New Opportunities for UV-Curable Powder Coatings

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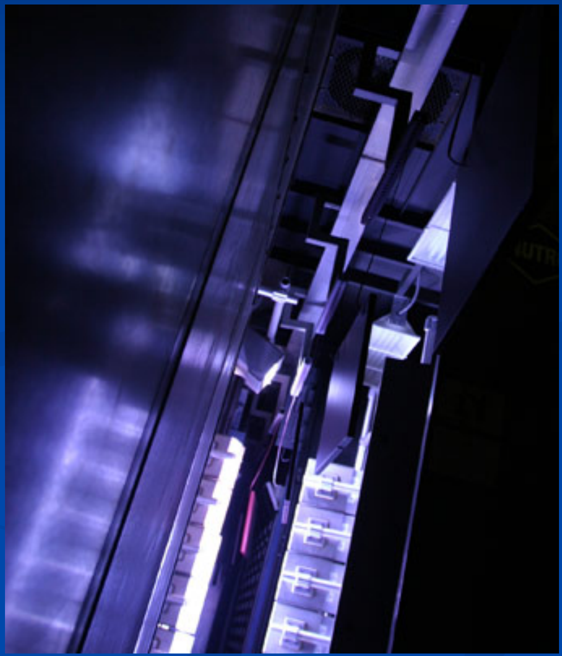
RadTech EXPO 2012

April 30 – May 2

Chicago, IL

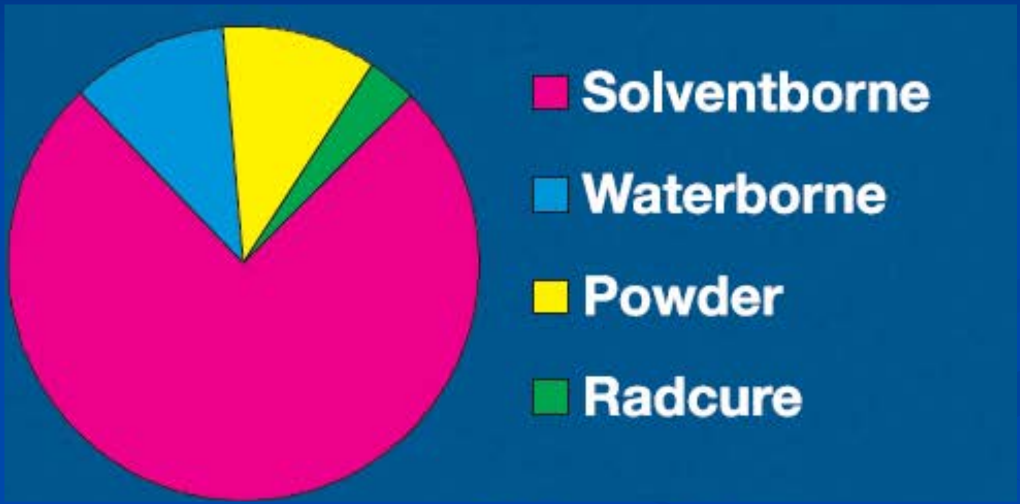
Outline

- UV-Cured Powder Coatings Overview
- Application Benefits
- UV-Cured Powder Chemistry
- Coating Performance/Applications
- Sustainability
- Future Opportunities & Conclusions



