Waterborne UV Coatings for Industrial Wood Applications

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Introduction

Waterborne (WB) UV curable coatings have become popular choices for industrial wood applications. Kitchen cabinet and furniture manufacturers choose these coatings because they have excellent resistance and mechanical properties, excellent application properties and very low solvent emissions. WB UV chemistry is gaining market share over traditional solvent based chemistry because it enables the end user to increase production efficiency and maintain a smaller manufacturing footprint. WB UV coatings have excellent block resistance immediately after cure which allows the coated parts to be stacked, packaged and shipped right off the production line with no dwell time for hardness development. The hardness development in the WB UV coating is dramatic and occurs in seconds. Solvent based nitrocellulose lacquers and conversion varnishes have been the coatings of choice for industrial wood applications for many years. Due to increasing regulations for lower volatile organic compound (VOC) and formaldehyde emissions, more environmentally friendly coatings are now in demand. WB UV coatings are the natural choice since they have the appearance of the solvent based coatings but have very low emissions.

Three types of solvent based coatings are commonly used in industrial wood applications. Nitrocellulose lacquer is typically a low solids blend of nitrocellulose and oils or oil based alkyds. These coatings are fast drying and have high gloss potential. They are typically used in residential furniture applications. They have the disadvantage of yellowing with time and can become brittle. They also have poor chemical resistance. Nitrocellulose lacquers have very high VOCs usually at 500 g/l or higher. Pre-catalyzed lacquers are blends of nitrocellulose, oils or oil based alkyds, plasticizers and urea-formaldehyde. They use a weak acid catalyst such as butyl acid phosphate. These coatings have a shelf life of approximately four months. They are used in office, institutional and residential furniture. Pre-catalyzed lacquers have better chemical resistances than nitrocellulose lacquers. They also have very high VOCs. Conversion varnishes are blends of oil based alkyds, urea formaldehyde and melamine. They use a strong acid catalyst such as p-toluene sulfonic acid. They have a pot life of 24 to 48 hours. They are used in kitchen cabinet, office furniture and residential furniture applications. Conversion varnishes have the best properties of the three types of solvent based coatings typically used for industrial wood. They have very high VOCs and formaldehyde emissions.

There are several different standards used to specify the properties needed for industrial wood applications. The Kitchen Cabinet Manufacturers Association (KCMA) outlines finishing tests for cabinets. The Architectural Woodwork Standards (AWS) include specifications for furniture coatings and individual furniture manufacturers have their own set of specifications. Each of these specifications includes tests for both chemical resistance and mechanical endurance.

A study has been conducted to compare the properties of several high performing WB UV coatings to the properties of a traditional solvent based conversion varnish. Table 1 provides a basic summary of the resins used to formulate these coatings. Both UV PUDs and blended combinations with acrylics have been evaluated. Binder solids ranged from 35 to 45% and most of the resins have high resolubility prior to cure with the exception of UV A which has very high hardness. This investigation details the performance of these resins for industrial wood applications according to KCMA, AWS and individual furniture manufacturer's specifications.

	% Solids (wt)	pH	Viscosity	Koenig Hardness Before UV (sec)	Koenig Hardness After UV (sec)	Chemistry
UV A	35	8.3	200	60	155	UV PUD
UV B	40	7.3	200	20	145	UV PUD
UV C	39	8.3	200	20	140	UV PUD
UV D	44	7.3	300	15	120	UV PUD Hybrid
UV E	44	7.5	300	10	125	UV PUD Hybrid
UV F	41	7.5	250	20	145	UV PUD Hybrid
UV G	40	7.8	200	10	125	UV PUD Hybrid
UV H	45	7.5	350	15	110	UV PUD Hybrid / Acrylic Modification
UV I	45	7.5	350	20	115	UV PUD Hybrid / Acrylic Modification

Table 1. Properties of UV Resins

Experimental:

The UV resins were formulated as described in Table 2. All formulations were adjusted to be equal in solids.

UV Resin	84.27
Defoamer	0.51
Surfactant	0.51
Matting Agent	1.34
Water	12.05
Photoinitiator	0.96
Rheology Modifier	0.36

Table 2. WB UV Formulation

Panel Preparation:

Panels were prepared following the 4 steps outlined below:

1. Spray approximately 3 wet mils of coating over 18X18 stained maple panel.
2. Air dry for 10 minutes.
3. Force dry for 10 minutes at 50C.
4. Cure with a mercury bulb at 500 mJ/cm^2.

