acetone does not strip off the UV-curable coatings; instead the entire piece must be sanded down to bare wood and refinished or entirely replaced. Other finishing problems include additional sanding and impurities in the coatings. Prestige does have filters in the lines to screen out the majority of impurities in the coatings, but occasionally receives batches that have enough impurities in them that the filter does not catch them all.

The operators did not have much trouble with the transition between coating systems. The systems are highly automated, but to achieve the finish Prestige requires, the spray line is operated with twice as many people as the equipment manufacturer suggested. The main reason for the extra labor is sanding. Because Prestige produces a true raised panel, an automated sander would only sand the raised center. For this reason, Prestige does all finish sanding on the automatic spray line by hand. However, prefinishing sanding can be done by a sanding machine and Prestige is in the process of implementing an orbital sander for prefinish sanding to reduce labor requirements.

Costs
The capital costs for the new finishing system were high, around $1.2 million. However, that cost included a new building in which to house the finishing lines, so the actual capital cost of the UV-curing and finishing equipment was much less than $1.2 million. An additional $150,000 was spent for associated electrical equipment. The costs of operating the UV-curable coating line also are higher, as the coatings themselves are more expensive and the usage per cabinet is approximately the same. Prestige also replaced the conventional guns in their spray booth with HVLP guns at a cost of $155 each.

Emissions
Prestige is a major source and is subject to the Wood Furniture NESHAP. The majority of the current emissions are from the stains and the spray booth that is used for touchup and repair. The emissions from the main finishing processes have been reduced significantly since the change to UV-curable coatings. Because of the changes in production, the best comparison is in pounds of VOC emissions per unit of product. With the old solvent-borne finishing materials, Prestige was emitting 2.7 pounds of VOCs per unit produced. After the change to UV-curable coatings, this number was reduced to 1.63 pounds of VOCs per unit produced, a 40 percent emissions reduction.

Case Study No. 19 Waterborne and UV-Cured Coatings
Riverside Furniture
Fort Smith, AR

Background

Riverside Furniture produces residential mid-grade and economy furniture. The primary species is oak, although poplar, maple, pine, cottonwood, ash and gum are used. Particleboard, fiberboard, and hardboard also are used to make printed-grain furniture. Riverside also does upholstery work, approximately 15 percent of their business. There are 700 different furniture models currently in production, with the majority as part of a group or overall theme. Turnover to new styles is high, around 25 percent per year. However, this turnover usually applies to pieces within the group, not the theme itself.

Riverside has seven facilities in Fort Smith, Arkansas, and one in Russellville, Arkansas. The Russellville facility is a milling operation, and the seven facilities in Fort Smith include a plywood plant and a research laboratory. Some of the larger plants also have their own mill rooms. Riverside has one million square feet of under-roof manufacturing space. Company-wide, Riverside has 1,400 employees. Riverside replaced some of their coatings with waterborne and UV-curable coatings in the early 1990s in anticipation of being subject to the Wood Furniture NESHAP.

Manufacturing and Coating Operations

Riverside receives mainly raw lumber. The milling operation in Russellville performs cutting and rough shaping of lumber for the smaller facilities, but the larger facilities have their own milling operations. Riverside also purchases some premilled products to finish, mainly chair components. Their end products fall into one of three main production categories: finished wood (70 percent), upholstered (15 percent) and printed-grain (15 percent). The following sections discuss the solid wood and printed-grain finishing operations.

Solid Wood Finishing

Four of Riverside’s facilities have finishing rooms. Each finishes a specific range of products. The smallest line finishes assorted small parts from knobs and handles up to chairs and small tables. The next largest is the fastest line and finishes primarily the occasional table line. The next line is a hybrid, finishing some smaller pieces, but also some of the larger pieces. The last, and largest, line finishes the largest pieces, such as wall units, roll-top desks, and headboards. There are 25 different acetone-based stains that currently are in use, in addition to the paints and prints. The following paragraphs describe the coating line in the largest facility, though the steps are similar in all of Riverside’s facilities.

