FEATURE

Wood Finishing with UV-Curable Coatings

By Lawrence C. Van Iseghem

Business today must cope with global competition, soaring labor rates, and increased regulations associated with air emissions, waste disposal, and safety and health. Managing an industrial wood finishing operation is demanding, and survival in today's business climate is not possible by ignoring these issues. For the wood finisher, it is essential to use finishes that are less labor intensive and are applied and dried fast to facilitate high-production speeds. They must also have a low impact on the work and natural environment. New technology is making a dramatic impact, but the transition to new finishes and their associated processes can be costly to implement and time consuming to learn.

This article is intended to provide information on UV-curable finishing systems from a non-chemist perspective.

Reality sets in very fast when considering all that confronts today's wood finisher no matter if they are associated with cabinetry, furniture, architectural moldings, millwork and doors, or hardwood flooring. Thankfully, UV-curable finishes including stains, primers, sealers, and topcoats are available that greatly reduce the pressures placed upon the industrial wood finisher. Many have already taken advantage of UV curing and its benefits, while others are actively pursuing this technology and hoping to move forward toward implementation. There are still others that are searching for answers and wondering if UV curing can help.

This article is intended to provide information on UV-curable finishing systems from a non-chemist perspective. It will provide insight in making an effective transition to UV-curable coatings and identify the opportunities that can be gained once the transition is complete.

Types of UV-Curable Coatings

The industrial wood finisher has essentially three options in types of UV-curable coatings to use—100% UV, water-reduced UV and solvent-reduced UV.

Each type of UV-curable coating can be applied by virtually any method of application. The selected method of application is dependent on the surface structure/property to be finished, the finish quality desired on that surface, and the production rate that finishing must conform to. The selection of the UV-curable coating type applied by any method is really a matter of finish build or thickness, the ease to achieve certain finish subtleties (gloss, leveling, etc.), and the ease of use of the coating system.

In general, if 100% UV-curable coatings can be used to produce the desired finish quality, it is best to set a course of action to use them. Costs, operation expenses and reporting requirements will be most advantageous with 100% UV-curable coatings. If very thin film builds are desired, less than 100% actives may be necessary and the use of water-reduced UV-curable coatings is most preferential. Water-reduced UV-curable coatings present significant advantages vs. solvent-reduced forms due to potential safety and air reporting factors. Let's examine each and their use in finishing operations.

100% UV Curable

These UV-curable coatings are liquid coatings that do not contain any evaporative solvent or water. Their nature is entirely active chemistry that converts directly to a solid finish upon exposure of the applied coating to ultraviolet energy. Since there is no requirement to dry the coating, the wood surface can immediately exit the application section of the finishing line and enter the UV-curing zone or UV "oven." Cure is instantaneous and parts exit the UV oven ready to be handled in the next stage of production. A very significant advantage with 100% UV-curable coatings is the fact that the excess coating may be re-used. Overspray, overflow from roll and flow coat operations, doctored excesses and other collected UV coating from other methods of application all may be captured for re-use.

UV-curable coatings enable the most rapid of production rates and any application method is possible. It is a proven fact that 100% UV-curable coatings can be and are routinely sprayed on large and small format wood surfaces. The footprint or length of a finishing line can be remarkably small and they are able to process woodwork at very rapid speeds. Large 4' x 8' panels and doors are applied by UV-curable coatings via reciprocating, rotary, and stationary spray guns at process speeds between 25-40 fpm. Mouldings and millwork can be processed at speeds up to and exceeding 350 fpm. Considering these speeds, it is surprising to learn that the length of the finishing line is only necessary to load and unload woodwork, sand or denib, apply coating and to perform UV cure.

Cleanup is easy with 100% UV-curable coatings. Since only UV energy and high heat affect the coating, prevention of exposure results in no need to clean up unless color changes are made with the coating to be applied. The over spray will not solidify, spray tips remain open and roll coaters, coating fluid reservoirs, and fluid lines need only be drained or emptied at the conclusion of finishing operations. Only periodic flushing is needed and a schedule can be best established by communicating with the coating supplier and the equipment manufacturer.