After sanding with a 3M Superfine Sanding Sponge apply a second coat at approximately 3 wet mils. Repeat steps 2 – 4. Wait 14 days before testing unless otherwise indicated in the test method.

Test methods:

Chemical/Stain Resistance: Apply enough chemical/stain to create a 0.25 to 0.5 inch diameter spot on the test panel. Cover with watch glass. Wait 16 – 20 hours. Remove chemical/stain and wash the surface of the panel with water. Rate each chemical/stain on a scale of 0 to 5 with 0 being complete destruction of the film and 5 being no effect on the film.
Chemicals used:
Vinegar, lemon juice, orange juice, grape juice, ketchup, coffee, olive oil, 1% detergent solution, mustard, water, nail polish remover (acetone based), ammonia, VM&P Naphtha, isopropyl alcohol (70%), red wine, Windex, 409 cleaner, Lysol, gasoline, Murphy's Oil Soap, 10% TSP, Betadine, Kiwi black shoe polish, sun screen (90 spf) and plasticizer.

Scrape Adhesion: Cut 4X7 inch piece from each test panel. Test adhesion with a BYK Balanced Beam Scrape Adhesion and Mar Tester with 5000 grams of weight using the loop stylus. Rate on a scale of 0 to 5 with 0 being complete removal of the film and 5 being no effect on the film.

Ball Point Pen Indentation: Cut 4X7 inch piece from each test panel. Test for ball point pen indentation with a BYK Balanced Beam Scrape Adhesion and Mar Tester with 300 grams of weight using the small pen #5785. Wait 1 hour before evaluating the panel. Rate on a pass/fail scale. Any indentation that can be seen from a distance of 24 inches is considered a failure.

Plasticizer Resistance: Apply a 2 inch square piece of red vinyl to the test panel. Apply a force of ½ lb/in^2. Place the specimen in an oven at 50C for 72 hours. After cooling at room temperature for 1 hour, remove the vinyl square. Evaluate for softening and blistering.

Green Print Resistance: After curing test panel wait 1 hour then apply a 2 inch square piece of # 10 cotton duck cloth to the finish. Apply a force of 2 lb/in^2 directly to the duck cloth. Wait 24 hours then remove cotton duck cloth. Evaluate for printing.

Hot Print Resistance: After curing the test panel wait 14 days then apply a 2 inch square piece of # 10 cotton duck cloth to the finish. Apply a force of 1 lb/in^2 directly to the duck cloth. Place the specimen in an oven at 60C for 24 hours. Remove the duck cloth and allow the specimen to cool for one hour. Evaluate for printing.

Resistance to Discoloration from Desk Top Office Equipment "Feet": Place a black SBR rubber "O" ring on the test panel. Apply a force of ½ lb/in^2. Place the specimen in an oven at 50C for 72 hours. After cooling at room temperature for 1 hour, remove the "O" ring. Evaluate for color change.

Boiling Water Resistance: Apply 10 ml boiling water to the test panel. Place a ceramic coffee cup full of boiling water on top of the 10 ml of water. Wait 1 hour. Remove the cup and wipe with paper towel. Wait 24 hours. Evaluate for whitening.

Scotch Brite Scratch Resistance: Make a 3 mil draw down on a Form 3B-H Leneta card. Air dry for 10 minutes then force dry for 10 minutes at 50C. Cure with mercury bulb at 500 mJ/cm^2. Wait 14 days before testing. Record the gloss (60^o) of the coating. Apply a 2 inch square from a green Scotch Brite Scrub Pad. Place a 200 gram weight on the pad. Slide the pad back and forth across the surface of the coating for 10 double rubs. Remove the pad and record the gloss. Report % gloss lost.

Koenig Pendulum Hardness: Make a 150 micron draw down on a glass panel. Air dry for 10 minutes then force dry for 10 minutes at 50C. Measure Koenig hardness before cure. Cure with mercury bulb at 500 mJ/cm^2. Measure Koenig hardness 1 hour and 7 days after cure.

