POWDER COATINGS FOR WOOD BASED PRODUCTS

An Overview of "How" Powder Coatings Can Be Used to Finish Products Made from Wood Based Materials.

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For over four decades, powder coatings have been successfully used as a protective and decorative finish on various metal products. However, many may be surprised to learn that, for] more than two decades, powder coatings have also been effectively applied to a wide range of non-metal materials, including wood, wood-based products, plastics, glass, and more. Items such as toys, office and home furniture, cabinets, and many other products now utilize powder coatings as a reputable finishing alternative.

In the second white paper, the following topics were discussed regarding 'Why' use powder coatings for WBS, including:

- Powder considerations for WBS
- Versatility of MDF
- Surface smoothness and porosity
- Moisture content
- Dimensional Stability
- Adhesion and surface prep
- Compatibility with curing temp
- Consistency in composition
- Edge sealing
- Powder coating advantages
- One step processing
- Design flexibility
- Versatility & Environmental Benefits
- Environmental friendliness
- Uniform finish & aesthetic appeal
- Production flexibility & efficiency
- Minimal waste and sustainability
- One-Step processing efficiency
- Material utilization and automation
- Sustainability of powder coatings
- Powder coatings as an alternative finish

This whitepaper will address the 'How' to apply powder coatings to WBS products.

The Application Process of Powder Coating

As mentioned earlier, powder coatings are applied in a one-step finishing process. Unlike traditional coatings, which are dissolved or suspended in a liquid medium such as solvent or water, powder coating is a dry coating applied in granular form. The material, finer than ground pepper but coarser than flour, is applied directly to the surface being coated. The powder is purchased ready for use and is manufactured to meet the customer's finish specifications. During the manufacturing process, raw materials—such as binders, resins, pigments, fillers, and additives—are blended and extruded. After exiting the extrusion machine, the powder coating

forms a homogeneous mass that is rolled into thin sheets, cooled, and broken into small chips. These chips are then pulverized into smaller powder particles and packaged in various bulk volume containers for shipment.

Powder Formulation

Powder coatings come in three main types: thermoset, UV curable, and thermoplastic. Thermoset powder coatings react to heat through a chemical molecular change called "crosslinking." During curing, polymer chains link together to form bonds, and once cured, the powder will not re-melt. UV curable powders differ in that they do not react to heat; instead, they contain a photoinitiator that crosslinks and cures the coating instantly upon exposure to UV light. Epoxies, acrylics, polyesters, and hybrids of these are examples of thermoset and UV curable powders, which constitute over 90% of the powders used in the wood finishing market.

Thermoplastic powders, on the other hand, do not crosslink when cured. Instead, they simply melt and flow over the surface of the part, hardening upon cooling. However, if reheated, they will re-melt. Vinyl, nylon, and fluorocarbon are examples of thermoplastic powders. Although thermoplastic powders are available, thermoset and UV curable powders are preferred in the wood coating industry for their ability to achieve the desired performance characteristics.

Application to Wood

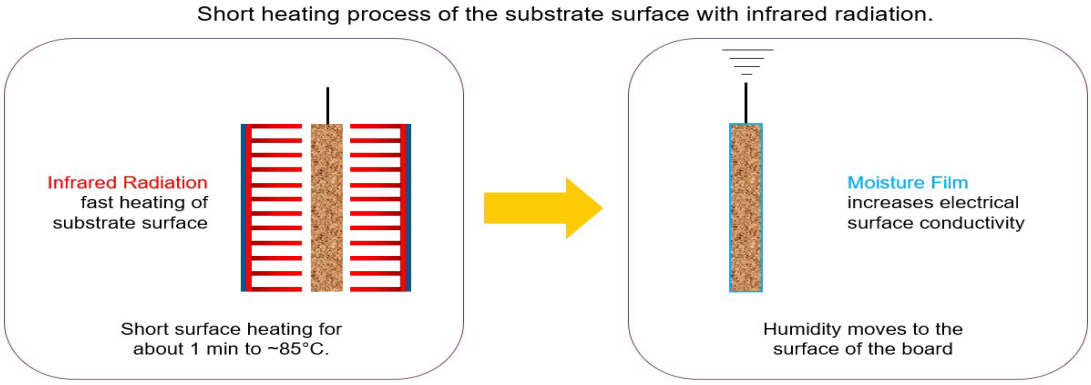
Once a wood product is routed to the desired shape, additional surface preparation is necessary before applying powder coating. This may include light sanding of surfaces and edges. To ensure a defect-free finish, excess dust or wood fibers must be removed using compressed air or vacuum. After preparation, the product is loaded onto a conveying system that transports it to the various stages of the powder coating process.

