Feature

UV&EB in the Flooring Industry—Reducing Greenhouse Gas Emissions & HAPs

By Jeffrey S. Ross

The environmental benefits of ultraviolet/electron beam (UV&EB) technology for coatings, inks and adhesives have been well documented in countless articles in the *RadTech Report*, technical papers and presentations at RadTech's e|5, and uv.eb West conferences.[1-7] Recently, the benefits were recognized by the South Coast Air Quality Management District (SCAQMD) in California and by the California State Assembly and city of Los Angeles with awards presented to RadTech for "Excellence in Advancement of Air Pollution Technology" and "Leadership in Advancing UV&EB Technology."[8] In prior years, the Environmental Protection Agency (EPA) has recognized the technology as superclean. Companies that used the technology have been exempt from certain record keeping and permit requirements. This special recognition is third-party verification that supports the claims that adopters of UV&EB technology are users of green manufacturing methods.

With new efforts to reduce greenhouse gas emissions on the immediate horizon, businesses can rely on UV&EB technology as a key tool to help reduce their environmental footprint by reducing both air pollution and their overall greenhouse gas emissions.

There are two primary advantages of UV&EB technology that have led to the recognition of the technology as "green." First, most UV&EB formulations do not contain significant quantities of volatile organic compounds (VOCs) or hazardous air pollutants (HAPs). Second, the energy to dry a UV&EB coating is much lower than that of a conventional solvent or even water-borne coating. Since much of the energy produced in North America is derived from fossil fuels, reduction in energy consumption is equivalent to greenhouse gas reductions. With new efforts to reduce greenhouse gas emissions on the immediate horizon, businesses can rely on UV&EB technology as a key tool to help reduce their environmental footprint by reducing both air pollution and their overall greenhouse gas emissions.

This article reviews and highlights some of the efforts of Armstrong World Industries Inc. to globally deploy UV&EB technology as part of its overall environmental strategy. It is adapted from a presentation delivered at RadTech's 2007 uv.eb West trade show, which built on some previously published commentary and case study work.[9-12] Armstrong's current policy relating to the environment will be reviewed, highlighting four key components important to the company's stakeholders. It will review how UV&EB technology fits well with the company's strategy to reduce energy consumption and emission of greenhouse gases. In addition, Armstrong's historical use of UV-finish systems for wood and vinyl flooring products will be presented. This includes integration of some of the developments made by DLW AG and Triangle Pacific prior to their acquisitions by Armstrong in 1998. After this background information, a typical wood flooring finish system will be described. Finally, the energy/greenhouse gas impact of choosing UV finish over "conventional" solvent- or water-borne coating for the stain component of that system is analyzed.

Armstrong's Environmental Policy

While this article focuses on UV&EB technology and its relationship to lower energy use and greenhouse gas reduction, it demonstrates Armstrong's longstanding commitment to and investment in responsible environmental practices. According to Armstrong Chairman and CEO Michael D. Lockhart:[13]

"Armstrong has a history of environmental stewardship. Our flooring business began by using cork waste to manufacture linoleum flooring. More recently, we introduced the Armstrong Ceiling Recycling Program that has recycled over 45 million pounds of material that otherwise would have gone into landfills. Now we are broadening our environmental stewardship efforts in four areas—energy, greenhouse gases, water and forest management. These are the areas in which our company has a significant impact. We are the largest wood flooring company in the world. Our ceiling operations are water-intensive and use a significant amount of energy. We are measuring our impact on the environment in the four focus areas. 2007 will become our baseline year for measuring progress toward meeting our improvement goals."

Like other progressive companies, Armstrong has an environmental policy that defines the guiding principles. Senior management ensures integration of these principles into daily business practices. Armstrong's environmental policy is reproduced below:[13]

"Armstrong recognizes the importance of protecting the environment and using resources responsibly. We are committed to exercising environmental stewardship in our dealings with customers, employees, the government and community neighbors, and in meeting an obligation to future generations.

