



UV-CURABLE AEROSPACE PAINT SYSTEMS

Presented by
Foster-Miller, Inc.

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Report Documentation Page

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Development Team: UV Curable Aerospace Coatings

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Aerospace Coatings

- ❖ Protective and decorative finishes for
 - Passenger aircraft
 - Military aircraft
 - Space vehicles

Estimated annual market of \$100 M

Total Aerospace Coatings Volume

- ❖ Primers/Topcoat 90%
- ❖ Specialty Coatings 10%

The Need

- ❖ Airframe coatings used by the DOD have long dry-to-fly times
- ❖ Airframe coatings used by the DOD contain excessive toxic pollutants:
 - VOCs - solvents to adjust consistency
 - Heavy metals - particularly chromate corrosion inhibitors
- ❖ Problems with these 'non-green' coatings include:
 - Health problems
 - Expensive emission controls
 - Environmental regulations ban future use
- ❖ Alternative coatings that are available are deficient in:
 - Application method - cannot spray
 - Cure time/cure temperature
 - Performance - adhesion, corrosion prevention
- ❖ New coating materials are needed that are:
 - Safe, environmentally compliant
 - Meet or exceed current performance specifications

Foster-Miller's UV Curable Coating

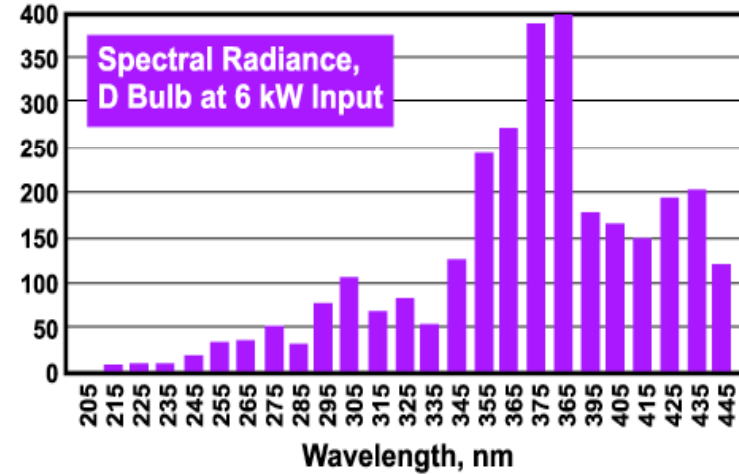
- ❖ Novel UV cure mechanism achieves rapid cure - reduces dry-to-fly time from days to minutes
- ❖ Family of resins - properties highly tailorable by changing resin backbone
- ❖ Environmentally compliant - No VOC's, HAP's or free diisocyanates
- ❖ Single-component product

Accomplishments

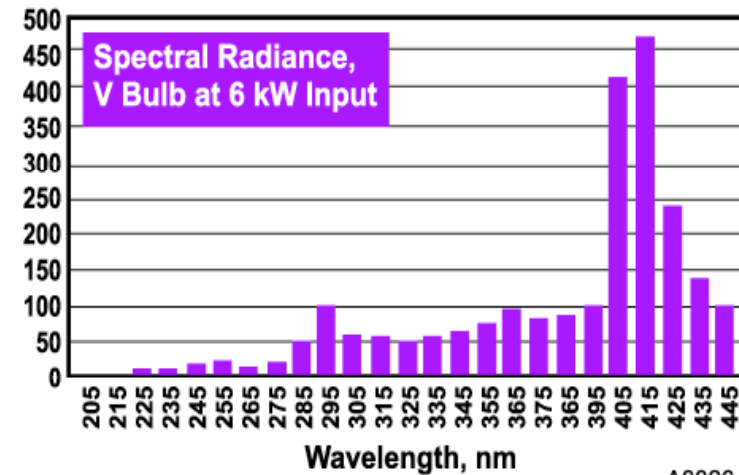
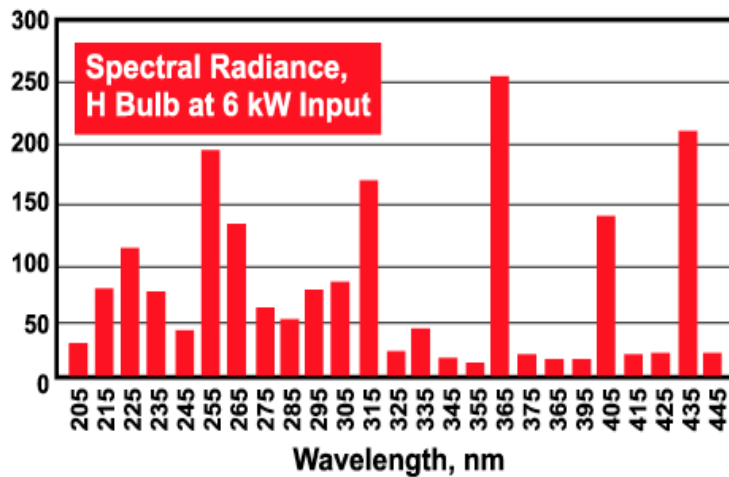
- ❖ Developed a variety of formulations with different properties as required by specific applications.
- ❖ Filled formulations were successfully cured in thickness ranging from 1-50 mils
- ❖ Multilayer application was successfully demonstrated up to 250 mils - layers were compatible and demonstrated good adhesion
- ❖ Scale-up - quantities have been scaled to the 25 gal level
- ❖ Gloss reduction when needed
- ❖ Uniform dispersion – resin system can be formulated and dispersed uniformly to ensure continuity of properties
- ❖ No voids or settling - coating is “frozen” in place by UV irradiation, repair is feasible
- ❖ Put together a vertically integrated team including suppliers, end users, and a manufacturer and convinced the community to obtain more funding