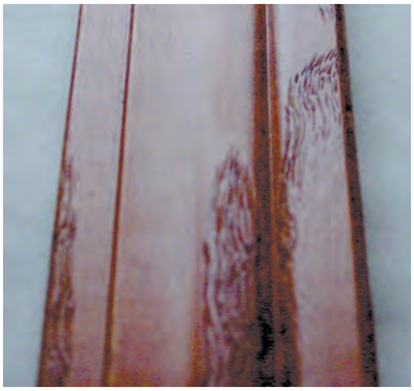
The downside of 100% UV-curable coatings is minimal and usually avoidable with adjustments to application techniques. The most common issue voiced in the industry is that 100% UV-curable coatings build thickness too fast and conventional finish appearance is not attainable. Another issue that is commonly referenced is that low gloss is difficult to obtain with this type of coating.

Although 100% UV-curable coatings can be applied to give thicknesses that result in a "plastic" laminate appearance, there are many finishing operations that desire this feature. High-build, attractive finishes are easily obtained and are found in custom aircraft interiors, yacht interiors, picture frame mouldings, full-filled floor coatings, tabletops and countertop coatings and other surfaces. Subtle finish appearance is, however, easily achieved by controlling the application rate of both seal coat and topcoat layers. Versatility is the key to 100% UV-curable coatings and a quality coating manufacturer can engineer the system to flow and process well at low-coat weights.

The finish gloss is usually dependent on the ability of a particulate in the coating composition to be present on the cured finish surface. The particulate will disrupt or scatter reflected light reducing the surface finish gloss. In the case of 100% UV-curable coatings, either the particulate has to be bigger than the thickness of the deposited coating layer or there has to be a mechanism that drives the particulate to the coating surface during cure. As you may suspect, the coating manufacturer faces a significant challenge when providing low-gloss options to the finisher. Some manufacturers depend on abundant particulate loading to achieve gloss control and others use finesse to manipulate where the particulate migrates during cure. In any case, gloss control is a factor to consider but not a factor of concern when dealing with a quality coatings manufacturer.

Another factor in 100% active UV-curable coatings is the presence of orange peel, and with lesser quality finishes, it can be especially noticed as the gloss is lowered. This is a result of two principle influences: the ability of the UV-curable composition to flow out well and the ability of the initial seal coat layer to perform on various wood species. It is advised to consult your coatings manufacturer with any difficulties associated with orange peel and to determine the cause and proper corrective action. This is a very correctable phenomenon and excellent surface uniformity is achievable regardless of the application thickness or gloss.

Pigmentation is another option available in 100% active form. Opaque whites, blacks and colors can be



Notice the subtle finish build and lack of orange peel in this spray application of self-sealing topcoat applied over a waterborne wiping stain.

achieved, but must be carefully engineered by the coating formulator. Care must be taken with colors that have absorption in the ultraviolet region as they reduce the amount of UV energy that can reach the chemistry. The UV chemistry will only work if it can "see" the UV energy. Colors that absorb UV energy prevent energy from reaching the chemistry. It is common to find that yellows, reds, blacks and some metallics are more challenging than other colors.

100% UV-curable coatings can vary somewhat in their user friendliness and they can vary significantly from manufacturer to manufacturer. Low viscosity spray, vacuum and flow coat UV-coating compositions may be formulated with higher monomer content. Depending on the monomer used, the coating may be more or less influential or sensitive to individuals exposed to contact. Furthermore, wood is very porous and low-viscosity materials will absorb readily into its structure and may not be able to "see" the necessary UV energy to cure effectively. Un-cured materials may migrate to the finish surface over time and may cause the finished wood surface to give off an unpleasant odor for a period of time. Proper formulation, application methods, UV-cure conditions, and a very short dwell time between application and cure will eliminate any unpleasant odors or possible skin exposure issues when handling finished parts.

Pictured above are two finished samples from a vacuum coat application of tinted 100% UV-curable pigmented topcoats.