Our policy on the environment is:

- *To exercise care in the selection and use of energy and raw materials.*
- *To provide for environmental safety in our work places and communities.*
- *To be prepared for emergencies and to act promptly and responsibly to protect people and the environment.*
- *To ensure all products conform to safety, environmental and quality standards.*
- *To reduce waste and embrace recycling in all our operations, and to dispose of waste materials in an environmentally responsible manner."*

The Fit Between UV&EB Technology and Environmental Policy

Why use UV&EB? First, the use of UV-process technology helps manage down the use of finite energy resources while minimizing the greenhouse gases from coatings operations. Second, moving from "conventional" coatings systems to "100% solids" UV-curable coatings systems reduces volatile emissions and associated transportation weights. A specific example of this is provided later in this paper. Figure 1 shows the volatile emissions and transportation weight reductions that one can achieve by changing to a 100% solids UV coating from a standard water- or solvent-based system.

Figure 1

Volatile emissions and transportation weight reductions for 100% solids UV coatings

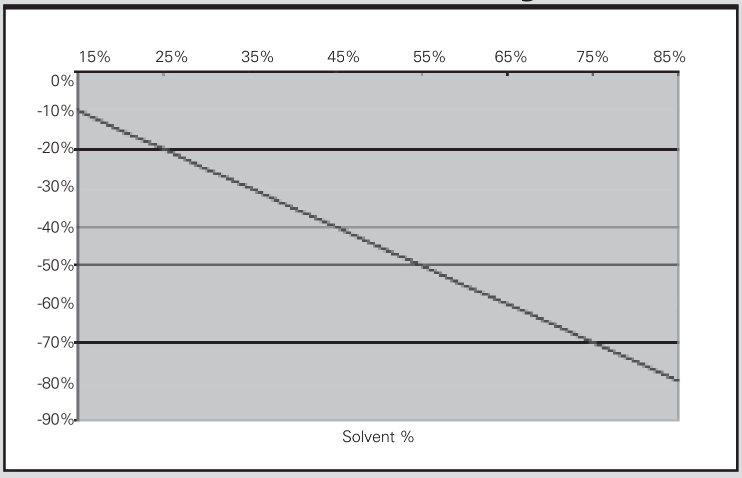


Figure 1 contains some assumptions. The first assumption is that a 100% solids system contains about 5% volatile material. For Armstrong coatings systems, this is a good assumption. Armstrong coatings' volatile content has been measured by ASTM D5403 and found to be substantially less than 5%.[14] So when reviewing Figure 1, the reader should note that there is a zero percent decrease for a coating with 5% solvent. For this figure, the 5% corresponds to materials such as a photoinitiator that might be considered as "volatile" material in a 100% solids coating. The second assumption is that the weight percent of solvent in a coating system is directly proportional to the fuel savings achieved if the solvent was eliminated. This may be a reasonable assumption. If a manufacturer purchased three truckloads of a 33% solids water-based coating system, and then changes to a 100% solids coating system, the new requirement would be only one truckload. The fuel savings and expense savings from the shipping, and the CO_2 emissions from the delivery would be reduced by about 60%. This assumption works if the coverage requirement and density of the coating are the same, otherwise slight corrections must be made.

Besides shipping advantages, there are several other ways that UV&EB coatings fit into a responsible environmental strategy. These include:

- Greatly reduced or eliminated VOCs and HAPs.
- Decreased total energy demand to dry and cure.
- No greenhouse gas emissions from the drying and curing process.
- Many coated floor products meet IAQ guidelines such as CA 1350 and can be certified as such under FloorScore™, which in turn makes building projects eligible for LEED credits.
- Reduced coating volumes decrease storage space footprint required for staging coatings for finishing operations.