Vertical or Horizontal Coating

Powder can be applied either horizontally or vertically. In typical horizontal applications, a conveyor moves the product while it lies flat, with the application equipment mounted above. The powder coating is then sprayed onto the exposed surface(s). In vertical arrangements, an overhead conveyor is used, and the application equipment coats both sides of the product as it passes through. Once coated, the conveying system transports the product to the curing process and eventually to an unloading area.

Preheat Requirement

Depending on the substrate, preheating may be necessary after surface preparation to promote conductivity. This is especially common when powder coating MDF and other wood-based substrates. Preheating helps improve coating success by driving moisture to the surface, making it more conductive. It also helps prevent outgassing or delamination during the final curing process.



If preheating is required, the product is transported to an oven and preheated to a specified temperature. The baseline temperature specification is provided by the powder coating manufacturer and can be adjusted to meet system performance and production needs. Once the product reaches the proper preheat temperature, it is quickly moved to the powder coating booth.

Powder Coating Application Process



Whether preheated or not, the wood product is then transported to the powder coating booth. Here, the coating is applied as a dry powder using spray guns that atomize and electrostatically charge the powder particles, directing them toward the product. To ensure uniformity and achieve the desired coating thickness, an additional electrostatic device emitting an opposite polarity may be used.

For preheated parts, the residual heat from the wood assists the electrostatic application equipment, helping to achieve the required film thickness for coating performance. This heat is especially important when

applying thicker coatings to wood and MDF products. In cases where a thin coating is applied, preheating may not be necessary.

Curing

After powder coating, the product moves on to the curing step. The applied powder adheres to the surface until it melts and cures. For thermoset powder, this curing process occurs in either an infrared or convection oven. Infrared ovens use radiant light energy to heat the part, allowing for controlled temperature zoning. Convection ovens, on the other hand, recirculate hot air to heat the part. For UV curable powder coatings, the powder melts at a low temperature (1-2 minutes at 210-265°F) in an oven before being exposed to UV light for curing.

Gas Catalytic IR



Electrical IR



IR & Convection Air



+ UV

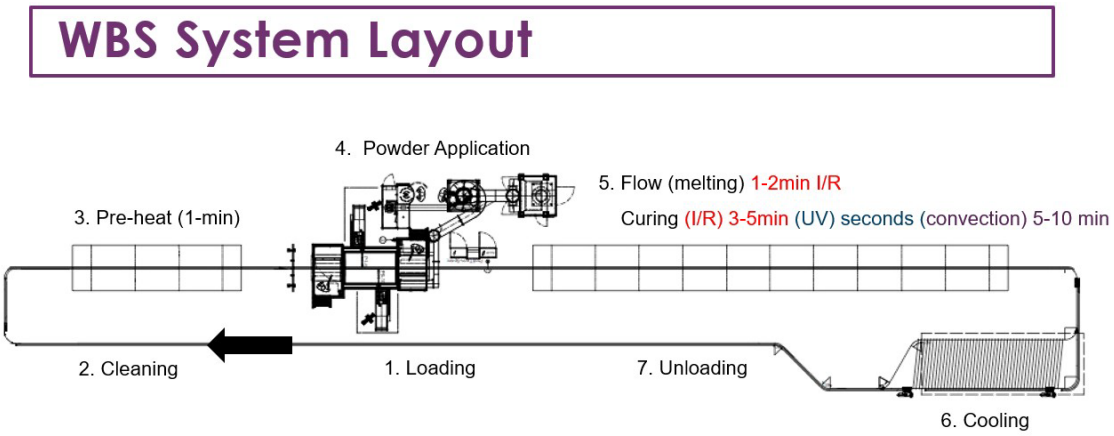


Unloading & Packing

After curing, the product is allowed to cool to a temperature suitable for handling. It may pass through a cooling chamber, or, in some systems, the length of the powder coating line is sufficient to cool the parts. Once cooled, the parts are unloaded and are ready for assembly or packaging for shipment.

