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CASE STUDIES:
LOW-VOC/HAP WOOD
FURNITURE COATINGS

Prepared for

Office of Air Quality Planning and Standards

Prepared by

**National Risk Management
Research Laboratory
Research Triangle Park, NC 27711**

FOREWORD

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E. Timothy Oppelt, Director
National Risk Management Research Laboratory

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Case Studies: Low-VOC/HAP Wood Furniture Coatings

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Abstract

Midwest Research Institute identified wood furniture manufacturing facilities that had converted at least one of their primary coating steps to low-volatile organic compound (VOC)/hazardous air pollutant (HAP) wood furniture coatings (high-solids, waterborne, ultraviolet (UV)-curable, or powder coatings). Twenty-five case studies were developed, based on visits to the facilities and discussions with plant personnel.

The case studies contain the following information:

- Products manufactured;
- Types of low-VOC/HAP coatings implemented;
- Equipment and process changes required;
- Problems encountered during the conversion;
- Advantages/disadvantages of the low-VOC/HAP coatings;
- Customer feedback;
- Costs associated with conversion; and
- Emissions and waste reductions.

General information about the wood furniture manufacturing industry's typical emissions and applicable regulations also is provided in this report. Each coating technology is discussed individually and facilities' experiences with the low-VOC/HAP coatings studied are summarized. The main goals of this study were to demonstrate that low-VOC/HAP coatings can be used successfully by some wood furniture manufacturers and to provide a resource to assist other manufacturers in converting to low-VOC/HAP coatings.

This report was submitted in fulfillment of Cooperative Agreement Number 824049-01 by Midwest Research Institute under the partial sponsorship of the United States Environmental Protection Agency. This report covers a period from March 1995 to February 2000.

Preface

This document was prepared by Midwest Research Institute (MRI) for the Office of Research and Development (ORD), U. S. Environmental Protection Agency (EPA), under Cooperative Assistance Agreement No. 824049-01, “Accelerate Development and Market Penetration of Very Low-VOC/HAP Wood Furniture Coatings.” Julian Jones is the EPA project officer. Questions concerning this document should be addressed to Amy Marshall at (919) 851-8181, ext. 5135, or amarshall@mriresearch.org.

Contents

Figures

Tables

Acronyms and Abbreviations

CAA	Clean Air Act
CFR	Code of Federal Regulations
cm	centimeter
CO	carbon monoxide
CTG	Control Techniques Guidelines
EPA	Environmental Protection Agency
ft	feet
g	grams
gal	gallon
HAP	Hazardous air pollutant
HVLP	High-volume/low-pressure
in	inch
IR	Infrared
kg	kilogram
l	liter
lb	pound
m	meter
MACT	Maximum achievable control technology
MDF	Medium density fiberboard
Mg	megagram
MSDS	Material safety data sheet
NAAQS	National Ambient Air Quality Standards
NESHAP	National emission standards for hazardous air pollutants
ORD	Office of Research and Development
OSHA	Occupational Safety and Health Administration
PM_{10}	particulate matter less than 10 μm in aerodynamic diameter
psi	pounds per square inch
PVC	Polyvinyl chloride
RACT	Reasonably available control technology
UV	Ultraviolet
VHAP	Volatile hazardous air pollutant
VOC	Volatile organic compound
yr	year

Conversion Factors

1 kg = 1000 g = 2.20 lb

1 Mg = 10^3 kg = 2204.62 lb = 1.10 ton

1 m = 100 cm = 39.37 in = 3.8 ft

1 m^2 = 10^4 cm^2 = 1550 in^2 = 10.76 ft^2

1 m^3 = 1000 l = 10^6 cm^3 = 35.31 ft^3 = 264.17 gal

$$T(^{o}C) = \frac{T(^{o}F) - 32}{1.8}$$

To convert from	to	Multiply by
lb/gal	g/l	119.83
ton/yr	Mg/yr	0.909

Chapter 1
Introduction

Many wood furniture manufacturing facilities are subject to surface coating regulations that require them to use finishes with low volatile organic compound (VOC) or hazardous air pollutant (HAP) contents. However, moving away from conventional, solvent-borne, nitrocellulose-based finishes that have been used for many years concerns some in the wood furniture industry. Each of the alternatives to traditional solvent-borne coating systems raises different concerns. Many furniture companies that tried waterborne coatings in their early stages of development found that the waterborne coatings did not perform as well as solvent-borne coatings. Common problems were related to appearance, grain raise, and dry time. Conversion to ultraviolet (UV)-cured systems often is viewed as capital intensive. Powder coatings recently have been used on wood but the technology is not yet fully developed for most applications in the wood furniture industry. To address these concerns, the U. S. Environmental Protection Agency (EPA) initiated a cooperative agreement with Midwest Research Institute (MRI) to find facilities that were using low-emitting coatings successfully and to provide information on their experiences to the industry. The low-VOC/HAP coatings studied were waterborne, UV-cured, high-solids, and powder coatings.

The primary goals of the project were to demonstrate that low-VOC/HAP coatings can be used successfully by wood furniture manufacturing facilities and to provide a resource to assist other wood furniture manufacturing facilities in converting to low-VOC/HAP coatings. Facilities that had converted one or more of their primary coating steps to low-VOC/HAP coatings and wanted to participate in this study were identified. Information was gathered using Internet searches, trade publications, trade associations, State agency personnel, technical assistance providers, and coating suppliers. Facility personnel were contacted by phone and, in most cases, a site visit was conducted. They were then given the opportunity to review and comment on the case study writeup for their facility before it was finalized. This report contains those case studies, as well as general technical information about low-VOC/HAP coatings.

The case studies include the following information:

- A discussion of the types of products the facility manufactures;
- A description of the coating processes and the types of low-VOC/HAP coatings implemented;
- Equipment and process changes that were required;
- Problems encountered in converting to low-VOC/HAP coatings;
- Advantages/disadvantages of the low-VOC/HAP coatings;
- Customer feedback on products finished with the low-VOC/HAP coatings;
- A discussion of the costs associated with the conversion process, including capital costs, research and development costs, and operating costs; and
- Emissions and waste reductions achieved.

Chapter 2 of this document discusses the regulatory requirements that apply to wood furniture manufacturing facilities. Information on the low-VOC/HAP coating technologies studied (high-solids, waterborne, UV-cured, and powder coatings) is provided in Chapter 3. Chapter 4 describes the facilities that were studied and presents the case studies in alphabetical order. This document also contains a glossary, references, and a bibliography.

Chapter 2
Wood Furniture Industry Regulatory Requirements

This chapter summarizes the emission and waste sources, regulatory requirements, and pollution prevention options in the wood furniture industry.

Emission Sources in the Wood Furniture Industry

There are many sources of VOC/HAP emissions in the wood furniture industry. These sources include:

- finishing operations (spray booths, flashoff areas, ovens);
- cleaning operations;
- mixing operations;
- touch-up and repair operations; and
- gluing operations.

Figure 2-1 shows emission and waste sources from finishing and cleaning operations. Wood furniture plants also can be sources of solid and hazardous waste. Sources of these types of waste include used cleaning solvent, waste coating, used rags, and empty coating, solvent, or adhesive containers. Used spray booth filters and lacquer dust (dried paint particles) also can be considered hazardous waste because of flammability issues.

Finishing

Finishing operations typically account for the largest portion of the facility-wide VOC/HAP emissions. Wood furniture finishing consists of the application of a series of color coats and/or clear coats. The furniture may be sanded, rubbed, or polished in between coats, and may pass through drying ovens or flashoff areas. It is assumed that all solvent in the applied finish evaporates during the finishing process, either as the coating is applied or as it dries or cures. Therefore, finishing emissions are calculated by multiplying the amount of coatings used by their VOC/HAP content. Typical pollutants emitted include alcohols, methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), toluene, and xylene. Acetone, although not considered a VOC or a HAP, also is emitted by the industry in large quantities.

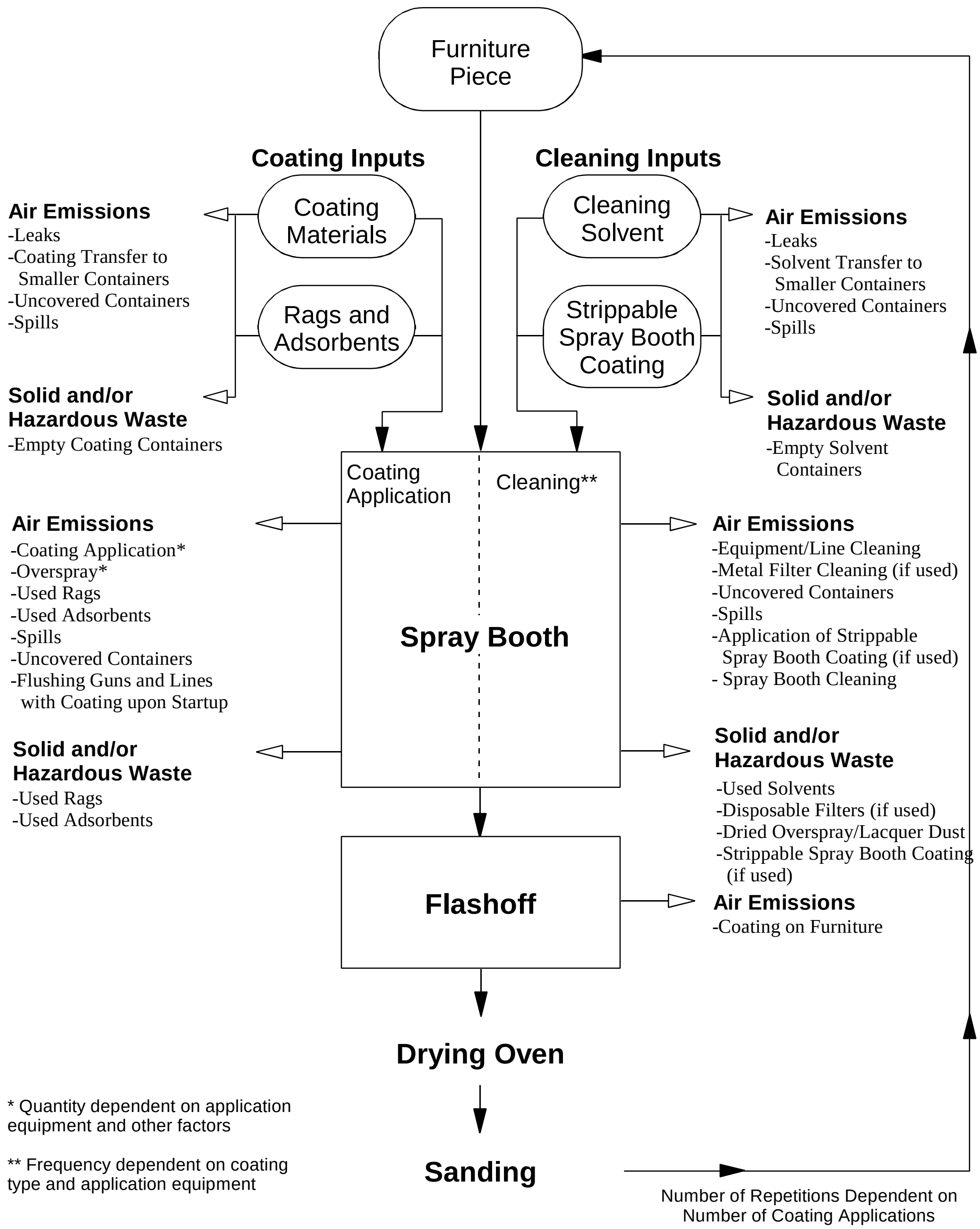


Figure 2-1. Emission and Waste Sources from Finishing and Cleaning Operations[1]

Finishing materials can be applied using various types of equipment and application may be manual or automatic. The most common manual techniques are wiping, dipping, and spraying. Finishes usually are sprayed in ventilated booths. Spray guns used, in order of increasing transfer efficiency, include conventional air spray, airless, air-assisted airless, electrostatic, and high-volume, low-pressure (HVLP). A high transfer efficiency means more of the sprayed finish is transferred to the piece being coated. Use of spray guns with higher transfer efficiencies reduces coating use and the associated emissions. Most spray booths are equipped with dry filters to control particulate (paint droplets) generated by overspray.

Automated application techniques include robotic (or reciprocating) spray, roll coating, and curtain coating. Many robotic spray booths are equipped with electronic eyes that sense the product to be coated and adjust the spray pattern to reduce overspray. These booths also may recycle overspray to reduce waste coating and emissions per piece. Roll coating is a highly efficient method of finishing, but is applicable only to flat pieces. Coating is applied to the piece traveling on a conveyor via cylindrical rolls. Excess coating also may be collected and recycled. Curtain coating is used for fairly flat pieces with positive profiles (pieces that don't have curved or angled areas that wouldn't come in contact with the falling film of coating). The piece travels on a conveyor and passes through a free-falling film of coating. Unused coating is collected under the conveyor and returned to the coating reservoir. In addition to having a high transfer efficiency, automated coating systems provide for a more consistent finish, eliminating the variation in operators' spray techniques. Automation also can reduce labor costs, since fewer operators typically are required to run an automated coating line.

Cleaning

Emissions of VOC/HAP are generated from cleaning operations if an organic solvent is used to clean application equipment, spray booths, or other equipment. Organic solvent is necessary to clean equipment that has been used to apply solvent-borne and UV-cured coatings, while hot water can be used to clean equipment that has been used to apply waterborne coatings. Roll coaters are cleaned by soaking the roll in either water or solvent, depending on the type of coating being used. Spray guns usually are cleaned by soaking the gun in solvent or sending solvent or water through the gun and atomizing the liquid into the booth ventilation system. This practice is common unless dedicated coating supply lines and spray guns are used for each color or type of coating. Using dedicated lines produces a significant reduction in cleaning emissions. If a facility is using powder coatings, there are little or no emissions of VOCs from cleaning, since the equipment can be wiped down with a cloth or blown out with air.

Mixing and Touch-up/Repair

Some VOC emissions may occur during mixing operations if volatile materials, such as thinning solvent, are used or if material leaks or is spilled. However, most facilities purchase their finishing materials ready to use (no thinning is required). Touch-up and repair operations are a source of VOC emissions if solvent is used to strip a piece of furniture or perform spot rework.

Gluing

Gluing operations can potentially be as large a source of emissions as finishing operations, depending on the type of glue used. In the past, glues containing methylene chloride were widely used and could account for a significant portion of a facility's HAP emissions. In recent years, wood furniture plants have transitioned to waterborne, hot melt, or low-VOC/HAP adhesives as alternatives.

Wood Furniture Industry Regulatory Requirements

In 1995, the EPA promulgated National Emission Standards for Hazardous Air Pollutants (NESHAP) for the wood furniture manufacturing industry.[2] The NESHAP applies to wood furniture manufacturing facilities that emit 10 tons or more per year of one HAP or 25 tons or more per year of any combination of HAPs. Facilities emitting 50 or more tons per year of HAPs were required to comply with the standards by December 1997, and facilities emitting less than 50 tons per year of HAPs were required to comply by December 1998. Facilities using less than 250 gallons of finishing materials per month and facilities performing incidental wood furniture manufacturing operations (such as a hobby shop at a military base) are exempt from the NESHAP. Facilities that only refinish and restore wood furniture are not subject to the NESHAP. The NESHAP requires facilities to implement work practice standards and provides pollution prevention alternatives as compliance options. Facilities can implement low-HAP coating and gluing technologies rather than installing an air pollution control device. For wood furniture manufacturing facilities, implementing low-VOC/HAP coatings often is the most cost-effective option. However, many facilities subject to the NESHAP simply reformulated their solvent-borne coatings to include solvents that are considered VOCs but not HAPs. Tables 2-1 and 2-2 summarize the HAP emission limits and work practice requirements in the Wood Furniture NESHAP.

In 1996, the EPA issued a Control Techniques Guideline (CTG) Document, which outlined methods of reducing VOC emissions from wood furniture finishing operations.[3] The CTG recommended the use of waterborne topcoats or high-solids sealers and topcoats as reasonably available control technology (RACT) for finishing operations. Table 2-3 summarizes the recommended VOC emission limits given in the CTG (RACT). States must implement rules that require wood furniture manufacturing facilities located in ozone nonattainment areas to control VOC emissions to levels at least as stringent as those recommended in the CTG. The complete text of the

Table 2-1. Summary of the Wood Furniture NESHAP Emission Limits[a]

Emission point	Limits for existing sources, lb VHAP/lb solids[a]	Limits for new sources, lb VHAP/lb solids[a]
Finishing operations		
(a) Achieve a weighted average VHAP content across all coatings; or	1	0.8
(b) Use compliant finishing materials		
-stains	1	1.0
-washcoats	1[b]	0.8[b]
-sealers	1	0.8
-topcoats	1	0.8
-basecoats	1[b]	0.8[b]
-enamels	1[b]	0.8[b]
-thinners (maximum percent HAP by weight allowable); or	10 percent	10 percent
(c) Use a control device; or	1[c]	0.8[c]
(d) Use a combination of (a), (b), and (c).	1	0.8
Cleaning operations		
Strippable spray booth coating	0.8 lb VOC/lb solids	0.8 lb VOC/lb solids
Gluing operations		
(a) Use compliant contact adhesives based on the following criteria:		
i. For aerosol adhesives, and for contact adhesives applied to nonporous substrates;	NA[d]	NA[d]
ii. For foam adhesive used in products subject to flammability testing;	1.8	0.2
iii. For all other contact adhesives (including foam adhesives used in products not subject to flammability testing but excluding aerosol adhesives and excluding contact adhesives used on nonporous substrates); or	1	0.2
(b) Use a control device.	1[e]	0.2[e]

[a] The limits refer to the maximum VHAP/VOC content as applied; that is, including the contribution of thinners or other solvents added to the coating before application.

[b] Washcoats, basecoats, and enamels must comply with the limits presented in this table if they are purchased premade; that is, if they are not formulated onsite by thinning other finishing materials. If they are formulated onsite, they must be formulated using compliant finishing materials (i.e., those that meet the limits specified in this table) and thinners containing no more than 3.0 percent VHAP by weight.

[c] The control device must operate at an efficiency that is equivalent to no greater than 1.0 pound of VHAP (0.8 for new sources) being emitted per pound of solids used.

[d] There is no limit on the VHAP content of these adhesives.

[e] The control device must operate at an efficiency that is equivalent to no greater than 1.0 pound of VHAP (0.2 for new sources) being emitted per pound of solids used.

Table 2-2. Summary of the Wood Furniture NESHAP Work Practice Requirements

Emission source	Work practice[a]
	Finishing operations
Equipment leaks	Develop a written inspection and maintenance plan to address and prevent leaks. Inspections must be made once per month.
Storage containers, including mixing equipment	Keep containers used for storing or mixing HAPs, or materials containing HAPs, covered when not in use.
Application equipment	Discontinue use of conventional air spray guns.[b]
	Cleaning and washoff operations
Gun/line cleaning	- Collect solvent into a closed container. - Cover all containers associated with cleaning when not in use.
Spray booth cleaning	Use solvents for cleaning spray booths only under certain conditions.[c]
Washoff/general cleaning	- Keep washoff tank covered when not in use. - Minimize dripping by tilting and/or rotating the part to drain as much solvent as possible. Allow sufficient dry time for the part. - Maintain a log of the number of parts washed off and the reason for the washoff. - Maintain a log of the quantity and type of solvent used for washoff and cleaning, as well as the quantity of solvent reused for other operations at the facility and the quantity of solvent sent off-site for disposal.
	Miscellaneous
Operator training	All operators shall be given annual training on proper application methods, cleaning procedures, and equipment use.
Implementation plan	Develop a plan to implement these work practice standards and maintain on-site.

[a] The work practice standards apply to both existing and new major sources.

[b] Conventional air spray guns will be allowed only in any of the following instances:
- when they are used to apply finishing materials that emit less than 1.0 lb VOC/lb solids;
- touchup and repair under limited conditions;
- when spray is automated;
- when add-on controls are employed;
- if the cumulative application is no more than 5.0 percent of the total gallons of finishing material applied; or
- if the permitting agency determines that it is economically or technologically infeasible to use other application technologies.

[c] Solvents can be used for cleaning conveyors and their enclosures and metal filters. Limited quantities, no more than 1.0 gallon, can also be used for spot cleaning when the spray booth coating is being replaced.

Table 2-3. CTG Reference Control Technologies and Corresponding Emission Limits

Reference control technology	VOC limit, lb VOC/lb solids[a]
Finishing operations	
Waterborne topcoats, or	0.8
Higher-solids sealers and topcoats	
- Sealers	1.9
- Topcoats	1.8
- Acid-cured alkyd amino vinyl sealers	2.3
- Acid-cured alkyd amino conversion varnishes	2.0
Cleaning operations	
Waterborne strippable spray booth coating	0.8

[a] Represents VOC limit as applied; that is, including the contribution of thinners or other solvents added to the coating.

NESHAP and CTG, as well as other guidance materials, may be found on EPA's Internet site at http://www.epa.gov/ttn/uatw/wood/riwood.html.

Many states have promulgated their own VOC regulations that wood furniture manufacturing facilities must follow. In some cases, these rules are more stringent than the levels recommended in the CTG. California, in particular, has some of the most stringent VOC regulations in the United States.