In the finishing process, the use of 100% UV-curable coatings is convenient since it is compatible with most traditional application equipment. Fluid pumping is, however, a very important consideration. 100% UV-curable coatings must not be delivered by a pump that subjects the coating to high shear forces such as a piston pump. This is especially important where coating application requires high-fluid pressure. Airless and air-assisted airless spray application must be facilitated by low-shear, high-pressure pumps. There are hybrid piston/diaphragm and/or bellows style pumps that are capable of delivering UV-curable coatings at high pressure without the risk of shear forces that may cause premature gel formation of the coating.

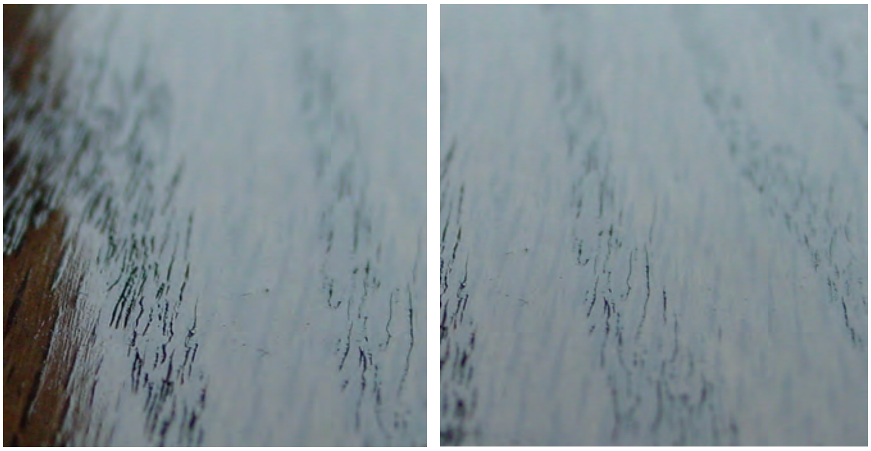
Water-Reduced UV Curable

The demand for water-reduced UV-curable coatings is predominant in high-volume door and panel finishing operations. These surfaces typically have a low-build appearances comparable to that created with traditional or conventional solventborne coatings. It was commonly believed that this appearance could only be achieved using UV coatings that were not 100% active. Today, that assumption persists, but there have been significant advances in chemistry and techniques that make low-build finishes possible with high-active/solid content, including 100% UV curable. Regardless, many UV-coating manufacturers offer water-reduced UV-curable coatings that are between 30-45% solid or active. The coatings are easily applied, dried and UV cured to provide excellent finish appearance, durability and resistance.

From a historical perspective, as the UV market evolved, many finishers retrofitted existing, conventional coating lines with UV ovens to accommodate UV-curable systems. These lines included lengthy drying ovens and when 100% UV-curable coatings were evaluated, they exhibited too much penetration into the wood surface. Compositionally, the UV-curable coatings were rich in monomer content to provide low-coating viscosity so as to promote flow and leveling, but also promoted wood surface penetration or "strike-in." In addition, the duration and heat the coating was exposed to through the drying oven section, caused uncured material to reside in the wood, and it was not possible to achieve quality finish characteristics.

Even though removal of the oven would solve the problem of finish quality, many finishers remained loyal to their equipment and sought alternatives. Water-reduced UV coatings became a viable option in making the transition to UV-curable systems for those with existing finishing lines. Only the addition of a UV oven to the end of the process line was necessary. In fact, it is common to see many new installations that are specifically designed for reduced forms of UV-curable coatings, in either water or solvent form.

Water-reduced UV-curable coatings permit excellent gloss and viscosity control and, therefore, apply easily with minimal or no process issues with VOCs/HAPs. Pigmented versions are available, and the use of many universal type colorants offer the capability of custom color matching. Any method of application can be used, although it is



A section of red oak panel (left) finished with water-reduced UV curable (40% solids). Another red oak panel (right) finished using 100% UV curable. Both products were spray applied, but notice the filled appearance in the deep grain areas of the 100% UV-curable finish vs. the water-reduced UV-curable finish. Build is more easily controlled with reduced UV-curable coatings.

most common to see spray and vacuum coat lines in operation.