QUV: Make a 4 mil draw down on a white ceramic tile. Air dry for 10 minutes then force dry for 10 minutes at 50C. Cure with mercury bulb at 500 mJ/cm^2. Wait 14 days before testing. Record L, a, b color data. Place tile in QUV cabinet with 351A bulbs and no condensation cycles. Wait 72 hours. Report color change.

Results and Discussion:

Among the 25 chemicals tested, six showed differentiation as indicated in Figure 1. The conversion varnish was particularly weak for nail polish remover and shoe polish, but all UV coatings showed excellent resistance. Specifically, UV A and UV B showed the best performance compared to the others in the UV group.

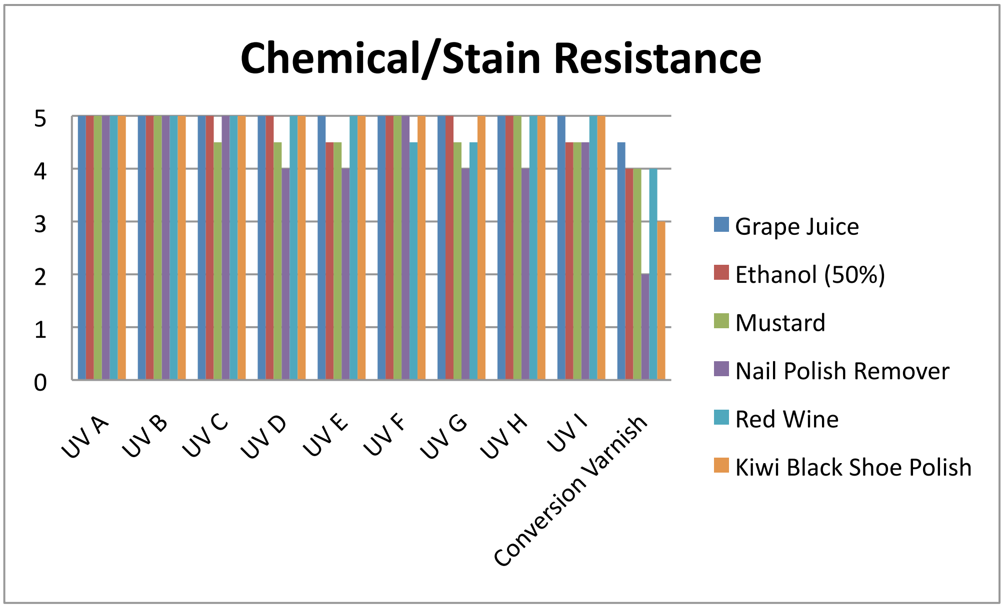

Figure 1.

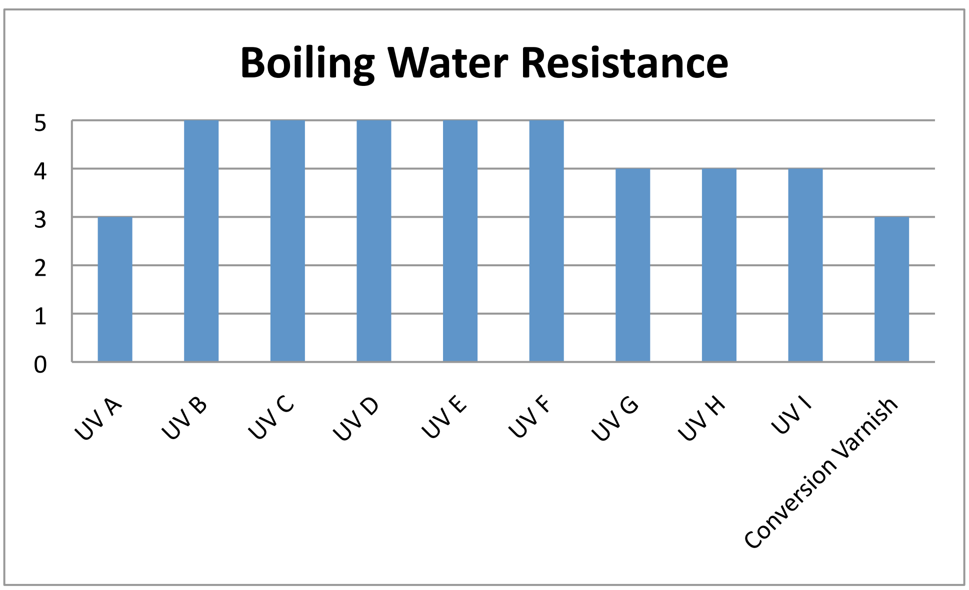

Figure 2.