These regulations forced the wood furniture industry to examine ways to reduce the VOC and HAP contents of their coatings, glues, and solvents, either to comply with the new regulations or avoid being subject to them. The 25 case studies developed under the EPA/MRI cooperative agreement are meant to provide the industry with information on pollution prevention measures facilities can implement to reduce their emissions.

Pollution Prevention in the Wood Furniture Industry[1]

Pollution prevention is the use of materials, processes, or practices that reduce or eliminate the creation of pollution or wastes at the source. Pollution prevention also is called source reduction, and includes practices that reduce the use of hazardous materials, energy, water, and other resources. For example, instead of controlling pollution with an add-on control device, a facility would institute work practices that prevent the pollution from being generated or reduce the amount generated. In addition to any emissions reductions achieved, pollution prevention practices also can serve to reduce operating costs, reduce permit fees, reduce liability and fire risk, improve employee morale, and enhance a company's image. Pollution prevention practices implemented in the wood furniture manufacturing industry include:

- Reducing or eliminating the VOC/HAP content in coatings and glues;
- Increasing coating solids content;
- Using a non-VOC/HAP cleaning material;

- Using more efficient application equipment (e.g., HVLP spray guns, robotic spray, or flat-line finishing) to reduce coating usage and overspray;
- Reducing the number of coating steps required to coat a piece;
- Implementing housekeeping measures, such as keeping containers of coating, solvent, glue, or cleaning rags covered and minimizing spills and leaks;
- Recycling of cleaning, finishing, and gluing materials;
- Using heat, instead of thinning solvent, to adjust viscosity;
- Using coating supply lines dedicated to a particular color to reduce cleaning solvent usage;
- Implementing an operator-training program to ensure operators are using equipment and materials efficiently and implementing the pollution prevention measures;
- Implementing equipment maintenance programs, such as a regular spray gun tip replacement schedule (as the tip becomes worn, the transfer efficiency can decrease); and
- Recycling waste wood, packing materials, and empty containers.

Because the quantity of VOCs and HAPs emitted is directly related to the amount of coating and glue used, the most common pollution prevention measures implemented to reduce volatile emissions involve reformulation of the coatings and glues. Chapter 3 presents information on four types of low-VOC/HAP coatings.

Chapter 3
Low-VOC/HAP Coating Technologies

This section provides information on four low-VOC/HAP wood coating technologies: high-solids, waterborne, UV-cured, and powder coatings. Table 3-1 gives a summary of the advantages associated with each technology.

High-Solids Coatings

Converting to high-solids coatings typically involves reformulating sealers and/or topcoats, and generally is an easy transition for a wood furniture manufacturing facility. When the coating system has a higher solids content, the amount of volatiles released as the coating cures is decreased, resulting in a direct reduction in facility emissions. Because sealers and topcoats can account for up to 65 percent of finishing emissions, the potential emissions reduction can be significant. Traditional solvent-borne nitrocellulose sealers and topcoats have an average solids content of less than 20 percent, while high-solids sealers and topcoats can contain from 30 to 50 percent solids.[1]

Reformulated high-solids coating systems generally are catalyzed conversion systems. In a catalyzed conversion system, the coating is cured partially through a polymerization reaction that creates a more durable and chemical resistant coating. However, the high-solids coatings are similar to traditional coatings because they are still solvent-borne, so the application method and coating behavior during application do not change significantly, allowing the operators to easily adjust to the new coating system.

Other advantages of high-solids coatings include reduced solvent waste and better coverage. One application of a high-solids coating can place twice the amount of solids on an item using less solvent. This increased coverage can lead to cost savings if the cost per gallon of coating did not increase substantially with the reformulation. However, the increase in solids content also results in an increase in viscosity, so adjustments to application equipment may be required. Some facilities heat the coating before application to reduce its viscosity.

Table 3-1. Advantages of Low-VOC/HAP Coating Technologies

High-Solids Coatings
Higher solids, better coverage Lower VOC/HAP content than traditional coatings Low capital cost to change Little or no equipment changes necessary Easy operator transition
Waterborne Coatings
Higher solids, better coverage Low VOC/HAP content Lower fire risks, no in-house storage requirements Hard finish Low capital cost to change Can clean equipment with water Less toxic coatings, no smell
UV-Cured Coatings
Very high solids, little or no solvent Low or no VOC/HAP content Very durable finish Cures in seconds – no dry time Automated line (labor savings)
Powder Coatings
100 percent solids – no solvent Very little VOC/HAP content Recycle overspray Very durable finish, only one coat necessary Automated line Short cure time Easy-to-clean equipment

The potential VOC/HAP emissions reductions associated with the use of high-solids coatings are not as great as the reductions that can be achieved using the other low-VOC/HAP coating technologies. High-solids coatings still are solvent-borne and a significant amount of solvent evaporates as the coating dries. From a pollution prevention perspective, high-solids coatings are an improvement over traditional solvent-borne coatings, but other technologies can provide a finish of equivalent quality with a greater VOC/HAP emissions reduction.

Waterborne Coatings

Converting to waterborne coatings generally is a less costly method of reducing VOC/HAP emissions than converting to UV-cured or powder coatings, and, therefore, is appealing to smaller wood furniture manufacturing facilities. The capital investment required to convert to waterborne coatings ranges from nominal to several thousand dollars to purchase stainless steel lines and equipment. The average facility studied replaced several gun or pump components, but not the entire coating line. The cost of the waterborne coatings themselves tends to be higher per gallon than traditional solvent-borne coatings; however, many facilities found that the higher solids content of the waterborne coatings provided better coverage and resulted in the use of a smaller volume of coating per piece.

The appearance of products finished with waterborne coatings often is the main hurdle to overcome. Some facilities described pieces finished with waterborne stains as being "muddy," or lacking the "depth" of a typical solvent-borne stain. Pieces that receive only a sealer and/or topcoat may appear as having a green tint in the wood, instead of the amber tint associated with solvent-borne coatings. However, working with the coating supplier to adjust the coating formulation often solved any appearance issues.

Waterborne coatings generally are applied using spray guns, although dipping, roll coating, and wiping also are used. Application of waterborne coatings by spray gun requires a different operator technique than that used to apply solvent-borne coatings. Several facilities noted that it was easier to train an employee who had never sprayed coatings before to spray waterborne coatings than to retrain one who had sprayed solvent-borne coatings for years. The waterborne coatings often must be applied sparingly to achieve the desired finish.

Another difficulty often associated with waterborne coatings is grain raise. The water in the coatings is absorbed by the wood, causing it to swell. Grain raise results in a finish that feels and looks rough. However, most facilities have found that, with the proper combination of coatings, equipment, and sanding, grain raise can be minimized to an acceptable level. Some facilities chose to use only a waterborne topcoat instead of a full waterborne system (waterborne stain, sealer, and topcoat). The sealer coat prevents the water in the topcoat from coming in contact with the wood and eliminates the problem of grain raise.

Waterborne coatings often require a longer drying time than typical solvent-borne coatings because the water in the coating does not evaporate as quickly as the solvent. Larger facilities often install ovens for use between coating steps to shorten drying times. Smaller facilities that use the same spray booth (with no oven) for each coating step, in more of a batch process, generally found that by the time they were ready to apply the next coating, or package the product, the piece was dry.

In addition to VOC and HAP emissions reductions, the main advantages cited by facilities that have switched to waterborne coatings include:

- elimination of the smell associated with solvent-borne coatings;
- reduction of fire risks and associated ease of storage (an explosion-proof storage room is not required);
- low capital investment;
- a more durable finish; and
- reductions in permit and license paperwork and/or fees.

Overall, the majority of the facilities studied under this project were satisfied with their waterborne finishes. Coating suppliers played a key role in the success of the coating system. Facilities had the most success when the coating suppliers were willing to provide the individual attention necessary to formulate the system to facility-specific needs and eliminate any problems. The adjustment period from solvent-borne to waterborne coatings (the period of testing and refining the coating system and the application technique) varied from facility to facility, but was generally several months.

UV-Cured Coatings

Installation of a UV-cured coating line may require a large capital investment. The large initial cost prevents some small wood furniture facilities from implementing a UV-cured coating system. However, once the system is in place, it generally is a very cost-effective method of production because transfer efficiency can be up to 100 percent and the lines typically are automated, requiring few operators.

The finishing line can be a flat line or a spray line. Coatings applied on a flat line, using roll coaters or curtain coaters, can contain up to 100 percent solids (meaning all of the coating components cure to form the final film) and have little or no emissions. This type of coating also may be sprayed, but water or solvent often is added to reduce the viscosity of the coating for easier application. Spray booths for UV-curable coatings generally are enclosed and automated, often with electronic eyes to sense when the product is present and reduce overspray. Most facilities find that the increased automation of a UV-curable coating line decreases the number of operators required to run the line.

Another advantage of UV-curable coating lines is the decrease in the amount of floor space required. A UV curing oven follows the coating application and cures the coating in a matter of seconds. Curing is accomplished by varying numbers of UV lamps at different intensities and positions. Since the cure time is so short, pieces can be assembled and stacked immediately after they are coated. Additional floor space for large drying ovens or areas for drying the product also are eliminated with this type of coating system.

A UV-cured finish is more durable than the typical solvent-borne finish. However, this durability makes rework of pieces with finishing defects very difficult; the product must be sanded to bare wood and refinished, with care taken not to sand through a veneer, or reduce the thickness of the board below the coating line's tolerance. One component manufacturer studied sells pieces with coating defects as "shop-grade" panels instead of reworking them. Rework is more of a problem for the retail salespeople than for the manufacturing facility. Retail stores commonly touch up pieces that have finishing blemishes, which is very easy with solvent-borne coatings because the new coating tends to "melt" into the old coating layer. With UV-cured finishes, this type of repair cannot be done. Damaged pieces must be sent back to the manufacturer for repair.

Equipment used to apply UV-curable coatings also can be difficult to clean. The coatings typically are viscous and sticky. In addition, they must be kept away from direct light to prevent them from curing in or on the equipment. Many facilities allow the coating to remain in the supply lines and coating reservoirs when not in use, and they cover the equipment to prevent the coating from curing. Flat line equipment (e.g., applicator rolls) generally is easier to clean than spray equipment because the roll can be removed from the line and soaked in cleaner or solvent.

The appearance of a UV-cured finish typically is aesthetically pleasing. High-gloss finishes can easily be achieved by applying either multiple coats or thicker coats. The clarity and depth of the finish is comparable to traditional nitrocellulose-based coatings.

Overall, case study facilities found the transition to a UV-cured coating line to be fairly smooth. Minor problems were encountered, but quickly overcome. The end result is a quality finish that is equivalent to the solvent-borne finishes previously used. Though the capital investment often is large, facilities can achieve a lower operating cost and higher production rate.

Powder Coatings

The newest low-VOC/HAP coating technology for wood is powder coating. Powder coatings produce the lowest VOC/HAP emissions (little to none) because there is no solvent in the coating. The general application process involves grounding and preheating the substrate, applying charged powder particles to the substrate by electrostatic spray gun; heating the substrate to cause the particles to "cure" or melt together to form a continuous coating; and cooling the substrate. At this time, powder-coating technology is best suited for flat, engineered-wood components (e.g., medium density fiberboard [MDF]) finished with pigmented coatings.

Powder coating has been used in the metal-finishing industry for many years, but application on wood introduces several potential problems. The main difficulty encountered with applying powder coatings to wood is creating adhesion between the powder particles and the wood prior to curing. Powder coating wood products is more difficult than powder coating metal because the wood does not conduct an electrical charge as well. The adhesion of the powder particles to the wood can be improved by heating the wood prior to applying the powder. Heating also equalizes the moisture across the surface, enhancing electrostatic deposition.

Another difficulty with powder on wood applications is the sensitivity of the wood to high temperatures. The powder cannot be cured at the temperatures typically used when coating metals. Excess temperatures would cause deformation of the wood. However, the powders used on wood have been specially formulated for low curing temperatures. Safety concerns include the potential for powders to form explosive mixtures with air.

Powder coatings produce a more consistent finish than sprayed liquid coatings because drips, runs, and bubbles are eliminated. This decrease in defects is especially important because the difficulty of rework causes most defective pieces to be scrapped. The finish also is more durable and chemical-resistant. Generally, only one coat is required to achieve the desired appearance, and the thickness of the coat can be controlled.

Powder coatings also have many economic advantages over other types of low-VOC/HAP coatings. Once implemented, the coating line is automated and requires few operators. Solvent is not necessary to clean the equipment. Any powder overspray can be collected and mixed with new powder for re-use. By collecting overspray, there is little to no coating waste. Any powder waste that is generated is not considered to be hazardous and can easily be disposed of. The production level is higher than that of a liquid line because only one coat is applied and the cure time is very short. Powder coating also costs less per coated area than liquid coatings. However, the technology is still very new; therefore, capital costs for researching and implementing the system are high.

Chapter 4
Case Studies

Facilities Studied

A total of 25 case studies were prepared under this project for a variety of facilities, products, and coating technologies. Visits were made to 23 of the facilities. Facilities ranged in size from 2 to 900 employees, with products ranging from coated panels used as casegood components to high-end furniture and cabinets. Table 4-1 shows the distribution of the facilities by product and coating type. Many facilities use more than one type of low-VOC/HAP coating technology, and those facilities appear in more than one category (e.g., one plant was using waterborne, UV-cured, and powder coatings). Nine of the facilities studied had converted all of their coating steps to low-VOC/HAP coatings.

Table 4-1. Breakdown of Facilities Studied by Product and Coating Type

Low-VOC/HAP Coating Technology	Product Type		
	Residential Furniture	Office/Institutional Furniture	Cabinets or Components
High-solids	3	1	2
Waterborne	7	4	4
UV-cured	2	4	4
Powder	0	1	0

Figure 4-1 shows the locations of the case study facilities throughout the United States. Facilities in 13 states were studied. The numbers on the map correspond to the number of facilities studied in the various states. Five facilities were located in ozone nonattainment areas. These areas are indicated on the map in Figure 4-1 using asterisks.

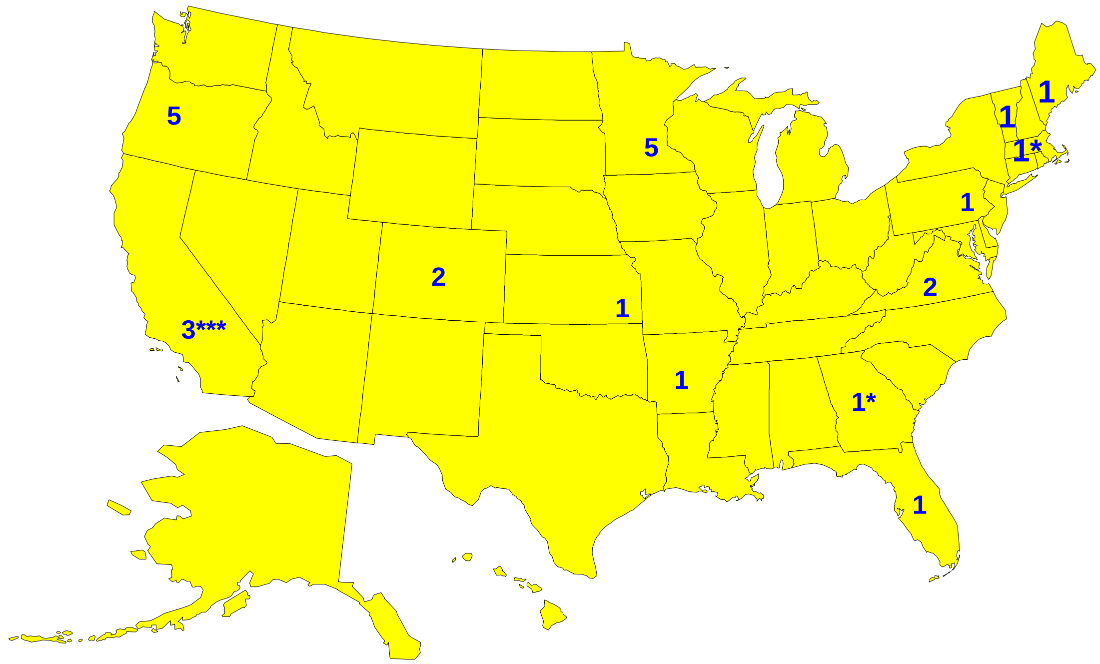


Figure 4-1. Case Study Facility Locations.

Reasons for Converting Coatings

The facilities cited several different reasons for switching to low-VOC/HAP coatings and implementing various other pollution prevention measures:

- A desire to use materials that are less hazardous;
- A commitment to the environment;
- To avoid being subject to the NESHAP;
- In anticipation of having to comply with the NESHAP;
- As part of an overall pollution prevention program;
- A desire for a higher-quality finish;
- To lower emissions; and
- To increase production without increasing emissions or exceeding permit limits.

Emissions Reductions Achieved

The facility-wide VOC emissions reductions achieved by implementing pollution prevention measures (such as low-VOC coatings) ranged from about 12 to 98 percent. For some facilities, quantifying the emissions reductions achieved was difficult or not possible, due to changes in production, changes in product line, or lack of records on previous coatings used and historical emissions. Quantifying reductions in HAP emissions sometimes was difficult because some facilities did not have information on their HAP emissions prior to being subject to the Wood Furniture NESHAP.

Costs

The costs incurred or saved in converting to the new coating systems included capital costs, material costs, labor costs, and energy costs (all costs are reported in US dollars). Facilities that converted to high-solids or waterborne coatings typically experienced the lowest conversion costs. Capital costs of a few thousand dollars typically were incurred, and involved the purchase of new spray guns, lines, and/or pumps. Facilities that experienced higher capital costs (up to $300,000) when converting to high-solids or waterborne coatings typically made other major changes to their finishing line or finishing area that were not required to use the new coatings. Capital costs for converting to UV-curable and powder coatings ranged from around $220,000 to over $2 million. Conversion to these types of coatings involves the purchase of new application and curing equipment. Costs and cost savings for materials, labor, and energy varied widely among facilities.

Cost savings were incurred when facilities were able to reduce labor costs, material usage, fire insurance, and permit/waste disposal fees. Often, a cost savings was experienced even if the cost of the coating increased, due to lower labor costs, a more efficient application technique, or higher coating solids content.

Other Benefits

The facilities studied achieved other benefits besides reductions in cost and emissions of VOCs and HAPs when they implemented pollution prevention measures. These other benefits include:

- Reduction or elimination of hazardous waste;
- Reduction in wasted materials (e.g., coating, solvent, or wood);
- Reduction of fire risk;
- Improved working conditions;
- Enhanced company image;
- Improved coating performance; and
- Increase in production capacity.

Case Studies

Table 4-2 presents a list of the facilities studied, the products manufactured at each facility, and the low-VOC/HAP coatings used. The 25 case studies then are presented in alphabetical order.

Table 4-2. List of Case Studies

No.	Facility	Product	Coating	Page
1	Accent Furniture San Bernardino, CA	Bedroom furniture	Waterborne stain, sealer	22
2	Artistic Finishes Roseville, MN	Custom finishing	UV-curable topcoats (clear and pigmented), stain Waterborne topcoat	26
3	Aspire San Diego, CA	Residential furniture	Waterborne topcoat	29
4	Automated Building Components Chanhassen, MN	Doors, fireplace mantels, molding	Waterborne stain, sealer, topcoat	32
5	Back to the Woods Redlands, CA	Custom furniture	Waterborne stain, sealer, topcoat	36
6	Bentwood Furniture Grants Pass, OR	Residential furniture	Low-VOC/HAP, higher-solids sealer, topcoat,	39
7	Columbia Forest Products Chatham, VA	Panels	UV-curable sealer, topcoat	42
8	Crystal Cabinet Works Princeton, MN	Cabinets	High-solids sealer, topcoat Waterborne adhesive	46
9	Design Fabricators Lafayette, CO	Store fixtures, conference tables, entertainment-type pieces	High-solids sealer, topcoat, low/no-HAP coatings	51
10	Ethan Allen Beecher Falls, VT	Residential furniture	High-solids sealer, topcoat	55
11	Geiger Brickel Atlanta, GA	Office furniture	Waterborne urethane topcoat, stain UV-curable sealer, topcoat	61
12	Hussey Seating Company N. Berwick, ME	Bleacher, stadium, and theater seating	Waterborne stain, sealer, topcoat UV-curable sealer, topcoat	66
13	Knoll E. Greenville, PA	Office furniture	Waterborne pigmented coatings UV-curable sealer, topcoat Powder pigmented coatings Hot melt adhesives	72
14	The Lane Company Altavista, VA	Home office furniture	UV-curable sealer, topcoat	78
15	Loewenstein Pompano Beach, FL	Seating	UV-curable sealer, topcoat	83
16	Northshore Wood Products Duluth, MN	Gifts, decorative items	Waterborne stain, sealer, topcoat	89
17	Pine-Tique Furniture Company Minnetonka, MN	Residential furniture	Waterborne stain, sealer, topcoat	93

Table 4-2 continued on following page

Table 4-2. List of Case Studies (Continued)

No.	Facility	Product	Coating	Page
18	Prestige Neodesha, KS	Cabinets	UV sealer, topcoat	97
19	Riverside Furniture Fort Smith, AR	Residential and home office furniture	Waterborne ink and basecoat, UV-curable filler, topcoat	101
20	Saloom Furniture Winchendon, MA	Tables, chairs, and hutches	High-solids sealer, topcoat Waterborne adhesives	107
21	Schrock Cabinets Grants Pass, OR	Cabinets	Waterborne stain, topcoat	112
22	Schrock Cabinets Hillsboro, OR	Cabinets	Waterborne pigmented primer, clear topcoat	115
23	Shafer Commercial Seating Denver, CO	Hotel and restaurant chairs, tables, booths	Waterborne stain, toner, sealer, topcoat Waterborne and hot melt adhesives	119
24	States Industries Eugene, OR	Panels	UV-curable filler, sealer, topcoat	124
25	Westwood Custom Cabinetry Salem, OR	Cabinets	Low-VOC/HAP coatings, high-solids sealer, topcoat	128

Case Study No. 1 – Waterborne Coatings
Accent Furniture
San Bernardino, CA

Background

Accent Furniture manufactures oak bedroom furniture. Their product is a mixture of solid oak and veneered medium density fiberboard (MDF). The manufacturing facility is approximately 80,000 square feet in size and there are two shifts. The day shift consists of approximately 200 employees, 20 of whom are in the finishing department. The night shift, with 60 employees, has only 15 in the finishing department. Accent has an annual production of about $15 million. The switch to a waterborne finishing system was prompted by a need to increase production without exceeding permit limitations.