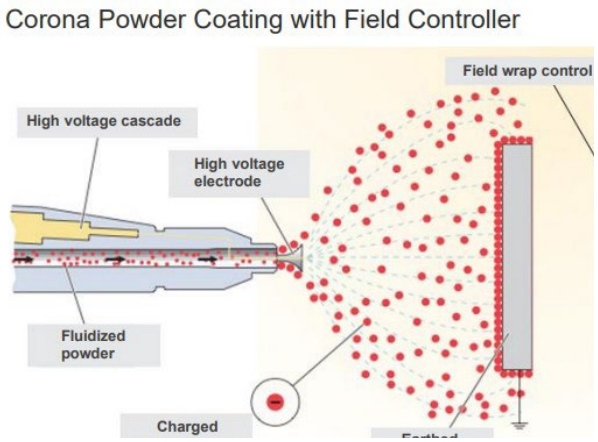
Powder Coating System Configuration

Powder systems vary in technical sophistication and can be designed to meet a wide range of performance, cost, and space requirements. From basic manual operations to complex multi-gun automated setups, there are many configurations to suit specific needs.



Electrostatic Spray

To apply the powder coating, electrostatic spray guns and counter electrode devices generate an electrostatic field, attracting the charged powder particles to the surface of the product. The powder delivery rate can be adjusted via control units, and factors like charge efficiency and powder flow consistency are critical for ensuring uniform coating thickness. Once optimal settings are established, they should be repeatable for consistent results.



Fatty Edge/Picture Frame Reduction

While it is possible to successfully apply powder coating without the use of a counter electrode or field controller, these devices assist in eliminating excess powder from the edges of the product. "Fatty edges" can cause defects like outgassing or blistering. Counter electrodes emit an electrostatic field opposite the spray guns and are positioned directly opposite of the powder

guns. Field Controllers emit an electrostatic the same polarity as the powder guns directly opposite the powder guns, which generates a force field effect. Both methods minimize the electrostatic wrap and edge coating thickness in turn producing an excellent finish appearance.

Booths and Recovery

The powder coating process takes place inside a booth designed to contain the powder, allowing for the recovery of over sprayed powder for reuse. The overspray, suspended in the air within the booth, passes through a separation process that recovers the powder particles. The clean air is then returned to the workspace, reducing the need for additional makeup air. Recovered powder is mixed with fresh powder for reuse, providing material utilization rates of over 90%.

Two types of recovery equipment are commonly used: cartridge filters and cyclone separators. The choice of system depends on production batch size, frequency of powder changes, and other operational factors. Understanding these needs is crucial when selecting a powder coating system.

Quality Control Testing

After coating, testing ensures the quality and performance of the powder-coated product. Testing evaluates aspects such as appearance, color, gloss, film thickness, adhesion, flexibility, chemical resistance, hardness, and cure. It helps maintain consistency, identifies areas for improvement, and confirms that the coating meets customer expectations.

Color

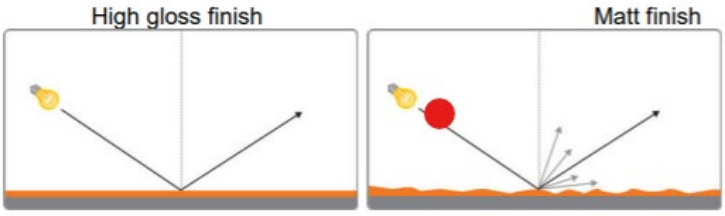
Color tolerances may vary dependent on the end use application. Factors that contribute to color variance include the surface being coated, powder coating applied thickness and substrate uniformity. When assembling parts that have been powder coated at separate times or with different material batches, a tight tolerance is crucial. Any significant color variation will be noticeable.