The boiling water resistance was tested and the results are given in Figure 2. The conversion varnish showed only mediocre performance while most of the UV coatings showed far superior performance. All of the coatings showed very good scrape adhesion (Figure 3) and resistance to discoloration from equipment feet (Figure 4). Figure 5 presents the scratch resistance of the coatings and clearly indicates the robustness of UV resins compared to the conversion varnish. The cured coatings are scratched with a green Scotch Brite scrub pad that contains a 200 gram weight. The gloss is recorded before and after the rubs and a % gloss loss is calculated. The lower the number, the better the performance. Most of the UV resins performed very well for this test. The high molar mass of these materials, the dense cross-linked network and the unique morphology of polyurethanes (hard and soft domains) results in a superior balance of chemical and mechanical properties.

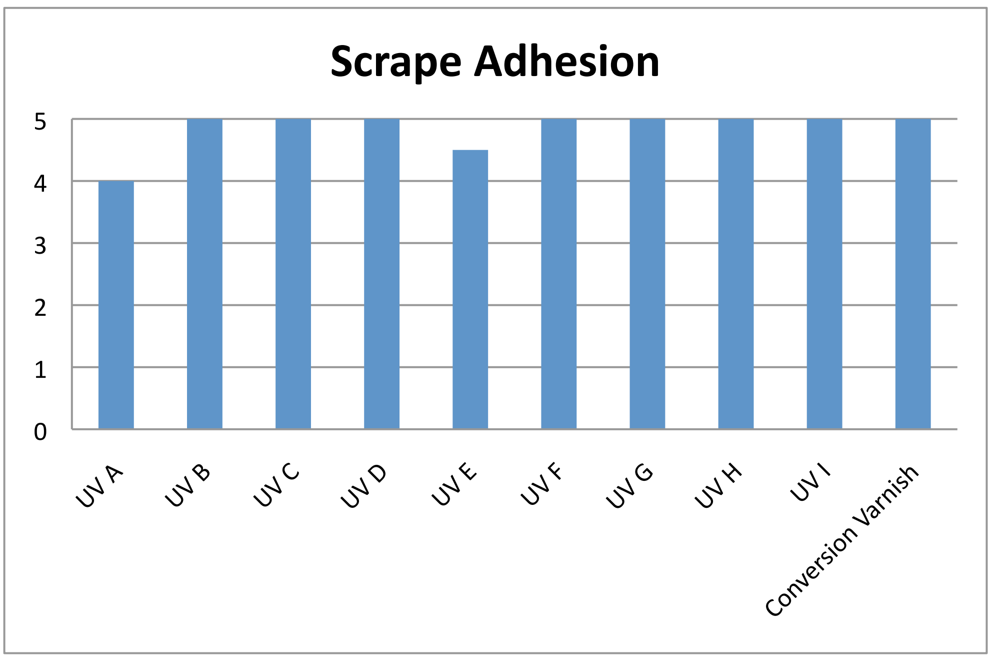

Figure 3.