Most UV coatings consist of a combination of four materials: monomers, oligomers or resins, photoinitiators and additives. Monomers are similar to the solvents used on conventional coating and finish systems. They are low in viscosity, can be used to dissolve oligomers and resins, and serve as a carrier for other additives such as fillers, flatting agents and various flow and leveling agents, etc. For UV systems though, the monomers are reactive materials that polymerize with each other and the resins they carry when the system is exposed to UV light. The result is a high-molecular weight solid resin. Because of this unique property, most UV monomers are not considered to be

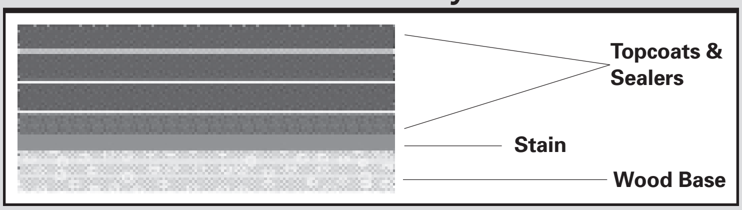
Table 1

Armstrong UV&EB technology timeline

1976:	First "no-wax" urethane (thiol-ene) coating for residential vinyl tile
1977:	First UV moisture-cured urethane acrylate for residential vinyl tile
1979:	First UV-cured urethane acrylate for residential vinyl tile
1980:	First polyester urethane acrylate for residential vinyl tile
1992:	Hybrid Sol-Gel type cationically cured topcoat for residential vinyl tile
1993:	First UV coating for heterogeneous commercial sheet vinyl
1995:	UV-polyester acrylate nitrogen inerted coating for sheet vinyl
1996:	First EB-cured urethane acrylate for residential vinyl tile
1996:	First EB-cured PNP adhesive for residential vinyl tile
1997:	UV low-gloss sheet vinyl
1998:	Armstrong acquired DLW AG & Triangle Pacific and with it a UV-coatings footprint consisting of 17 flooring manufacturing facilities in North America and Europe • **Brands included:** Genuine Linoleum, Bruce, Hartco, Robbins, Desso • **Products included:** Linoleum, Commercial Carpet and Resilient Flooring, Sports Flooring, Artificial Turf, Engineered Wood Flooring, Solid Hardwood Flooring (3/4" and 5/16"), Parquet Flooring, Impregnated Flooring, Laminate Flooring, Adhesives, Installation & Maintenance Accessories • **First from TriPac in 1993:** UV-cured, high-abrasion finish system with aluminum oxide for engineered wood flooring • **First from DLW in 1994:** Four meter wide cushion vinyl flooring with UV-cured finish
2003:	UV-cured topcoats deployed on homogeneous commercial sheet flooring
2004:	First UV coating for linoleum
2006:	UV coatings applied to all commercial sheet flooring
2007:	Expanded capacity for engineered and solid wood flooring with UV-finish systems

FIGURE 2

Generic cross section of a factory finish for wood



VOCs or HAPs. Using materials such as these in a coating or finish system is a classic example of pollution prevention.[15]

The reduced energy demand to dry and cure UV&EB materials is documented in a specific example for 100% solids wood stains later in this report. Similar calculations can be and are being completed for linoleum, commercial sheet flooring, cushion vinyl flooring, and several types of resilient tile products. In addition to the energy demand reduction, because no gas ovens are required to cure 100% solids UV&EB coatings, there are no direct emissions of greenhouse gases. The only contribution to greenhouse gas emissions is from the electricity used to drive the UV lamps. As shown later in this report, that number is far less than a direct gas-fired oven.

A benefit of many UV coating/finishing systems for flooring is that products using them have been tested and certified under the FloorScore™ program.[16] Currently, this program, which is administered by the Resilient Floor Covering Institute, uses an independent lab to analyze and report on the compliance of floor coverings for indoor air quality. Products that meet the rigid standards of CA1350[17] under this program are eligible for LEED points. LEED (Leadership in Energy and Environmental Design) is a building project rating system administered by the U.S. Green Building Council (*www.USGBC.org*). According to USGBC, LEED "is the nationally accepted benchmark for the design, construction and operation of high-performance green buildings." Its purpose is to promote "a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality."

