United States
Environmental Protection
Agency

National Risk Management
Research Laboratory
Cincinnati, OH 45268

Research and Development | EPA/600/SR-97/083 | September 1997

EPA

Project Summary

Utilizing Low Volatile Organic Content Exterior Coatings for Wood Furniture

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Abstract

This report provides an evaluation of commercially viable source reduction techniques implemented by a manufacturer of wood chairs, bar stools and settees in various styles ranging from classic American to European contemporary.

As federal EPA regulations became more stringent for volatile organic compound (VOC) emissions in the woodworking industry, the Dinaire Corporation began testing alternative formulations employed as waterborne finishes, sealers and topcoats. In an effort to minimize costly investments in air emission control equipment, the company examined and implemented a number of source reduction techniques that dictated modifications to raw material formulations as well as equipment needed to apply and cure surface finishes.

By phasing in low VOC, water-based formulations in conjunction with high-volume low-pressure spray systems, an ultraviolet curing system and procedural modifications, Dinaire was able to show reductions in the quantities of hazardous waste as well as the overall loadings of volatile organic compounds released as hazardous air pollutants.

The reductions in air emission loadings negated the need for costly improvements in air emission control equipment.

The Project Summary was developed by the National Risk Management Research Laboratory's Sustainable Technology Division, Cincinnati, OH to announce the key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The process of finishing wood household furniture generally employs a number of operations, such as; glue sizing or bleaching, cleaning/stripping, coating, drying, sanding, rubbing/buffing, equipment cleaning and repair touch-up. These operations will provide household furniture with a pleasing appearance, a feeling of smoothness and the protection of the wood.

The finishing process typically yields:

- volatile organic compound (VOC) emissions, including hazardous air pollutants such as xylene and toluene
- liquid waste comprising of spent stains, wash coats, fillers, various sealers, discarded solvent and wastewater generated from paint overspray abatement systems
- solid wastes including overspray solids, solvent-laden residues, rags and wood dust and scrap

The Dinaire Corporation is a manufacturer of wood furniture products, primarily dinette sets. In an effort to minimize volatile organic compound emissions as well as hazardous waste, the company undertook a program to identify and test alternative low-VOC waterborne finishing formulations that would be economically advantageous in terms of minimizing expenditures associated with the proper management of hazardous waste and the control of hazardous air pollutants.

Taking into account the variable product line and quality specifications, Dinaire was challenged in its quest to identify and implement alternative stains and coating formulations containing reduced loadings of volatile organic compounds characterized as hazardous air pollutants. The company's operations complicated the evaluations since two facilities were involved in the manufacturing operations and the equipment needed to apply the surface finishes was not uniform at each facility. Quality issues did pose some barriers to implementing, on a company-wide scale, alternative low VOC, waterborne coatings.

Low-VOC, waterborne sealants and coatings were identified for wood furniture, however, the conversion dictated investments in new equipment for applying the formulations and curing the finished products. The purpose of this project was to analyze and document the applicability, adequacy and advantages of finishing the surfaces of wood furniture with low-VOC, waterborne coatings. The analysis factor in the findings, observations and recommendations of the Pollution Prevention Opportunity Assessments published by Science Applications International Corporation under EPA contract 68D0068, Pollution Prevention Initiative within the Great Lakes Basin. The technical and economic analysis also summarized some of the findings of Dinaire's alternative formulation evaluations.

This project was completed under the terms of the Erie County WRITE Program as a joint effort by Dinaire Corporation located in Buffalo, NY; Erie County Department of Environment and Planning, Buffalo, NY, Recra Environmental, Inc., Amherst, New York; and the USEPA Office of Research and Development, Cincinnati, OH.

Procedure

The Dinaire Corporation employs a systematic approach to manufacturing and assembling wood furniture at its two facilities located at Gruner Rd. and Ohio St. The Gruner Rd. facility manufacturers table tops, whereas the Ohio St. facility manufacturers chairs. The surface finishes on the tables and chairs must conform to required quality specifications, including color.