Product sample

Manufacturing and Coating Operations

Accent receives most of their lumber raw, with the exception of some precut moldings. The pieces are cut and assembled before finishing. The waterborne stains are applied by hand with wet rags. The stain is hand wiped in a circular motion to push the pigment into the wood. Accent may switch all of their staining to spray application with HVLP guns in the future. After staining, the product is lightly sanded to smooth down any grain raise that may have occurred. The waterborne sealer is pumped directly out of the 55-gallon drum and applied using HVLP guns in a spray booth. Sealer can be applied before the stain is completely dry without lowering the quality of the finish. The sealer then is lightly sanded. Because Accent desires a very natural finish, no topcoat is applied. However, to protect the finish, a low-VOC wax is hand

Application of hand-wiped stain

rubbed into the finish. The staging area is equipped with several fans to ensure that the product is completely dry before it is packaged.

Gluing Operations
Accent had been using a solvent-borne, but low-VOC, glue. However, after changing to the waterborne stain and sealer, they tested several alternative glues. A waterborne, white wood glue was found to adhere better in conjunction with the new waterborne coatings. All assembly now is done with the waterborne glue.

Application of sealer

Cleaning Operations
Accent produces very little waste from cleaning the waterborne coating application equipment. The guns are not drained, and leaving the coating in them prevents the need to clean them daily. Any necessary cleaning of tips or guns is done with hot water.

Previously, Accent was hand wiping solvent-borne stains. This produced a large number of rags (around 10 to 12 thousand per week). These rags were collected and sent to a laundry service so they could be reused. With the waterborne system, Accent hopes to reduce the number of rags to 100 per week and launder them in-house.

Another benefit of the waterborne finishing system is filter disposal. Used spray booth filters can be thrown into the dumpster. With the solvent-borne system, the used filters had to be wetted and Accent paid a disposal company to haul them away.

Conversion to Waterborne Coatings
In 1993, Accent began using a high-solids system. In 1998, it became apparent that coating emissions had to decrease in order to expand operations under the current permit, and Accent decided to be proactive and switch to an alternative type of coating, rather than simply reformulate their coatings again or install an add-on control device. After researching the alternative low-VOC coatings that were available, Accent decided to use a waterborne system. This decision was based on many factors including: the dramatic decrease in VOC content (as compared to their high-solids system), improved working environment, affordability of the system, and the reduced fire risk.

Accent was concerned with the possibility of grain raise with the waterborne coatings. A waterborne product had been tested in 1995, but the finish was of very poor quality with excessive grain raise. Several of the manufacturers that Accent contacted had waterborne systems that were extremely complex and required several extra steps in the finishing process. These additional steps would alleviate the grain raise problem, but would require more time and manpower per piece than the current solvent-borne system. Accent then was contacted by a new supplier, Western EcoTec, who promised their product would provide a simple system without the problems Accent had experienced before. Although the waterborne system requires a sanding step after the stain is applied, this has not added a step to the finishing line. Accent was previously sanding before staining, and has found that eliminating that presanding step (while adding the sanding after staining) does not compromise the finish. Only the solid oak components are presanded.

The finish Accent achieved with the Western EcoTec system is quite satisfactory. The grain raise is minimal - slightly more than with the solvent-borne product they had been using, but definitely acceptable. The waterborne system produces a better color than the solvent-borne system and is easier to sand. The color is matched so closely, the product finished with the waterborne system is almost indistinguishable from the product finished with the previous system. The consistency also is excellent. While the color is not quite as deep as it was with the solvent-borne system, the difference is minimal, and Accent feels it is worth the environmental and safety benefits.

The main problem Accent encountered with the waterborne finishing system was retraining the operators to apply the waterborne coatings. For example, the waterborne stain needs to be rubbed into the product in a circular motion to work the pigment into the wood, something that was not necessary for the solvent-borne system. In addition, the waterborne sealer cannot be applied as heavily as the solvent-borne sealer. However, once the operators had a chance to adjust to the new system, they found the elimination of the solvent odor and ease in removing any stain that was spilled on their hands or clothing to be well worth the adjustment in application technique.

Benefits of the waterborne system include: better work environment for the employees, lower fire risks, affordable implementation, and elimination of the need to increase the permit limit to expand their business. Another important benefit is the customer reaction. Before changing to the waterborne system, Accent would periodically receive a return because the customer complained that the product smelled funny when they removed it from the box. The customer was smelling the odor associated with solvent-borne coatings that is not present in a waterborne finishing system.

Costs

The costs to implement the system were minimal, only a few thousand dollars. Only a few pieces of new equipment were required. The old spray guns needed to be replaced with HVLP guns, and some of the hoses and filters were replaced. The current pumps were acceptable, but may be replaced at a later date. Other possible future expenses include a drying oven and/or dehumidifier to further reduce the drying time.

Accent did note a significant increase in the cost of the coatings themselves. The waterborne coatings cost approximately 70 percent more than the solvent-borne system Accent had been using. However, Accent's fire insurance decreased and cleaning service charges associated with the solvent-borne rags are expected to be eliminated. Although this still makes the waterborne system more expensive to operate, Accent feels the extra cost is well worth the safety and environmental benefits.

Emissions

Facility personnel stated that when they were using the solvent-borne system, Accent was operating at their monthly permit limitation, 1,800 pounds of VOCs, preventing expansion without increasing their permit limit. Using the waterborne system has approximately halved Accent's monthly emissions, allowing them to increase production under their current permit. Accent is subject to the Wood Furniture NESHAP, although their switch to waterborne coatings has significantly reduced their HAP emissions.

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. 3 – Waterborne Coatings
Aspire Furniture
San Diego, CA

Background

Aspire Furniture specializes in decorative and faux-finishing techniques. They manufacture furniture in three main styles: faux stone, parchment, and white- or gold-wash. Substrates finished include wood, paper on wood, and fiberboard encased in resin. Their main products include tables and cabinets. Aspire has 15 manufacturing employees. They began using waterborne coatings after their coating usage began to increase and in anticipation of becoming subject to local VOC regulations. Aspire is located in an ozone nonattainment area.

Manufacturing and Coating Processes

The manufacturing facility consists of a milling/assembly area and the finishing area. Wood tables are purchased premade, while the wood cabinet components and faux stone table tops are manufactured on-site. There is one spray booth, one brushing area, and one sanding booth. The majority of the coatings are applied using HVLP guns.

Spray booth

The faux stone table tops are made by encasing a MDF substrate in a resin and cement mixture to achieve a stone texture. The table tops then are sanded, and a sealer and topcoat are applied. A parchment-type appearance is achieved by gluing pieces of paper to a wood substrate. A sealer is applied, the product is sanded, and a topcoat is applied. Aspire also is developing a "crackle" finish for some of their products. Glue is applied to the substrate and chipped off in places. A casing paint, color coat, and topcoat then are applied to achieve the desired appearance.

Product samples

The white- or gold-wash coatings are applied to wood substrates such as bedroom furniture, table bases, and cabinets. A tinted sealer is applied, a topcoat is applied, and then white or gold highlights are applied by hand using a brush. Pieces are allowed to dry at least 48 hours before being packaged and shipped or put on display in the retail store located on-site. Equipment is cleaned primarily with hot water. Spray gun tips are cleaned once per week with solvent.

Conversion to Waterborne Coatings

Aspire initially used a solvent-borne lacquer to coat the faux stone products, but that coating had a high VOC content, and was not acceptable under local regulations Aspire would have to meet once their coating usage exceeded 500 gallons. They began to investigate waterborne coatings for these products in 1992. Since the faux stone surface is porous, the coating had to be customized to their needs. Occasionally, bubbles would appear in the topcoat or there would be pits in the coating that would cause stains to show. They also had problems with checking and cracking, and replaced many defective table tops that were coated with their initial waterborne coating. Facility personnel also noted that candle wax stains waterborne coatings.

In 1996, Aspire began using waterborne coatings manufactured by Western EcoTec Coatings, and the performance of the waterborne topcoat improved. Although the coating has a longer dry time and the final film is softer than the old lacquer, facility personnel stated that their current waterborne topcoat is much better than the first ones they tried. Aspire continues to investigate high-quality, low-VOC coatings for these products.

Product sample

Aspire also had problems with the first waterborne coatings they tested on their parchment-look products. They stated that they tended to take on a green tint over time. Aspire also incurred replacement costs on these products due to coating problems.

Aspire has had the most success with the waterborne coatings they use on their white- and gold-washed wood products. They have had no problems with this finish; the appearance and performance are the same as the solvent-borne finish they used previously. Facility personnel stated that their clients did not notice any difference when they started using waterborne finishes on these products. Aspire suggested that the reason they did not have problems with these coatings is that so much testing has been done on these types of coatings in the wood furniture industry.

Aspire currently is trying to develop a market for their newest decorative finish. They stated that the appearance is achieved by brushing a small amount of naphtha on the coated piece. However, local regulations prohibit the use of any material with a VOC content of greater than 700 grams per liter. Therefore, since their usage has increased to the point where they are subject to these regulations, they are working with Western EcoTec to develop a waterborne coating that will achieve the same appearance. They stated that the waterborne coatings they have tried to date do not achieve the desired appearance.

When Aspire began using waterborne coatings, they bought HVLP spray guns. The operators had a hard time learning how to apply the new coatings with the new guns. They had to learn the proper application technique for the waterborne coatings and wanted to turn up the pressure on the spray guns since they were used to conventional spray. However, the operators have adjusted, and now have a much healthier work environment.

Costs

The greatest costs incurred were in replacing products due to coating defects. These costs include material, labor, and freight costs. The facility also converted from conventional spray guns ($200 per gun) to HVLP guns ($700 per gun). The waterborne topcoat, which accounts for the majority of the coating sprayed at the facility, costs less than the old solvent-borne lacquer ($20 per gallon versus $60 per gallon) and has a higher solids content (about 30 percent by weight). Thus, Aspire has experienced a cost savings in coating materials by converting to waterborne coatings and switching to HVLP spray guns.

Emissions

Approximately 95 percent of the materials Aspire uses are waterborne, low-VOC, no-HAP coatings. Coating usage was about 900 gallons in 1997. The majority of the coatings sprayed at the facility are clear topcoats that have a VOC content of about 200 grams per liter. The local standard (San Diego Air Pollution Control District's Rule 67.11) limits the VOC content of clear topcoats to 680 grams per liter. The old solvent-borne topcoat used had a VOC content of about 780 grams per liter. Therefore, they have cut their emissions by about 75 percent as a result of switching to waterborne coatings. Since Aspire's emissions and coating usage are low, they are not subject to the Wood Furniture NESHAP.

Case Study No. 4 – Waterborne Coatings
Automated Building Components
Chanhassen, MN

Background

Automated Building Components (ABC) finishes and distributes a variety of millwork, including exterior/interior doors, windows, fireplace mantels, stair components, and moldings. The majority of their products are oak, although some are maple. About half of the annual production is interior trim packages and 40 percent of them are finished on-site. These "prefinished" parts provide 3 percent of total revenue and are sold to residential building contractors. ABC uses 12 different finishes with an annual production of 3 million feet per year. Two shifts are run daily, with five or six people per shift in the finishing department. The finishing department consists of two finishing lines, one manual and one automatic. In 1993, ABC began investigating the use of a waterborne finishing system to allow expansion within the current permit restraints.

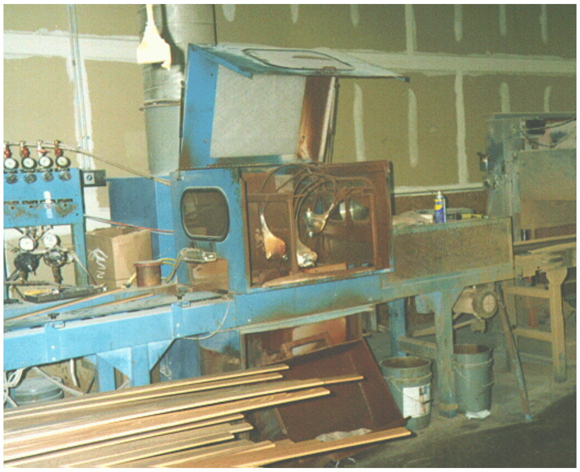

Product sample

Manufacturing and Coating Operations

The manual finishing line consists of one spray booth in which operators apply stain, sealer, and topcoat. Stains are applied using HVLP guns and the sealer and topcoat are applied using airless guns. The spray booth has four coating supply lines for stains. Three are dedicated lines for the most popular colors (to reduce necessary line flushing and gun cleaning) and the fourth line is used for the remaining colors. Parts are laid flat on a cart in the spray booth, the stain is applied, and the parts are hung on an overhead line and moved out of the booth to be hand wiped and to dry. The rags used for wiping are sent to a laundry service for cleaning and then are reused. The hanging parts again are moved into the spray booth, sealer is applied, and the parts again are moved out of the spray booth to dry and are hand sanded. The topcoat is applied in the same manner as the sealer.


Spray booth

The automatic line finishes smaller flat products such as moldings. The product is loaded onto a conveyor belt at the beginning of the process. First, the stain is applied by an automated HVLP gun. Overspray is collected, filtered, and reused. The conveyor then carries the product through a wiping machine which dries the stain enough that the sealer can be applied by an automated airless gun. The product is racked and allowed to air dry. Once the product is dry, it is run through the same line again, but this time only the airless gun is active, applying a topcoat. The parts again are racked and allowed to air dry before being packaged and shipped. For products that only receive a clearcoat, the staining step is omitted and only the airless gun is used.



Automatic line

The sealer and topcoat are received in 55-gallon drums, which require a minimal fee to be removed. The stains are received in 5-gallon buckets, which can be recycled at no cost if the handles are removed.

Cleaning Operations

All of the guns are soaked nightly and cleaned throughly once a week. A toluene-based lacquer thinner is used for the majority of the cleaning. Where possible, the coating is allowed to dry completely and is chipped off of the equipment to reduce the amount of cleaning solvent used. All parts that come in contact with the coatings have been covered in plastic to reduce the amount of coating that will stick to them.

Conversion to Waterborne Coatings

ABC was finishing with traditional solvent-borne coatings when permit constraints threatened to impede expansion of their operations. Because expansion was necessary to continue to meet increasing customer demand, alternative coatings that would not cause them to exceed current permit limits were researched. ABC was outsourcing some finishing work to a company that was using no-HAP, low-VOC waterborne finishes with little problem and producing a high-quality product. This contact prompted the move to waterborne finishing at ABC.

The manual finishing line required little modification to apply waterborne coatings. Carbon steel parts on both the pumps and guns needed to be replaced with stainless steel, but entirely new equipment was not necessary. The coating supply lines also were updated to stainless steel to allow for installation of a recirculating system.

However, this expense was not required; the coatings could have been pumped directly out of the barrel at the spray booth without any regulatory or fire safety violations.

When the waterborne coating system first was implemented, ABC experienced problems with the tips of the spray guns plugging. This problem was gradually alleviated by adding a series of filters before the gun tip to catch any impurities. It also is probable that the amount of impurities was reduced as the coating supplier increased the quality of the coatings.

Another problem encountered with the waterborne coatings was color matching. This was quickly solved by the coating supplier making minor modifications to the stains. The coating supplier was very helpful throughout the entire conversion process, from helping to select the best equipment for ABC's waterborne finishes to making any necessary reformulation to improve the quality of the product.

Typically, increased drying time is an issue faced by companies that have switched to waterborne coatings. ABC has added a few fans to speed the drying time but has experienced few difficulties because of the way their production area is set up. All products off the automated flat line are racked, and by the time the end of the batch is finished, the beginning of the batch is dry enough either to apply the topcoat or be moved to the shipping area. Similarly, on the manual line, by the time a coating has been applied to all of the products on the line, the pieces at beginning of the line are dry enough for the next step.

An important benefit of the waterborne system is the quality of the product. The waterborne finish is more durable and resistant to yellowing than the original solvent-borne finish. The waterborne coatings also provide a larger selection of colors, eleven more than the four offered in the solvent-borne line.

The waterborne finishing system also has provided other benefits. The reductions in fire and health hazards are worth far more than the physical cost reduction enjoyed due to decreased permit and emission fees, increased coverage, and higher transfer efficiency (due to the new equipment).

Costs

The manual finishing line required little adjustment to be compatible with the waterborne coatings, and the adaptation was done at minimal cost. The total equipment renovation cost was $18,000. However, the entire cost was not due to the change to waterborne coatings. The switch to a stainless steel recirculation system was costly, but not necessary for a successful conversion. Although the automated flat line required new HVLP guns and pumps for the stain, these upgrades were not a direct cost of the conversion process because the equipment that was being used was old and needed to be replaced. The new guns have quickly paid for themselves because of their higher transfer efficiency. Any coating that would normally be considered waste is recovered by the overspray reclamation system and reused.

The waterborne coatings cost $20 per gallon, whereas the solvent-borne coatings were only $7 per gallon. This represents only a small increase in overall cost for two main reasons. First, the waterborne coatings contain a much higher percentage of solids and therefore cover twice the amount of wood per gallon. Secondly, the overspray reclamation system installed with the waterborne equipment recovers what would have been waste coating under the old system.

The switch to waterborne coatings required 400 man-hours in lost productivity. However, while the switch was taking place, actual production volume and product quality never suffered. This is exemplified by the fact that the sales staff and customers never realized there was a change until after the fact. Now, they are very satisfied with the quality of the waterborne coatings, which are more durable than the original solvent-borne coatings.

Including the decreases in license and emission fees, the overall cost savings is estimated to be over $60,000 per year. This figure includes savings from the higher transfer efficiency of the new spray guns, increased coating coverage, and the overspray reclamation system.

Emissions

After implementation of the waterborne coating system, emissions were reduced while the production of coated product was simultaneously increased. According to ABC, toluene usage for cleaning was reduced by 3,800 pounds, or 22 percent, in the first year after waterborne coatings were implemented. In the same year, total VOC emissions were reduced by 13,880 pounds, or 26 percent. The following year, toluene usage was reduced by 90 percent and VOC emissions fell an additional 94 percent.

Currently, annual coating usage is 2,805 gallons each for topcoat and sealer and 2,325 gallons for stains. Facility personnel stated that total VOC emissions currently are under 2.5 tons per year, and that toluene usage for cleaning is down to 80 gallons per year, with emissions of 171 pounds per year.

ABC also noted that hazardous waste production has been nearly eliminated due to the overspray reclamation system; this is an annual reduction of almost 2,000 gallons. Because the waterborne coatings are no-HAP coatings, all HAP emissions from the finishing process also have been eliminated.

Case Study No. 5 – Waterborne Coatings
Back to the Woods
Redlands, CA

Background
Back to the Woods is a small custom furniture shop. The owner, Kevin Lura, has one part-time employee. Lura builds and finishes custom furniture, such as tables, desks, chairs, shelves, and other items. He has been making furniture for about 15 years. He switched to waterborne coatings to avoid the health and fire risks associated with the use of solvent-borne coatings.

Manufacturing and Coating
Lura manufactures furniture in his shop. He most often uses quartersawn oak, because he likes the high-end appearance, and sands all pieces before they are coated. To minimize the effects of grain raise from the waterborne coatings, he has experimented with wetting the piece to induce grain raise, sanding it, and then coating. Pieces are finished in the area of the shop nearest the door, and cardboard is used to catch any overspray. Finishes are sprayed with an HVLP gun from a small pot. Lura no longer uses a spray booth to finish, since the waterborne coatings are non-toxic and non-flammable.


Product sample

A stain and two coats each of sealer and topcoat are typically applied. The stain is sprayed, then wiped and allowed to dry. Lura uses three main stain colors, but expects to start mixing his own custom colors as his business expands. If color matching is required, he either applies two coats of stain or dilutes the stain with water to achieve the desired color. Two coats of sealer are applied, with dry time after each coat, and then sanded using Scotch Brite™ pads. Two coats of topcoat are applied and allowed to dry after each coat. The sealer and topcoat are applied sparingly to prevent long dry times. Since the waterborne coatings are high-solids coatings, he does not apply as much coating on each piece as he did when he used solvent-borne coatings. Cleanup is accomplished using hot water.

Conversion to Waterborne Coatings

Lura previously used solvent-borne coatings, but wanted to switch to waterborne coatings because of the smell, and to reduce health and fire risks. He did not want to switch to acetone-based coatings, because of the smell and fire risk. The first waterborne sealers and topcoats he tried several years ago plugged the spray gun and caused excessive grain raise. As noted above, Lura has experimented with prewetting to control grain raise, which is an issue with the quartersawn oak he uses for many of his products. Increased dry time of the clearcoats was an issue.