For example, delta E (the difference between two colors) of 1.0 would be typically acceptable for pastel colors. The human eye is not as sensitive to highly chromatic colors (i.e. bright colors) so delta E of up to 2.0 may not be noticeable in saturated colors (such as black or dark shades).

Application Note: Powder coating wood-based substrates usually requires preheating the substrate, applying powder, and curing the coating. There are two temperature settings involved, and both will influence the color, gloss and smoothness of the final product. Optimizing this for different substrates and powder formulations is critical to the application consistency and performance.

Gloss

Gloss is associated with the capacity of a surface to reflect more light in some angles than in others. Surfaces with brilliant or highly polished finish reflect images clearly. Most of the light that hits the surface is reflected at the same angle, resulting in a higher gloss as shown in the figure below. Semi-gloss and matte surfaces reflect images less distinctly and with reduced intensity at the incident angle due to scattering of the light.



Gloss measurement is based on the amount of light reflected on the surface relative to a polished glass reference standard, measured in Gloss Units (GU). The amount of light reflected on the surface is dependent on the angle of incidence and the properties of the surface. Normally gloss is measured at a 60-degree angle, but to measure high gloss (DOI) and matte finishes, it is better to use 20 degrees and 85 degrees respectively. The gloss reading may vary depending on the surface being coated and the thickness of the coating.

Film Thickness

There are several non-destructive and destructive tests used to measure the dry film thickness (DFT) of the cured coating on wood-based substrates. The powder coating manufacturer will recommend an ideal film thickness range for the coating. A low film build leaves the surface more porous, causing finish failures when exposed to water or other cleaning compounds. These agents can penetrate the coating, causing the substrate to swell. Too high of a film build is also problematic, causing finish defects such as orange peel or sagging. The coating also poses the risk of not properly curing if the film thickness is too high.

Cure Testing

The most common test to check the cure of the powder coating is a solvent rub test. Follow the recommended solvent and number of rubs by the powder manufacturer or test standard. If there is a slight or no color transfer, then the product is adequately cured. It is recommended to monitor the spot that was tested with the solvent to see if it remains soft or if it recovers to a hard surface by fingernail scratch. A product formulated for wood- based substrates should be well cured to achieve all the performance characteristics required.

If variations are noticed such as excessive color transfer or softening of the coating, oven temperature or dwell time in the oven may need to be modified. When adjusting your process make sure color and gloss are within specifications with the improved cure.

Adhesion Testing

Adhesion to wood-based substrates is usually not a concern due to the high polarity of the wood's surface. A crosshatch test can be used to measure the overall brittleness of the painted surface. If the coating is flaking, this may be due to brittle finish, the wood-based substrate, or both. When repainting parts due to defects, inter-coat adhesion is critical and may be measured using crosshatch testing.

Flexibility

Uncoated wood-based substrates can exhibit thickness swelling in a humid environment. Wood that is powder coated is also susceptible to this problem and can be avoided through careful consideration of substrate, powder coating type and processes.

The flexibility test was developed to test the powder coating over time under severe swelling of the board. This is performed by drilling a partially deep hole close to the edge of the board and filling it up with water. The product dimensional changes will vary with the amount of water. A product that passes this test will be very unlikely to fail in the field under varying humidity conditions.

Chemical Resistance and Staining

Common household chemicals should not affect the powder coated finish on wood-based substrates. Though common cleaners such as Windex, 409 etc. can be used to clean the surface, aggressive cleaners containing solvents may affect the surface. If higher chemical resistance is needed, additives can be added into the powder formulation and should be discussed with the coating manufacturer in advance. Other spot testing standards are also available.

Hardness of the Powder Coating

There are a variety of hardness tests available for scratch and abrasion testing. When using these tests for comparative purposes, it is important to keep in mind these tests are subjective and depend on the strength of the testing operator. Test results may not be the same as one sample to the next.

Determining the 'pencil hardness' – or the scratch resistance by means of marking with pencils, is one method for testing the scratch resistance of powder coatings on wood-based substrates. With this method, pencils of different hardness are moved at a certain angle and with a certain force across the surface being tested. The 'pencil hardness' of the coating is defined by two consecutive levels of pencil hardness, where the softer one leaves only a writing track, and the harder one causes a tangible deformation of the powder coating.