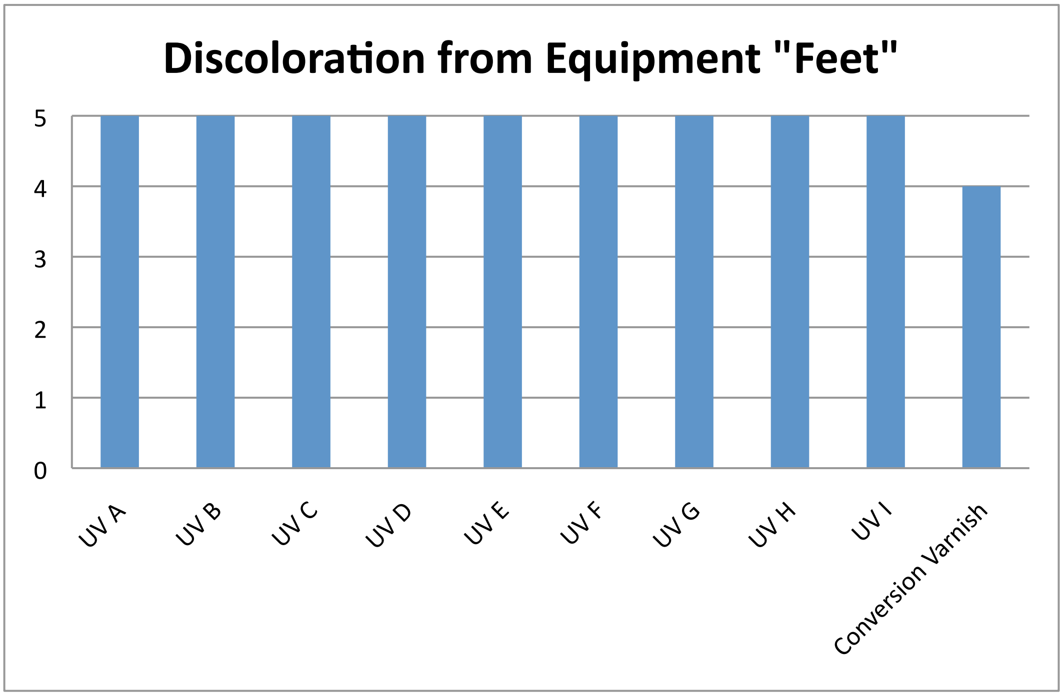

Figure 4.

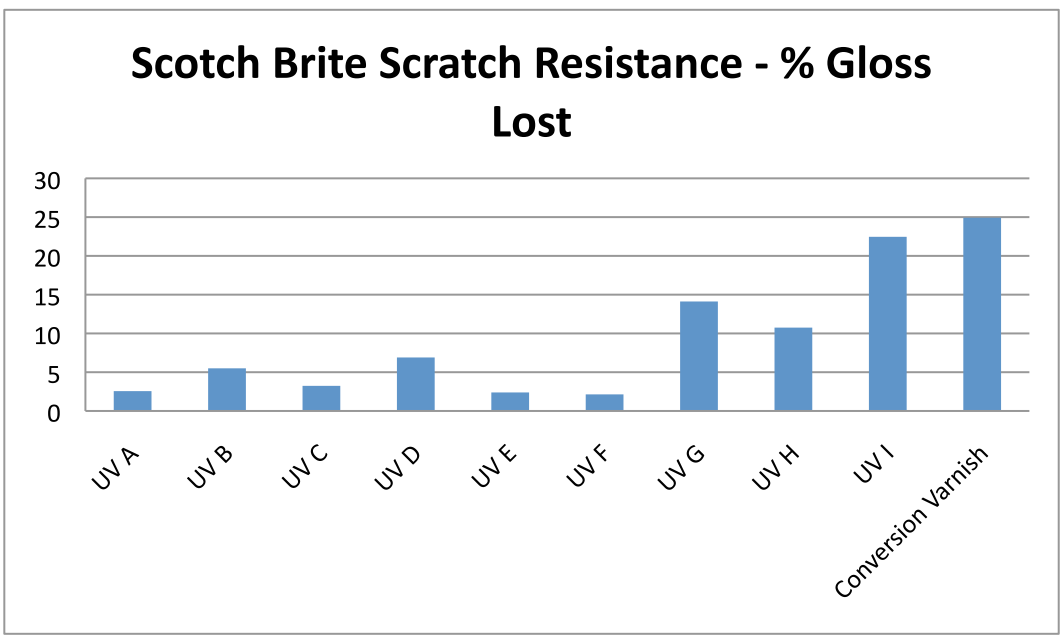

Figure 5.

Ball point pen indentation was also tested and as expected, the UV coatings performed very well with slight inferior performance from the conversion varnish (Figure 6). Mechanical properties were also tested, including both hot and green print resistance which was excellent for all samples.