Some of the process sensitivities encountered include the difficulty to obtain finish build (when you wish for it to build fast and easily) and incomplete drying prior to UV cure. Obviously, the build issue is a direct result of solid content, just as it is a factor associated with all low-solid content finishes. The dryness of the water-reduced UV curable can be a true concern.

Finish defects will occur if the coating is not fully dry prior to UV cure. A common defect observed is the presence of white spots in the finish especially where the coating thickness is slightly higher. For example, thicker deposits of coating may tend to exist in crevices, corners and depressions on the surface. These white spots are created when suspended UV-sensitive material undergoes cure before it has a chance to dry and form a continuous film. The cured, non-film formed mass of material scatters reflected light, and it will appear as a white spot or area. Other finish defects may include blisters and bubbles present in the cured finish. These are formed by the combination of heat from the UV lamps and from the exothermic reaction of the dry UV-sensitive material during cure. Water and other volatiles will rapidly flash out of the coating causing these defects.

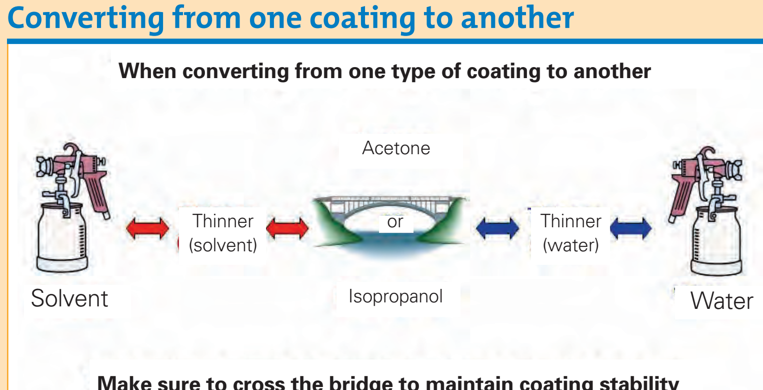
In the use of water-reduced or waterborne UV-curable coatings, it is very important to make sure that all wetted parts are non-corrosive. Fittings, regulators, and valves should be of stainless steel. In some instances, aluminum components can be used, but maintenance is important to prevent any corrosion or white rust formation. Any fluid pump system can be used as the content of water buffers the effect of shear forces on the UV-sensitive components.

Capturing coating excesses is possible for improved transfer efficiency, but it is not as simple as for 100% UV-curable coatings. Collected and reclaimed coating must be monitored for any viscosity shift and adjusted accordingly with water and/or any co-solvent content that was originally in the composition and may have evaporated. The coating manufacturer can provide guidance in the adjustments that may be necessary to effectively reclaim the coating.

Cleanup is readily done by flushing with water. A secondary rinse can be done for any deposits that are stubborn and for dried deposits of material. If this is necessary, a water miscible (compatible) solvent is required (such as acetone or isopropyl alcohol), which are referred to as bridge solvents. The transition to water-based coatings from solvent-based coatings or vice versa must always go across the bridge solvent when considering the wetted parts and fluid path the coating must take in application. It is necessary to drain the system of coating, flush with a suitable thinner (a solvent for solvent-based coatings and water for water-based coatings), followed by flushing with a bridge solvent, a flush with the thinner for the new coating to be used, and lastly to charge the system with the new coating (Figure 1). In this manner,

Figure 1

Converting from one coating to another



coagulation of solid content and other incompatibility issues are avoided that can cause substantial downtime and repair.

Solvent-Reduced UV Curable

The finishing process associated with conventional solvent-based coatings is well established and understood by most industrial wood finishers. Therefore, it is a simple transition for finishers who wish to make the switch to solvent-reduced UV-curable coatings. The same process equipment can be used including pumps, applicators, and drying ovens, and the addition of a UV-curing oven will complete the process change.

UV-curable coatings chemistry has been reviewed in many publications. Simple comparisons will show that UV-curable coatings perform similarly to thermoset coatings offering maximum durability and resistance to chemicals and water. The action of UV curing, however, is exceptionally rapid and very desirable from a wood finisher's perspective. Solvent-reduced UV-curable coatings offer the wood finisher the easiest means to reduce labor and maximize productivity, but do not offer the most optimum system from a regulatory point of view.