Coating Industry Today

- Industrial Coatings Market



- Radiation cure products are growing faster than the total coatings market

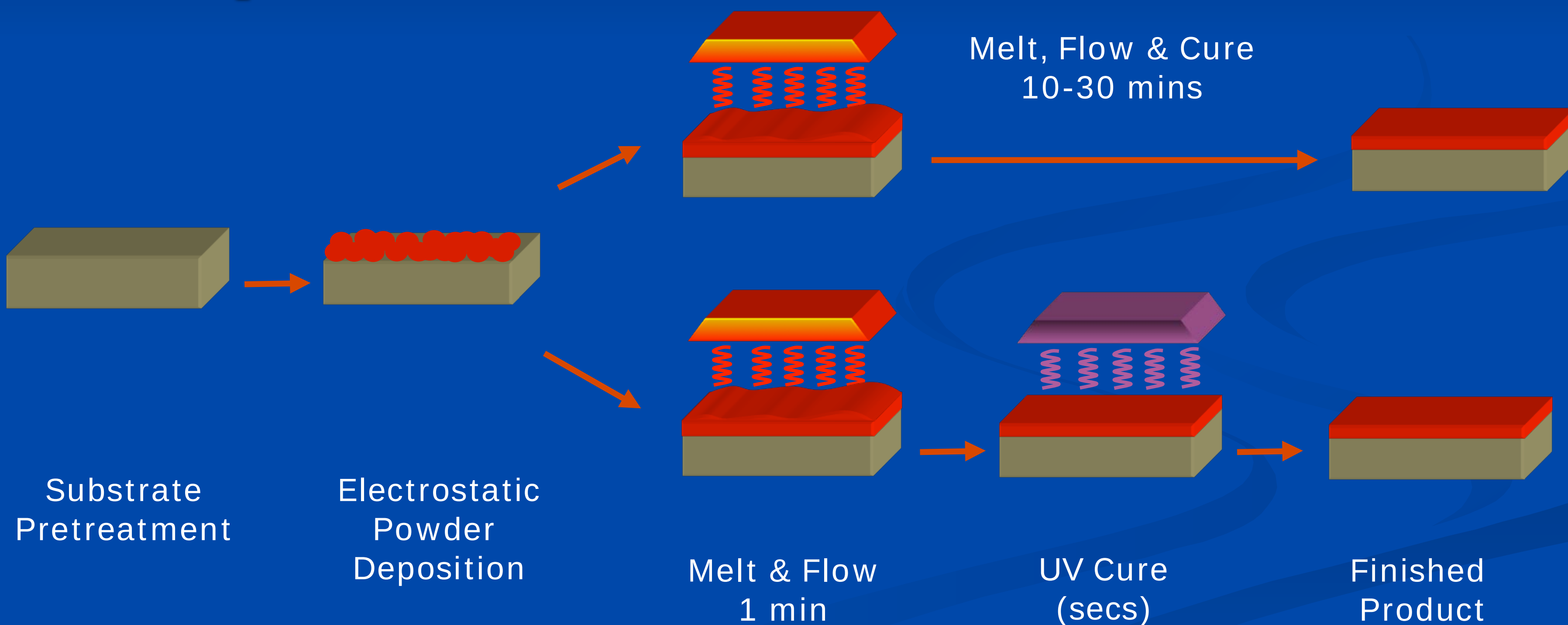
Powder Coating

- Thermoset or thermally cured powder coatings were developed in the 1960s as functional coatings and have been adapted and developed for a variety of applications
  - Powder coatings provide superior wear resistance, barrier properties, and cost effectiveness
  - Products include home appliances, industrial equipment, automotive primer, top coat
  - Powder coatings have no VOCs or HAPs
  - Metal substrates are ideal for electrostatic powder application
  - Thermal cure cycle for powder coating ranges from 20 to 60 minutes depending on chemistry and part geometry