In-Depth Cure

UV light-producing bulbs are arranged in tandem to fully cure the coating test sample



Surface Cure



Spray of Primer



HVLP Spray Gun
Gravity Feed



Test Panel Orientation
In Spray Booth



Final Sprayed
Test Panel

Key Requirements for UV Curable Top Coating

- ❖ Adhesion
 - 5B for dry crosshatch adhesion before and after oil immersion
 - 5A for X-cross adhesion after 24 hours in DI water at room temp
- ❖ Impact resistance
 - >40% elongation for aircraft
 - >5% elongation for ground support vehicles
- ❖ Low temperature flexibility at -51°C by 180° bending
- ❖ Fluid resistance in lube oil (MIL-L-23699) at 121°C for 24 hours
- ❖ Water resistance in DI water at RT for 24 hours
- ❖ Hardness
- ❖ Color: Federal Standard 595B #36173
 - ΔE change < 1
 - Gloss < 5 at 60°
- ❖ Accelerated weathering by Xeon Arc exposure
 - ΔE change < 1 and gloss change < 1 after 3000 hours

Properties of Foster-Miller's UV Curable Coating for an Aerospace Application-II

Test	Test Method	Test Condition	UV-Curable Coating Data	Pass/Fail
Hardness	ASTM D2240 Shore A		80	Pass
VOC	ASTM D5403-93	RT	1%	Pass
Cure Shrinkage		In Any Dimension or Volume	None	Pass
Percent Elongation @ Break	ASTM D412 Die, C, 0.2 in/min	RT	36	Pass
		-65°F	7	Pass
Water Immersion		24 Hours RT	No Marring or Coating Removal	Pass
Resistance to Operational Fluids		7 Days 49°C, JP-8 Oil, Coolant	No Softening, Wrinkling, Blistering, Loss of Adhesion	Pass
		7 Days 65°C, Hydraulic Fluid	No Softening, Wrinkling, Blistering, Loss of Adhesion	Pass
		7 Days 121°F, Lubricating Oil	No Softening, Wrinkling, Blistering, Loss of Adhesion	Pass
Flexibility	ASTM D522	-65°F, 1 in. Mandrel	No Cracks Over 3/16 in. Mandrel	Pass
		RT, 1 in. Mandrel		Pass
Chemical Resistance	ASTM D5402 (using 50 double rubs)	RT	No Significant Loss of Material, Swelling, Hardness Change or Cracking	Pass
Storage Stability	GC Head Space Analysis, NMAN Method 2501	2 year observation, data taken at periodic intervals	No decomposition	Pass
In-Vitro Testing	Corrositex Skin Model	Ocular and Dermal Simulated Human Skin	Not corrosive	Pass

Properties of Foster-Miller's UV Curable Coating for an Aerospace Application-III