Wood used in the manufacture of Dinaire's products is cut into desired shapes and sizes either by automatic machinery or manually with hand held power tools. To produce wood materials of the desired size and physical properties, laminated wood is designed and produced at Dinaire's facilities. The laminates are made by taking strips of wood and gluing them together. The adhesive bonding of the laminated wood is cured at room temperature yielding emissions comprising of fumes from the glue and dust particulates from the wood cutting operations.

The goals established by the Gruner Rd. facility dealt with the identification of low-VOC, waterborne coats for table tops that would assist Dinaire in complying with federal and state regulations governing hazardous air pollutants emitted from wood furniture operations. To achieve this goal, the company defined the following equipment specifications:

- Venjakob double head spray system
- Denibber - 180 grit
- Venjakob surface cleaner
- Venjakob dual eight-gun carousel spray machine equipped with 1.8 Kremlin air-assisted, airless spray gun
- Venjakob triple head, brush wiping machine
- the Superfici dual 200-watt lamp ultraviolet (UV) modular curing unit

During the course of Dinaire's evaluations, table tops were finished using the Venjakob automatic spray equipment. This equipment utilizes high-volume, low-pressure spray guns. All of the table tops are UV cured. In their assessment of equipment modifications, Dinaire was able to confirm commercial applications for UV cured coatings on wood substrates. The expanded use of UV curing was accomplished as a result of technological advances involving the development of high- molecular weight, low-viscosity resins.

The goals established by the Ohio St. facility dealt with the identification and use of a low-VOC, waterborne self-sealing topcoat for the final coat and a low-VOC, waterborne self-sealing topcoat for the second coat of sealer. To achieve this goal, the following equipment specifications were identified.

- Accuspray HVLP Stain Guns #10 air cap, #51 tip
- Enviro-Sealer Guns, Binks BBR HVLP, #95-P air cap, #91, top 12 oz. fluid delivery (45 sec.), 8 to 10 lbs. atomizing air, 9/16(minimum air hose, 2.5 wet mil thickness
- Accuspray HVLP waterborne lacquer gun
- Devilbiss JGA 501 spray gun and Binks BBR HVLP 95-P air cap, #94 tip for acrylic basecoat.

Results and Discussions

The evaluations that were undertaken by Dinaire took into account a number of environmental as well as economic and productivity interests. In comparison to finishing processes employing solvent-based formulations, Dinaire was able to show a number of advantages to low-VOC, waterborne formulations as long as quality specifications were adequately addressed. Based on the diverse operating requirements, the company's evaluations generated positive results summarized herein.

Procedural and Equipment Modifications

With the alternatives that were specified and tested, the table top operations utilize a low-VOC, waterbased finish that is UV cured. These operations also utilize a solventbased, high-solids formulation that is utilized as a top coat. The equipment supplied by Venjakob applies coatings to exact wet mil thickness (2.5-3.0). Any overspray is recovered and reused as a sealant. Between each application step, table tops are UV cured.

In selecting UV-curing equipment, Dinaire had to weigh the following factors:

- The process does not lend itself well to simple hand-spray applications; as such the UV equipment necessitates investments in automated systems.
- The selected UV system requires "line of sight" radiation; as such three-dimensional pieces will be difficult to finish and applications by design will generally involve flat-top components.
- Since most wood finishing is done for aesthetic and design functions, finishing adjustments may have to be made often to address changes in custom specifications.
- The cost of the UV processor is comparatively high, however; investments appear justified based on predefined improvements in productivity.
- Extra care must be used when utilizing UV to ensure workplace safety as a result of ozone formation. Constant ventilation will be required to remove the ozone and heat formed, and maintain the ideal operating temperatures on the terminals, the neck and the radiation surface.
- While the dry film thickness applied with high-solids UV-cured coatings does improve the utilization of top coatings, improvements in transfer application efficiency must be considered.
- Unlike most other industrial finishing applications, wood finishes almost always require a multi-step system applied over a natural variable substrate.

