Waterborne UV Curable Resins for Industrial Wood Applications

Laurie Morris
Alberdingk Boley, Inc.

Solvent based varnishes and lacquers have been the coatings of choice for industrial wood applications for many years. These coatings can provide an attractive durable finish that is cost effective. Kitchen cabinet and furniture manufacturers choose these coatings because they are fast drying, they are easily repaired, they tolerate climate differences well and they are extremely forgiving. Some of these coatings have good chemical and water resistance and good wear resistance. The disadvantage of these chemistries is the high volatile organic compounds (VOC), the extreme flammability, the odor which causes poor indoor air quality, the formaldehyde emissions and the pot life incurred when the conversion varnish is catalyzed with an acid catalyst. Due to increasing regulations, more environmentally friendly alternatives are now being considered. Waterborne (WB) acrylics, polyurethane dispersions (PUDs) and WB UV coatings are becoming more common for use in industrial wood applications because they have excellent resistance and mechanical properties, excellent application properties and very low solvent emissions. Self-crosslinking acrylics have very good durability and moderately fast drying times. PUDs have very good abrasion and wear resistance. 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 acrylics, polyurethane dispersions and WB UV coatings can be formulated to pass Kitchen Cabinet Manufacturers Association and Architectural Woodworking Standards specifications. WB chemistries can provide the appearance and resistance properties of solvent-based coatings with lower VOCs, lower flammability and decreased toxicity.

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.

Water-based self-crosslinking acrylic emulsions and polyurethane dispersions can be excellent alternatives to solvent-based products for industrial wood applications. Acrylic emulsions offer very good chemical and block resistance, superior hardness values, outstanding durability and weatherability and improved adhesion to non-porous surfaces. They have fast dry times enabling the cabinet or furniture manufacturer to handle the parts soon after application. PUDs offer excellent abrasion resistance, flexibility and scratch and mar resistance. They are good blending partners with acrylic emulsions to improve mechanical properties. Both acrylic emulsions and PUDs can react with crosslinking chemistries such as polyisocyanates, polyaziridine or carbodiimides to form 2K coatings with improved properties.

Waterborne 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 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. The chemical and stain resistance of WB UV coatings is superior to that of solvent-based conversion varnishes.

Experimental – WB UV:

A study has been conducted to compare the properties of three WB UV coatings with commercially available solvent-based conversion varnish, water-based conversion varnish and water-based pre-catalyzed lacquer. The project plan was to develop high performance WB UV resins and investigate their performance for industrial wood applications. These coatings were tested according to Kitchen Cabinet Manufacturers Association (KCMA), American Woodworking Standards (AWS) and individual furniture manufacturer's specifications.

Panel Preparation:

UV Coatings:
Spray approximately 3 wet mils of coating over 18X18 stained birch plywood panel; air dry for 10 minutes; force dry for 10 minutes at 50C. Cure with mercury bulb at 500 mJ/cm^2. Sand with 3M Superfine Sanding Sponge. Apply a second coat at approximately 3 wet mils. Air dry for 10 minutes then force dry for 10 minutes at 50C. Cure with mercury bulb at 500 mJ/cm^2. Wait 7 days before testing unless otherwise indicated in test method.
For edge soak, coat and cure all sides of a 4"X4" solid oak panel.
Other Coatings:

Spray approximately 3 wet mils of coating over 18X18 stained birch plywood panel; air dry for 10 minutes; force dry for 30 minutes at 50C. Apply a second coat at approximately 3 wet mils. Air dry for 10 minutes then force dry for 30 minutes at 50C. Wait 7 days before testing unless otherwise indicated in test method.
For edge soak, coat all sides of a 4”X4” solid oak panel.

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.
Scrape Adhesion**:**
Cut 4X4 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 4X4 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.
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.
Hot and Cold Check Resistance:
Cut a 4”X4” piece from each panel. Cycle as follows: Place panel in humidity cabinet at 50C and 70% humidity for one hour. Remove for 30 minutes and allow to reach original

room temperature and humidity. Place in freezer at -10C for one hour. Remove and allow to reach original room temperature and humidity. Repeat for five cycles.

