Developing A No-VOC Wood Topcoat

By Eddy Huang
AeroVironment Inc.
Monrovia, Calif.
and
Robert McCrillis
Environmental Protection Agency
Research Triangle Park, N.C.

A two-component water-based epoxy topcoat has been developed with the potential to match the performance of a solvent-based system and which could replace current solvent systems.

To develop a low-/no-VOC wood topcoat, joint research was conducted which examined promising technologies sufficiently mature for demonstration to wood product manufacturers. The high-value-added coating products were developed in this project with existing technical know-how, data, and patents related to new technology.

A zero-VOC wood topcoat which consists of an epoxy component and an amine curing component was patented by Adhesive Coatings Co. (ADCO), San Mateo, Calif. The absence of organic solvents means this topcoat is less hazardous to use and emits practically no VOCs. (Unless otherwise stated, all volatile organic compound [VOC] content data in this article are less water and exempt compounds.)

A two-component water-based epoxy wood coating system, based on the ADCO topcoat chemistry developed in this project, has the potential to replace a significant share of current organic solvent systems in use. The zero-VOC topcoat's high gloss and excellent chemical resistance properties are ideal for the wood manufacturing industry's flat stock; particle, chip, and wood flower products; spray primers for door skins; and finishing systems for interior wood products such as furniture and kitchen cabinets. This material can be manufactured using readily available raw materials and standard resin manufacturing equipment without polluting the atmosphere.

Coating Characteristics

The most important properties for low-VOC coating technologies are:

- dial-a-cure, or control cure speed through selection/matching of curing agent, including ultra-fast cure (air cure in minutes) and high speed application (forced cure in seconds);
- friendly to adverse application conditions, including the ability to cure under broad temperature range and on wet or dry surfaces;
- high solvents liquid, using water emulsions with water as the continuous phase (no solvents, keying agents, film coalescing aids present or required; and
- environmentally sound, so the coatings are water reducible and water cleanup of materials is possible, contain no solvent (low-VOC) or free isocyanate, and emit no or low formaldehyde.

The two-component water-based epoxy topcoat developed in this project has the potential to meet the performance of the solvent-based system and can replace current solvent systems. The attractive coatings properties which make it promising can be applied in the wood products area. These properties include:

- low or no formaldehyde;
- extreme water and chemical resistance;
- fast cure
- liquid at high solids;
- low temperature cure; and
- no solvents, thus low-/no-VOC.

The ADCO wood topcoat is a two-part, chemically cured, water reducible, air dry epoxy coating for use as a durable coating on wood surfaces and products. It can be used as a sealant and a high gloss, durable topcoat that gives a lacquer-like, clear finish. The absence of organic solvents, in the formulation or during curing, results in zero emission of VOCs and hazardous air pollutants (HAPs).

The self-contained manufacturing process also emits no significant air pollutants. The polymer/curing agent screening matrix, performance characteristics, and chemical/stain resistance of the no-VOC topcoat are discussed in the following section.

Polymer Formulation Testing

Polymer variations of ADCO's basic EnviroPolymer (A) in combination with each of several proprietary curing agents (B) were conducted. All combinations contained low or no VOCs. Up to eight ratios were evaluated for each combination; the best ratio observed was then selected for further evaluation by applying the coating to solid oak.

Four variations of EnviroPolymer A-1 (EP 180-60), A-2 (EP 200-60), A-3 (EP 510-60), and A-4 (EP H-60) were used in this project. Four proprietary curing agents B-1 (80-70), B-2 (65-71), B-3 (65-99), and B-4 (81-93) were identified as being the most likely to yield promising results.

The initial ratings used to identify the most promising ratios for further evaluation were (1) excellent/very promising, (2) good/somewhat promising, (3) fair/possible, and (4)

zero-VOC topcoat developed in this project meets the same cure rate without radiation equipment investment, hazard to the employees' eyes, or skin sensitivities. In addition, the complete finish can be applied after assembly.

In the zero-VOC wood coating market research, the need for new products was discussed with the manufacturing leaders of regenerated wood products such as particle board, chip board, and wood flake products. There are many product opportunities for application of this technology. Efforts were focused on promising possibilities such as binders for particle, chip, and wood flower products; spray primers for door skins; surfacers for concrete form boards to replace paper laminate; and finishing systems for interior wood products such as furniture and kitchen cabinets.

It is anticipated that the zero-VOC wood topcoat developed in this project will set new industry standards by addressing the following problems:

Formaldehyde. All manufacturers seek low or no formaldehyde exposure to their employees, the manufacturing site, and the customer or user.

Lower moisture transmission. All manufacturers seek to reduce changes in product dimension from water penetration and the resulting degradation caused by swelling and warping.

Exterior market. All manufacturers seek to upgrade their product line and achieve penetration in the exterior product market.

Down-time cleanup. All manufacturers of regenerated board must shut down periodically for cleanup (to reduce the green board rejection rate and fire hazard).

Progress has been made to formulate low-VOC coating systems, however many of these use ethylene glycol ethers which are more toxic than most of the solvents used with nitrocellulose systems.

Energy. All the products used by the mills require extensive time/temperature cure or drying cycles. Low temperature or fast air dry would lend improved economics to the industry and/or provide a large competitive advantage.