All stained furniture is assembled prior to finishing. There are several large areas to stock assembled pieces prior to finishing to allow them to be loaded onto the finishing line with the smallest number of color changes. The finish line is a cart line. The first spray booth is 80 feet in length. This booth can accommodate six operators with three different stain color lines each, as well as paints in pressure pots. The paints and stains are both applied using HVLP guns. The stain lines are part of a recirculation system. Color changes occur three or four times per day during typical production. The lines are cleaned by blowing air through them to remove the old stain color. If a lighter color will be used next, it also is necessary to run solvent through the lines.

After staining, the carts are conveyed through a forced-air oven to dry the stain (or paint). The pieces then are scuff sanded by hand and a washcoat is applied. This washcoat consists of a 50/50 mix of sealer and thinner and is used to seal the pores in the wood. This coat also is dried in an oven. The next step is to apply filler, which accents the grain of the wood. After drying in an oven, a coat of a high-solids sealer is applied. The sealer is dried in an oven. The last coating step is to apply the high-solids topcoat. Up to two coats are applied, and each is dried in an oven. The washcoat, sealer, and topcoat are all applied using air-assisted airless guns.

Riverside also has a small spray booth off the main cart line which is used to coat smaller products, such as knobs or drawer sides. This helps to alleviate back-ups on the main spray line and is more cost effective than running a cart through the main line with only a few smaller pieces on it.

The cart line now moves through the hardware area where any hang tags and hardware are attached. At the same time, the product is given a thorough inspection. Any pieces with defects in them are pulled off the line and the defect is marked with tape. The product is fixed, on-site if possible. Once the problem is eliminated, the product is put back on the line, where it progresses to the packaging and shipping stations. After being packaged, the cart line leads to a roller line onto which the products are transferred for direct, automated loading into a truck for shipping.

Printed-Grain Products

Riverside also produces a printed-grain finish for their more economical products. These products account for approximately 15 percent of their business. The print room facility employs 30 to 40 people. The finish line is a circular conveyor. The primary substrate is particleboard, although fiberboard and hardboard also are used. All panels have been shaped and edged prior to finishing. The entire printing process takes only 5½ minutes per pass through the line.

The boards are loaded onto the conveyor and first pass through a sander to ensure a smooth finish. The UV-curable filler then is applied and cured by UV lamps. The filler is sanded and a waterborne basecoat is applied. The basecoat is much like a primer for paint applications. The color of the basecoat is matched to that of the final wood grain and it ensures an even, flawless finish. The basecoat is applied by two or three direct roll coaters and dried in a gas-fired oven. The wood grain now is printed by up to three of six consecutive roll coaters. The wood grain is created by applying waterborne ink to an engraved cylinder which then leaves the grain pattern on the board. The waterborne inks dry quickly; there is no need to use an oven. A sealer then is applied as a tie coat if the product will be used as a component in a piece that will receive a topcoat in the finish rooms. If the product's finish is considered complete after the print room, a UV-curable topcoat is applied by a reverse roll coater and cured by UV lamps.

Cleaning Operations

Solid Wood Products

All equipment is cleaned with solvents such as acetone. The overhead lines to the main spray booth have reduced necessary cleaning because they can carry three different stain colors simultaneously. When the lines are purged to change stain color, they are blown out with compressed air. The stain is collected in its original container and saved for later use. No solvent is used, except when changing from a dark color to a lighter color.

Printed-Grain Products

Most of the equipment used to apply waterborne coatings can be cleaned using hot water, although the cleaning must be done immediately. If a roll is changed, it must be wiped down immediately to keep the coating from hardening. The engraved rolls for applying the waterborne ink grain must be cleaned with acetone or isobutyl acetate to remove the waterborne coating from the crevices before it hardens.

The roll coater used to apply the UV-cured filler is covered overnight to prevent the coating from being exposed to light and curing, and is cleaned once per week. The topcoat roll coater and coating reservoir are cleaned each night so dust and other particles do not accumulate in the coating overnight.