Product storage

Lura began working with Western EcoTec Coatings in 1997 to develop a coating system customized to his needs. At first, the waterborne stains produced a muddy appearance that was undesirable, but their appearance has improved with reformulation. He now uses waterborne products exclusively, except for a few stain colors that are not yet available in the waterborne products.

The quality of the finish has improved as Western EcoTec has adjusted the coatings and Lura has adjusted his application technique to the waterborne coatings. Now that the waterborne stains produce the desired appearance, Lura stated that they are actually easier to work with, as far as diluting them to achieve the desired color or appearance. He had problems with a few tables he finished, but experimentation with diluting and finishing techniques has overcome these problems. However, adjustments are necessary to account for the fact that waterborne stains tend to bring out a green tint in the wood, while solvent-borne stains tend to bring out a brown tint. Lura also remarked that the appearance of the stain improves when the sealer is applied, and it sometimes takes 24 hours for the true color to emerge.

He initially had problems caused by applying too much sealer or topcoat. Less of the waterborne coating is required to produce the desired film thickness, since the solids content is high. Too much clearcoat tended to result in a very long dry time and a blue hue. In addition, the waterborne coatings do not “melt” into themselves when a thick coat is applied, like the solvent-borne coatings do (this also tends to complicate rework). When he adjusted the amount of clearcoat he was applying, the dry time and appearance improved. Lura is very satisfied with the waterborne coating system he is currently using, and says the extra effort and the learning process is well worth the reduced health and fire risks. As he has experimented with application techniques, the quality of the final product has improved, and will continue to improve.

Costs
The coating cost per gallon has remained essentially the same. However, since the waterborne coatings have a much higher solids content than traditional solvent-borne coatings (around 28 percent for the sealer and topcoat), less coating is needed for each piece. Using the HVLP gun also results in a material savings, because of the higher transfer efficiency associated with the gun's use. The use of a ventilated spray booth and the associated operating costs also have been eliminated.

Emissions
Back to the Woods is located in an ozone nonattainment area. However, Lura currently uses less than 100 gallons per year of coatings. Therefore, he is not subject to any emission standards or VOC limits. The waterborne coatings he uses all have a VOC content of less than 275 grams per liter and contain no HAPs.

Case Study No. 6 – High-Solids Coatings
Bentwood Furniture
Grants Pass, OR

Background

Bentwood Furniture is an independent furniture manufacturer that sells nationwide and in Canada, with annual sales of about $9 million. They manufacture dining room, bedroom, and home theater furniture. The facility runs two 8-hour shifts, Monday through Friday, and occasionally operates on Saturdays for shipping and rework. Bentwood has 89 employees, 11 of whom are finishing employees. They switched to high-solids, low-HAP coatings in 1997 to reduce emissions and ensure compliance with the Wood Furniture NESHAP. They plan to switch to waterborne coatings sometime in the future.

Manufacturing and Coating Operations

Bentwood manufactures all their furniture on-site (only the chair cushions are assembled off-site). Raw lumber (oak, cherry, and myrtle wood) is received at the facility and is milled into various furniture components. The wood chips and sawdust from the milling operations are sold to a local firm. The furniture may be assembled before (e.g., a chair) or after (e.g., an entertainment center) it is coated.


Milling operations

Bentwood has one coating line that is approximately 100 feet long and circular in shape. The product is suspended from hooks and travels around the line 3 times -- once each for application of stain, sealer, and topcoat. The pieces are placed on the line at intervals of approximately 1 minute to allow adequate time for the spray operator to coat each piece. On the first pass around the line, the stain is hand wiped onto the piece; Bentwood has 10 to 12 different stain colors that they can apply to different products. The sealer is applied using an HVLP or airless spray gun. The piece is sanded and then the topcoat (usually low-gloss) is applied using an HVLP or airless spray gun. The line speed varies by product, but is typically 8 to 12 feet per minute (one pass around the line takes about 12½ minutes).

There are no drying ovens on the finishing line. To ensure each piece is fully dried before packaging, operators let the finished product sit for about half an hour in an area at the end of the finishing line before stacking or packaging. Products with finishing defects are sanded and recoated (no solvent is used for rework). Products with defects in the wood are disassembled, and the defective component is replaced.

Coatings are received in 55-gallon drums from two coating suppliers. Bentwood uses U.S. Cellulose stains and Lilly sealers and topcoats. Enough coating for about one week of operation is received with each shipment. The empty drums are returned to the coating suppliers for reuse. In the future, Bentwood plans to start using large totes in containment areas.

Cleaning Operations

Bentwood currently uses acetone to clean their spray guns. The solvent is sprayed into the spray booth. Cleaning rags are sent off-site to be laundered and are reused. The facility previously used paper spray booth filters and changed them twice per week. They now use fiberglass-based filters which last twice as long and therefore create less solid waste.

Conversion to High-Solids Coatings

Bentwood switched their coatings in 1997. They reduced both VOC and HAP emissions by going to a high-solids, low-HAP sealer and topcoat. They also reduced the VOC and HAP content of some stains. A conversion to waterborne coatings is planned in the next few years. When Bentwood makes the switch, the plant will be expanded and new spray equipment and drying ovens will be purchased. They plan to convert to a finishing line that uses tow carts under a hanging line and will stay with their current coating suppliers.

Spray line

Facility personnel stated that the conversion to the high-solids, low-HAP sealers and topcoats was smooth. No additional operator training due to the coatings change was necessary. Their coating suppliers had worked with similar facilities to convert their coating systems, so the conversion process at Bentwood was relatively smooth. The coating suppliers brought small amounts of each coating for the facility to test, and the coatings were reformulated only once due to excessive dry time. The change to HVLP guns for all staining and some sealer and topcoat application did require some additional operator training.

The new coatings do contain some acetone. If the temperature in the finishing room gets too high, it sometimes is necessary to add more acetone to the coating to prevent too much solvent from evaporating before the coating reaches the piece. However, since acetone is neither a VOC nor a HAP, this thinning does not contribute to the facility's overall VOC or HAP emissions.

Costs

The switch to low-HAP coatings has reduced their permit cost and the paperwork required by their permit because they have reduced their HAP emissions. They also use less coating per piece because their new coatings have a higher solids content and they use HVLP guns for most of their coating application. This has created a cost savings for the company because the coating cost per gallon remained about the same overall.

Emissions

Bentwood stated that they were emitting over 10 tons each of nine different HAPs with their old system, and now emit about 20 tons of total HAPs, which consist largely of glycol ethers and xylene. Bentwood uses two types of sealer and two types of topcoat. The material safety data sheet (MSDS) showed that these coatings range in solids content from 20 to 32 percent and have HAP contents of 0.16 to 0.38 pound of HAP per pound solids.

Product sample

Customer Feedback

Facility personnel stated that their customers like the products finished with the new coatings. They particularly like the depth of the new stains. There has been no change in the number of complaints received. Bentwood is satisfied with their new finishing system and the reductions in cost and labor it has given them.

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

Background

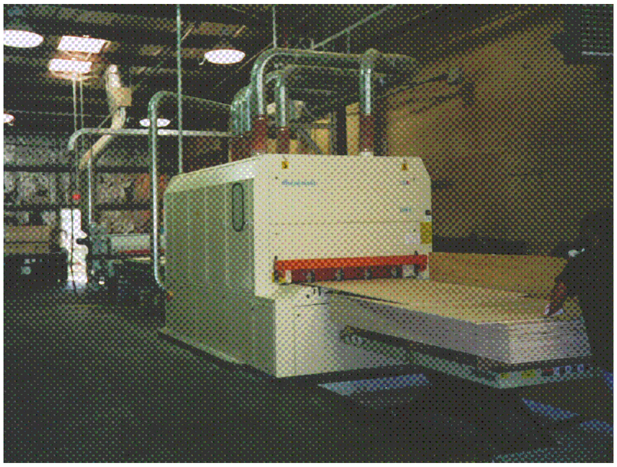

Product sample

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

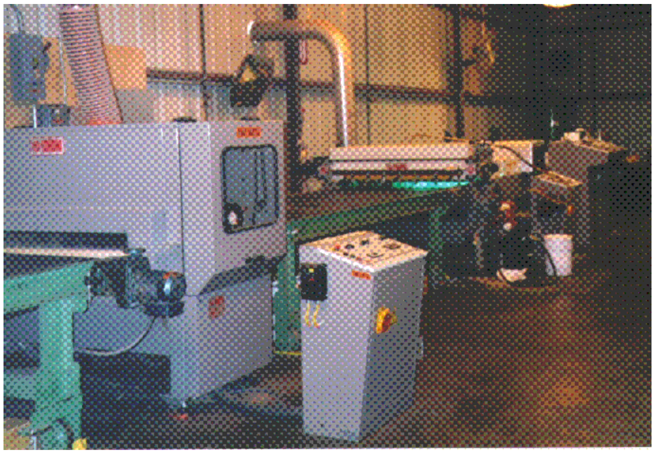
The first UV coating line was instituted in June 1995 due to customer requests for a prefinished product, which was previously unavailable. Customer demand also played a role in choosing to use UV coatings over traditional solvent-borne products. Not only do UV coatings produce significantly less emissions, 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.



Older UV oven

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.



New UV line

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. 8 – Low-VOC/HAP Coatings and Waterborne Adhesives
Crystal Cabinet Works, Inc.
Princeton, MN

Background

Crystal Cabinet Works (Crystal) was founded in 1947 and produces high-quality custom cabinetry for kitchen, bath, or home theater use. There are two facilities located in Princeton, Minnesota: a small component manufacturing facility and a larger facility that machines, builds, finishes, and assembles cabinetry. Total weekly production averages around 2,300 cabinets a week, of which 90 to 95 percent are coated. In mid-1995, Crystal began to reformulate their coatings and adhesives as part of an overall pollution prevention effort.

Product sample

Manufacturing and Coating Operations

Crystal's products consist of solid wood (birch, red oak, hickory, cherry, pine, maple, or heartwood maple) or engineered wood products (particleboard, MDF, or plywood). One facility mills the solid lumber into moldings, linear material for door stiles and rails, and some door panels. These components are transported to the other larger facility, combined with other components that are milled at that facility, then shaped, finished, and assembled to produce the final product.

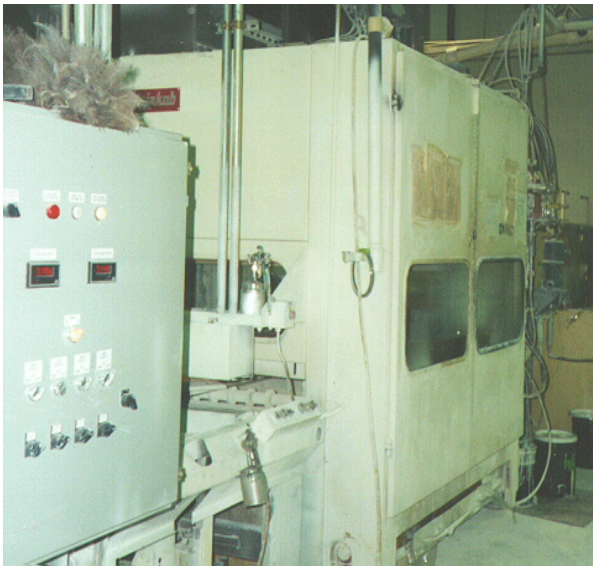
The cabinet components first are cut, shaped, and sanded. The type of shaping and sanding machines depends on the style of the desired final product. Waste solid wood door panels are collected, returned to the milling plant, taken apart, glued together into new door panels, then planed to a half-inch thickness for use as thinner panel inserts. This practice allows Crystal to reuse defective door panels and reduce the amount of wood waste generated. The wood waste that cannot be reused is chipped and sold as animal bedding. After shaping and sanding, the parts are taken to either the assembly or finishing areas. Products are finished before assembly, after assembly, or a combination of the two.

The first step in the finishing department is to clean the product with an automated brush/vacuum machine to remove all sanding dust or particles. Crystal has two finishing lines: an automated flat line and a manual cart line. The manual line is used to finish assembled, or partially assembled, three-dimensional products that cannot be accommodated by the automated flatline system. On the manual line, the parts are placed on tow carts that move automatically through the spray booths. The coatings are applied manually with air-assisted airless guns, which have a manufacturer-rated transfer efficiency of 75 to 80 percent.

First, a stain is applied and hand wiped in the stain booth. Next, a sealer or primer is applied, then dried in an oven and hand sanded. This sealer or primer step is then repeated, passing through the same oven. The final coating is either a clear topcoat or enamel and is applied in the topcoat booth and dried in the second oven. When the finishing process is complete, the product is unloaded and prepared for assembly.

Spray booth

The spray booths on the automated flat line have several features to help increase efficiency and prevent pollution. First of all, electronic eyes minimize overspray and wasted finishing material by triggering the guns only when the eye senses product as it travels through the spray booth. The spray guns themselves are air-assisted airless guns, again with a manufacturer-rated transfer efficiency of 75 to 80 percent.



Automated line

In the first automated spray booth on the flat line, the product receives a stain, primer, or glaze. Stains or glazes are hand wiped. All coatings applied on the flat line are dried in one of two stack ovens, with a required residence time of approximately 45 minutes to dry the coating. The time required varies depending on the type of coating applied. For primer coats, a halogen IR oven is used. The IR oven has a cure time of approximately 2½ minutes; the exact time varies by coating. The proper cure is achieved by varying the line speed through the oven, the air flow, and the temperature of the oven. The process then is repeated for the other side of the panel.

In the second spray booth on the automated line, the product receives a coat of sealer and is dried in a conventional stack oven. Both sides of the piece are coated and dried. The product is sanded, and a second coat of sealer is applied to both sides. The third line is used to apply the topcoat. The product is dried in a stack oven, and the opposite side of the piece receives a topcoat and is dried.

Most wood coatings and solvents are received in 55-gallon drums and 5-gallon buckets. Sealer and topcoat are shipped by dual tanker trucks and stored in bulk storage tanks. As needed, these coatings are dispensed into 55-gallon drums. Some used drums collect hazardous waste (cleaning solvent or waste coating) and the rest are recycled or sent back to the manufacturer.

Gluing Operations

Crystal also replaced a solvent-borne contact adhesive with a waterborne alternative. Prior to 1995, the contact adhesive used at Crystal to adhere laminates to engineered wood contained methylene chloride, a suspect carcinogen and known HAP. This system was replaced by a waterborne neoprene-rubber contact adhesive that is applied by HVLP guns and dried by IR lamps. The final waterborne system provides better adhesion than the original glue and greater coverage per drum, reducing overall costs. The environmental and health benefits are even greater, although not as easily quantified.

Cleaning Operations

Due to the high volume of custom work, color changes are frequent at Crystal. Each time the color is changed, the lines must be flushed with cleaning solvent to remove all of the previous color. This practice can produce a high volume of solvent waste, the majority of which is acetone, toluene, and methyl ethyl ketone (MEK). However, in March of 1999, Crystal installed an automatic color changer on its flat line in order to reduce amount of flushing solvent and time required to switch colors.

In addition to cleaning the lines, the spray equipment and conveyors also must be cleaned. To reduce the amount of cleaning solvent used, the spray booths are cleaned with dry methods, such as chipping off dried coating that has accumulated on the walls of the spray booths.

Conversion to Low-VOC/HAP Coatings and Waterborne Adhesives

The switch to low-VOC/HAP finishes was relatively easy for Crystal Cabinet Works. Because high-solids coatings already were in use, equipment changes were unnecessary and adjustments to the sealer and topcoat were minimal. The sealer and topcoat already were high-solids catalyzed coatings and required only minor adjustments to comply with any regulatory requirements. The stains required more reformulation, however, and color matching was a problem. Each color was tested two to five times before a suitable finish was established, a process that required 18 months. Once the change was made, the quality of the finish was equivalent to that of the original finish and the change was generally unnoticed by customers. Increased drying time also was an issue, but was resolved with the addition of IR lamps to the coating line to replace conventional ovens.

The change in glues was more difficult, expensive, and labor-intensive than the coatings reformulation project. However, methylene chloride's status as both a suspect carcinogen and HAP provided several incentives for changing the glue: reduced environmental impacts, improved employee health, and compliance with increasingly stringent EPA and OSHA regulations. Methylene chloride emissions from gluing operations were substantial, at 24 tons per year for both facilities combined. Although it would have been possible to switch to another solvent-borne adhesive, Crystal recognized the opportunity to change to a high quality waterborne glue, virtually eliminating the environmental and health hazards.

Because of previous experience with glue failure, Crystal spent extra time and resources to ensure the best combination of technology was utilized. Over a period of 18 months, 16 glues were tested for several characteristics. The primary characteristic sought for this new glue was bond strength: in order to maintain product quality, it had to be equivalent to (or better than) the methylene chloride-based glue. The workability of the glue also was important; it had to both maximize tackiness and minimize dry time. Each glue was tested under different process variables to find the most effective application method. These process variables included: drying method (air or IR), application method (spraying or roll coating), and setting/bonding pressure (J-roll or pinch-roll). A waterborne neoprene-rubber contact adhesive was chosen, applied by HVLP guns, and dried by IR lamps. This system provides not only a safer glue with virtually no HAP or VOC emissions, but also one with greater bond strength than the glue it replaced.

Costs

Costs to reformulate the finishes were minimal because the sealer and topcoat required only very minor changes. However, the stains required several reformulations to achieve the desired appearance. This reformulation took approximately 18 months of research and development to accomplish. No new equipment was required because high-efficiency guns already were in use.

The methylene chloride-based glue was not only an environmental hazard, but dangerous to the health of the employees as well. Therefore, Crystal felt they needed to provide a better working environment for their employees. The equipment costs, including new HVLP guns and IR lamps, were approximately $110,000. In addition, labor costs from research and development, although not measured, were substantial because three full-time employees worked on the project for 18 months. However, the waterborne glue is only marginally more expensive per gallon ($16.50 compared to $15.00 for the methylene chloride-based glue) while the coverage is more than twice that of the old glue. In 5 months, 15 drums of the old glue were used; during an equivalent period of time, only 7 drums of the new waterborne glue are used. This increase in coverage has halved the glue supply costs.

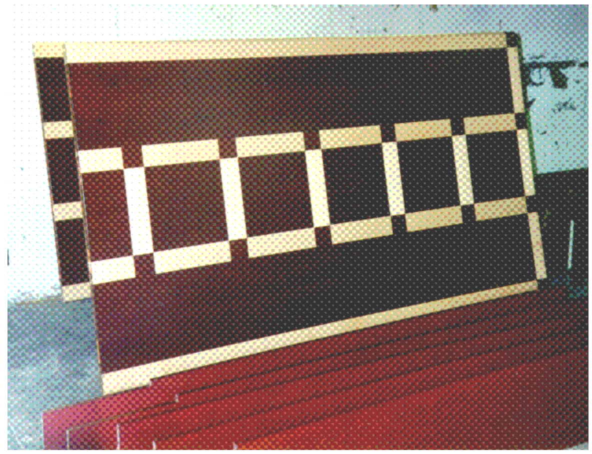
Emissions

According to Crystal, the reformulation of the finishing materials caused a significant decrease in their annual VOC emissions. In 1994, 472 tons of VOCs were emitted. By 1997, this number had been reduced to 152 tons of VOCs, representing a decrease of over 67 percent. The HAP emissions also decreased dramatically; Crystal is subject to the Wood Furniture NESHAP and was in compliance by late 1996. The change to a waterborne glue provided most of the HAP decrease; the previous glue was 88 percent methylene chloride. The new waterborne glue also has a low VOC content, only 0.10 pound VOC per gallon. Facility personnel stated that when Crystal converted to the waterborne glue, their toxic chemical use was reduced by 16 tons per year.

Case Study No. 9 – High-Solids Coatings
Design Fabricators
Lafayette, CO

Background

Design Fabricators produces custom store fixtures and entertainment/ornamental items. Most of their production consists of coated wood products made from sheet goods; 60 to 70 percent of the coatings are clear sealers or topcoats. A small percentage of the coatings, five to ten percent of total sales, are used to coat metal or fiberglass. The plant operates five days a week with two shifts. The number of hours worked and number of employees vary seasonally, but averages close to 200 employees on two 8-hour shifts. Approximately 25 of those employees are in the finishing department.


Product sample

In October 1994, Design Fabricators moved into their current location. Prior to the move, the local community raised concerns over emissions and the odor of the solvent-borne coatings. The company was interested in pursuing new finishing techniques and lowering emissions, but they found that information about low-VOC/HAP coatings was not readily available. By November 1995, alternative coatings were under serious consideration and were being tested for quality, durability, and cost effectiveness. The new coating system was fully implemented in early 1996.

Manufacturing and Coating Operations

Most commonly, raw material is purchased in sheet form. The sheet goods are then cut to size and edged with laminate or wood tape if necessary. Both processes are automated. Some solid woods, which need to be ripped, planed, and milled, also are used for products such as tables and benches.