UV Powder Coatings

- Differentiating characteristic of UV-cured powder coating

  Separation of Melt & Flow from Cure



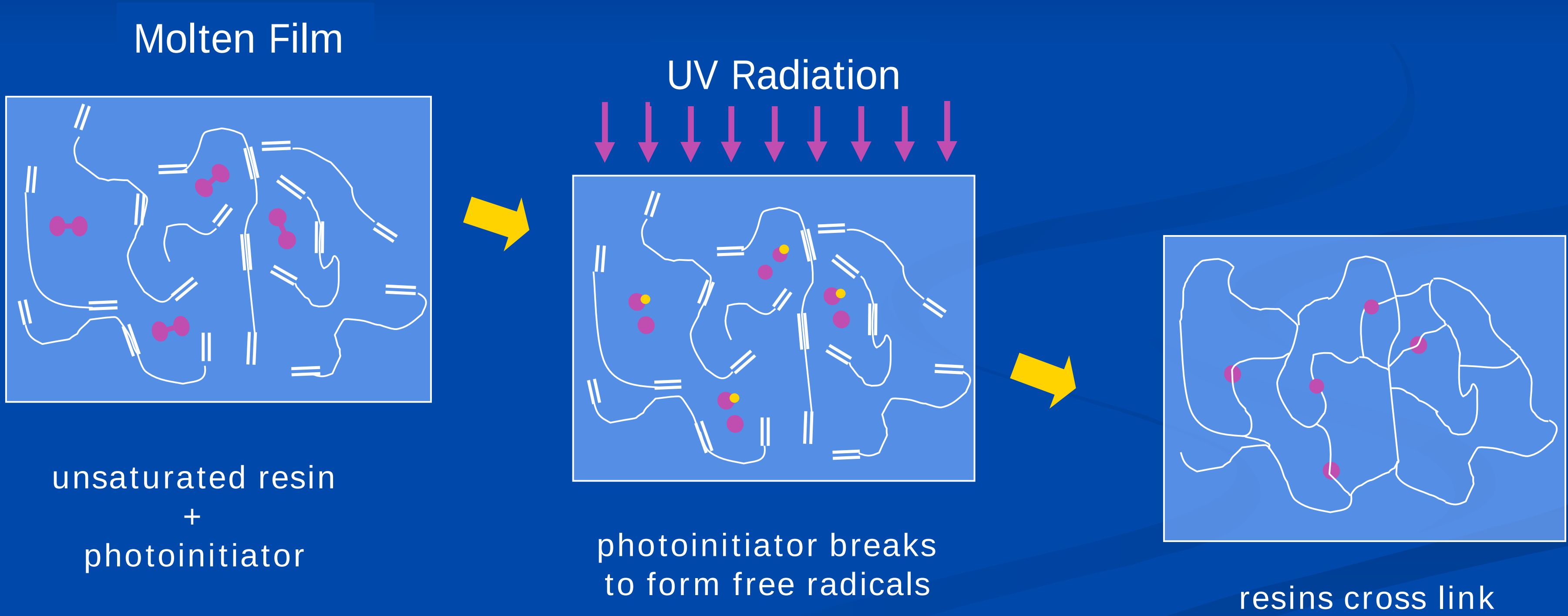
Low Temperature - 200℉

UV Powder Formulation

Resin – Unsaturated	60 – 95 wt %
Photo Initiator	0.5 – 3.0 wt %
Surface and Depth	
Flow Control Agent	0.5 – 2.0 wt %
Degassing	0.5 – 4.0 wt %
Pigments	0.1 – 20 wt %
Filler/Extender	0 – 35 wt %
Additives	0.25 – 1 wt %
Specific Property	

UV Formulation

- UV Curing
  - Surface temperature 200°F - 240°F



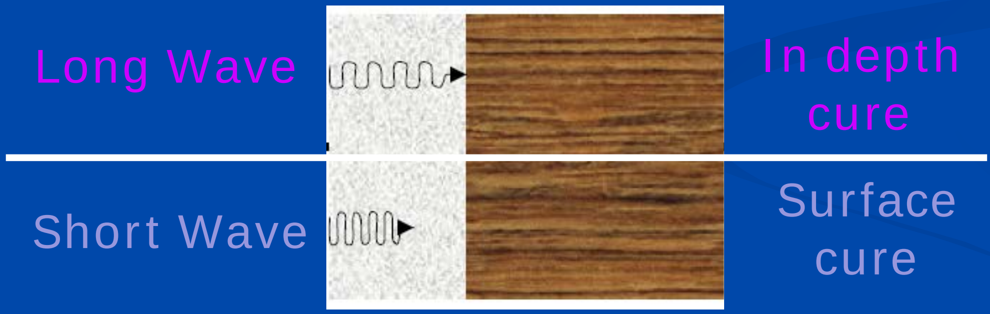
UV Curing Parameters

- Intensity
  - Power or density of UV energy
  - Typical 1000 - 3000 mW/cm^2 UV V
  - Ideal conditions - high intensity over short time
- Exposure
  - Total energy received at coating surface
  - Typical 1000 - 3000 mJ/cm^2 UV V

  Intensity (mW/cm^2) X time (secs) = Exposure (mJ/cm^2)
- Spectrum

UV Spectrum

- UV Spectrum required for different applications
  - Clear/Tints — Mercury
  - Opaque — Iron additive and Gallium additive Mercury