Edge Soak:

Place a cellulose sponge in a plastic container. Level container and fill with detergent solution (1% Dawn® dish soap by weight in water) to one half inch below top level of sponge. Place panel on sponge, cut side down. Permit to stand for 24 hours.

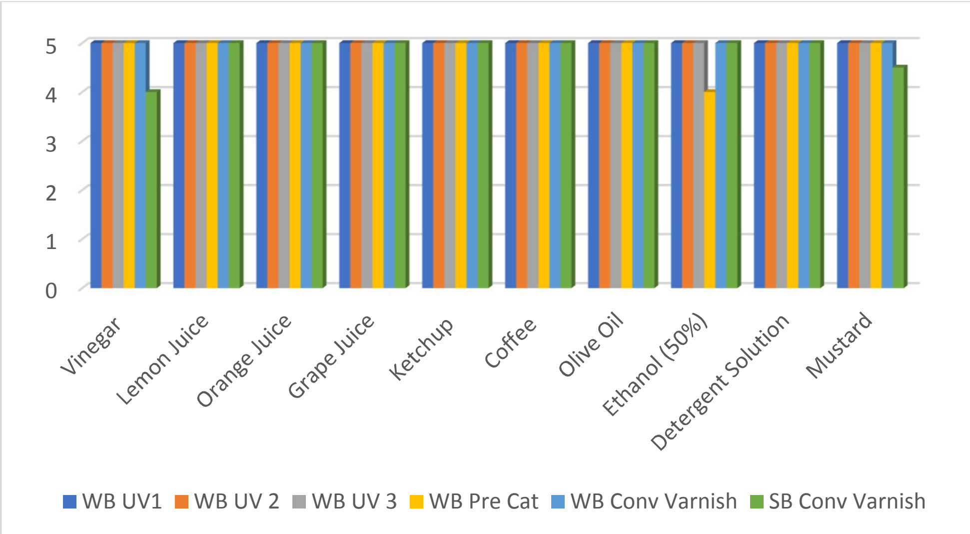
Formulations:

	A	B	C
WB UV 1	73.12	0	0
WB UV 2	0	83.9	0
WB UV 3	0	0	79.27
Surfactant	0.5	0.57	0.57
Defoamer	0.5	0.57	0.57
Water	23.42	13.26	17.91
Photoinitiator	0.82	0.94	0.94
Rheology Modifier 1	0.66	0.75	0.75
Rheology Modifier 2	0.98	0	0
% Solids by weight	36.62	35.31	35.03
% Solids by Volume	32	32	32

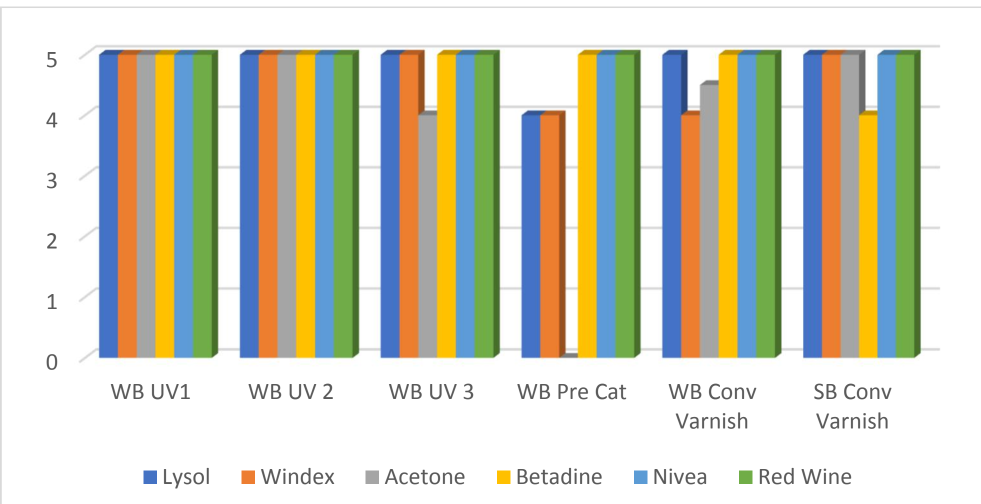
Data:

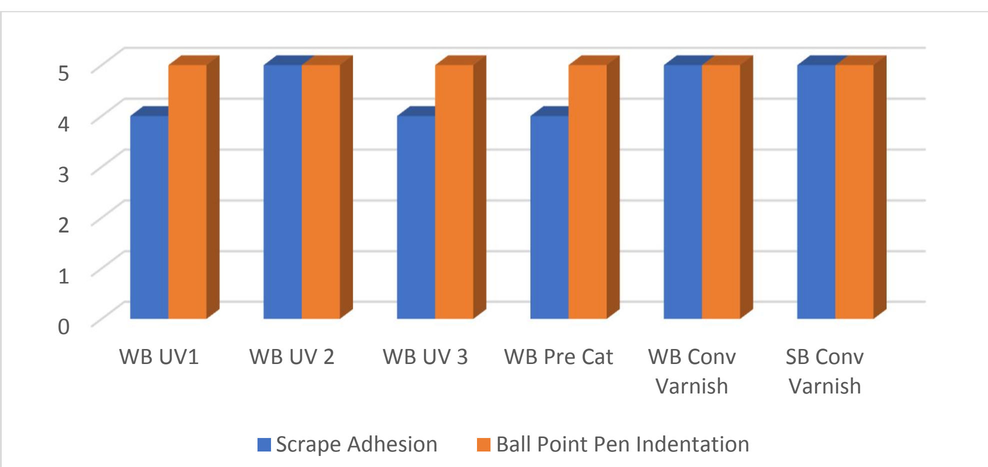
	VOC (g/l)
WB UV 1	< 10
WB UV 2	< 50
WB UV 3	< 25
WB Pre-Cat Lacquer	< 185
WB Conversion Varnish	< 200
SB Conversion Varnish	< 500

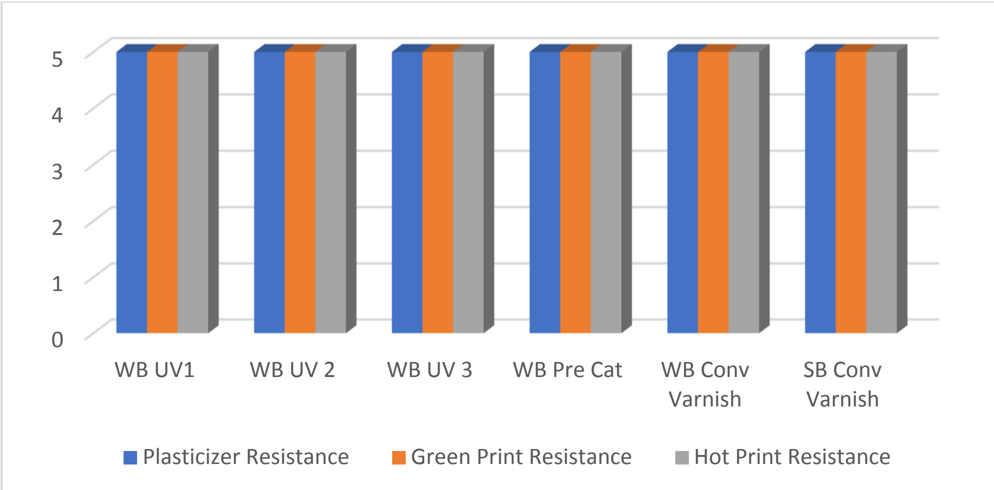
Chemical Resistance – KCMA – 24 hour dwell (except mustard 1 hour dwell)