Test	Test Method	Test Condition	UV-Curable Coating Data	Pass/Fail
Condition in Container		RT	Homogeneous Free From Skins, Lumps an Gelled or Coarse Particles	Pass
VOC		RT	Zero VOC	Pass
Cure Time	ASTM D2240 Shore A	4 Hours Hardness	Instant Cure, 84-87 Shore A	Pass
	ASTM D2240 Shore A	5 Days Hardness	Instant Cure, 84-87 Shore A	Pass
Ultimate Tensile Strength, psi	ASTM D412 Die C, 0.2 in./min	-65°F	1650	Pass
		RT	450	Pass
	ASTM D412 Die C, 20 in./min	250°F	140	Pass
		275°F	120	Pass
		MIL-PRF-87252	430	Pass
		MIL-DTL-83133	275	Pass
		MIL-PRF-83282	390	Pass
		MIL-PRF-23699	310	Pass
		AMS 1424	350	Pass
		Heat Cycle	370	Pass
		ASTM B117 for 500 Hours	430	Pass
		ASTM B117 for 2000 Hours	354	Pass
	100% Relative Humidity per ASTM D2247 @120°F for 30 Days	480	Pass	
ASTM G85 Annex A4		Future Testing		

Properties of Foster-Miller's UV Curable Coating for Application III (continued)

Test	Test Method	Test Condition	UV-Curable Coating Data	Pass/Fail
Percent Elongation @ Break	ASTM D412 Die C, 0.2 in./min	-65°F	35	Pass
		RT	55	Pass
		250°F	13	Pass
		275°F	9	Pass
	ASTM D412 Die C, 20 in./min	MIL-PRF-87252	42	Pass
		MIL-DTL-83133	27.4	Pass
		MIL-PRF-83282	41	Pass
		MIL-PRF-23699	32	Pass
		AMS 1424	51	Pass
		Heat Cycle	25	Pass
		ASTM B117 for 500 Hours	52	Pass
		ASTM B117 for 2000 Hours	73	Pass
		100% Relative Humidity per ASTM D2247 @120°F for 30 Days	333	Pass
		ASTM G85 Annex A4		Future Testing

Properties of Foster-Miller's UV Curable Coating for Application III (continued)

Test	Test Method	Test Condition	UV-Curable Coating Data	Pass/Fail
Flexibility	Coupons shall be tested in Three-Point Bending Mode Over a 6 in. Span with the Coating Facing Down at -65°F	-65°F	no signs of cracking or loss of adhesion in the bend area	Pass
		MIL-PRF-87252	no signs of cracking or loss of adhesion in the bend area	Pass
		MIL-DTL-83133	no signs of cracking or loss of adhesion in the bend area	Pass
		MIL-PRF-83282	no signs of cracking or loss of adhesion in the bend area	Pass
		MIL-PRF-23699	no signs of cracking or loss of adhesion in the bend area	Pass
		AMS 1424	no signs of cracking or loss of adhesion in the bend area	Pass
		Heat Cycle	no signs of cracking or loss of adhesion in the bend area	Pass
		ASTM B117 for 500 Hours	no signs of cracking or loss of adhesion in the bend area	Pass
		ASTM B117 for 2000 Hours	no signs of cracking or loss of adhesion in the bend area	Pass
		100% Relative Humidity per ASTM D2247 @120°F for 30 Days	no signs of cracking or loss of adhesion in the bend area	Pass
		ASTM G85 Annex A4		Future Testing
Chemical Resistance	ASTM D5402 (Using 50 MEK double rubs)	RT	No Significant Loss of Material, Swelling, Hardness Change or Cracking	Pass

Properties of Foster-Miller's UV Curable Coating for an Aerospace Application-III

Test	Test Method	Test Condition	UV-Curable Coating Data	Pass/Fail
Condition in Container		RT	Homogeneous Free From Skins, Lumps an Gelled or Coarse Particles	Pass
VOC		RT	Zero VOC	Pass
Cure Time	ASTM D2240 Shore A	4 Hours Hardness	Instant Cure, 84-87 Shore A	Pass
	ASTM D2240 Shore A	5 Days Hardness	Instant Cure, 84-87 Shore A	Pass
Ultimate Tensile Strength, psi	ASTM D412 Die C, 0.2 in./min	-65°F	1650	Pass
	ASTM D412 Die C, 20 in./min	RT	450	Pass
		250°F	140	Pass
		275°F	120	Pass
		MIL-PRF-87252	430	Pass
		MIL-DTL-83133	275	Pass
		MIL-PRF-83282	390	Pass
		MIL-PRF-23699	310	Pass
		AMS 1424	350	Pass
		Heat Cycle	370	Pass
		ASTM B117 for 500 Hours	430	Pass
		ASTM B117 for 2000 Hours		Pass
		100% Relative Humidity per ASTM D2247 @120°F for 30 Days	480	Pass
		ASTM G85 Annex A4		Pass