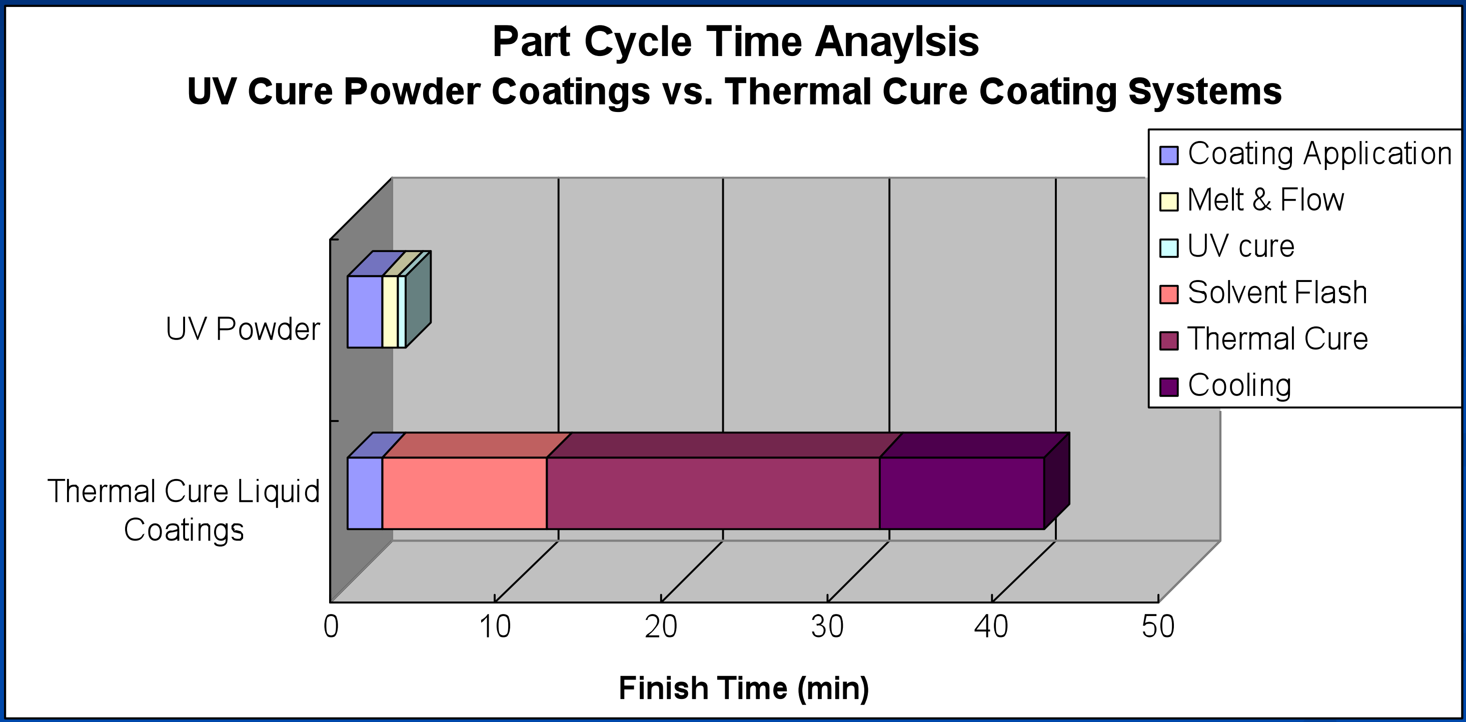
Application Process Advantages

- Powder Coating Advantages
  - Easier to blend, process and control during application
  - Easily cleaned up with an industrial vacuum
- Powder coatings can be reclaimed and re-sprayed or sprayed to waste 98% material utilization
- Color changes do not require any purging materials or solvents and can be accomplished in minutes

Environmental Benefits

- UV-cured powder coatings are solvent free and do not contain any VOCs or HAPs –REACH Compliant
- Waste & Permits
  - No sludge, solvent handling or disposal
  - EPA permits
  - Solvent incineration
  - Costly waste disposal
- Efficient material usage – less material waste
- Non toxic - recyclable - Zero Waste Stream operation

Operational Efficiencies



Total Cycle Time

UV Powder – 20 minutes

Thermal Liquid Cure – 1 hour plus

UV Powder Process Benefits

- Higher Quality Finished Products
  - Minimizes substrate thermal exposure
  - Reduces out gassing
  - Reduces potential for substrate degradation
- Lower Cost of Quality
  - Ability to adjust faster on the fly
  - Reduced number of parts on the line - lower work in progress
  - Fewer defects