Finishing department

The components are then taken directly to either the assembly area or the finishing department. Depending on the product, it may be finished before or


Product assembly

after assembly. In the assembly area, there are specified areas for different jobs. Products are assembled and sanded by hand. In the finishing department, the product is taken into one of the two spray booths and placed on hangers (the larger items are rolled in on trolleys). The hangers are moved manually throughout the finishing area, with the operators taking care not to touch the product until the finish is cured. Most of the coatings are applied using air-assisted airless guns, although a small number of custom jobs require conventional spray guns. The coatings are pumped from 55-gallon drums in the paint kitchen directly to the spray guns in the booths. The only exception is the catalyzed conversion varnish, which is mixed in 5-gallon batches and put into smaller pumps located in the spray booth. The stain is applied first and is hand wiped for some products. The product then is sprayed with a sealer and sanded. Finally, a topcoat is applied and the product is allowed to air dry. After the finish has cured, the product is packaged and shipped to the customer.

Conversion to High-Solids, Low-HAP Finishes

Design Fabricators tested several different coatings and suppliers before settling on their current finishing system. First, waterborne coatings were used on some of the smaller orders, but they caused several problems. The biggest problem was grain raise. When a waterborne product is applied to wood, especially the softer species, the grain of the wood absorbs the water and stands up, or raises. Grain raise results in a rougher finish that lacks the smoothness that is typically achieved using solvent-borne coatings. In an attempt to rectify this problem and smooth the grain, additional sanding was required. However, the operators often sanded through the seal coat. This would cause the grain to raise again when the topcoat was applied because the wood was re-exposed to a waterborne coating.

Another problem encountered with the waterborne coatings was drying time. To prevent the parts from sticking together, waterborne products generally require a much longer drying time before they can be stacked or shipped. This problem can be helped by adding drying ovens to speed the curing process. However, additional equipment would not only be expensive, but would also require more space than the facility can devote to finishing. A third problem Design Fabricators encountered with their waterborne coatings was a softer finish that was not as durable. Because of these difficulties, waterborne coatings were not chosen for the new system.

Design Fabricators next considered UV-cured coatings. Ultraviolet-cured coatings have the low-VOC/HAP advantage of waterborne products while producing a durable, high-quality finish. Grain raise is avoided because UV-cured coatings can have up to 100 percent solids and no water. The very-high solids content prevents the VOC and HAP emissions associated with traditional solvent-borne coatings. The curing time also is very short, only a few seconds. However, UV-cured coatings are most feasible for flatline finishing, making UV finishing impractical for Design Fabricators because of the wide variety of shaped pieces that they finish.

The final coating system tested by Design Fabricators included a high-solids catalyzed conversion varnish and low-HAP sealers and stains. The VOC and HAP content of these coatings is still low due to the high solids content, and the problems experienced with the waterborne coatings tested by the facility were avoided because the coating is acetone based. The acetone-based coatings are applied using spray guns, allowing easy finishing of shaped pieces. The main problem with acetone-based finishes is that they tend to dry too quickly. However, drying time may be adjusted by adding other solvents. Acetone also is very flammable, and fire risks are an important issue. However, because of the high-quality finish and compatibility with the existing finishing line, the high-solids, low-VOC/HAP system was selected. The new topcoat has around 40 percent solids, where the old topcoat had about 18 percent solids. Gradually, the old precatalyzed topcoats are being phased out and replaced with the high-solids catalyzed conversion varnishes. Catalyzed finishes have a higher solids content and result in a more durable finish. The harder finish is achieved because the coating is not only dried, but is cured by a polymerization reaction controlled by the amount of catalyst in the coating.

The transition to high-solids coatings was fairly smooth for Design Fabricators. There was a learning-curve period of six to eight months during which the operators became familiar with the new coatings and different coatings combinations were tried to achieve the best finish possible. Because the new system is compatible with the original solvent-borne system, the operators were able to make the minor adjustment rapidly. The coating process did not undergo much change when the coatings were changed. The new coatings are applied manually using spray guns, as were the old coatings.

Costs

Although the new finishes cost more per gallon ($18 per gallon versus $11 per gallon for the topcoat), the overall costs are approximately the same because of the higher coverage associated with high-solids coatings. Design Fabricators feels any slight increase in cost is worthwhile; the high-solids finishes are not only lower-emitting, they also produce a quality finish equal to, if not better than, the original solvent-borne system.

Emissions
According to data provided by the facility, the switch to high-solids coatings resulted in a considerable decrease in the annual VOC and HAP emissions for the plant. The coatings changes also served to address the local community's concerns about their emissions. The new coatings typically average around 1 pound of VOC per pound of solids. In 1995, before beginning the switch to the lower-emitting coatings, around 44 tons of VOCs were emitted. After the complete conversion to the new system, only about 36 tons of VOCs were emitted over a 12-month period. Although the difference seems small, the company's sales increased during that two year period ($10.1 million in 1995 versus $13.7 million in 1997). Design Fabricators was able to increase production and still lower their total mass emissions and their emissions per dollar of sales.

The reduction in HAP emissions was even greater. In 1995, approximately 20 tons of HAPs were emitted. By 1998, HAP emissions were almost eliminated, while production nearly doubled. The new coatings contain from 0.04 to 0.46 pound HAP per pound of solids. In addition, the glues, cleaning solvent, and stain base contain no HAPs.

Case Study No. 10 – High-Solids Coatings
Ethan Allen
Beecher Falls, VT

Background

Ethan Allen's Beecher Falls facility manufactures several styles of high-quality bedroom and non-upholstered living room furniture. The plant has approximately 500 employees and is the main economic force in the Beecher Falls area. The facility is located in the northeastern-most point in Vermont, on the border with both New Hampshire and Canada.

This facility was one of the largest emitters of air pollutants in the State. Every year their reports under SARA Title III publicized their position as one of the State's "worst polluters." In an effort to improve their image within Vermont and to comply with both Vermont's air toxics rule and the Wood Furniture NESHAP, the Beecher Falls plant decided to make changes that would reduce their air emissions. This case study describes the conversion to high-solids sealers and topcoats and other pollution prevention efforts.

Manufacturing and Coating Operations

Previously, the Beecher Falls facility used traditional nitrocellulose-based sealer and lacquer that contained 18 percent and 20 percent solids, respectively. With the traditional coatings, one sealer and two lacquer applications were necessary to meet the company's quality standards. The coatings were applied using conventional spray guns. In an effort to reduce VOC emissions in the early 1990s, Beecher Falls switched to a higher-solids sealer and lacquer that contained approximately 24 percent and 28 percent solids, respectively. They encountered no problems upon switching to these higher solids coatings. Beecher Falls continued to investigate high-solids coatings in an effort to use an even higher-solids product to further reduce air emissions.

After careful evaluation, including pilot testing at the plant, they chose a 35 percent solids sealer and lacquer. The new system was fully operational by March 1995 and is currently in use. Because of the higher solids content of the new lacquer, the need for a second lacquer application was eliminated.

In the late 1980s, the Beecher Falls facility began using HVLP guns for some of their coating applications. The main motivation for this switch was the ergonomics of the lighter guns. However, in 1993 a study was done at the facility to investigate replacing all of the conventional guns with HVLP. On-line testing indicated an increased average transfer efficiency from 30 to 60 percent. This improved coverage reduced the amount of coating lost to overspray as well as the emissions from that overspray. The HVLP guns were implemented quickly.

Conversion to High-Solids Coatings

Through instituting a pollution prevention program, the Beecher Falls Division of Ethan Allen reduced VOC and HAP emissions by 28 and 55 percent, respectively, improved the work environment for its employees, and improved the efficiency of its production process. None of the changes made by Beecher Falls required a substantial capital investment, and each had a short payback period, making the changes economically attractive.

Beecher Falls was able to increase coating solids by working with their coating supplier and their equipment supplier to develop a satisfactory system. For example, the high-solids material could not be applied at room temperature with the HVLP spray guns. There were two feasible alternatives to make the HVLP guns work: using high pressure guns (1,500 to 3,000 psi) or heating the coating material to lower its viscosity. Beecher Falls chose to electrically heat the material in the coating supply line so that it reaches the gun at approximately 90^{o} F. In addition, they modified the HVLP gun cap, nozzle, and tip to enable proper coating application. These modifications have not increased the pressure at the point of atomization beyond the 10 psi definition for HVLP.

The primary benefit to Beecher Falls has been that only one lacquer application is now needed to achieve adequate build. This eliminated the use of the second lacquer spray booth, and the two spray operators were transferred to other positions. At Beecher Falls, this newly available space was particularly valuable, and allowed for changes in the layout of the finishing department to make it more efficient. The elimination of one spray booth also reduced maintenance requirements, and subsequently the amount of solvent cleaner needed. The elimination of the second lacquer coat eliminated the need to sand the surface between coats (scuff sanding), again eliminating the need for two employees to perform this operation.

Reducing the lacquer application to one coat also produced savings on coating material, as well as reducing labor and air emissions. However, eliminating the second lacquer application requires stricter quality control and operator care when the single topcoat is applied. There is no longer a margin for error with the first coat that can be made up for with the second coat. Initially, repair requirements increased. The facility was able to overcome this problem with operator retraining and technique adjustments.

Beecher Falls believes that the new coatings and spray guns have improved worker health and safety conditions at their plant. There is less bounceback when the coatings are applied, reducing potential worker exposure. Lower bounceback also lowers overspray and reduces material use and air emissions further. After an initial period of adjustment, sealer and lacquer operators have expressed satisfaction with the new coatings and appreciate their improved work environment.

The sealer coat now has a better build, so when it is sanded there are less “cut throughs” (the operators do not sand completely through the sealer). This reduces the amount of touch-up required before lacquer application by approximately 30 percent over the previous sealer. The new lacquer covers defects better and reduces lacquer runs and sag, subsequently decreasing the need for final product repairs by approximately 50 percent. By switching to the high-solids sealer and lacquer, Beecher Falls believes that their final product quality has a fuller feel and better build. However, because the sealer coat has a higher build, it is more difficult to sand and requires an average of 30 percent more time per item. To maintain the same production level, two additional workers have been added to the sanding station. In addition, Beecher Falls replaced their block sanders with orbital sanders and now uses a different grit paper.

Other start-up problems the facility experienced with the new coatings were overcome. For instance, the high-solids sealer requires more time to dry, so Beecher Falls increased the airflow in the sealer flashoff area. The longer drying time and increased airflow increased the potential for dirt to contaminate the coating as it dried. Beecher Falls constructed a flashoff tunnel to help prevent the contamination. Layout changes to the finishing area were required to construct the tunnel.

Other Pollution Prevention and Recycling Efforts

HVLP guns

In the late 1980s, Beecher Falls began using HVLP guns for some of their coating applications because they are lighter and therefore ergonomically preferable when compared to conventional spray guns. Early in 1993, plant personnel investigated the possible benefits of replacing all of the remaining conventional spray guns with HVLP guns. Thorough testing on the actual finishing line for basecoat and stain application revealed (1) an average increase in transfer efficiency from 30 percent with conventional guns to 60 percent with HVLP guns, (2) a 39 percent reduction in the amount of finishing material used to coat the same item, and (3) a corresponding decrease in air emissions from the stations that had been using conventional spray guns.

At the time of the test, Beecher Falls still had 25 conventional spray guns. Approximately 53,000 gallons of finishing material was being sprayed from these 25 guns each year. A 39 percent reduction in material use translated into a savings of over 20,000 gallons of finishing material each year. Beecher Falls estimated that over $145,000 in finishing material purchase costs would be avoided each year if HVLP spray guns were used throughout the plant. The cost of each new HVLP spray gun was approximately $325, or a one-time $8,125 capital cost to produce a savings of over $145,000 each year thereafter. The payback period was less than 3 weeks. The conversion to HVLP spray guns was immediately approved and implemented. The only additional cost was training the operators on how to properly use the new spray equipment.

Waterborne basecoat
Beecher Falls has reformulated their color primer to a waterborne material. However, the waterborne material meets the facility's quality specifications only for opaque enamel applications. The black enamel used over the aqueous primer is still nitrocellulose-based due to space constraints that cannot support the increased drying time that would be required if aqueous paint were used. Only certain portions of some pieces are painted black, so the overall air emissions from the facility are not significantly affected by the switch to a waterborne primer because it is not used in large quantities.

Waterborne spray booth coating
The spray-on strippable spray booth coating used at Beecher Falls now is waterborne. With 23 spray booths in use, and stain booths coated every 6 weeks and the others coated 4 times each year on average, this coating change also helps to reduce air emissions.

Lacquer dust reclamation
The sealer and topcoat spray booths use metal filters. The filters are brushed at the end of each day to remove as much lacquer dust as possible. The lacquer dust is collected along with dust that has accumulated on the floor and placed in a 55-gallon drum. The dust is hand sifted through filters to remove impurities and then mixed with solvent to make a topcoat material that is used to coat the interior of drawers and backs of items. Beecher Falls uses approximately three 55-gallon drums of reclaimed lacquer dust each week, diverting it from disposal. Approximately one drum of unusable dust (the filter reject) requires disposal as a hazardous waste every month. Including the avoided cost of disposal and the 3 to 4 hours of labor spent on the reclamation effort each day, Beecher Falls estimates that it costs them approximately $4 per gallon to reclaim their lacquer dust, much less than the cost of purchasing new sealer or lacquer. The main drawback to the lacquer dust reclamation effort is that the recovered dust is potentially explosive. Extra care must be taken when handing and storing this material.

Costs
The costs of the conversion to high-solids sealer and lacquer are given below. The internal rate of return was 316 percent and the payback period was 4 months (based on a 5-year analysis, no depreciation of equipment).

Item	Savings or (Cost)
Labor	$175,000 per year
Materials	($42,000) per year
Capital Costs	($42,000)
Internal Rate of Return	316 percent
Net Present Value	$462,176
Payback Period	4 months

Labor

Elimination of two lacquer operators and two scuff sanders, reductions in pre- and post-lacquer touch up, and the addition of two sealer sanders combine for an estimated annual labor savings of approximately $175,000.

Material

The new high-solids coatings are twice as expensive as the original low-solids coatings on a per-gallon basis. However, because the solids content is higher, less material is needed to achieve the same dry mil thickness. In addition, one lacquer application was eliminated. Therefore, the total quantity of coating used is less. Beecher Falls estimated an increased material cost of approximately $42,000 per year. Beecher Falls has not determined the effect on electricity costs resulting from the in-line heaters and the increased airflow in the sealer flashoff area. However, due to the elimination of the second lacquer spray booth and its ventilation requirements, they do not believe there is a substantial increase.

Capital Costs

The cost of adding the in-line electrical heating systems and the flashoff tunnel was approximately $42,000.

Emissions

Air emissions of HAPs and VOCs from the Beecher Falls plant are almost exclusively from the finishing process. Prior to their pollution prevention efforts, the production of furniture involved the application of 70 different finishing materials in a total of nine separate applications. These were all low-solids, solvent-borne coatings. All finishing material is applied manually using a spray gun. In 1992, the plant reported total VOC emissions of 300 tons and HAP emissions of 95.6 tons to the U.S. Environmental Protection Agency.

The VOC and HAP emission reductions have been substantial because air emissions are directly related to the amount of coating used. Eliminating one lacquer application reduced material usage for lacquer coating by 46 percent. If the new coating formulations had the same VOC and HAP content as the old coatings, VOC and HAP emissions from the lacquer application step would be reduced by 46 percent. However, the coating formulations are not the same (42 percent fewer VOCs and 83 percent fewer HAPs), so reportable emissions from the lacquer application step have been reduced by more than 46 percent.

In 1995, production at Beecher Falls was 18.5 percent higher than in 1992, yet total VOC emissions were 257 tons per year and HAP emissions were 50.5 tons per year. Taking increased production into account, VOC and HAP reductions on a per part basis were 28 and 55 percent, respectively. No portion of the emission reduction was achieved through reformulating any coatings with acetone. Some stains and basecoats have been reformulated with acetone as the primary solvent; however, Ethan Allen has included acetone emissions in the 257 tons per year VOC figure. Acetone was removed from the U.S. EPA's VOC list on June 16, 1995 and is not a listed HAP, but it remains as a listed hazardous air contaminant under Vermont regulations.

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 the 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, or the ETI project, please contact Jennifer Griffith at (617) 367-8558, ext. 303.

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

Background

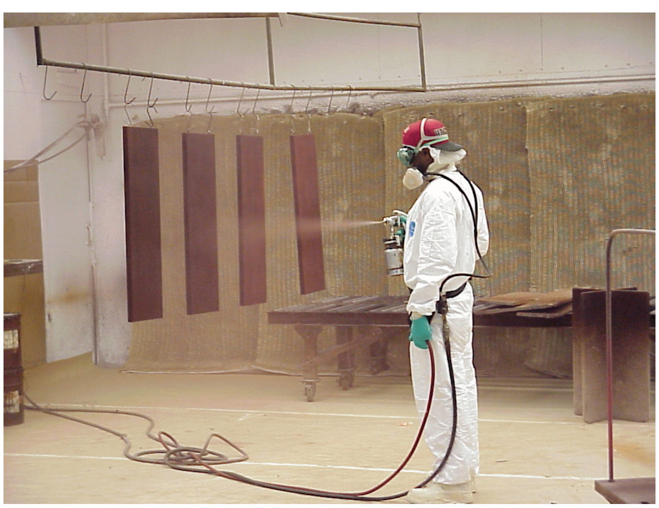
Geiger Brickel began producing high-end wood office furniture in Toronto, Ontario, in 1964. The company has two manufacturing facilities in Atlanta, referred to as the Fulton facility and the Assembly to Order (ATO) facility. The Fulton facility began operation in 1978, has about 290 employees, and produces 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.



Shading spray booth

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.


Waterborne urethane spray booth

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.

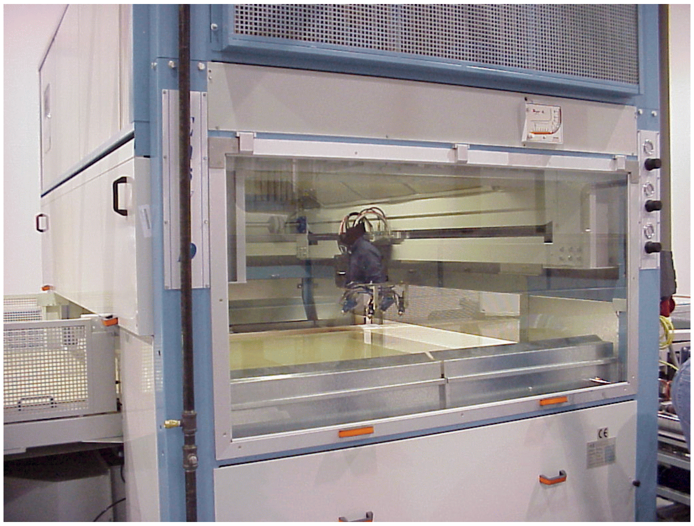

Reciprocating sprayer

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^{o} 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^{o} and 78^{o} 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^{o} 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

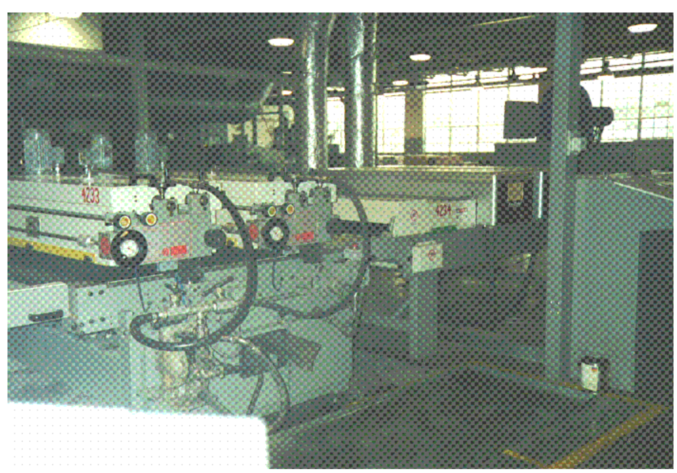
Background

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



UV coating line

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.


Robotic spray booth and curtain coater

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[4, 5]
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.


Product sample

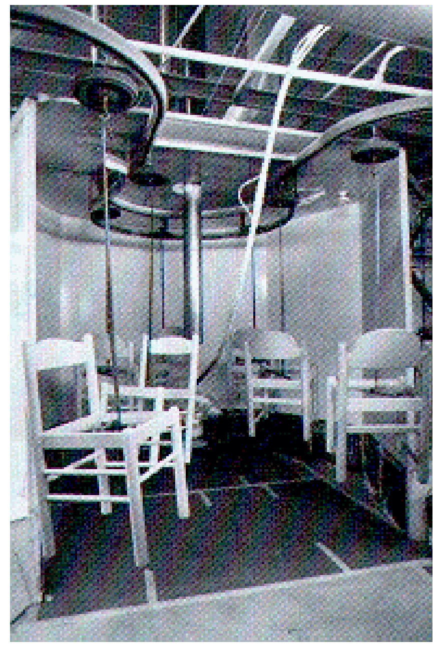
The Pompano Beach facility has reduced emissions in both their finishing and gluing operations. In mid-1984, Loewenstein began investigating the use of UV-curable coatings in an attempt to increase finish quality and speed the required curing time. By 1987, different technologies were being tested at 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.



Disk booth

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. 16 – Waterborne Coatings
Northshore Wood Products
Duluth, MN

Background

Northshore Wood Products manufactures gift and decorative accessories such as clocks, shelves, and plate racks. Some small fixture work also is done on a contract basis. There are twenty employees; work is done by hand and all of their products are finished. The main wood species used is oak, although other species are used. Northshore offers eight stain colors on any of their products; the most popular is the medium oak finish. The decision to use waterborne coatings was prompted by a problem with disposal of rags used to hand wipe their solvent-borne stains.