Properties of Foster-Miller's UV Curable Coating for an Aerospace Application-IV (2 layers of 1 mil each)

Test	Test Method	Test Condition	Specification	UV-Curable Coating Data	Pass/Fail
Dry Adhesion	ASTM D-3359	Crosshatch	5B		Pass
Wet Adhesion		24 Hours, RT, Water	4A minimum	No Marring or Coating Removal	Pass
Solvent Resistance	ASTM D5402	RT	25 double rubs	No Significant Loss of Material, Swelling, Hardness Change or Cracking	Pass
Humidity		30 Days	Visual adhesion		In Future
Heat Resistance		1 hr. @ 250°F	$\Delta E < 1.0$, compared with FED-STD-595 #13528		In Future
Weather		500 Xenon Arc	$\Delta E < 1.0$, compared with FED-STD-595 #13528		In Future
Flexibility	ASTM D3924	Impact testing 3.6 lb x 10	Elongation not less than 40%		Pass
	ASTM D522	1" Mandrel Low Temp at -51°C	No crack		In test
Resistance to Operational Fluids		7 Days 49°C, JP-8	No Softening, Wrinkling, Blistering, Loss of Adhesion		Pass
		24 hrs, 65°C, Hydraulic Fluid	No Softening, Wrinkling, Blistering, Loss of Adhesion		Pass
		24 hrs 121°C, Lubricating Oil	No Softening, Wrinkling, Blistering, Loss of Adhesion		Pass
Color	ASTM D-2244	RT	$\Delta E < 1.0$, compared with FED-STD-595 #13528	0.9	Pass
Gloss	ASTM D-523	RT	>90	~60	Fail
Hiding Power	Color meter	RT	>95%	95	Pass

Scale-Up Of Materials and Processes

Out of the Lab and Into The Factory

Scale-Up Of Resin Synthesis



3 Liter, 1998 - 2003



2, 15 Liter, 2004 - 2006



2, 30 Liter, 2007

- Sufficient for 25 Gallons of Coating
- 75 L Reactors On Order

Scale-Up Of Coating Blending

Beakers and Buckets,
1998 - 2005



10 Gallon, 2006 - 2007



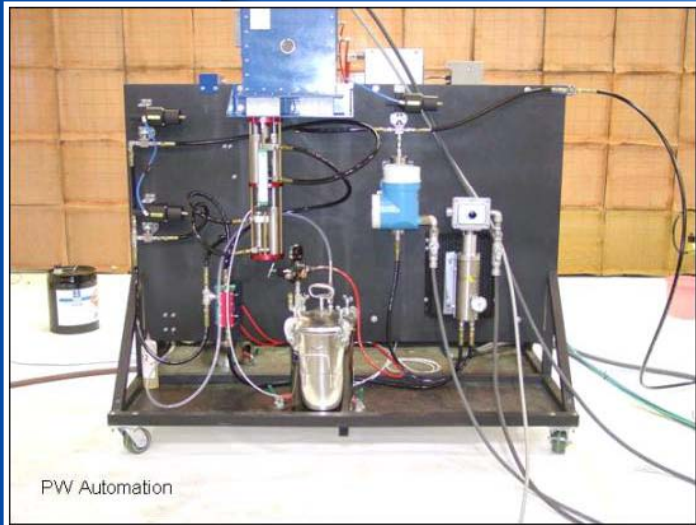
100 Gallon Mix Vessel,
2008 and Beyond

Robotic Application Of UV Cure Coating



Fluid
Test Stand
Controller

Fluid
Test Stand



Robotic Spray System Spraying Contoured Mock-up Part



Robotic UV Curing Of Coatings

Dem Val Lamp Setup



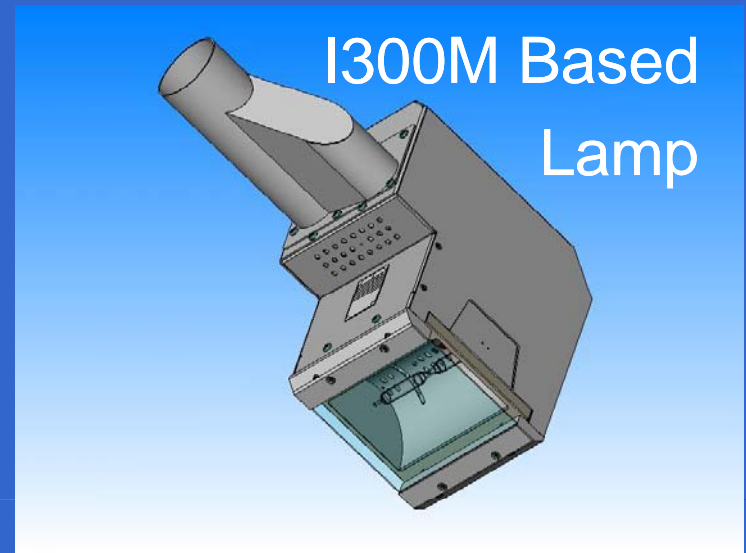
- 2006 Repair DemVal
- Std Bench Lamp
- Hula Skirt Shroud
- Air Cooling Ducts