Finish Capabilities

Multi- Component

Metallic

UV Powder for MDF Substrates

Test Standard	Category	Test Description	UV-W06-SS2	UV-W06A-SS2
ASTM D4138 Method A	Film Thickness	Tooke Gauge - Destructive	3-4 mils	3-5 mils
ASTM D4060	Abrasion Resistance	Taber Abrasion Test - CS-17 Wheel 500gm, 500 cycles	32.4 mg loss	29.1 mg loss
ASTM D3363-05	Scratch Resistance – Pencil Hardness	Hardness – Wolff-Wilborn 300 gm load, 45° / no scratch	2H	3H
ASTM D523	Gloss Measurement	60° NOVO-GLOSS meter	22-25 units	16-20 units
NEMA LD3-1995	Impact Resistance	224 g steel ball (1/2 lb) 1 ½" dia.	No cracking at 55"	No cracking at 35"
NEMA LD3 - 2005 3.4	Clean ability / Stain Resistance	Reagents: 10% citric acid, vegetable oil, coffee, milk, catsup, mustard, vinegar, red lipstick, grape juice, black permanent marker, water washable black marker, and # 2 pencil	No permanent effect on sample surface	No permanent effect on sample surface
	Cure	MEK swap - 50 double rubs	No softening or color loss	No softening or color loss
NEMA LD3 - 2005 3.4	Hot water	Pool of boiling water placed on surface, pot placed in water for 20 minutes	No blistering	No blistering
ASTM D3359 Method B	Adhesion	Cross Hatch Adhesion – MDF must be present on piece of coating removed	No loss of adhesion	No loss of adhesion

Plastic Substrates

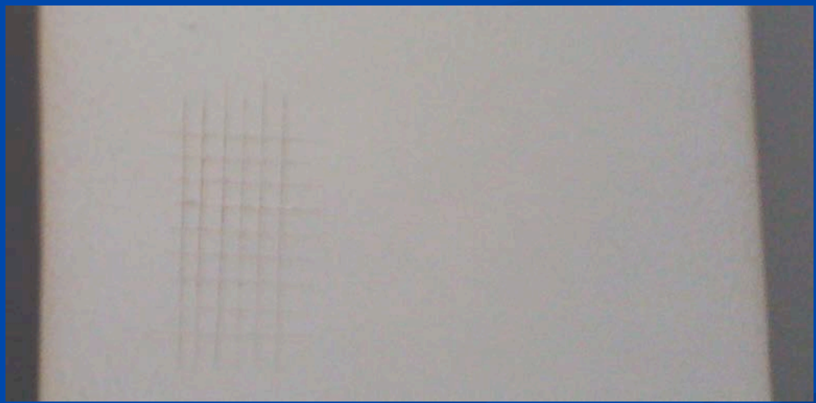
- UV Powder on Plastics
  - Reduce inventory
  - Reduce costs

Plastic Substrates	Pretreatment	Cross Hatch	Impact Resistance	Pencil Hardness
ABS	Yes	5B	35”	2H
Nylon 6	Yes	5B	50”	2H
PPO	No	5B	50”	2H
Polyamide	Yes	5B	50”	2H
SMC	Yes	5B	50”	2H

Heat Sensitive Substrates

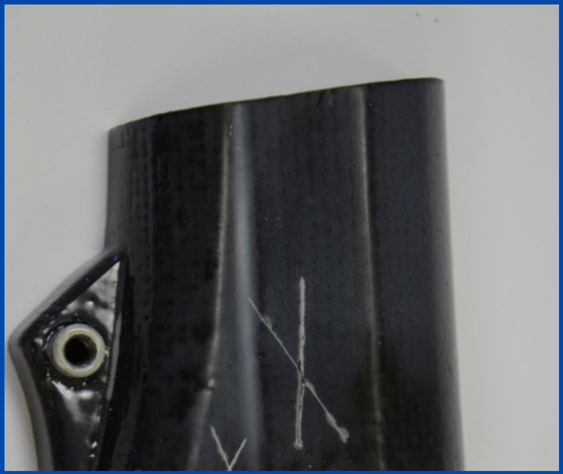
- RIM – reaction injected molding (high density urethane foam)
- Heat sensitivity < 300°F
- Porous substrate

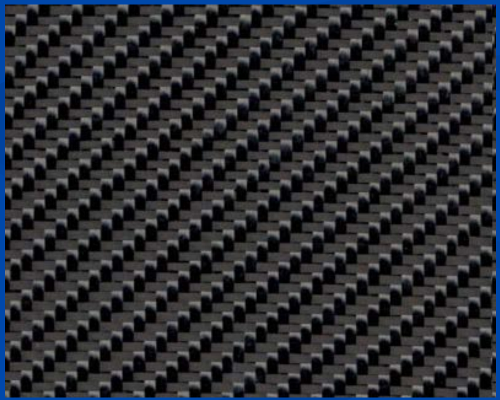
Film Thickness	ASTM D 4138 Method A	3.0 mils
Adhesion	ASTM D3359 Method B	5B
Impact	ANSI 124.5 (1.5" dia., ½ lb steel ball)	35" PASS
Coating Deflection	3"x9" deflected 1"	PASS