The use of solvents enables effective viscosity reduction, especially in the use of very viscous UV-sensitive components that may be present in the coating formulation. Therefore, monomer content can be minimal and issues associated with wood penetration and incomplete UV cure can be avoided. Leveling, flow, atomization, coating uniformity, surface film build control and other properties can be controlled by using reduced forms of UV-curable coatings. Compared to water-reduced forms, solvent usage enables more rapid drying and thereby faster production rates with lower energy consumption.

It is quite easy and effective to flush and clean wetted parts with solvents. It is very desirable when considering the cleanable conveyor belt used in flat line spray systems. Solvents are effective in removing overspray on the conveyor belt, and they dry rapidly, preventing any coating contamination that may transfer to the bottom side of woodwork that may follow.

Solvent-reduced UV-curable coatings enable dramatic opportunities, but they still have negative environmental impacts similar to conventional solvent coatings. VOCs may still be present and must be dealt with appropriately. Newer formulations make substantial use of acetone, n-butyl acetate, and other compliant solvents, but flammability hazards can present significant safety concerns. Reclamation capability for improved transfer efficiency is somewhat more limited relative to water-reduced forms, and any accumulated waste material must be handled as hazardous.

Advice to the finisher considering the use of or currently using solvent-reduced UV-curable coatings—explore the options that exist with water-reduced and 100% UV-curable coatings. It is very likely that you can achieve the desired finish characteristics and performance with one of those systems and avoid the use of solvents that can be costly to use and difficult to dispose.

Finishing Factors

All wood finishers will agree that there is considerable variability in wood species, and often special considerations are necessary in finishing one relative to another. As we come close to the end of this paper, some factors associated with wood finishing and the ability to finish well with UV-curable coatings will be discussed.

The proper seal coat application is illustrated in the picture on the left. Roll coat application of 100% UV curable was performed to achieve the surface appearance where dry spots and lack of build is observed. This application thickness enables ease of sanding denib and permits excellent finish uniformity upon topcoat application as shown on the right.

Virtually any wood species can be finished to high standards, but the selection and use of the proper UV-curable coating requires certain considerations.

Seal Coat

Regardless of the use of self-sealing topcoats or separate sealer and topcoat in the finishing process, it is essential to apply the correct amount of sealer when using UV-curable coatings, most especially with 100% forms. The wood finisher is strongly advised to be very careful *not* to apply substantial film build of 100% UV-curable coatings to the wood surface when sealing. The properly sealed wood surface should look visibly dry and starved for coating. Experience will demonstrate that an effective seal coat has been applied in this manner and dramatic improvement in topcoat uniformity will result. It is of equal importance to cure the applied seal coat layer immediately after application as any delay will result in excessive seal coat "strike-in" and cure will be compromised. Water- or solvent-reduced UV-curable coatings should be applied similarly as conventional waterborne or solventborne coatings and thickness is not as critical as it is with the 100% form.

Excessive seal coat application will result in irregular areas of thicker film build and aggressive sanding will be required to produce a uniform surface for topcoat application. It is common to see what is best described as an "oatmeal" or broad "orange peel" in the surface texture of the final finish. This effect is magnified if the flow characteristics of the coating formulation are not well designed.

Intercoat Adhesion

There are a few UV-curable coating compositions that exhibit excellent adhesion without intercoat abrasion, sanding or denibbing, but application of overcoats must be within a short period of time after the previous coat (up to 24 hours in certain cases). Thereafter, and like most other UV-curable coatings, abrasion is necessary to achieve quality intercoat adhesion. The chemistry, once cured, is incredibly resistant to chemicals and to itself upon topcoat application. Adhesion is not, therefore, substantially achieved by chemical interaction, but more by mechanical means.