Standard
Bench Lamp
Mounted To
A Robotic
System



Future Robotic Arm Lamp Concept



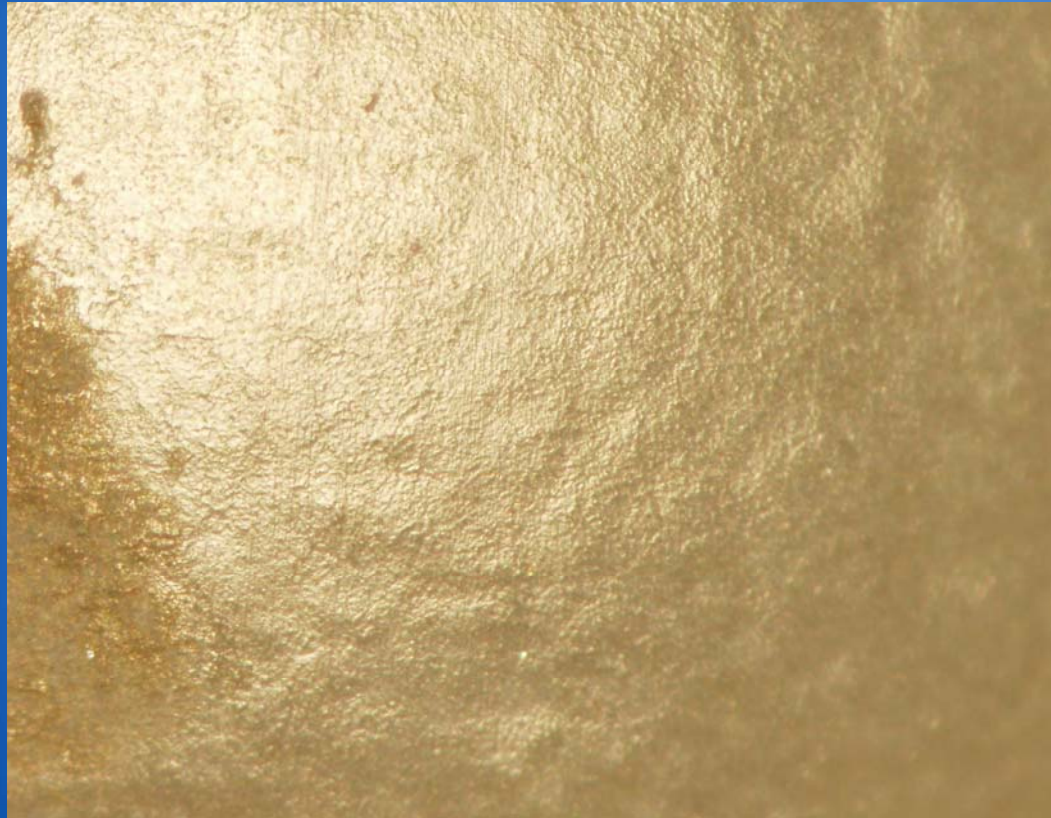
- Quartz Lamp Cover
- Cooling Air Ducting
- Fume Collection
- Robot Arm Mounting

Conclusions

- ❖ Independent performance tests showed FMI's UV-cure topcoat had excellent adhesion, good low temperature flexibility, and borderline oil resistance.
- ❖ The initial color and gloss of the coating met the Air Force standards.
- ❖ The FMI formulation is suitable for other Air Force applications, including coating ground support vehicles
- ❖ FMI Has Scaled One Coating To Large Scale Production Standards
- ❖ FMI, PWA, Fusion UV and NGC Have Developed Spray and Cure Systems for Aircraft Production Applications

Back-up Slides

GE Impact Test of Formulation 7



40% elongation in 10X magnification

Adhesion of Formulation 7



Wet adhesion

Dry adhesion

Adhesion of Formulation 7 (continued)