Heat Sensitive Substrates

- Composites - Carbon Fiber
  - Required temperature below 300°F
  - Conductivity ideal for electrostatic coatings





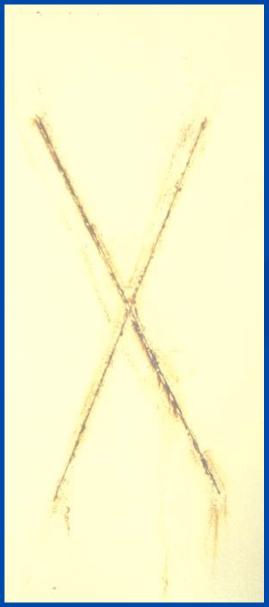
Metal

		Fe-P	Zn-P	Aluminum
Hardness	ASTM D3363	H-2H	H-2H	
Film Thickness	ASTM D 4138 Method A	2.0 mils	2.5 mils	2.0 mils
Adhesion	ASTM D 3359 Method B	5B	4B	5B
Impact - Direct	ASTM D 2794	160 in/lb	160 in/lb	NA
Conical Mandrel	ASTM D 522			PASS 1/16”

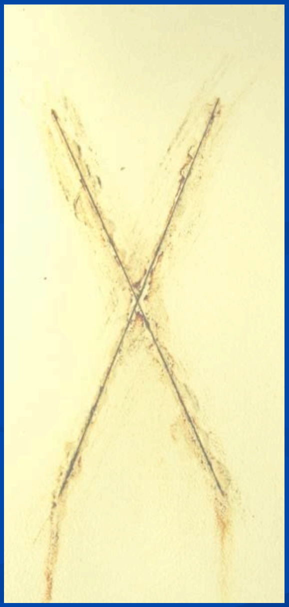
Corrosion Resistance

- ASTM B 117 < 1/8" Salt Spray Test
- CRS –pretreatment Iron Phosphate

250 hrs



500 hrs



750 hrs

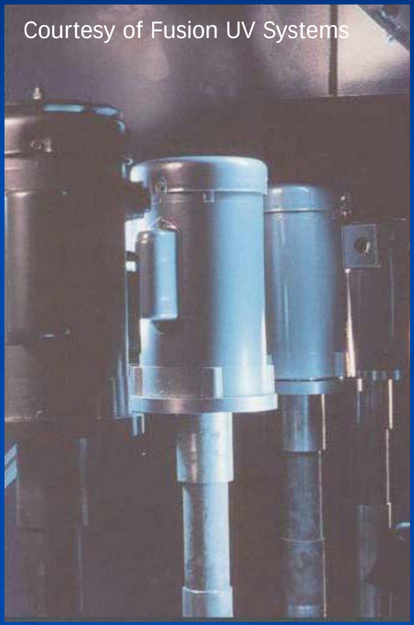
Chemical Resistance

- Test Duration – 24 hours
- Reagents un-covered for duration of test
- Verification of visual inspection of the treated surface with each reagent shows no damage or impaired surface results after 24 hour exposure

Reagent	Effect
Engine oil	no effect
Gearbox oil	no effect
Hydraulic oil	no effect
Brake fluid	Slight gloss loss
Antifreeze	no effect
Cold cleaner	no effect
Inert cleaner	no effect
E95	no effect
Unleaded gas	Slight/moderate gloss loss (a ring)
Diesel fuel	no effect
Battery fluid	no effect

Pre-Assembled Components

- Fully assembled components containing heat sensitive parts
  - Plastics
  - Lubricating oils
  - Rubber
  - Confined vessels
  - Electrical components and circuitry