Hoffman scratch test is a more quantitative method to establish the surface hardness of the powder coating. The Taber abrasion test indicates hardness and wear resistance of the powder

coating. It is always better to use this as a comparative test to see if one product is better than the other. Most of the time we are concerned about the surface hardness and not through hardness.

Powder Coating Appearance Evaluation

One of the advantages of powder coating is how the finished product looks and performs. Appearance defects such as outgassing bubbles, blisters, protrusions from wood fiber, and edge cracking during preheat/cure need to be monitored and addressed.

Summary

This is the last of three white papers which explores what powder coatings are and their applications in the Wood-Based Substrate (WBS) market. The previous two papers focused on the 'What' and the 'Why'. Together, these papers will provide a solid foundation for applying powder coatings to WBS products.

Glossary of Common Terms for Wood Finishing and Powder Coating

Back Ionization: An excessive buildup of charged powder particles limiting further powder being deposited on the substrate. This can reverse the electrical charge applied to the surface, repelling additional powder.

Blistering: The formation of bubbles or pimples on the surface of the finished product.

Cartridge Filter: A cylindrical filter unit used to separate powder from air for recovery and reuse.

Checks: A pattern of small cracks in the finish.

Cold Checking: Small cracks that appear in the dried film after it is repeatedly subjected to sudden and appreciable reductions in temperature.

Corona Charge: The process of including a static electric charge on powder particles by passing the powder through an electrostatic field generated by a high voltage device in the powder coating spray applicator/gun.

Counter Electrode: A device emitting an electrostatic field of opposite polarity compared to the field produced by the powder coating spray applicator/gun.

Cure Schedule: The time/temperature relationship required to fuse a powder coating.

Cyclone: A type of recovery unit using a centrifugal process to separate powder particles from airflow.

Delivery: The process of moving the powder through the application equipment to the product.

Discoloration: Alteration of original color.

Edge Coverage: Ability of a powder to flow over, build and adhere to sharp corners, angles and edges.

Edge Cracking: Delaminating or separating of MDF layers due to heat stress from pre-heat process.

Electrostatic Spray Technique: A deposition method of spraying and charging powder so that it is deposited on a grounded substrate. See corona charging

Fatty Edges: Increased thickness along the perimeter of the work being coated, generally seen as rounder, thicker edge.

Faraday Cage Effect: A condition that may exist on a substrate due to its geometric configuration that may inhibit the electrostatic deposition of powder particles at a specific localized area.

Field Controller: A device emitting an electrostatic field of similar polarity compared to the field produced by the powder coating spray applicator/gun.

Film Formation: The forming of a continuous film by melting powder particles and fusing them together by the application of energy.

Fluidizing: A process of suspending the powder in a continuous stream of air giving it "fluid-like" characteristics. Used to facilitate transfer of the powder to the spray application device.

Fusion: The melting and flow of individual powder particles when heated to form a continuous film.

Grounding: The electrical grounding of an item to be coated.

Impact Fusion: The combining of powder particles to form a solid mass during the delivery and application process.

Lower Explosive Limit (LEL): The lower point for a range of concentrations of organic particles suspended in air, which can be ignited by sufficient energy source.

Micron/Mills: Common unit of measurement of coating thickness. 25.4 microns equals one mil (one thousandth of an inch)

Orange Peel: A pebbled surface similar to that of an orange skin.

Outgassing: Blistering of the coating during the curing process; caused by heat forcing volatiles through the coating.

Particle Size: The average diameter of a powder particle having irregular boundaries that can be determined to have diameter through various test methods.

Photoinitiator: A key ingredient added in UV cured powder coatings. The photoinitiator absorbs ultraviolet light to create free radicals that crosslink the coating and cure it instantly.

Powder Spray Booth: Specially designed enclosure, in which powder coatings are introduced,

contained and recovered during the coating process.

Printing: The impression left in the finished surface after pressure has been removed.

Recovery: The process of removing non-deposited powder from the air before reclaiming it for reuse.

Residue: Dirt or dust in the finish.