Conversion to Waterborne and UV-Cured Coatings

Finished Wood Products

The four finish rooms at Riverside have increased the solids content of their coatings and decreased the HAP content. This reformulation necessitated additional operator training because of the differences between the old and new systems. These differences include the higher solids content and different base solvents, which affect the viscosity of the coating. However, since the adjustment was made, the finish is more durable than the old finish. This is due mainly to the better build achieved by the higher-solids product. Riverside is testing spray application of waterborne topcoats, but has not yet achieved the quality they want. Waterborne topcoats that have been tested have produced cloudy finishes and the overspray does not rewet as with conventional lacquer.

Color-matching is a complicated process for Riverside. Not only are they concerned with matching vendors' back-stock of the same product group, matching within the same piece of furniture is a concern. This problem is two-fold. First, the piece is often composed of multiple species of wood, each of which absorbs the color from the stain differently. Second, the piece and/or its components may be finished in several different finish rooms. Riverside makes color standards which catalogue the finish color at each step of the finishing process. These standards are distributed to each finish room to ensure all stock conforms to the same color standards.

The finish rooms also have made reductions in their hazardous waste production. All spray guns have been replaced with HVLP guns, which have a higher transfer efficiency and therefore reduce overspray. Line heaters have been added to adjust the viscosity of the high-solids sealers and topcoats for easier spraying. The coating left in the bottom of the barrels that cannot easily be pumped into the guns also is saved for reuse. The sealer and topcoat bottoms are mixed with solvent and added to new drums. The stain bottoms are combined together to make a “dip stain” that is used to dip parts such as cleats for shelves for which an exact color match is not required because of low visibility.

Another waste reduction activity is gun tip regulation. Riverside found that gun tips were often being used beyond their most efficient ranges, gradually spraying more and more coating as the tip wore out. The operators often did not notice this increase in coating use until the gun actually began to drip coating as it was spraying. Testing showed that the coating wasted by not replacing the tips often enough was far more expensive than replacing the tips on a more regular schedule. Replacing a tip pays for itself in a few days in saved coating. Currently, all guns are regularly tested for efficiency and tips are replaced as soon as they reach the edge of the target zone.

Glaze booth filters have been replaced with a Styrofoam™ product. The new Styrofoam™ product can be dissolved in waste solvent and disposed of. The traditional fiberglass filters had a slight risk of spontaneous combustion due to the linseed oil in the glaze. The Styrofoam™ filters are a new addition, but are working well thus far.

All customer feedback regarding the change has been positive. Their customers have noted the increased durability and enjoy the more resistant finish. The color and clarity also have improved because of the increased attention to the condition of the spray guns.

Printed-Grain Products

More extensive changes were made in the print room. Riverside began researching available coating alternatives in 1990. Several different coating systems were tested before the change to UV-curable fillers and topcoats was made. Riverside tested some waterborne coatings, but they were of inferior quality and therefore unacceptable. Riverside experienced difficulties with grain raise, cloudiness, and the finished pieces sticking together when stacked. Many different coating suppliers were tried, but none could provide the right combination for Riverside.

UV-curable coatings then were explored and solvent-borne UV-curable fillers and topcoats were implemented. Riverside continued to explore other pollution prevention options and replaced the solvent-borne UV-curable filler and topcoat with 100 percent solids UV-curable filler and topcoat. They experienced several problems with the 100 percent solids UV-curable topcoat, most noticeably a "ropiness" to the finish that previously was not present. Riverside was determined that the 100 percent solids UV-curable coatings could be successful, and implemented a new reverse roll coating machine for the topcoat that dramatically increased the quality of the finish.

In 1993, Riverside began investigating waterborne basecoats and inks. There were a multitude of small adjustments that needed to be made to produce a usable product. While each adjustment was minor, the entire process was very time and labor intensive. By 1996, the waterborne basecoats and inks were in full production. Waterborne inks allow the UV-curable topcoat to be applied without the need for a sealer on certain products. For products that still require a sealer, waterborne sealers are being investigated. Products that have been tried to date have caused the finished panels to stick to each other when they are stacked.