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Sanding

UV-curable coating compositions are very hard and more difficult to sand. This is one reason certain industrial wood finishers will use a separate sanding sealer as opposed to a self-sealing topcoat. Topcoats are the final wear surface and should be tough and durable. Therefore, they do not sand well. Sanding sealers can be designed to sand readily and dust up well without any clogging of the media used. Self-sealing topcoats are a compromise between the two extremes. Regardless of the composition, the grade of sanding media is very important. If the media is too coarse, sanding lines may remain, and it may be difficult to prevent potential seal coat removal in spots. The resulting topcoat uniformity will be poor in either case. If the media is too fine, the surface may not wet out well upon topcoat application. Orange peel can be observed, and/or adhesion will not be complete.

Rough surfaces are easier to coat well than smooth surfaces, and it is always necessary to develop a micro-roughness for topcoat uniformity. Assuming proper seal coat application, if adhesion is poor and/or orange peel is noticeable, reduce the grit count of your sanding media, and look for improvement.

The quality of raw-wood preparation is also important for quality adhesion of UV-curable coatings. Sanding with media that is too fine may cause the pore structure of the wood surface to be packed and filled with sanding dust. This will prevent adequate binding of the seal coat to the intact wood structure. If seal coat adhesion is compromised, evaluate a reduction in media grit, and check the UV energy delivered for effective cure as one or both may be the contributor to lack of adhesion.

Cure Conditions

Considering 100% UV-curable coatings, low-irradiance cure will result in lower gloss values and higher irradiance cure will result in higher gloss values. This phenomenon is a direct result of the ability of the flatting additive to be expressed at the surface of the finish. Slower cure allows thermal effects to push flatting additives to the surface better in 100% UV-curable coatings. If the finisher observes a drop of 5-10 in gloss value, the irradiance of the UV lamps may be falling out of the desired performance level, and the lamps should be checked.

Pitch, Sap and Oils

Oak, maple and other common hardwoods are relatively straightforward in finishing. Sap woods and oily wood species, however, can present challenges. The heat of high-intensity

UV-curing lamps and the exothermic reaction of the UV-coating chemistry can and often does draw pitch, sap and oils to the wood surface during cure. Imagine trying to coat, cure and maintain adhesion to a liquid surface. It isn't possible, and it isn't possible to adhere 100% UV-curable coatings to softened sap and oils accumulating on a surface. Water- or solvent-reduced UV-curable coatings do not exhibit this effect to any significant degree, but should adhesion fail, investigating pitch, sap and/or oil content may be worthwhile.

Wood is typically harvested, kiln dried and heat processed to fix pitch and sap. Hardwoods should always be in the 5-8% moisture range for quality finishing. In pine species and other sapwoods, the moisture content is higher for quality finishing at 12-18%. Sapwoods lower than 12% moisture content can present dimensional problems such as warping and twisting. Further, pitch and sap are typically "fixed" at temperatures near 165˚F. The lumber is held at the prescribed temperature for a specific duration and full treatment can also risk warping and twisting. Depending on the quality of wood and its treatment, variability in finish quality can result from lumber of the same source over time and from pallet to pallet.

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Other environmental factors are important to quality finishing and some affect certain species more than others. For example, poplar, aspen, birch and other soft hardwoods can attract moisture rapidly, and any cold storage of lumber can influence the surface moisture content of the wood once it is brought into warmer temperatures. Moisture will condense on the surface of cold lumber in a warm environment. Although, not necessarily a problem with water-reduced UV-curable coatings, solvent-reduced and 100% UV-curable coatings do not adhere well to moist surfaces. Lumber should always be equilibrated prior to finishing and soft hardwoods will benefit by the use of surface heating prior to finishing. It is common to find a short, in-line, infrared (IR) heating zone just prior to coating application for these species.

Concluding Remarks

A number of concepts have been presented that impact the ability of the industrial wood finisher to achieve a quality finish when using UV-curable coatings. For the experienced UV finisher, many of these concepts are reminders, but hopefully some deeper insight has been gained. For the finisher new to UV-curable coatings, perhaps some of the difficulties in making an effective transition to this wonderful technology will be minimal. To all finishers, the best of success with UV curing as it is truly designed to target your benefit. ◗

—Lawrence C. Van Iseghem is president of Van Technologies, Duluth, Minn.