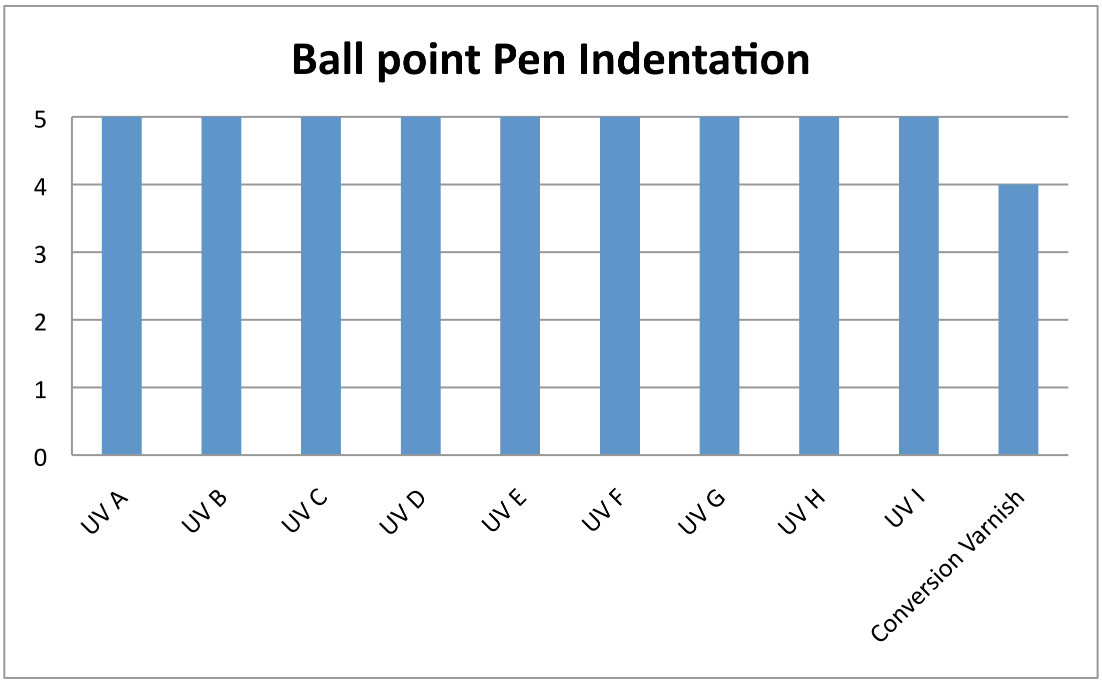

Figure 6.

As expected, the best "anfeuerung" or wood warmth was achieved by the conversion varnish. However, UV B and UV C were only slightly inferior and gave an overall impressive look that would enhance the appearance of any wood substrate (Figure 7). Koenig hardness was also measured after cure (Figure 8). While all of the coatings produced hard surfaces (>100 seconds), the conversion varnish, UV A, UV B and UV F were among the hardest (>140 seconds). The excellent chemical resistance of these resins coupled with the abrasion performance of PUDs makes these resins good candidates for different applications such as flooring.