Costs

Coating costs have increased 1.5 to 2 cents per square foot coated since the coatings changes have been implemented. While this change may sound minor, with 15 million square feet coated yearly, it quickly turns into a major expense. However, the switch to waterborne coatings also has greatly reduced the amount of solvent cleaner purchased. Taking this reduction into consideration, the increase in cost is minimal. Wood stains have not increased in cost significantly. Any minor cost increases have been offset by the increased coverage of the high-solids coatings and improved application efficiencies. Hidden costs include extensive research and engineering for the air permit modifications which were required to implement many of the improvements.

Emissions

The main pollution prevention efforts began in 1990. From 1989 to 1998, VOC emissions per unit of production have been reduced 22 percent. However, this number is deceptively small. In 1989, the majority of Riverside's business was desks, which are composed of large flat surfaces that are easy to coat with little overspray. Currently, the largest market for Riverside is small occasional tables, which have more smaller parts and therefore a higher percentage of overspray per piece. The VOC emissions reduction includes a reduction of 100,000 pounds per year of methyl isobutyl ketone (MIBK). The MIBK was used as a cleaning agent for the solvent-borne line, but with the waterborne and UV-curable lines, specialized low-VOC/HAP cleaners are used. During roughly the same time, Riverside reduced HAP use by 65 percent.

Riverside is subject to the Wood Furniture NESHAP and uses an averaging approach. All coatings currently used at Riverside's facilities are compliant with the NESHAP and average less than 0.4 pound of HAP per pound of solids.

Case Study No. 24 UV-Cured Coatings
States Industries
Eugene, OR

Background

States Industries manufactures and coats plywood panels. The coated panels are used as interior paneling or as components in cabinets, drawers, and store fixtures. They have a large portion of the U.S. interior wall paneling business. States is a major source of HAP emissions due to their plywood pressing operations, and have been subject to the VOC emission limits (RACT) in the CTG for Factory Surface Coating of Flat Wood Paneling since 1977. The plant operates 6 days per week, 24 hours per day. The seventh day is set aside for maintenance activities. States began using UV-curable sealers and topcoats in 1993.

Manufacturing and Coating Operations

States Industries began manufacturing plywood at their Eugene facility in 1966. They dry 1/6-inch Douglas fir in the veneer dryer and use it as core material. A variety of wood species are used as the face veneers. A urea-formaldehyde glue then is applied to both sides of every other layer of the plywood using a roll coater. The layers are hand stacked and then loaded into a press. After pressing, the plywood is manually removed and stacked for later sizing. A portion of the plywood the facility manufactures is coated on-site, and the remainder is sold unfinished.

The majority of the surface coating is done on oak, maple, or birch plywood panels, but States also coats panels made of particleboard and particleboard with wood veneer. The panels coated range in thickness from 1/8 to 1½ inches, and are typically 4 feet wide and 6 to 8 feet long. The number of coating application steps in the coating line depends on the type of product being coated. All products receive a sealer and topcoat as the final steps in the coating process.

Five-gallon buckets are used at the line to supply the coatings to the application equipment and are replenished as needed during each shift. If a piece of equipment applying UV-curable coatings is not in use, the coating reservoir is covered so the leftover coating will not cure.

If the product being produced is interior paneling, the panel often has grooves cut lengthwise, and the grooves are painted. If oak panels are being coated, the panels are bleached, after the grooving step, to remove the tannic acid in the wood. Previously, the facility used bleach containing methanol, but is now using a formulation containing phosphoric acid. The panels are each flooded with the bleaching solution (the solution is sprayed then rolled) on both sides and stacked to dry for 24 hours. The panels are buffed after bleaching.

At the beginning of the surface coating line, an operator feeds the panels one at a time onto a conveyor system. The panels are first presanded with sandpaper. The particulate emissions from all sanding or buffing steps are sent to the baghouse. The panels may then receive a UV-curable filler using a reverse roll coater with a chrome wiper roll. The panels are cured in a UV oven for approximately 2 seconds. The UV ovens on the coating line contain 300 watt-per-inch lamps. The panels then go through a second sanding step using sandpaper.