Product sample

Manufacturing and Coating Operations

Northshore Wood Products purchases kiln-dried lumber and does all cutting and shaping on-site for most orders. Occasionally, a larger order is out-sourced to another company for shaping. All pieces are sanded and finished. The first step of the finishing process for smaller parts is to dip them into the waterborne stain. After dipping, the pieces are immediately hand wiped to removed excess stain and are placed on racks to dry. Stain is hand wiped onto some of the larger parts that cannot be dipped.


Sealer spray booth

The pieces then are moved to the spray booth where the sealer coat is applied using an HVLP gun. The parts are racked again, and allowed to dry. Some pieces receive a coat of sealer on both sides. Once the seal coat is dry (35 to 40 minutes per side), the pieces are sanded to smooth down any grain raise that has occurred. The topcoat is applied with an HVLP gun and the pieces once again are racked to dry before being packaged for shipping.

Cleaning Operations

Before switching to the waterborne finishing system, disposal of cleaning rags from the solvent-borne system was a major problem for Northshore. In 1995, the local waste disposal facility tightened the requirements for products it would accept for incineration.

When the facility stopped accepting solvent-borne stain rags from Northshore, it became apparent that exploring other stain options was necessary. The solvent-borne stain rags were classified as hazardous waste and could only be disposed of at high cost. With the waterborne system however, cleaning rags can be disposed of in Northshore's dumpster at no additional cost. The coating lines and spray guns are drained and cleaned daily. The waterborne coatings are extremely hard when dry, so Northshore uses a special cleaning solution designed by their coating manufacturer to clean the waterborne coatings from the equipment.

Conversion to Waterborne Coatings

The switch from solvent-borne to waterborne coatings was a long and complicated process. Northshore tried products from several different coating manufacturers, but none provided an acceptable waterborne stain, sealer, or topcoat. Northshore then turned to another coating supplier, Van Technologies. As a smaller supplier, Van Technologies provided personal service not offered by the larger suppliers. Problems with the coatings were immediately addressed and quickly resolved. A suitable stain was developed, solving the hazardous waste generation and disposal issue. As the product evolved, the clarity and uniformity of the stains improved, although the quality was not as good as the original solvent-borne system. Necessary reformulations were performed in a timely manner. In short, Van Technologies listened to what Northshore needed and created a coating system to achieve the desired result. The process was lengthy; it took months to create the right coatings, and the process is continuing to evolve. Initially, the waterborne sealer produced a very cloudy finish that was unacceptable to Northshore. To avoid an inferior finish, but still use the waterborne products, two coats of waterborne topcoat were applied. One coat replaced the seal coat, and the other functioned as the typical topcoat. While this system produced a high-quality finish, the cost was higher because the topcoat is more expensive. Fortunately, the problems with the waterborne sealer were corrected and Northshore now applies one coat of waterborne sealer and one coat of waterborne topcoat. The result is a quality finish using waterborne stains, sealers, and topcoats.

Because the majority of their pieces are small, Northshore applies their stain by dipping the product into the stain container. After the switch to waterborne coatings, the dipping process caused several problems. The stain was forming bubbles on the surface of the product, causing an inconsistent finish. There also were problems with the waterborne stain spoiling; wood spores were contaminating the stain when pieces were dipped in the stain container. Northshore began spraying the stains in an attempt to eliminate these problems and also to reduce the coating time and grain raise. Unfortunately, the grain raise was not decreased and the spraying actually slowed the process down. At this point, Van Technologies reformulated the stain. They decreased the surface tension to prevent the bubbling and added a fungicide to prevent the wood spores from spoiling the stain. This reformulation allowed Northshore Wood Products to return to the original dipping process.

Northshore has not experienced many problems with the dry time of their waterborne coatings. They have installed several fans to keep the air in the facility circulating, and the time it takes for the operators to move the product through the finishing process usually is sufficient for the coating to dry between steps. Grain raise also has not been a prominent problem. The new sealer coats well and holds the grain down. Light sanding before the topcoat is applied eliminates any grain raise that does occur and the topcoat smooths out the final finish.

The operators went through a period of adjustment while the change was being made, but are now happy with the waterborne finishes. The elimination of the smell associated with the solvent-borne coatings and reduction in health risks made the adjustment to the new application techniques required by the waterborne coatings worthwhile.

Advantages of the waterborne system are numerous. The elimination of the hazardous waste generation and subsequent disposal costs was one immediate benefit that prompted the switch. The reduction in fire hazards and improved working environment for the operators also were considerations that began the investigation into the waterborne coatings. Also, when Northshore was using the solvent-borne coatings, the humidity produced by the nearby lake would cause blushing of the lacquers, a problem eliminated with the waterborne topcoats.

Solvent-borne coatings are still in use for the natural finished oak products (no stain is applied) because Northshore has not found a waterborne coating that can produce the amber color the solvent-borne coatings add to the wood color. However, natural finish items make up only one percent of total sales, making the VOC/HAP emissions and waste disposal problems from them minimal.

Costs

The costs of the conversion were relatively low, mainly because there was not a lot of equipment to be replaced. Nozzle tips for the HVLP guns were changed to a different size, but the pressure pots were not replaced with stainless steel. Instead, the pots were sprayed with a coating of the waterborne product to seal them, and Northshore has not experienced any problems with this method.

The ongoing cost of using the waterborne coatings is higher than that of the solvent-borne system. This is because the waterborne coatings cost more per gallon and have approximately equivalent coverage. Normally, the coverage with a waterborne product is greater because of the increased solids content. The coverage was not increased for Northshore partially because of the increased thickness of the sealer to help in reducing grain raise. In terms of cost per square foot coated, the waterborne system costs approximately 17 percent more. However, Northshore feels this cost increase is worthwhile due to the increased safety of the work environment.

Emissions
Because of the size of their operation, Northshore has never had an emissions problem, but the switch to waterborne coatings has nearly eliminated HAP emissions and reduced VOC emissions. The original coatings produced a total of 2.18 tons of VOCs per year and 2.12 tons of HAPs per year. With the new waterborne finishing system, these emissions have been reduced to 0.38 ton of VOC per year and 0.01 ton of HAP per year.

Customer Feedback
Customer response was negative at the beginning; there were complaints that the new product did not match in color with the old product. There also were complaints about the increased roughness of the finish. As the coating quality improved, especially the sealer, the negative comments decreased. In fact, the waterborne topcoat provides a more durable finish than the solvent-borne lacquers did.

Case Study No. 17 – Waterborne Coatings
The Pine-Tique Furniture Company
Minnetonka, MN

Background

The Pine-Tique Furniture Company was founded in 1973 and originally produced only Early American style pine furniture. Today, they have expanded to include more styles and many wood species. The catalogue currently contains over 125 pieces, and Pine-Tique also manufactures custom designs. There are 25 employees on two shifts. The finishing department includes eight full-time and two part-time employees. Pine-Tique finishes an annual total of about 148,000 board feet. They began testing waterborne coatings in 1996. In 1998, approximately half of their production was finished with a waterborne system; the rest was finished with a solvent-borne system.

Reasons for Conversion

In 1995, it was obvious to the management at Pine-Tique that an expansion of their production capacity was necessary to keep up with growing customer demand. However, the decision also was made that, if possible, the expansion would occur without increasing VOC/HAP emissions. This decision prompted research into currently available alternative coatings. In 1996, Pine-Tique began the process of testing waterborne coatings with the assistance of the Minnesota Technical Assistance Program and the Minnesota Pollution Control Agency.

New Designs

A new finishing area was designed and built to accommodate the projected increase in production. The new finishing area would consist of two sanding and two spraying work stations. The sanding stations provide the prep-sanding before finishes are applied and sealer sanding between coats. Sanding is done by hand with random orbital disc sanders and fine grit paper to minimize grain raise. All sanders are attached to a central dust collection system to trap particulate matter. The sanding stations also are used for attaching final hardware.

Carts provide easy movement between stations

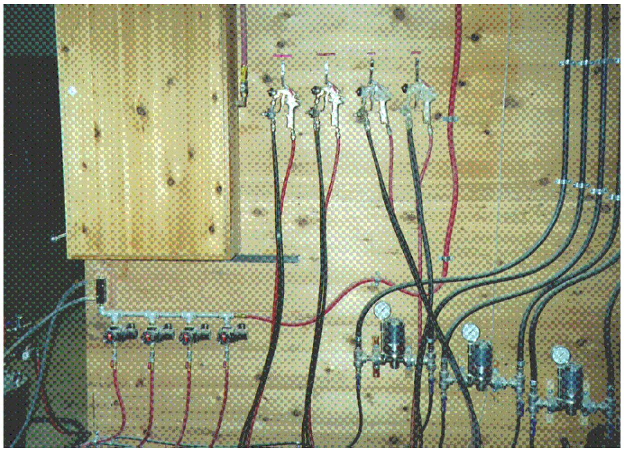
Operator convenience and comfort was the primary concern when designing the new work stations. All furniture is placed on wheeled carts to allow easy movement from one station to another. Each of the four stations is equipped with a custom-designed, built-in floor lift that allows the operator to lock and lift the various sized furniture carts to the desired height and rotate the pieces 360 degrees while finishing. This configuration is much easier on the operators and allows Pine-Tique to finish a wider variety of products than the standard conveyorized finishing line. The custom furniture lifts were built with the help of a small grant from Minnesota OSHA.


Spray booth

Many spray equipment changes were necessary because Pine-Tique's original system was not compatible with waterborne coatings. Pumps and fluid lines needed to be plastic or stainless steel to be waterborne compatible, and conventional spray guns were replaced with HVLP guns. The spray equipment changes were facilitated by a low-interest loan made available by the Small Business Assistance Program of the Minnesota Pollution Control Agency.

Another operator-friendly feature of the new finishing area at Pine-Tique is in the paint kitchen. Each of four coating pump systems is attached to a lift system, which lifts the pump high enough to allow an empty drum to be easily rolled out and replaced.

Each spray booth is outfitted with four dedicated lines (two different toners, a sealer, and a topcoat, all waterborne) that are on a circulating system and receive their coatings directly from the 55-gallon drums in the paint kitchen. These coating lines are completely independent of each other, allowing operators in both spray booths to spray the same coating simultaneously, if necessary. The waterborne finishing system typically consists of a toner, wiping stain, sealer, and topcoat. Because there are not dedicated lines for the stain colors, they are applied from pressure pots and 5-gallon pumping systems.


Dedicated spray lines

There are no dedicated lines for the solvent-borne coatings because Pine-Tique hopes to continue to decrease the amount they use over time. Smaller quantities of solvent-borne coatings are applied using conventional spray guns from pressure pots. The larger quantities of solvent-borne coatings are applied using conventional spray guns and pumped from 55-gallon drums. All drums and pressure pots are on rollers to facilitate movement between spray booths and the paint kitchen.

Cleaning Operations

Cleaning operations at Pine-Tique are minimal because of the use of dedicated lines. Dedicated lines eliminate the need for flushing between color changes. Line flushing generates a large quantity of wastewater and cleaning solution. Eliminating line flushing dramatically decreases the amount of cleaning solution used and wastewater generated. However, the waterborne stains currently are not on a dedicated line system; Pine-Tique hopes to install dedicated lines for the most popular stain colors in the future to further reduce cleaning.

Pine-Tique buys a cleaning solution from their coating supplier that is formulated specifically for cleaning their waterborne coatings. A typical cleaning cycle consists of two 1-quart rinses of water followed by one 8-ounce rinse of cleaning solution. Only five to six gallons of wastewater is produced per week; any pollutants are so dilute that the wastewater can be sent through the municipal sewer system.

Conversion to Waterborne Coatings

The development period was a two-year process, during which the quality of products finished with the new waterborne coatings was disappointing. The final finish was rougher due to grain raise and lacked the depth of color desired by Pine-Tique. In 1998, the waterborne testing process began to gain speed. A new coating supplier, Van Technologies, provided a waterborne coating system which produced a high-quality finish equivalent to the original solvent-borne system. Van Technologies also reformulated their coatings to meet Pine-Tique's individual needs, a service the previous suppliers did not provide.

Operator training was accomplished mainly through trade magazine articles on waterborne finishing techniques. There was not much of a change because the waterborne coatings are applied by spray guns, as the original solvent-borne system was. The conventional spray guns from the solvent-borne system were replaced with HVLP guns for the waterborne system, but the operators found the differences between the two types to be minimal. There also are differences in the behavior of the coatings during application, but they were identified and resolved fairly quickly by the operators.

Currently, approximately 50 percent of the facility's products are finished with the waterborne system. All new product lines are finished with the waterborne system, but some of the older product lines still are finished with the conventional solvent-borne system to avoid any color-matching problems with vendors' back-stock. Gradually, the older product lines are being converted to the waterborne system, and Pine-Tique hopes that they will eventually convert 80 percent of their production to the waterborne coatings.

Costs
The major expense for Pine-Tique was the purchase and installation of water-compatible equipment. The lines and pumps were replaced with plastic or stainless steel. The spray guns were replaced with HVLP guns. Stainless steel equipment, on average, was two or three times the cost of the equipment Pine-Tique originally was using. The total capital expenditure for new equipment was $24,000.

There also was a cost difference in the coatings themselves. The waterborne coatings cost approximately twice as much per gallon as the equivalent solvent-borne coatings. However, because of a higher solids content per gallon than common solvent-borne coatings, the amount of waterborne coating used per board foot of wood is less than the solvent-borne coating. So, the better coverage rate of the waterborne coating offsets part of its higher cost. Since the waterborne finish is more durable (increased scratch and chemical resistance), and provides environmental and workplace health benefits, Pine-Tique feels the improvements outweigh the cost difference.

Emissions
Pine-Tique's standard solvent-borne lacquer contains 5.5 pounds of VOCs per gallon. The new waterborne topcoat contains 2.92 pounds of VOCs per gallon, and the sealer contains only 2.81 pounds of VOCs per gallon. All waterborne products used at Pine-Tique also are no-HAP products. This change in VOC/HAP content dramatically reduced the facility-wide emissions.

In 1995, when an all solvent-borne coating system was in place, Pine-Tique emitted 8,970 pounds of VOCs. Taking production into account, this is equivalent to 0.10 pound of VOC per board foot of furniture produced. In 1998, the VOC emissions were 9,427 pounds. Because of the increase in production, this is equivalent to 0.064 pound of VOC per board foot of furniture produced. From 1995 to 1998, there was a 75 percent increase in production but only a 10 percent increase in VOC emissions.

Customer Feedback
Customer reaction was negative at the beginning of Pine-Tique’s conversion to waterborne coatings. In 1996, the finish was rough and lacked the depth of color achieved by the solvent-borne system. However, as the coatings were reformulated, the finish quality improved and the customer complaints ceased. The current waterborne system provides a more durable finish than the solvent-borne system. Pine-Tique is pleased with the continued improvement of the quality of the waterborne coatings that they are applying.

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

Background

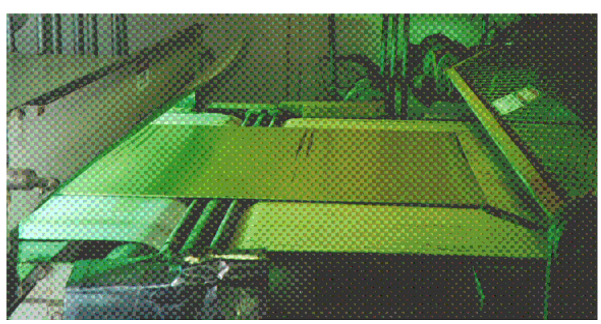
Prestige was founded in 1967 and produces all-wood, semi-custom cabinetry. Oak, maple, cherry, and hickory are the primary wood species and are finished with eight different stain colors. While some plywood veneers are used, there is no particleboard in any of Prestige's products. Prestige operates one 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.

Automated flat line

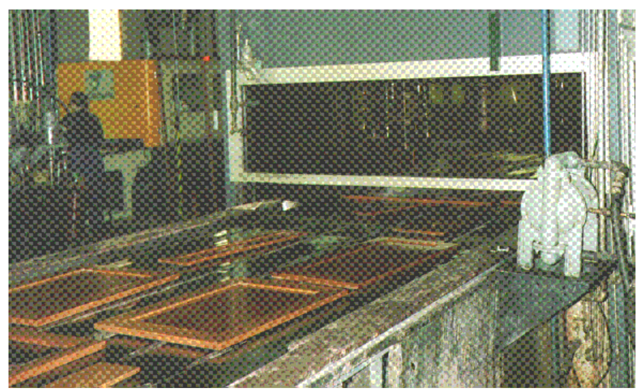
Prestige operates two automated finishing lines: a flat line and a spray line. There also are two small spray booths, one for touch-up and repair and one to apply coating to parts that cannot be finished on the automated lines. The pieces that cannot be finished by the automated lines make up a small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



UV oven

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.


Automated spray line

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.


Hand-wiping stain on component edges

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.


Spray booth

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.

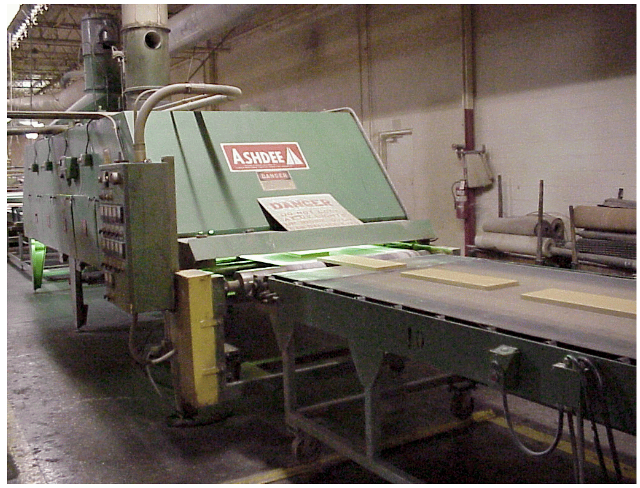
Riverside also has a small spray booth off the main cart line which is used to coat smaller products, such as knobs or drawer sides. This helps to alleviate back-ups on the main spray line and is more cost effective than running a cart through the main line with only a few smaller pieces on it.

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.



UV oven

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. 20 – High-Solids Coatings and Waterborne Adhesives
Saloom Furniture
Winchendon, MA

Background

Saloom Furniture Company manufactures casual dining furniture and is based in Massachusetts. The company was started in 1982 by Peter Saloom and has evolved into a multi-million dollar company with more than 125 employees. The company expects to have more than $13 million in sales in 1998.


Product sample

Saloom's basic business philosophy is to design, finish, market, and distribute. Customers can choose their own colors, fabrics, and tile designs, and Saloom will deliver the finished furniture in 3 to 4 weeks to the customer. Dining tables with ceramic tile inserts in wood frames were one of Saloom's first products, and this product has continued to be their best seller. They have added chairs and bar stools in the last few years to complement the tables and round out their product lines. They also coat a small volume of case pieces, such as buffets and hutches.

Saloom's manufacturing facility is located in Winchendon, MA, and is their only manufacturing facility. They consider themselves more of a finishing and final assembly operation type of furniture manufacturing facility. Of Saloom's 125 total employees, about 75 are directly associated with the manufacturing operations. Lloyd LeBlanc is the production manager and provided most of the information for this case study. The manufacturing facility works 1 shift, 5 days per week, with an occasional Saturday morning or extra hours on some days during their peak seasons. With their current production lines and floor space, they can increase the manufacturing staff by 40 percent before they would have to add a second shift. Saloom experienced 20 percent growth in 1998.

Winchendon is located in an area designated as attainment for ozone and the air quality monitors in the area show that the region attains the ozone standard. However, Massachusetts is within the political boundaries of the Ozone Transport Region.

Manufacturing and Coating Operations

Saloom receives most of their furniture components premilled and ready for final assembly and finishing. Most of the tables and chairs are made of solid maple or solid oak. The manufacturing area basically is divided into two lines. One line is used for assembling and finishing chairs and table base components. The second line is used to assemble and finish the wooden table tops or wooden frames. When Saloom added chairs to complement their table product lines, the facility's chemical usage more than doubled because of the additional surface area to be coated.

Chairs and Table Base Finishing Area

At the time of the visit to Saloom's facility, the production line was coating 230 pieces per day. Each coating is applied in a separate spray booth with HVLP spray guns. Pieces that will receive a stain first are sanded, and then toner is applied. Eight colors of toner currently are used, each with a dedicated line and gun. The toner is not wiped, and the pieces are left to dry about 30 minutes before receiving the next coating. The next spray booth is used to apply stain or whitewash. The stains are hand wiped and the pieces are inspected. The products receive a sealer, which is sanded by hand, and then receive a topcoat.

Some pieces receive only a sealer and topcoat if a natural appearance is desired. If the piece is to receive a color coat instead of a stain, it is sanded and finished with two coats of either white, black, or green paint. After the final coat, the pieces are inspected and sent on a conveyor to the packaging area.

Table Finishing Area

The table tops enter the finishing area from the sanding area via a conveyor and are taken to the toner booth where they are sprayed (except for the tile-top table frames, which do not receive toner). Dry time is approximately 30 minutes. The next step is the stain booth, where the stain is hand wiped and allowed to dry for 30 minutes. The table tops then go to the sealer booth, receive a sealer, and are allowed to dry for 1 hour. They are lightly sanded and sent to the clean room for the topcoat application. The tables are allowed to dry and are inspected. Casegood components also are finished in this area.