As such variable colors, glosses and open-pore finishes may be difficult to achieve with a UV system.

- The UV-curable coatings are not compatible with oil-based stains, such as linseed oil. As such, a UV coating would prevent complete curing.
- The conversion to UV-curable coatings would not eliminate the use of formulations with minimal solvent content. The formulations applied to the table tops would still need to be properly managed.

The company's investment in the UV-curing system factored in the following advantages:

- High solid coatings formulations can be effectively applied with variable product specifications, reducing the VOC loadings of the applied coatings.
- Because of the high-solids content of coatings, the company can achieve high-film thicknesses with significantly fewer coats and process steps that are comparatively attained with low-solids, conventional coatings.
- Because the polymer is completely cross-linked, the film's properties, in terms of surface scratch resistance and chemical resistance, are as high or higher than films that have been chemically cross-linked with external catalysts.
- UV coatings generally cure within as little as one to two seconds of exposure to UV light yielding the benefit of high production throughput as a result of the fast cure cycle.
- The extremely fast cure rates allow for short ovens and conveyor systems; as such the facility does not have to allocate valuable plant space for coatings to cure in storage.
- Although a detailed energy conservation analysis had not been completed, the company noted that the UV system consumes less energy than gas-fired curing ovens.

The installation of HVLP spray guns improved the transfer efficiencies of high-solids, water based formulations reducing the wet film thickness for ultimate coating.

In addition to reducing overspray emissions, the improvements in transfer efficiency have resulted in as much as a 50% reduction in the use of coating materials. To optimize the benefits of HVLP spray equipment, the company continues to investigate productivity gains attributed to improvements in transfer efficiency. For example, Dinaire is able to stain 12 chairs with each gallon of stain using automated HVLP spray guns, whereas 5-7 chairs were stained with each gallon of stain prior to the transfer efficiency improvements.

As the facility has converted to high-volume, low-pressure HVLP spray guns, procedural changes and upgrades have been made with the chair finishing operations resulting in a reduction in the number of solvent based coatings, as well as fugitive air emissions from the spray booths. With employee training, excessive overspray has also been minimized. In addition, the consumption of solvents in the various formulations has been reduced.

Prior to implementing a spray system, the company's operations involved dipping and hand-wiping coatings. This change reduced the generation of waste rags containing solvents, thus reducing employee exposure to fumes while allowing for higher production rates.

Quality Issues

Quality issues did pose some major barriers to implementing an alternative finishing system utilizing a low-VOC water-borne formulation. During the evaluation phase, the company documented problems, such as raising of wood grains, yellowing of stains after prolinged sunlight, inconsistencies in stain quality, and quantities of select formulations contained unacceptable concentrations of formaldehyde.

These problems were eventually dealt with; however, the company ultimately had to change suppliers and impose procedural modifications for operators and inventory managment to ensure adherence to plant quality controls.

Environmental

The changes implemented by the company resulted in a number of environmental benefits. These improvements assisted the company in their efforts to minimize capital investments dictated by regulatory standards governing the control of hazardous air pollutants from the wood furniture finishing operations.

The combined changes in operations and formulations showed:

- 80-90% reduction in the costs associated with managing hazardous waste
- significant reductions in the VOC content of materials used as sealants and topcoats
- reduction in waste overspray attributed to both the use of low-VOC, waterborne formulations and improvements in transfer efficiency attainable with HVLP spray applications of high-solids coatings
- reduction in energy consumed with UV-cured formulations

In comparison to the old operations, reliant on low-solid content solvent-based coatings, the topcoat overspray can be recovered and reused as sealant. The company is attempting to recover stain overspray; however, reuse opportunities are limited due to inconsistencies in the recovered stain quality.