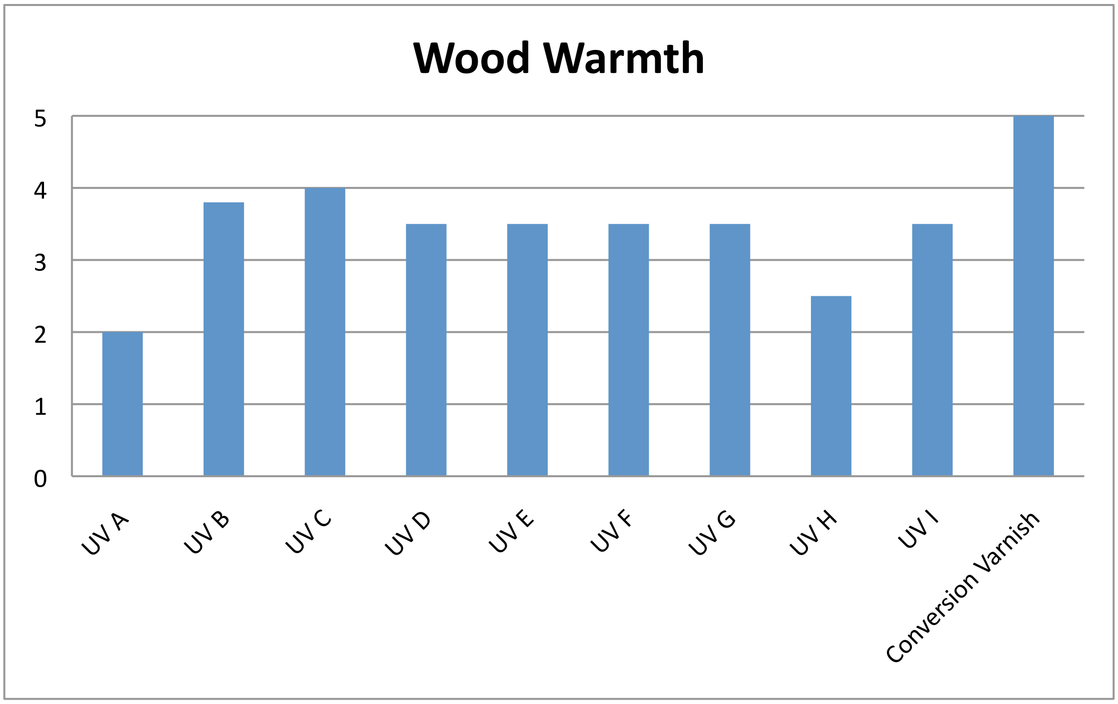

Figure 7.

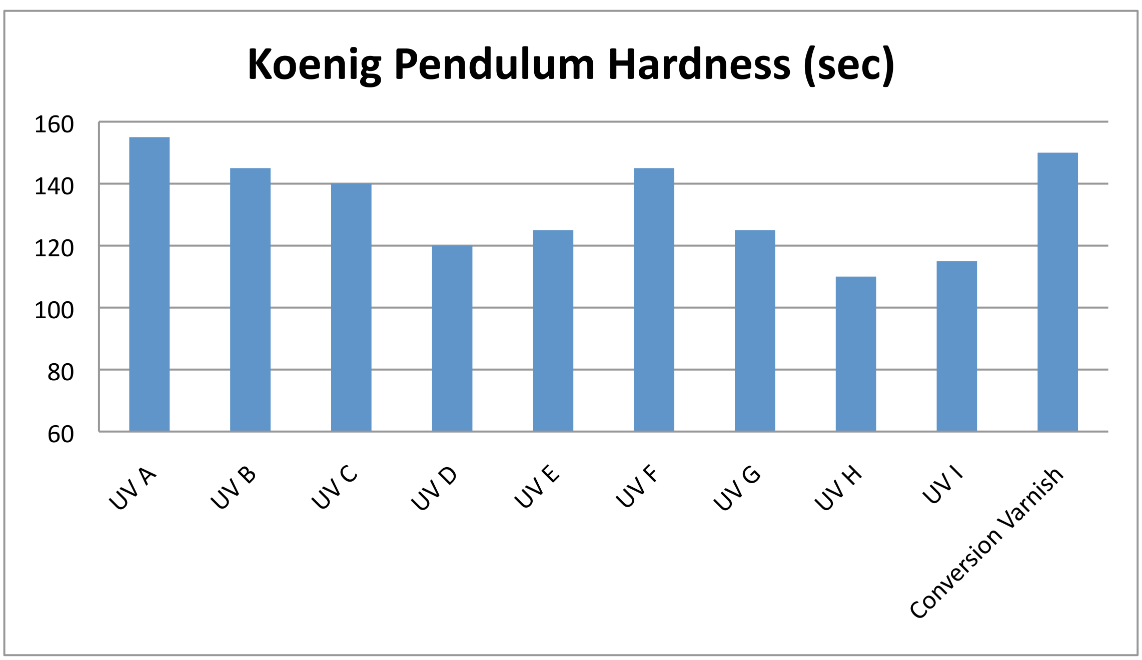

Figure 8.

Conclusions

WB UV technology is a viable alternative to solvent based chemistries for industrial wood coatings applications. The UV coatings in this study performed very well in all tests as specified by KCMA and some furniture manufacturer standards. Along with performance benefits, the VOC is significantly lower (Conversion varnish: 550 g/l vs. UV: 50 g/l).

Waterborne UV coating technology is continuing to improve as raw material suppliers and coatings manufacturers better understand the value proposition of this technology. As these coatings become more robust and higher performing, WB UV will continue to be adopted by the industry. This is evident in the high volume cabinet and wood furniture markets where WB UV coatings are becoming the standard technology.