Gluing Operations

Saloom produces 40 to 45 tables per day and approximately half of those have inlaid ceramic tiles. The tiles are glued to the table tops and then silicone grout is applied around the tile edges. The grout is applied in an area enclosed with plastic curtains to prevent any particles from migrating to the finishing area where they can cause "fisheye" defects in the topcoat. Tables are packaged and shipped unassembled.

The adhesive currently used by Saloom in their manufacturing operations is "Titebond™ Solvent-Free Construction Adhesive" supplied by Franklin International, Inc. As suggested by the name, the material has a very-low VOC content: 0.043 lb/gal VOC.

Saloom started manufacturing plastic laminate table tops in 1997. The contact cement used on some of the plastic components had a high VOC and HAP content, but no other glues that they tested performed as well. They wanted to continue reducing air emissions and the product line was not selling well, so they discontinued the product line instead of furthering their marketing efforts. Some of their other table tops are solid Corian® or granite tops and have no associated coatings or emissions.

Cleaning Operations
The finishing line operators change the sealer and topcoat booth filters daily and clean the spray booths thoroughly once per week with solvent (e.g., booth stripper or lacquer thinner). Cardboard also is used to cover the floor during cleaning operations. The spray gun tips are cleaned daily with lacquer thinner and the coating lines are flushed once per week. Having dedicated lines for each color coat eliminates the need for flushing the lines during color changes.

Facility Experience with Coating and Glue Alternatives
Saloom looks for products that have low impact on the environment. They started manufacturing and finishing solid-wood top tables five years ago and have evaluated several different types of finishes. Saloom tests all finishes for usability and durability. They have their own internal tests based on their experience with customers. Over the past few years, Saloom has tested several waterborne finishes, but none of them have been able to meet their performance standards. Issues they experienced with the waterborne coatings tested included: longer dry times; rough finish due to grain raise ; need for multiple coats to achieve the same finish resulting in higher material costs; and cloudy clearcoats. The dry times for the coatings tested were about four times as long as the coating they currently use. Because Saloom does not have the available floor space to handle that many additional in-process parts between spray booths, they will have to install some type of forced drying system if they begin using waterborne coatings.

Due to regulatory issues and a desire to keep their emissions under 50 tons per year, Saloom expects that they will be switching to some type of hybrid waterborne system in the next 2 to 4 years and will most likely install IR ovens to cure the coatings. They expect to convert to a waterborne topcoat first, and then eventually convert to a waterborne sealer and stain if they can find a high-quality product suited to their applications. They estimate that conversion to a waterborne topcoat will reduce their emissions by 20 percent.

Saloom also investigated high-solids, catalyzed coatings to replace solvent-borne nitrocellulose lacquers. One of the current nitrocellulose lacquers has a solids content of 35 percent by weight and a VOC content of 5.1 lb/gal. Saloom is using high-solids, catalyzed sealers and topcoats applied with HVLP spray guns. There are ten spray booths located in the facility and they usually are dedicated to a given type of coating applied to a specific product or group of products. However, because much of the coating operation involves physical moving of the parts into and out of the spray booth by the operator(s), there is a lot of flexibility as to how the booths can be used. Saloom is satisfied with the performance of the high-solids coatings.

Saloom invested in HVLP guns, but they feel that operator training is essential to achieving any savings in overspray. Initially, the operators wanted to apply the coatings the same way they did with airless equipment and turn up the pressure on the HVLP guns. To ensure operators were using the guns correctly, Saloom tried several types of process checks for the coating operations, such as (1) limiting the amount of coating operators could use per product; (2) flow checks on the lines; and (3) in-house enforcement actions. LeBlanc commented that they had a hard time getting operators to use the equipment correctly.

Other alternatives Saloom investigated include electrostatic spray and flatline finishing with UV-curable coatings. They found that they cannot use electrostatic application equipment for coating solid wood materials, and flatline and/or UV-curing equipment is cost prohibitive for the number of tables they are producing.

Saloom switched to waterborne adhesives four years ago for gluing ceramic tiles to table tops. Prior to the switch, they were using a high-emitting solvent-borne glue that was 12 percent VOCs per gallon. With the waterborne glue there are virtually no VOC or HAP emissions. One of the results of switching to the waterborne adhesives was having to allow for a slightly longer dry time. However, the operators find this glue easier to use, because the solvent-borne glue dried so quickly they could not apply it to the whole table top at once. The total amount of adhesive used remained the same with the switch to waterborne glue. The silicone grout used between the ceramic tiles has no VOCs. LeBlanc indicated Saloom had to make sure there were no negative interactions between the grout and the waterborne adhesive.

Sherwin Williams and C. E. Bradley are used exclusively as coating suppliers and provide excellent service and support. LeBlanc said he has tried other coating suppliers, but did not experience the same level of customer service. Service is important to Saloom because of all the variables that can affect the final finish: wood, climate, application equipment, and application technique.

Costs

The Saloom representatives were not able to provide any cost information concerning the previous operational changes involving coatings and adhesives; however, they are anticipating the process change to the hybrid system to increase their operating costs by 5 to 10 percent.

Emissions

Saloom's VOC emissions in 1997 were 23.8 tons per year and they used approximately 10,000 gallons of coatings and solvents. Saloom's current permit allows 23 tons of

VOC emissions per year, compared to a 12 ton per year limit in 1992. LeBlanc stated that Saloom has requested a higher VOC limit (49 tons per year) to accommodate the growth that they have experienced, and the expected growth in the next 5 years. The State permit authority is in the final stages of approving the higher limit. Saloom also is subject to the Wood Furniture NESHAP.

Summary

Saloom has a good history of being proactive in their efforts to reduce and minimize VOC emissions, and is utilizing work practices, operator training programs, and housekeeping measures to minimize VOC and HAP emissions. They have reduced solvent use for gun cleaning and have dedicated color lines and pots at the finishing operations. Saloom has developed an internal operator training manual for finishers which has resulted in less rework and less material (coating and cleanup solvent) usage.

Saloom wants to develop a hybrid waterborne coating system utilizing a waterborne topcoat. They hope to start using waterborne stain(s) and sealer(s) eventually, but are concerned about the grain raise issue with current products on the market. These changes could reduce the VOC emissions another 20 percent.

Saloom anticipates being able to double their current production without doubling their VOC emissions. They believe that the coating suppliers will make improvements in their coatings before Saloom gets close to the new (proposed) limit of 49 tons of VOCs per year and they will find a waterborne finishing system that meets their needs.

Case Study No. 21 – Waterborne Coatings
Schrock Cabinets
Grants Pass, OR

Background

Schrock's Grants Pass plant has about 150 manufacturing employees. The manufacturing process at Grants Pass is similar to Schrock's other facilities. However, because this facility manufactures a specialty product line, cabinets from the Grants Pass plant are not mixed with cabinets from other Schrock facilities. The primary woods used for the cabinets are alder, oak, and maple.

The Grants Pass facility is not located in an ozone nonattainment area but is located within 100 miles of a designated Class I area. Under their Oregon permit, the facility has a cap on their annual VOC emissions. The facility also is subject to the Wood Furniture NESHAP.

Schrock Cabinets has made a corporate commitment to reduce their VOC and HAP emissions through the use of low-VOC and low-HAP coatings. The facilities in Hillsboro and Grants Pass, Oregon, are well below their State-imposed VOC limits and both met the HAP limits included in the Wood Furniture NESHAP months before the compliance date. While meeting the regulatory requirements was a primary driver in the decision to convert to a hybrid waterborne coating system, the company has moved beyond what is required by the regulations because of their commitment to the environment.

Manufacturing and Coating Operations

Cabinet doors are purchased premade from several different vendors. Cabinet components are finished on a hanging line. In a typical finishing sequence, one coat each of stain, sealer, and topcoat are applied, although two coats of stain or two coats of sealer are used for some applications. Stains are applied with HVLP spray guns, and sealer and topcoat are applied with air-assisted airless guns. All cabinets are finished and then assembled. The finishing line runs at about 26 feet per minute and production is about 500 cabinets per day. The majority of the facility's coatings are supplied by Akzo.

Conversion to Waterborne Coatings

The Grants Pass facility began online testing of waterborne stains in July 1996. In November 1996, the plant began using waterborne stains full-time. To date, the conversion to waterborne stains has been a success. In many cases, the waterborne stains actually provide a richer color than the solvent-borne stains used previously. The cost of the waterborne stains is 5 to 25 percent less than the solvent-borne stains.

Most of the testing of the waterborne stains focused on ensuring that the color of products finished with the waterborne stains was the same as the color of products finished with the solvent-borne stains. Although the facility's products are not mixed with products from other plants, which makes the color matching process easier, it is still important that the color match that of previous product lines. Schrock successfully converted to the waterborne coatings without sacrificing product quality. The color achieved with the waterborne stains used at the Grants Pass facility is richer than the color achieved with the solvent-borne stains.

The other issue with waterborne stains is grain raise. Schrock has found that surface preparation is the key to overcoming this problem. It is important to sand the product well before staining to rid the surface of as much fiber as possible. After staining, the parts are sanded again. Because of the grain raise, some parts, particularly those made of alder or veneers, receive two coats of sealer.

With the solvent-borne stains, the parts were wiped after the stain application. The facility has found that their waterborne stains work best without wiping. The facility was able to continue to use the same sealer and topcoat formulations that they used with the solvent-borne stains until they made the conversion to waterborne topcoats.

Unlike waterborne sealers and topcoats, waterborne stains do not require coalescing solvents. Therefore, the VOC content of the waterborne stains is very low. Facility personnel indicated that the waterborne stains used at the Grants Pass facility have a VOC content of about 0.01 pound VOC/pound solids.

The Grants Pass facility also conducted testing of waterborne topcoats. They found that the topcoat is not completely cured by the time it comes off the finishing line, so the finished pieces stick together if stacked on top of each other. They place the finished parts in a rack until the topcoat is completely cured, but plan to extend the finishing line and add a drying oven to cure the topcoat more quickly. Lengthening the finishing line will cost the facility about $200,000.

Costs

The cost of converting to waterborne stains has been minimal. Some labor and material costs were incurred during testing, but the waterborne stains are actually less expensive, in most cases, than the solvent-borne stains. The facility already had stainless steel lines in place. Labor costs are higher with the waterborne stains. The facility was able to eliminate a wiper because the waterborne stains do not have to be wiped, but they have added sanders because of the grain raising problem. The net increase in labor is about 1.5 people.

The primary cost involved in the conversion to waterborne topcoats is the pieces that must be reworked due to finishing defects. The planned modifications to the finishing line also are a significant cost. The waterborne topcoats cost more than the solvent-borne topcoats used previously, but they have a higher solids content than the solvent-borne topcoats.

Emissions

The Grants Pass facility is well below their VOC emissions cap and meets the HAP limits under the Wood Furniture NESHAP. According to data supplied by the facility, when they were applying a full solvent-borne system, they averaged 5.03 pounds of VOCs per gallon. With the hybrid waterborne system, they average 3.09 pounds of VOCs per gallon, a reduction of almost 40 percent. The facility can increase production significantly and still keep their emissions under the VOC cap.

Case Study No. 22 – Waterborne Coatings
Schrock Cabinets
Hillsboro, OR

Background

Schrock's Hillsboro, Oregon, cabinet plant employs approximately 300 people. The majority of the cabinets manufactured at the facility, approximately 90 percent, have a clear finish. The other 10 percent are finished with a pigmented topcoat. Oak, maple, hickory, and cherry are the primary woods used at the facility.

The Hillsboro plant is subject to reasonably available control technology (RACT) regulations. The facility has a yearly cap on their VOC emissions and a VOC limit on their topcoats. The facility is a major source and is subject to the Wood Furniture NESHAP.

Schrock Cabinets has made a corporate commitment to reduce their VOC and HAP emissions through the use of low-VOC and low-HAP coatings. The facilities in Hillsboro and Grants Pass, Oregon, are well below their State-imposed VOC limits and both met the HAP limits included in the Wood Furniture NESHAP months before the compliance date. While meeting the regulatory requirements was a primary driver in the decision to convert to low-VOC and low-HAP coatings, the company has moved beyond what is required by the regulations because of their commitment to the environment.

Manufacturing and Coating Operations

Cabinet doors are purchased premade from several different vendors. Cabinet components are finished on a hanging line. The line runs 22 to 25 feet per minute. In a typical finishing sequence, one coat each of stain, sealer, and topcoat are applied, although two coats of stain are used for some applications. Stains are applied with HVLP spray guns, and sealer and topcoat are applied with air-assisted airless guns. All cabinets are assembled after they are finished. In 1992, the facility converted to waterborne clear topcoats. They began using waterborne pigmented topcoats in 1998.

The waterborne topcoats are approximately 37 percent solids, with small quantities of glycol ether (about 2 percent) and methanol (about 5 percent). The facility also uses sealers with a relatively high solids content of about 38 percent. They have worked to reformulate their stains with less HAPs. They also have done some preliminary work with waterborne stains. Eventually, they will begin using waterborne stains, but they have no set date for doing so. One of the major problems with moving the facility to waterborne stains is color matching. The products manufactured at the Hillsboro facility are mixed and matched with products manufactured at other Schrock facilities. Because the color has to match the color of the products from other Schrock facilities, the Hillsboro facility probably will not convert to waterborne stains until the other

Schrock facilities that manufacture products for the same lines also convert to waterborne stains.

Conversion to Waterborne Topcoats

The conversion to waterborne clear topcoats at the facility was fairly smooth. Another Schrock facility had already converted to waterborne topcoats, and the Hillsboro facility was able to learn from their successes and failures. Testing was conducted at the Hillsboro facility intermittently for about 9 months before the facility converted to waterborne topcoats full-time. The Hillsboro plant had the advantage of already having stainless steel lines in place. Switching to stainless steel lines often is a large part of the cost of converting to waterborne coatings.

Although the conversion to waterborne topcoats was not extremely difficult, there still are some problems with the waterborne topcoats that the facility did not have with the solvent-borne topcoats. When the facility was using solvent-borne topcoats, parts removed from the finishing line could immediately be stacked. With the waterborne topcoats, parts removed from the finishing line must be placed in racks so they do not touch other parts. Parts that come in contact with each other will stick together because the topcoat is not completely cured when the part comes off the finishing line. Schrock extended their finishing line to help with this problem, but even with the additional drying time, the parts are not completely cured when they come off the line. Placing the parts in a rack until they are completely cured has helped to solve the problem, but it also requires some additional storage space.

Another problem with the waterborne topcoats appears only sporadically. The problem relates to the appearance of the finished product. For some pieces finished with the waterborne topcoats, the topcoat will move or creep away from the sides leaving a noticeable blemish in the finish. This problem affects approximately 1 percent of the finished parts. It tends to occur most on products manufactured with plywood. The blemish cannot be repaired and the finished part is scrapped. Schrock has worked closely with their coating supplier, Akzo, to try and identify the reason for this problem. At different times they thought they had the problem solved only to have it recur. Potential causes of the problem include hand lotions used by operators handling the product, latex gloves used by the operators, mold release agents in the plywood, or operator error. Errors by the operator applying the sealer are particularly critical. If the product is not sealed correctly, the waterborne topcoat will penetrate the wood, causing grain raising and other problems. In general, the waterborne coatings are more sensitive to changes or operator error than the solvent-borne coatings. While waterborne coatings are being used successfully at Schrock, the rejection rate for finished parts is higher than it was with solvent-borne coatings.

The switch to waterborne topcoats did require some retraining of the spray booth operators. The application techniques for waterborne coatings are somewhat different than for solvent-borne coatings. Although some initial training was required, the waterborne topcoats are, in some ways, easier to apply correctly. The waterborne topcoats have a milky appearance when they are first applied. Therefore, it is easier for the operator to tell where he or she has applied coating. They are less likely to miss spots with the waterborne coatings. The coatings lose their milky appearance as they dry, and the final product has a clear finish.

Switching to the waterborne pigmented topcoats was not as easy. For several years waterborne pigmented topcoats were not viable because they did not have sufficient elasticity. The lack of elasticity led to cracking at the joints. However, by working closely with their coating supplier, this problem was overcome and the transition to waterborne pigmented topcoats was made. Schrock's main issue with the waterborne pigmented coatings is that they settle out more rapidly than the solvent-borne coatings used previously.

Costs

Initially, the cost of the waterborne topcoats was approximately twice that of the solvent-borne topcoats, but has improved over time. The waterborne topcoats have a higher solids content than the solvent-borne topcoats so less coating is needed per piece. Other costs incurred by the facility in converting to waterborne topcoats include labor and materials associated with the testing and the capital cost of extending the finishing line. As discussed earlier, the facility already had stainless steel lines in place, which helped reduce the cost of converting to the waterborne topcoats.

The primary cost associated with the use of waterborne coatings now is the cost associated with the rejected pieces. These costs include the labor associated with milling and finishing the part and the cost of the finishing materials and wood. With a rejection rate of 1 percent of the finished product, this cost is significant. Schrock also has experienced an increase in cleanup and disposal costs, in part due to the shorter shelf life of the waterborne pigmented coatings.

Emissions

With the waterborne topcoats, Schrock is well below their VOC emissions cap. According to the facility, the VOC content of the waterborne topcoats is approximately half that of the old solvent-borne topcoat (2.48 pounds of VOCs per gallon versus 4.9 pounds of VOCs per gallon). They comply with the emission limits in the Wood Furniture NESHAP, which became effective for them in December 1997, using an averaging approach. With an average HAP emission rate of less than 0.6 pound HAP per pound solids, they are well below the NESHAP limit of 1.0 pound HAP per pound solids.

Customer Feedback

Schrock has not experienced any increase in customer complaints since moving to the waterborne topcoats. Product quality has not suffered. The cabinets finished with the waterborne topcoats meet all standards for resistance and durability established by the Kitchen Cabinet Manufacturers Association.

Case Study No. 23 – Waterborne Coatings
Shafer Commercial Seating
Denver, CO

Background

Shafer Commercial Seating manufactures chairs, tables, and booths for hotels and restaurants. They supply both solid wood and upholstered wood chairs. Their products are mostly solid wood, but some laminate is used, particularly for the booths and some table tops. The facility has 18 employees in their finishing department during the day shift, 5 during the night shift, and operates 5 days per week. Shafer is subject to the Wood Furniture NESHAP, although their current actual HAP emissions are below the major source threshold. Approximately 375 chairs per day and 150 table tops per week are coated at the facility, although Shafer does some time-consuming custom work that occasionally reduces these averages. Shafer converted to waterborne coatings in 1996 to reduce their VOC and HAP emissions.

Manufacturing and Coating Operations

Shafer imports their chair frames, which are made primarily of European beech. The chair frames are coated, and then upholstery may be added. The wood components for the tables and booths are milled on-site. Oak, maple, mahogany, and cherry are the primary wood species used, but Shafer also fills custom orders for other species. Laminates typically are used as booth components.

Coating line

Shafer has one coating line. During the day shift, chairs are coated. Table tops and a smaller number of chairs are coated during the night shift. The chairs move along the coating line on pallets that hang from an overhead conveyor system. The table tops are fastened to vertical bars that hang from the overhead conveyor. The line travels at about 6 feet per minute.

Chairs are finished only with waterborne coatings. The chair frames first are sanded by hand. The stain is sprayed onto the chair (as little as possible, to prevent excessive grain raise) and wiped by hand. The stain is sprayed using Kremlin air-mix guns, similar to air-assisted airless guns, and each stain color has a dedicated line from the mix room. Custom colors are sprayed from small pressure pots at the line. A toner (a diluted stain) is applied using an HVLP gun to even out the stain color and the piece is wiped a second time. The chair then passes through an IR oven to dry the stain. Fans also have been installed above the conveyors to aid in the drying process.

The sealer then is applied using airless spray guns. The facility found that this type of gun allows them to apply more sealer than an air-assisted airless gun. The chair then passes through a second IR oven and makes two passes through cooling air. Next, the chairs are taken off the line, one at a time, and placed in a machine that uses ceramic beads to polish, or “pound in,” the sealer. Before Shafer started using this machine, the operators would sometimes sand through the sealer in an attempt to control the grain raise caused by the waterborne coatings. The chairs are lightly sanded by hand and any dust is wiped off before the topcoat is applied.

Sealer application

IR oven

The chairs receive the first topcoat and pass through another IR oven for drying. The topcoat is applied using the air-mix spray guns. The chairs then are lightly sanded and receive a final topcoat. The last step is the final IR oven. Chairs with finish defects are sanded and refinished if the defect cannot be repaired by applying another topcoat.

Table tops do not go through as many coating steps as the chair frames. They first receive a waterborne stain, which is hand wiped. This stain is toned, as necessary, to even out the color. An IR oven dries the stain. The table tops do not receive a sealer, but do receive a solvent-borne, high-solids topcoat. This coating is about 35 percent solids, contains some acetone, and has less than 1 pound VOC per pound solids. The first topcoat is dried in an IR oven and then sanded. A final topcoat is applied and then dried in an IR oven. After the table tops are coated, the bases are attached.

Coatings are received in 5-gallon buckets (stains) or 55-gallon fiberboard drums. The used fiberboard drums are crushed once any leftover coating is dried. The used coating containers are not hazardous waste, and are disposed of as landfill waste.