The panel then may be embossed, but this step is typically used only when particleboard panels are being coated. A stain then may be applied, using a direct roll coater. The stains used are waterborne and have low solids contents. An IR oven at 250°F is used to dry the panels after the stain coat. Excess heat also is used from a natural gas oven in another part of the line. A reverse roll coater may then be used to apply a color coat. The color coats (referred to as flood coats) are waterborne, but contain a small amount of VOCs (about 8 percent), primarily 2-butoxy ethanol. A natural gas-fired oven is used to cure the coating. The panels then are sanded.

A direct roll coater then may be used to apply either a waterborne sanding sealer or a basecoat. The basecoat is applied to hide the panel's natural wood grain. An IR oven is used to cure this coating, and the panel is sanded with 400 grit sandpaper. An offset printer may be used to produce a simulated oak or cherry wood grain. An oven using excess heat from another oven in the line is used to dry this coating. A differential roll coater may be used to apply a waterborne toner, which is the last color coat the panels can receive. A natural gas-fired oven is used to cure this coating. If the panel did not receive the waterborne sealer, it then receives a UV-curable sealer, is partially cured in a UV oven, receives a UV-curable topcoat, and is fully cured in the final UV oven.

The finished panels are inspected for defects and stacked on pallets. If the panel is to be finished on both sides, it goes through the coating line a second time. In the components division, coated panels used for components such as drawer sides and bottoms are cut, grooved, and sorted. They then are stacked on pallets for packaging and shipment. Any dust generated during cutting is exhausted to a baghouse.

There also is a small coating line in the lab for testing new colors on 16-inch by 24-inch panels. The coating line consists of a small roll coater and UV oven. The boards are sent through the line three times to receive one coat each of stain, sealer, and topcoat. Colors are matched by eye; no automated equipment is used for color matching or mixing.

Coatings are stored in drums or totes at ambient conditions in a small building near the laboratory. The acetone supplier takes their drums back and reuses them, but the facility has difficulty disposing of the other drums. Some coatings also are supplied in lined fiber barrels. The UV-curable sealer and topcoat are supplied in large stainless steel tote tanks that are returned to the coating supplier when empty and are reused.

Cleaning Operations
Acetone is used to clean the roll coaters (1997 acetone usage was 600 gallons). The facility experimented with lacquer thinner, glycol, and MEK, but found acetone works the best to clean the equipment and dries faster than MEK. No additional maintenance is required as a result of the switch to the UV-cured coatings.

States also used approximately 250,000 gallons of water for cleaning in 1997. All wastewater generated by the plant is treated on-site. A flocculator and filter press are used to remove the solids, which are disposed of as municipal waste. The remaining water then is treated, and much of it is recycled to the plywood manufacturing process for glue mixing and washing the glue application equipment.

Conversion to UV-Cured Coatings and Associated Emissions Reductions
In 1993, States switched to UV-curable sealers and topcoats. Product quality was the primary driving force, although the company also had made an environmental commitment and wanted to reduce their HAP emissions (e.g., methanol and formaldehyde). Prior to the switch, the facility was emitting 400 to 500 tons of methanol per year. States currently is using waterborne stains, sealers, and color coats, and UV-curable fillers, sealers, and topcoats.

According to facility personnel, the switch to UV-curable sealers and topcoats was fairly smooth. As part of the conversion, they bought new roll coaters and UV curing ovens. The coating supplier performed most of the testing on States' coating line, and it was about 6 months before the facility was fully satisfied with the new coating system. Facility personnel stated that the coating supplier was instrumental in providing advice on what new equipment to purchase. The UV-curable coatings contain no HAPs, and a small amount of VOCs. They do have to watch for problems with blushing and streaking, but most quality problems are related to the condition of the machinery, the ambient conditions in the plant, or the quality of the sanding the piece receives prior to being coated.

The conversion to UV-curable coatings did not require additional finishing employees, but did require employee training. This training consisted of formal training provided by the coating supplier and more informal on-the-job training. Instruction was provided on the new equipment, proper handling of UV-curable coatings, and the safety issues with the new UV curing ovens. The UV-curable coatings have almost 100 percent solids and the waterborne coatings have 45 to 60 percent solids. Facility personnel indicated that the coating supplier is continually working to improve the UV technology, and that the price of the UV-curable coatings has decreased since States began using them.