During the company's period of evaluation, the operations were able to phase in low-VOC waterborne stains and high-solids coatings. These new formulations assisted the company in reducing the loadings of volatile organic compounds emitted as air emissions. Operations can yield a finished product in 2 to 3 steps ensuring 2.5 to 3.0mil finish at each application, in comparison to the old operations which required as many as 4 to 5 procedural steps resulting in 1.4 to 2.1 mil finish.

A number of the modifications selected by the company can be categorized as source control techniques, which contribute to the reduction in the generated quantities of hazardous waste. During the evaluation period, the quantities of ignitable waste (D001) were reduced by greater than 95%.

Economic

The fixed cost for the project including the purchase and installation of the HVLP guns and Superfici UV curing unit was calculated to be $50,740. Annual operation and maintenance costs were assumed to be $1,000 for the economic analysis supplementing this project.

The Net Present Value (NPV) for the project was determined by factoring in the equipment purchase NPV, tax savings on depreciation NPV, and savings on variable costs NPV. Since the substitution of low-VOC coatings for solvent coatings was only partially implemented by Dinaire, assumptions on the economic impact from a complete substitution had to be made. Based on these assumptions, the project provided a positive net present value and a payback period of 2.68 years. Once fully implemented, the low-VOC coating alternatives will improve the overall economics of the project.

Some of miscellaneous savings attributed to the changes:

- average cost per gallon of low-VOC stains approximately 5.5% lower than the cost per gallon of solvent stain

- total cost of disposing of hazardous waste generated by the Ohio St. facility reduced from $17,925 in 1990 to $765 in 1994
- total cost of disposing of hazardous waste generated at Gruner Rd. reduced from $15,785 in 1990, to $8,050 in 1994

Conclusion

The decision by Dinaire Corporation to phase in lowVOC water based stains and high-solid content topcoats has provided a number of benefits justifying ongoing investment in the company's strategy to minimize reliance on all solvent-based stains and topcoats associated with wood furniture finishing operations.

Despite various quality issues, Dinaire was able to achieve customer specifications; however, inventory management, proper equipment controls, and operator training were all important elements to sustaining the changes.

Investments in a modular ultraviolet (UV) curing system resulted in significant gains in productivity. The fast curing cycle translates into greater product throughput and control over product quality.

The improvements in spray transfer efficiency as well as the conversion to high-solids coatings resulted in better utilization of resources, including costly finishes, energy, and labor. With HVLP spray guns, the stain utilization was improved 40-70%, significantly reducing air emissions attributed to overspray and solvent use.

In addition to improving productivity and resource utilization, the investments in the new finishing operations helped Dinaire comply with air regulations and, in doing so, avoided capital-intensive air abatement control equipment.

By reducing exposure to solvent-laden stains and topcoats, work place safety and environment was improved. The risks posed by the company's reliance on solvent based formulations have been minimized to a level that can be better controlled. The reduced reliance on hazardous air pollutants has also minimized discarded oversprays posing environmental compliance issues.

In terms of positive economic impact, the changes provided a good net present value and a payback that has the potential to improve with full implementation of the low VOC strategy. With implementation of these changes, economic savings were recognized in terms of better resource utilization, including, energy, labor and raw materials, reduced disposal charges for hazardous waste, reduced charges for stains and coatings used in operations, reduced costs for controlling overspray, and reduced costs for controlling emissions of hazardous air pollutants in relation to applicable regulations.

The full report was submitted in fulfillment of CR-816762 Erie County Department of Environment and Planning under the sponsorship of the U.S. EPA. Paul Kranz is with Erie County Department of Environment and Planning, Buffalo, NY 14202. James E. Stadelmaier and Thomas F. Stanczyk is with Recra Environmental, Inc., Amherst, NY 14228. Paul R

***Paul Randall** is the EPA Project Officer (see below).*

The complete report, entitled "Utilizing Low Volatile Organic Content Exterior Coatings for Wood Furniture," (Order No. PB98-100415; Cost: $21.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
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