Courtesy of Fusion UV Systems

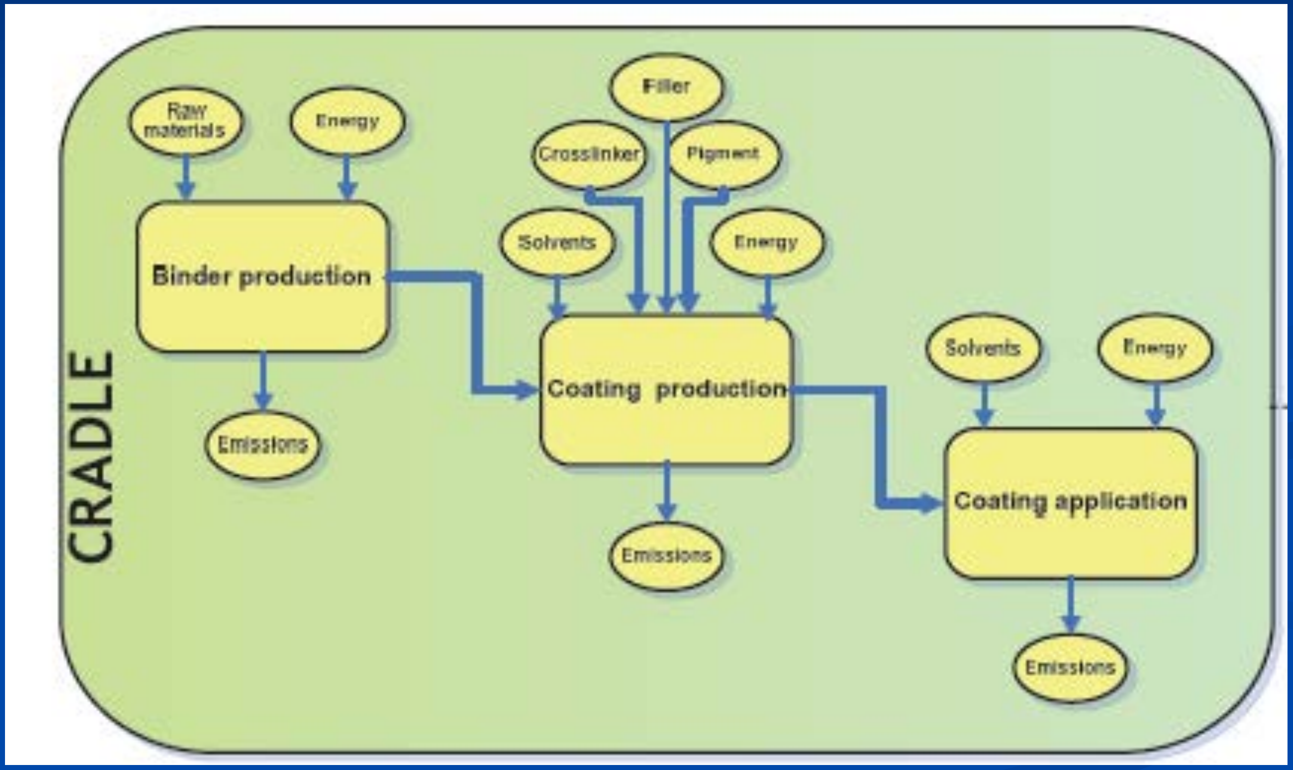
Sustainability

Assumptions for this Life Cycle Assessment	
Substrate	MDF, 19 mm
Average Surface Area	0.5 m2, coated both sides
Coating	TiO_2
Pigment/Resin/Filler	20/60/20 for all (avg)
Solid Contents	100% all powders 50% for all 2-k systems 40% for waterborne UV
Layer Thickness	150 um (6 mils)
Curing Temperature	Depending on System
Sanding	Not factored
Utilization % (Transfer Efficiency)	95% Powder 90% Waterborne UV 60% 2k solventborne and waterborne
Solvent Treatment	Incineration
Durability, Functionality, End of Life	No differentiation

Collaboration with DSM Coating Resins, originally presented at 2011 Decorative Surface Conference, Orlando, FL, USA.