Toxic air emissions. Some facilities in the furniture industry may use water-based formulations containing toxic compounds, most notably ethylene glycol ethers.[10] Most water-borne wood coatings used glycol ethers in their formulations to stay in compliance.

Most wood furniture is finished with nitrocellulose resin-based coatings averaging 750 g/l VOC and 375 g/l hazardous air pollutants (HAPs). In the finishing of an average dining room table (4 x 6 ft.), about 9 kilograms of VOCs and 4.5 kilograms of HAPs are emitted.

While progress has been made to formulate low-VOC coating systems, many of these use ethylene glycol ethers which are more toxic than most of the solvents used with nitrocellulose systems. Based on the South Coast Air Quality Management District/Southern California Edison/California Furniture Manufacturers Association cooperative study of low-VOC coatings for wood furniture, the VOC/air toxic compounds contained in the commercially available water-based clear topcoat were evaluated. In Table IV, the VOC/air toxic contents of ADCO's zero-VOC coating were compared with commercial coatings which met the VOC content requirement of 275 g/l.

Many resin and coatings manufacturers have done research on low-VOC coatings for the wood furniture industry. Penetration into the market place has been slow. Without regulatory pressure, there is no incentive to switch from traditional high-VOC nitrocellulose coating systems.

Several wood furniture manufacturers and coating suppliers were contacted to identify wood coating concerns, current application methods, costs, and critical areas for product improvements. Marketing information related to the wood coatings market was collected.

This information was reviewed to establish what specific data still need to be collected and how it should be used in structuring the planned market survey of wood coating suppliers. The product marketing discussions have centered on how to commercialize specific low-/no-VOC finished coating applications resulting from this project.

TABLE IV. VOC/Toxic Compounds Contained In Water-Borne Coatings

Manufacturer/ topcoat	VOC (g/l)	HAPs Name	HAPs Weight (percent)
ADCO topcoat	<10[a]	None	0
Akzo 680-60C018-115 w/b	210	Ethylene glycol monobutyl ether	6.2
		Diethylene glycol monobutyl ether	3.9
AMT 01TC-0090-50 w/b	240	Propylene glycol n-butyl ether	1–10
Guardsman 45-1065-40 w/b	270	Diethylene glycol monobutyl ether	6.0
		Propylene glycol n-butyl ether	3.0
Lilly 787W43 w/b	240	Propylene glycol n-butyl ether	3.4
Pinnacle 137-CL-1	270	Triethylamine	<5.0
		Ethylene glycol monobutyl ether	3.0
		Diethylene glycol monobutyl ether	3.0
Sherwin-Williams T70C510 w/r	270	Ethylene glycol monobutyl ether	4.8
		Diethylene glycol monobutyl ether	9.2
Sinclair WL 14-9	200	Diethylene glycol monobutyl ether	3.0
Watercolor topcoat	100	Propylene glycol n-butyl ether	1–10

[a]Detection limit of test method.

Conclusions And Recommendations

The resulting topcoat showed good performance characteristics in terms of adhesion, gloss value, dry time, hardness, level of solvents, and chemical/stain resistance in laboratory development tests. The VOC contents of the clear topcoat and the white pigmented topcoat were less

than 10 g/l, the detection limit of the test method. This coating's performance and properties in finished material were compared favorably with other low-VOC water-borne wood coatings.

Demonstration of the new topcoat at one or more furniture manufacturing facilities would be the next step in commercializing this technology. Further development work may be required in parallel with each demonstration to tailor rheology, dry time, etc. to the host's furniture finishing line.

The identification and/or development of compatible low-/no-VOC stain and sealer wood coatings would provide a complete low-/no-VOC wood coating system.

References

[1] D 523-89, "Standard Test Method for Specular Gloss," American Society for Testing and Materials (ASTM), 1916 Race St., Philadelphia, Pa.

[2] D 3359-93, "Standard Test Method for Measuring Adhesion by Tape Test," ASTM.

[3] D 2197-86, "Standard Test Method for Adhesion of Organic Coatings by Scrape Adhesion," ASTM.

[4] D 1308-87, "Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes," ASTM.

[5] *A Cooperative Study - Evaluation of Low VOC Coatings for Wood Furniture.* South Coast Air Quality Management District, Southern California Edison Company Customer Technology Application Center, and California Furniture Manufacturers Association (released in June 1994).

[6] Choa, C.B. and S. Hom. *Laboratory Methods of Analysis for Enforcement Samples.* "Method 304-91, Determination of Volatile Organic Compounds (VOC) in Various Materials," South Coast Air Quality Management District, Diamond Bar, Calif., June 1991.

[7] D 1475-90, "Standard Test Method for Density of Paint, Varnish, Lacquer, and Related Products," ASTM.

[8] D 2369-93, "Standard Test Method for Volatile Content of Coatings," ASTM.

[9] D 3792-91, "Standard Test Method for Water Content of Water-Reducible Paints by Direct Injection into a Gas Chromatograph," ASTM.

[10] Supplemental Environmental Assessment for: Proposed Amended Rule 1136 - Wood Products Coatings, June 1994. South Coast Air Quality Management District, Diamond Bar, Calif. ❐