Runs: Defects in the finish caused by an excessive amount of liquid material being applied, so that a portion of that material flows down in an irregular or curtained effect.

Scratches: Abrasions in the finish surface produced after finish is cured.

Surface Appearance: Generally, refers to the smoothness and gloss of powder coating films and the presence and degree of surface defects.

System Utilization or System Efficiency: The combined efficiency of each component in the system, resulting in total material usage compared to the amount of material entered into the system.

Transfer Efficiency: The ratio of the powder deposited on the work piece compared to the amount of powder sprayed during a fixed time.

Touch-Up: A process of repairing scratches or damaged spots in a finish.

Virgin Powder: Powder that has not been previously sprayed as opposed to reclaimed powder.

Wrap: Characteristics of electrostatic application for the powder to seek out and adhere to parts of the substrate not in direct line of site of the delivery point.

FINSIHING LINE COMPONENTS COMPARISON		
Component	Liquid Paint	Powder Coating
Board Preparation	Sanding of surface and edges may be required	Sanding of surface and edges may be required
Preheat Oven	No	Depends
Spray Guns	Non-electrostatic manual and automatic air spray guns	Electrostatic powder manual or automatic spray guns and counter electrode device
Spray Booths	2 automatic or 2 manual booths	1 automatic or 1 manual or a combination of both
Flash-off Tunnel	Yes	No
Cure Oven	Yes	Yes
Solvent Exhaust	Yes	No
Air Make-Up required	Yes	No
Paint Room Mix	Yes	No
Color Change Capability	Yes	Yes
Recovery and reuse of overspray materials	No	Yes
Number of coating layers to achieve desired appearance	3-8	1-2

	Paint	**Powder**
Cost Range: Solids Content: Specific Gravity: Efficiency:	$30.00 - $100.00 per gallon 65% Not Applicable 30% - 40% (Air Assisted Airless)	$10.00 - $20.00 per pound 100% 1.4 40% - 70% (Spray-to-Waste) 90% - 98% (Reclaim & Re-Use)
Coverage per Mil Thickness:	1600 x 65% x 35% = 364 sq-ft/gal	$\frac{192.3 \times 99\% \times 95\%}{1.4}$ = 129 sq-ft/lb.
Applied cost **per mil** of coating thickness:	$\frac{\$50.00}{364}$ = $0.137 per sq. ft.	$\frac{\$15.00}{129}$ = $0.116 per sq. ft.
Industry Standard: *Liquid: 1600 per sq. ft. per gallon of paint at 1 mil thickness with 100% efficiency and 100% solid* *Powder: 192.3 sq-ft per pound of powder at 1 mil thickness with 100% efficiency and 1.0 specific gravity*		

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ALTERNATIC MATERIAL COST WORKSHEET		
Material cost is usually the largest single operating cost of any production finishing operation. This worksheet is designed to compare applied material cost. Applied cost is a function of the cost and solids content of the coating material as it is actually applied, material utilization efficiency (recognizing that liquid paint overspray is lost forever), and the thickness of the applied coating.		
	Liquid Paint	Powder Coating
A. Coating cost	$ _____ /gal	$ _____ /lb
B. Percent volume solids (as received)	___%	99%
C. Specific gravity	Not applicable	____
D. Additive (solvent or water) cost	$ _____ /gal	Not applicable
E. Percent of additive (solvent or water) per gallon of mixed paint*	___%	Not applicable
F. Cost of usable coating (as sprayed) (D x E) + [A x (1-E)]	$ _____ /gal	Not applicable
G. Volume solids, usable coating B x (1-E)	___%	99%
H. Dry film thickness	____ mils	____ mils
I. System utilization efficiency	___%	___%
J. Coverage, sq.f.t/gal	(1600 x G x I) / H 1600 x G x I H 1600 x____x____÷_____ = _____ sqft/gal	(192.3 x B x I) / (C x H) 192.3 x B x I (C x H) 192.3 x____x____÷(__x___) = _____ sqft/lb
K. Applied cost, $/sq.ft.	(F / J) _____ ÷_____ = $ _____ /sqft	(A / J) _____ ÷_____ = $ _____ /sqft