Finally, reducing the manufacturing footprint is a key element of sustainable manufacturing. Less square footage in new construction means lower usage of materials and energy. UV&EB finish systems use less space than conventional ovens. In the example below, the UV footprint is about 50 square feet as compared to 150 square feet for a conventional oven. In addition, less storage space is required to stage materials for the finishing operation.

History of UV&EB Use at Armstrong

A more technically detailed review of Armstrong's use of UV&EB coatings was presented at a RadTech technical meeting several years ago.[18] Table 1 shows a timeline for UV/EB deployments at Armstrong. It started with the deployment of a thiolene coating system from W. R. Grace in the mid 1970s. That system was soon replaced with an improved system, and change occurred rapidly through the early 1980s. The next major advancements occurred in the early 1990s as several flooring companies worldwide including Armstrong, DLW AG (later acquired by Armstrong), Tarkett, Domco, Mannington and Congoleum, worked with various equipment suppliers to develop wide-width (2-4 meter) coating technology for UV&EB-curable resins. Technological solutions to problems like "gloss banding" were varied and creative. Some examples included ultra-wide width UV lamps, special mirror systems, overlapped lamps, machine direction and offset lamps, and end-butted microwave powered lamps. Meanwhile, the wood industry was developing technology for "factory finish" for solid and engineered wood flooring. Armstrong was using vendor facilities and an in-house pilot plant to develop EB-cure technology for radiation-curable urethanes and PNP (Place and Press) adhesives. By the second half of the 1990s, two production EB systems were installed for resilient flooring, and Bruce Hardwood Flooring, a division of Triangle Pacific, had launched its second generation of Permion coatings. Permion was a coating technology brand that Bruce used to differentiate aluminum oxide containing topcoat systems that had high-abrasion resistance. Currently,

FIGURE 3

Cross sectional view of ten-layer UV finish for wood

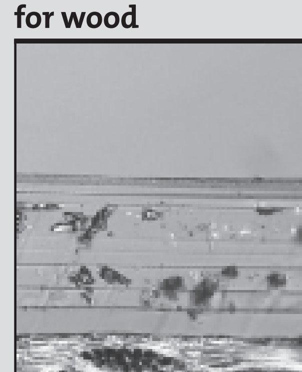
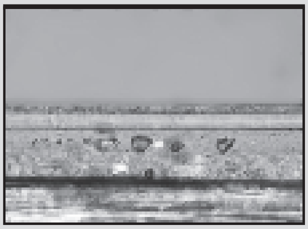


FIGURE 4

Cross sectional view of seven-layer factory finish for wood



nearly all commercial sheet flooring marketed worldwide uses a UV-cured topcoat. This includes genuine linoleum with UV-cured NatureCote™, which was launched in Europe in 2004 and in the U.S. this year.

The following section has an example calculation and comparison of the greenhouse gas emission footprint of a "conventional" solvent or water-based coating and a 100% solids UV-curable coating. The actual calculation was performed using data from a recent installation on one of Armstrong's wood finish lines. To help the reader understand the significance of the calculation, it seems worthwhile to briefly describe the elements of factory finished wood flooring. Figure 2 shows a diagram of a generic wood floor coating system. Figures 3 and 4 show actual photomicrographs of a 10-layer factory finish and a seven-layer factory finish. Both finishes are UV cured. The differences are in the type of stain used, in the number of layers and the type of materials used in each layer. For example, Figure 3's 10-layer system uses a 100% solids UV-curable stain layer, whereas Figure 4's seven-layer finish system contains a solvent-based stain. Both finish systems have slight differences in the number and specific type of sealers and topcoats that go over the stain. The example calculation will compare the stain layers for these two systems.