Gluing Operations

Shafer uses waterborne and hot melt glues. Hot melt glues are used for applying edge banding and for applying foam to wood. Waterborne products are used for applying wood to wood and vinyl to wood. The operators had to be retrained when the facility switched from solvent-borne glues to waterborne glues. With the waterborne glues, the glue is applied to both pieces, allowed to dry, and then the pieces are put together to form the bond. With the solvent-borne glue, the operators sprayed the glue and immediately bonded the pieces together. Shafer tried a two-component glue, but it did not perform well and tended to clog their equipment. Glues are received in steel drums or plastic containers. Empty steel drums are sent to a local facility for recycling, and the empty plastic containers are disposed of as landfill waste.

Cleaning Operations

Shafer uses hot water to clean the equipment that is used to apply the waterborne coatings. They tried using a waterborne cleaning solution they bought from their coating supplier, but it proved to be too hard on their equipment. They do not clean the equipment often, since dedicated lines are used for each color of stain, and for the sealer and topcoat. The same sealer and topcoat are applied to most products. The gun tips are cleaned regularly, however, and the equipment is cleaned after applying a custom color. Shafer formerly used solvent to clean all equipment.

Conversion to Waterborne Coatings

Shafer began researching waterborne coatings in the early 1990s. They wanted to reduce emissions, and their management made a commitment to switch to waterborne coatings. They performed extensive testing in 1995, and began using the waterborne coatings in production in February 1996. These coatings replaced traditional solvent-borne coatings. They depended heavily on their coating supplier for advice on equipment selection, particularly the IR ovens. The coating system has undergone several changes from the original system because of problems with foaming, dry time, performance, and color. Facility personnel stated that it took 3 months to produce a product with an acceptable finish with the new system. They would like to further improve upon the appearance they currently achieve.

Shafer's largest obstacle in making the waterborne system work has been the waterborne stains. They have had problems with dry time, excessive grain raise, and color consistency. At first, the water in the new stain would evaporate before they could wipe the stain. The coating supplier reformulated the stain to prevent this problem. Shafer would like to be able to take the chairs off the coating line after the stain application to allow for more drying time, but their current space does not allow that. If the stain is not dry before additional coatings are applied, the topcoat does not perform as well. Therefore, they have increased the IR oven air circulation and temperature, and added fans above the line to further aid in drying.

The waterborne stain also causes grain raise, which produces a rougher finish. Shafer had to add the piece of polishing equipment because operators were sanding through the seal coat in an attempt to control the grain raise caused by the waterborne stains. When the seal coat was sanded through, the topcoat then caused a second grain raise. Shafer personnel feel that their product is not as smooth to the touch as a product finished with a traditional solvent-borne coating.

Color consistency also is an issue with the waterborne stains. During the test period, the color of any particular stain they received from the coating supplier was not consistent from shipment to shipment, and some of the stains would separate in their containers during shipment. Shafer still has to adjust some of their stains with dye to achieve a consistent color between shipments, especially for dark colors. They also had to add a toning step to the coating process to even out the color of the stain on the wood. In their original solvent-borne system, they stained, sealed, and applied two topcoats. For every 20 gallons of stain purchased, about 1 gallon is used in the toning step. The waterborne stains Shafer uses do not produce a product with the same appearance as the solvent-borne stains they had been using. Facility personnel characterize the finish achieved by the waterborne stains as “muddy,” because the natural grain of the wood does not show through as well.

With the waterborne sealers, the main issue is the operator’s ability to sand the coating. The waterborne sealer is harder than the solvent-borne sealer the facility used previously, and requires extra effort to sand. As mentioned previously, the seal coat sometimes was sanded through in an attempt to smooth out the roughness caused by grain raise.

The waterborne topcoat has a higher solids content than the solvent-borne topcoat used previously (41 percent solids versus 25 percent solids). However, the facility still applies two coats of topcoat because they can’t apply a sufficient amount of the waterborne coating in one step. Shafer tried a catalyzed waterborne topcoat, but even though it produced a better looking product, it was more costly and was hard on their equipment because it was so viscous. They had to turn up the pressure on their spray guns and the coating tended to clog the guns or catalyze inside the guns. They rebuilt their spray guns every 2 to 3 days while they were testing this coating. Therefore, they discontinued use of the catalyzed topcoat.

For the table tops, Shafer currently is investigating a waterborne urethane topcoat to replace their solvent-borne topcoat. The urethane coating would allow them to apply one coat of topcoat instead of two. Orange peel and hardness are issues with this coating that they are trying to resolve with the coating supplier.

Shafer continues to experiment with waterborne coating systems from several other suppliers, including European suppliers, in an attempt to find a system that produces a better appearance than they currently are achieving. Shafer was the first furniture company in their area to switch to a waterborne system, and their coating supplier did not have much experience with waterborne systems at that time. Facility personnel expected a faster conversion and a more consistent product. They also feel that because acetone is no longer considered a VOC, many coating suppliers simply have reformulated their solvent-borne coatings to contain acetone in order to reduce the VOC/HAP content, and have not made enough of an effort to improve their waterborne systems.

Costs

During the conversion to the waterborne system, the facility spent about $300,000 rearranging their finishing area, adding new equipment, and changing the configuration of their line to accommodate the new coating system. They had to purchase and install stainless steel lines, mixing pots, and guns, which cost approximately $50,000. The waterborne coatings also are more expensive than the solvent-borne coatings they were using. The stains have increased in cost to as much as $50 per gallon. The topcoats have increased in cost from approximately $10.50 per gallon to approximately $16 per gallon. Although the solids content of the clearcoats is higher, Shafer still applies two coats of topcoat, so they do not believe they are using much less of the waterborne coating. Due to problems with grain raise and the hardness of the sanding sealer, they have increased the amount of sandpaper they purchase. Shafer also estimates they have lost about $1 million in sales because of problems with products that had been coated with the new waterborne coatings. The company did, however, experience a savings in fire insurance with the switch to waterborne coatings, and their use of hot water instead of solvent for cleaning equipment also results in a small cost savings.

Emissions

Shafer has reduced their emissions of both VOCs and HAPs over the past few years. Their current VOC emissions are far less than their permit limit of 90 tons per year. In 1995, their VOC emissions were over 80 tons per year. In 1996, this number decreased to 32 tons, and in 1997, to 15 tons. Shafer’s HAP emissions were 17 tons in 1996 and 4 tons in 1997. Their 1998 emissions through September were approximately 11.5 tons of VOCs and 2.6 tons of HAPs. Their HAP emissions are primarily glycol ethers.

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.


Plywood press

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.


UV oven

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^{o} 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.

Case Study No. 25 – High-Solids Coatings
Westwood Custom Cabinetry
Salem, OR

Background

Westwood Custom Cabinetry began coating cabinets in 1971 and was bought in February 1998 by Elkay. Their new sister plant in Minnesota, Medallion Cabinets, manufactures the same products. There are 83 manufacturing employees at the Salem facility, including 12 to 13 finishing employees, who work Monday through Friday on an 8-hour shift. Westwood converted to high-solids, low-HAP coatings to comply with the Wood Furniture NESHAP.

Product sample

Manufacturing and Coating Operations

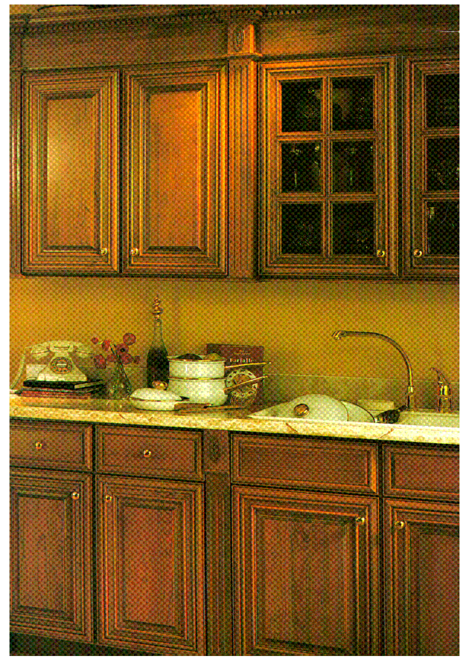
Westwood receives most of their components premilled. A few cabinet components, such as box and drawer parts, are received prefinished. The types of wood coated are oak, maple, hickory, and cherry. They will eventually coat pine as well.

The manufacturing section of the facility is divided into two areas. One area is used for assembling prefinished box and drawer parts manufactured of particleboard and paper laminate or maple veneer. The second area includes the finish room, where cabinet doors and molding are finished and assembled. At the time of the visit to the facility, Westwood was beginning to switch to a new product line and had implemented a plan to minimize leftover coatings and components from the old product line. The new product line will be finished with the low-HAP coating system.

The facility has one coating line that moves at approximately 26 feet per minute. The parts move on a conveyor system that has 100 trays with paper honeycomb-type disposable liners. These liners are replaced every 3 to 4 months, depending on the facility's production volume. The parts are coated in three steps. The first step in the coating process is a spray booth used to apply stain to the parts. Some stains are wiped after they are sprayed on the piece, and some are not. The parts then pass through a flashoff oven, which uses heat from the other ovens in the line. The parts may then be touched up by hand using thinning solvent or additional stain if the color is uneven, particularly for darker stain colors. A catalyzed sealer is then applied, the parts pass through another oven for drying, and the parts are sanded by hand. Finally, a catalyzed topcoat is applied, and the parts pass through the final drying oven. All coatings are applied using HVLP guns manufactured by Kremlin.

One finishing cycle takes approximately 45 minutes to complete; cabinet doors pass through the line twice so both the front and back are finished. When the facility begins coating the new product line, some of the colors will require a dye before the stain is applied.

The stains are received in 55-gallon drums; the sealer and topcoat are received in large stainless steel totes. The stains are pumped from the drums directly to color-dedicated spray guns at the coating line. Therefore, a color change does not require the lines and guns to be flushed with solvent. The sealer and coating are catalyzed 5 gallons at a time and taken in buckets to the finishing line. At the end of the shift, any unused coating is put back into the tote. The totes are returned to the coating supplier and reused. The empty stain barrels are given away or crushed as scrap.


Product sample

Cleaning Operations
The facility uses thinner purchased from their coating supplier, Akzo, to clean the spray guns that apply the catalyzed sealer and topcoat. The guns used to apply the stains are cleaned less often, since each color has a dedicated line and gun. The thinner contains less than 10 percent HAPs, per the Wood Furniture NESHAP requirements. They spray the thinner directly into the spray booths, and estimate approximately 3 gallons of cleaning solvent is used per day. The spray booth filters are changed every one to two days. Both the spray booth filters and tray liners are landfilled. The facility produces no hazardous waste.

Conversion to High-Solids/Low-HAP Coatings
Westwood has transitioned from a toluene- and xylene-based catalyzed conversion varnish system to low-HAP, catalyzed sealers and topcoats and low-HAP stains. Westwood experimented with some waterborne coatings, but experienced problems with dry time, clarity, and grain raise. Cost also was an issue in choosing not to switch to waterborne coatings (equipment changes would have been necessary). They tested a total of about 150 gallons of waterborne sealer and topcoat, as well as a small amount of waterborne stain.

The switch to low-HAP coatings required no changes to the configuration of the coating line and no additional operator training. The new HVLP guns did require some operator training. The operators received instruction in the technical aspects of the new product line’s colors and the additional dye that some pieces will receive prior to the stain.

Some training will be provided by the coating supplier's local representative, who visits the facility weekly.

Costs

All coatings are applied using HVLP guns manufactured by Kremlin. These guns were purchased to replace older HVLP guns and air-assisted airless guns. New guns and lines were purchased and installed at a cost of approximately $80,000. The old HVLP guns had been adjusted to use a higher pressure and larger tips so they could apply sufficient coating for the speed of the line. Therefore, they were not achieving the high transfer efficiency typical of HVLP guns. They also were heavy and cumbersome for the operators to use. The newer guns are lighter and supply a sufficient amount of coating to accommodate the speed of the line. The new sealer and topcoat cost about $1.30 more per gallon, but with the new HVLP guns and the higher solids content, Westwood will be applying less coating per piece. Therefore, they are likely to experience a cost savings.

Emissions

Westwood's permit limits them to 276 tons of VOCs per year. They also are subject to the Wood Furniture NESHAP. All their new coatings have HAP contents below the NESHAP limits. According to data supplied by the facility, in 1997, the average emissions were 2.51 pounds of VOCs and 1.28 pounds of HAPs per cabinet. The facility began spraying the new low-VOC/HAP coatings in 1998, and expected a decrease in emissions as well as increased transfer efficiency due to the new HVLP guns. For the first half of 1998, facility data indicated that VOC emissions were 1.74 pounds per cabinet and HAP emissions were 0.86 pound per cabinet.

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Glossary

Airless spray means a spray gun that atomizes the finish material by forcing it through a small opening at high pressure.

Air-assisted airless spray means a spray system that uses an airless spray unit with a compressed air jet to finalize breakup and help shape the spray pattern of the finish material.

Basecoat means a coat of colored material, usually opaque, that is applied before graining inks, glazing coats, or other opaque finishing materials, and is usually topcoated for protection.

Capital cost means the purchase price of any new equipment.

Casegoods means furniture, as in bookcases or bureaus, that provides interior storage space.

Checking means a finishing defect characterized by lines that appear in the surface of the finish.

Coating solids (or solids) means the part of the coating which remains after the coating is dried or cured.

Continuous coater means a finishing system that continuously applies finishing materials onto furniture parts moving along a conveyor. Finishing materials that are not transferred to the part are recycled to a reservoir. Several types of application methods can be used with a continuous coater, including spraying, curtain coating, roll coating, dip coating, and flow coating.

Conventional air spray means a spray coating method in which the coating is atomized by mixing it with compressed air and applied at an air pressure greater than 10 pounds per square inch gauge (psig) at the point of atomization. Airless and air-assisted airless spray technologies are not conventional air spray because the coating is not atomized by mixing it with compressed air. Electrostatic spray technology also is not considered conventional air spray because an electrostatic charge is employed to attract the coating to the piece.

Curtain coater means a coating method where the part passes under a free-falling film of coating. The excess coating is caught in a trough and recirculated.

Dip coat means to dip an object into a vat of coating material and drain off any excess coating.

Disk means a rotating head that delivers paint horizontally 360 degrees around the head and uses an omega loop conveyor line. A disk usually is mounted horizontally on a vertical reciprocator.

Dry time means the amount of time necessary for the coating to harden before it can be sanded and re-coated.

Electrostatic application means charging of atomized paint droplets for deposition by electrostatic attraction.

Enamel means a coat of colored material, usually opaque, that is applied as a protective topcoat over a basecoat, primer, or previously applied enamel coats. In some cases, another finishing material may be applied as a topcoat over the enamel.

Filler means a material which is applied to a wood product, and whose primary function is to build up, or fill the voids and imperfections in the wood product to be coated.

Flash-off time means the time required between applications of successive wet-on-wet coatings or between application and baking to allow the bulk of the solvents in the coating to rise slowly and evaporate. In baked coatings, the flash-off time helps to prevent solvent boil off and film blistering.

Flatline finishing means a finishing operation in which the pieces to be coated are lying flat on a conveyor.

Glaze means a type of stain used to soften or blend the original color without obscuring it.

Gloss means the capacity of a surface to reflect light.

Grain raise means the swelling and standing up of wood fibers due to the absorption of water or solvent. This swelling results in a finish that appears and feels rough.

Hazardous air pollutant (HAP) means any air pollutant listed in or pursuant to section 112(b) of the Clean Air Act.

Highlight means a color coat that is applied sparingly to accent and give character to the wood.

High-volume, low-pressure (HVLP) spray means equipment used to apply coating by means of a spray gun which is operated between 0.1 and 10.0 pounds per square inch gauge (psig) air pressure, measured dynamically at the center of the air cap and at the air horns.

Ink means a fluid that contains dyes and/or colorants and is used to make markings, but not to protect surfaces.

Lacquer means a coating composition based on synthetic thermoplastic film-forming material dissolved in organic solvent and dried primarily by solvent evaporation. Typical lacquers include those based on nitrocellulose, other cellulose derivatives, vinyl resins, and acrylic resins.

Medium density fiberboard (MDF) means a composite panel primarily composed of cellulosic fibers (usually wood), in which the primary source of physical integrity is provided through addition of a bonding system cured under heat and pressure.

Mil means a unit of length equal to 1/1000 inch.

Nitrocellulose means a binder (or resin) based on polymer from cotton cellulose. Nitrocellulose primarily is used in lacquers.

Orange peel means an irregularity in the surface of a paint film resulting from an inability of the wet film to level out after being applied. Orange peel appears as a characteristically uneven or dimply surface to the eye, but usually feels smooth to the touch.

Organic solvent means a volatile organic liquid that is used for dissolving or dispersing constituents in a coating or contact adhesive, adjusting the viscosity of a coating or contact adhesive, or cleaning equipment. When used in a coating or contact adhesive, the organic solvent evaporates during drying and does not become a part of the dried film.

Overspray means any portion of a spray-applied coating that does not land on a part and which is deposited on the surrounding surfaces.

Ozone nonattainment area means an area that does not attain the National Ambient Air Quality Standard (NAAQS) for ozone, pursuant to Section 107 of the Clean Air Act.

Particleboard means a composite panel primarily composed of cellulosic materials (usually wood), generally in the form of discrete pieces or particles, as distinguished from fibers, bonded together with a bonding system, and which may contain additives.

Pollution prevention means the use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source. It includes practices that reduce the use of hazardous materials, energy, water, or other resources through conservation or more efficient use.

Powder coatings means any coating applied as a dry (without solvent or other carrier), finely divided solid which adheres to the substrate as a continuous film when melted and fused.

Roll coater means a series of mechanical rollers that applies a thin coating on the wood product.

Sealer means a finishing material used to seal the pores of a wood substrate before additional coats of finishing material are applied.

Sealer sand means to sand the wood product after sealing to smooth the overall system and remove any wood fiber roughness.

Solvent means a liquid used in a coating or contact adhesive to dissolve or disperse constituents and/or to adjust viscosity. It evaporates during drying and does not become a part of the dried film.

Solvent-borne means coatings in which VOCs are the major solvent or dispersant.

Stain means any color coat having a very low solids content (e.g., less than 10 percent) that is applied in single or multiple coats directly to the substrate. It includes, but is not limited to, non-grain-raising stains, equalizer stains, prestains, sap stains, body stains, no-wipe stains, penetrating stains, and toners.

Thinner means a volatile liquid that is used to dilute coatings or contact adhesives (to reduce viscosity, color strength, and solids, or to modify drying conditions).

Toner means a washcoat that contains binders and dyes or pigments to add tint to a coated surface.

Topcoat means the last film-building finishing material that is applied in a finishing system.

Transfer efficiency means the ratio of the weight of coating solids deposited on an object to the total weight of coating solids used in a coating application step, expressed as a percentage.

UV-curable means coatings that are cured through chemical cross-linking of specialized resins. The reaction is initiated by exposure of a photo-initiator catalyst in the coating to UV light.

Veneer means a thin sheet of material, as in (1) a layer of wood of a superior value or excellent grain to be glued to an inferior wood to provide a protective or ornamental facing, or (2) any of the thin layers bonded together to form plywood.

Viscosity means the property of a fluid whereby it tends to resist relative motion within itself. A thick liquid, such as syrup, has a high viscosity.

Volatile organic compound (VOC) means any organic compound which participates in atmospheric photochemical reactions; i.e., any organic compound other than those which EPA's Administrator designates as having negligible photochemical reactivity. A VOC may be measured by a reference method, an equivalent method, an alternative method, or by procedures specified under any rule. A reference method, an equivalent method, or an alternative method, however, may also measure nonreactive organic compounds. In such cases, the owner or operator may exclude the nonreactive organic compounds when determining compliance with a standard. For a list of compounds that the Administrator has designated as having negligible photochemical reactivity, refer to 40 CFR Part 51.100.

Washcoat means a transparent special purpose finishing material having a low solids content (e.g., less than 12 percent) applied over initial stains to protect, to control color, and to stiffen the wood fibers in order to aid sanding.

Washoff operations means those operations in which organic solvent is used to remove coating from wood furniture or a wood furniture component.

Waterborne coatings means coatings in which water is the major solvent or dispersant.

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National Pollution Prevention Roundtable. 2000 P Street, NW, Suite 708, Washington, DC 20036. http://www.nppr.org

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16. ABSTRACT The report gives results of a study in which wood furniture manufacturing facilities were identified that had converted at least one of their primary coating steps to low-volatile organic compound (VOC)/hazardous air pollutant (HAP) wood furniture coatings: high-solids, waterborne, ultraviolet (UV)-curable, or powder coatings. Twenty-five case studies were developed based on visits to the facilities and discussions with plant personnel. The case studies identify: products manufactured, types of low-VOC/HAP coatings implemented, equipment and process changes required, problems encountered during conversions, advantages/disadvantages of the low-VOC/HAP coatings, customer feedback, costs associated with conversions, and emissions and waste reductions. The report provides general information about the wood furniture manufacturing industry's typical emissions and applicable regulations. It discusses each coating technology individually and summarizes facilities' experiences with the low-VOC/HAP coatings studied. The main goals of this study were to demonstrate that low-VOC/HAP coatings can be used successfully by some wood furniture manufacturers and to provide a resource to assist other manufacturers in converting to low-VOC/HAP coatings.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Organic Compounds	Pollution Control	13B	07C
Wood	Volatility	Stationary Sources	11L	20M
Furniture	Toxicity	Volatile Organic Compounds (VOCs)	15E	06T
Coatings		Hazardous Air Pollutants (HAPs)	11C	
Manufacturing			05C	
Emission			14G	

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