Sustainability

- Scope of Life Cycle Assessment



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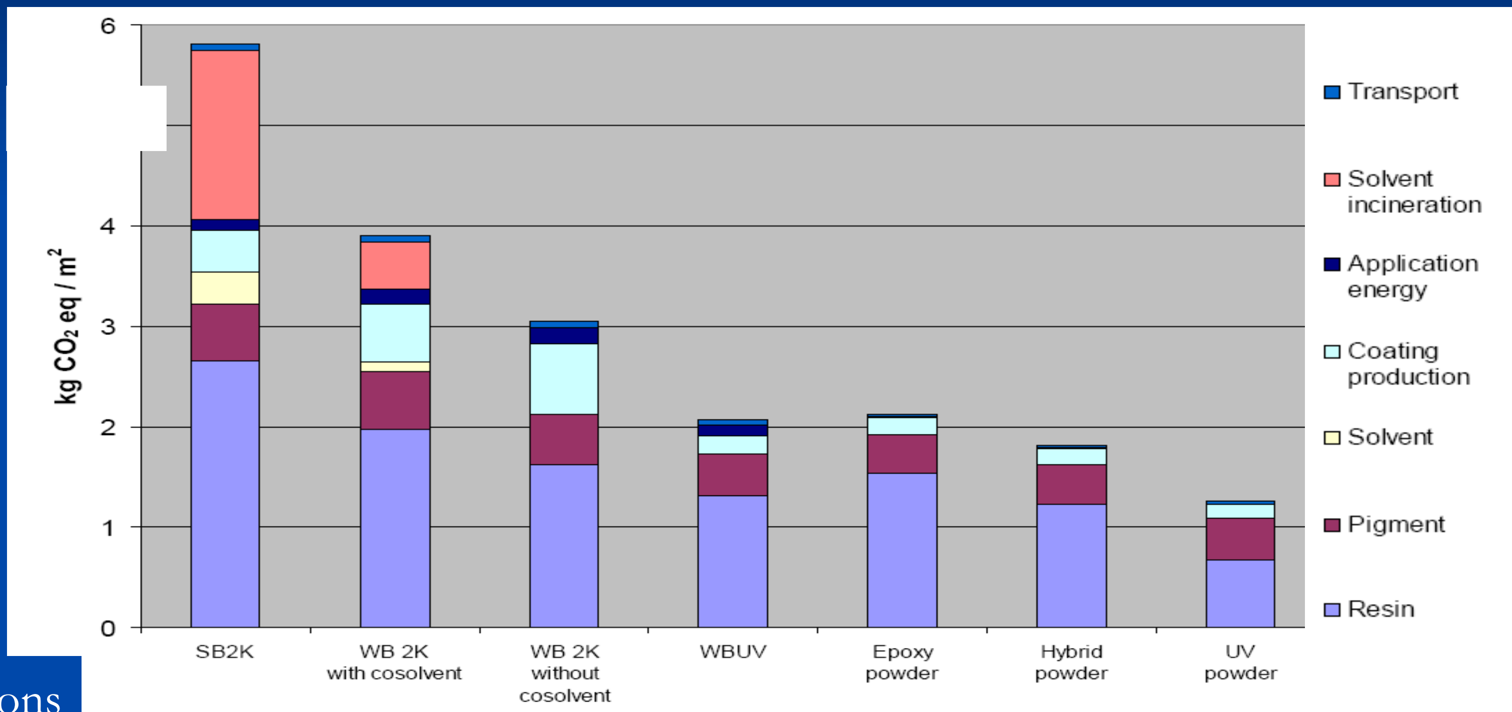
Sustainability

- Coatings Life Cycle Assessment



Assumptions

Substrate : MDF 0.75" Thick Coating both sides Surface area – 5.4 sq ft Pigment/Resin/Filler 20/60/20 for all (avg) TiO2	Solid Content	100% all powders 50% for all 2-k systems 40% for waterborne UV	Utilization % (Transfer Efficiency)	95% Powder 90% Waterborne UV 60% 2k solvent and waterborne

Sustainability – Findings

- Solvent-based coatings have the highest environmental footprint
  - High CFP to produce and dispose solvents
- Waterborne paints (conventional and UV 100% solids) have lower environmental impact
- UV-curable powder coatings have the *lowest* environmental impact of coating materials

Coating Technology Impact on Carbon Footprint

	Solventborne-2K	Waterborne-UV	UV Powder
Carbon Dioxide, CO_2 (kg/m^2)	0.96 / mil of coating	0.35 / mil of coating	0.21 / mil of coating
Typical Coating Thickness	5 mils	2 mils	2 mils
Coating Carbon Footprint (CO_2)	4.8 kg/m^2	0.7 kg/m^2	0.41 kg/m^2

10 x More

Future of UV-Cured Powder Coatings

- Continue developing UV-cured powder coatings for heat sensitive substrates
  - Innovative applications → Greater value & lower cost
- Heat sensitive substrates used in a variety of applications
  - Automotive
  - Consumer Products
  - Recreation

Conclusion

- UV-cured powder coatings present a new opportunity to finish a variety of heat sensitive materials
  - Low substrate thermal exposure
  - Durable powder coating finishes on heat sensitive substrates
- Provide safe, non-toxic environmentally friendly finish
- UV-cured powder coatings have the *lowest* Carbon Footprint of any commercially available coating technology
- A safe, sustainable high value finishing technology for a wide range of heat sensitive substrates now and into the future

Keyland Polymer Ltd.

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