Figure 5 is a chart that shows the greenhouse gas emission footprint in pounds per hour as a function of UV bulb width, and for several different operating power levels. The figure works for mercury (Hg) arc lamps and microwave-powered lamps, as well as additive lamps of both types. The key number is the applied power level, not what is inside the bulb. A similar chart could be created for lower power systems like UV LEDs. Currently, most UV systems for flat line wood coating operations are Hg arc lamps and are operated at either 200 or 300 W/inch. This example used an applied power level of 300 W/inch. The data in the chart was obtained from the U.S. Department of Energy Web site[19]. The data used was a U.S. 50-state weighted average, which included various types of power sources, not the data from a particular location or state. Referring to Figure 5, a single UV lamp operating at 300W/inch at a lamp width of 60 inches has a greenhouse gas emission equivalent of approximately 25 lbs/hour. For two lamps used together, the emission equivalent is about 50 lbs/hour.

The final comparison of the solvent system is shown in Figure 6. It combines the data on emissions per hour for two 60-inch Hg arc lamps with the emissions data for a 1.2 MBTUH high-velocity gas fired oven. The result is clear from the figure. The UV-curable coating emission equivalents are less than half those from the conventional oven drying system. The result is more significant because a complete energy audit has not been included in Figure 6. Additional items not included on the gas oven side:[20]

- Emissions from combustion of the solvents, which are burned in the oven.
- Additional motors used for make-up air required due to operation of an oven.
- Higher transportation energy/ emissions related to the solvent, which is evaporated in the oven.

Summary

Armstrong's 30-year heritage of using UV&EB technology to produce

FIGURE 5

Emissions footprint of UV lamps as a function of UV lamp width

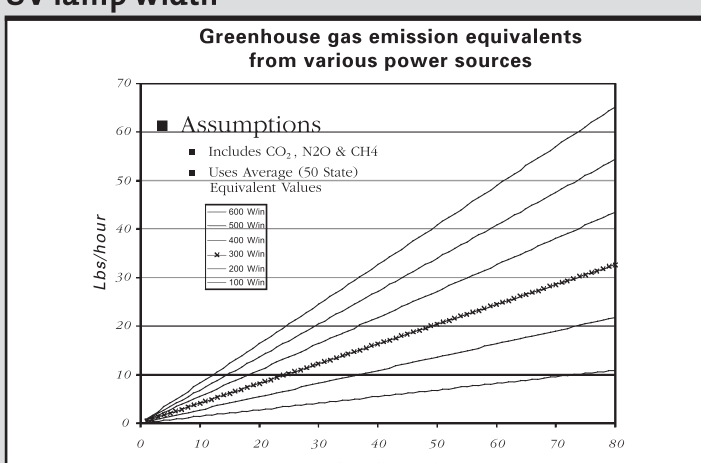
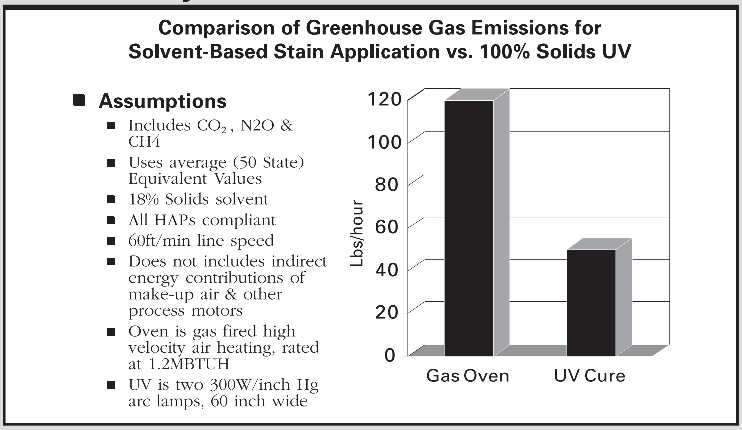


Figure 6

Emission comparison of solvent-based and 100% solids stain systems



high-performing products has made, and continues to make, a solid contribution to the reduction of greenhouse gas emissions during the manufacturing of flooring products. As demonstrated here, it is a relatively simple matter to generate numbers that highlight the environmental benefits of using UV&EB technology. Companies that wish to demonstrate a similar commitment to environmental stewardship can easily calculate and validate assumptions on the environmental benefits of UV&EB, and should be encouraged by the often superior performance properties of UV&EB-cured coatings versus common alternatives.

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