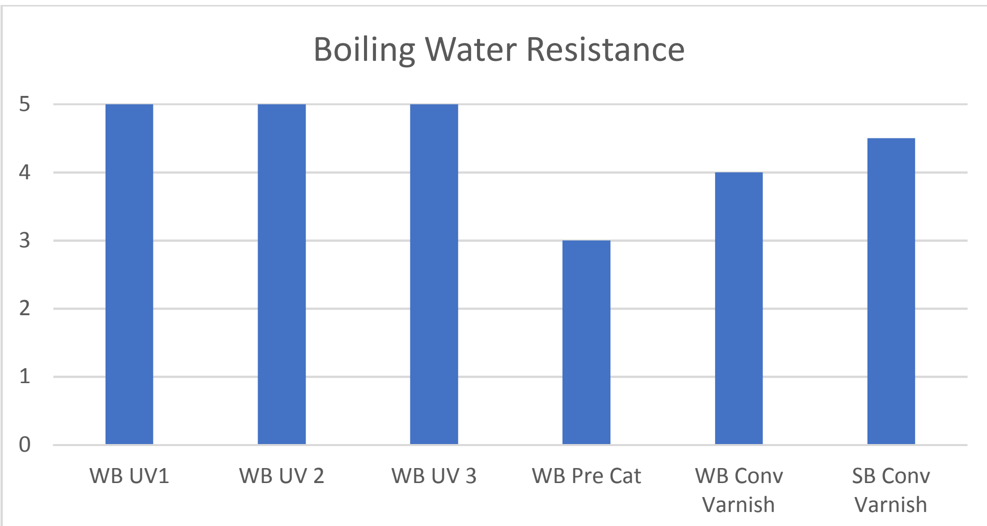


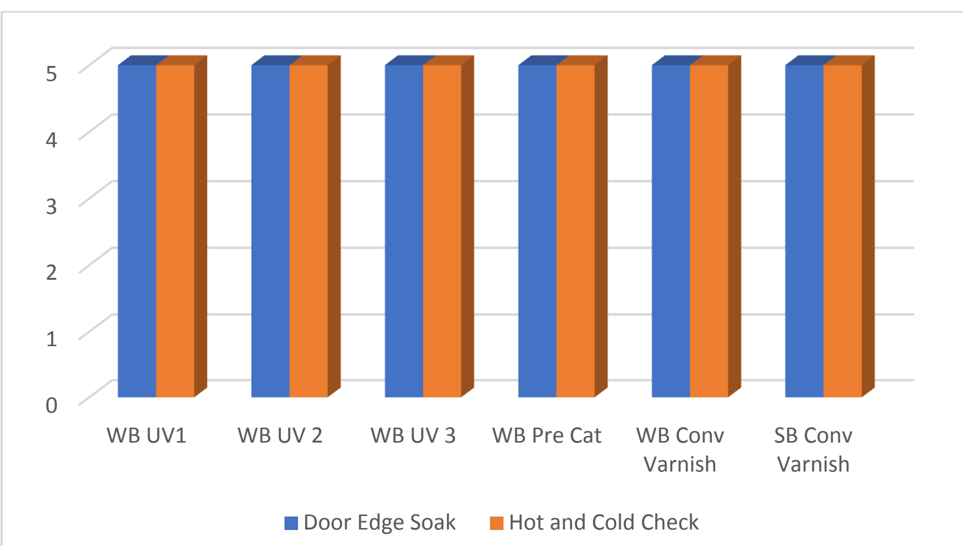
Chemical Resistance – Other – 16 hour dwell






5
4
3
2
1
0
WB UV1
WB UV 2
WB UV 3
WB Pre Cat
WB Conv Varnish
SB Conv Varnish
Plasticizer Resistance
Green Print Resistance
Hot Print Resistance


Boiling Water Resistance
5
4
3
2
1
0
WB UV1
WB UV 2
WB UV 3
WB Pre Cat
WB Conv Varnish
SB Conv Varnish


5
4
3
2
1
0
WB UV1
WB UV 2
WB UV 3
WB Pre Cat
WB Conv Varnish
SB Conv Varnish
Door Edge Soak
Hot and Cold Check

Conclusions:

- All of the WB UV coatings have excellent chemical resistance. WB conversion varnish and SB conversion varnish have very good chemical resistance. WB Pre-Cat Lacquer has adequate chemical resistance for KCMA coatings.
- WB UV 2, WB conversion varnish and SB conversion varnish have the best scrape adhesion.
- All of the coatings have excellent ball point pen indentation, plasticizer resistance, hot print and green print resistance, hot and cold check resistance and edge soak.
- All of the WB UV coatings have superior boiling water resistance.

Water-based coatings made from WB UV resins are good candidates for industrial wood coatings. They have very good chemical resistance and mechanical properties. They can be formulated at low VOCs and have low toxicity. They are viable alternatives to solvent-based chemistries.