Architectural Applications for Liquid and Powder Fluoropolymer Coatings – An Objective Review (CX004)

PPG Industrial Coatings Building Products Group
Fluoropolymer Development Timeline

1948
PVDF invented at DuPont

1950’s
PVDF developed

1965
Kynar license program developed

1970’s
Kynar coatings gain wide acceptance

1982
FEVE Introduced

1980’s
IR-reflective pigmentation introduced

1990’s
Fluoropolymers for waterborne and powder coatings introduced

1996
Hylar® 5000

2000’s
Fluoropolymers for waterborne and powder coatings introduced
Global Coating Practices

Global Architectural Extrusion Market

- Europe
- Asia
- US
- South America

Chart showing the distribution of architectural extrusion markets by region and coating type (powder, liquid, total).
World Latitude

Ultra-Durable Polyester is dominant in Europe. UV light is less intense at this latitude.

Europe is on the same Latitude as Canada.
Previous Barriers to US Powder Adoption

- Custom Color/ Fast Turnaround
- Economic Small Batch Availability
- Applied Cost
- Appearance
- Liquid Infrastructure
- Lack of AAMA 2605 powder initiatives to penetrate the architect/ specifier community
Powder Path to the Market

Powder coatings have been a residential and job shop market until recently.

- Architect firms want to be environmentally conscience
- Monumental buildings projects utilizing powder

*PNC Tower*  
*55 Hudson Yards*  
*Pier 17*
Powder Coating Application - 2010
San Jose International Airport
Basics of Liquid & Powder Coatings
Manufacturing & Application
# AAMA Market Segments

<table>
<thead>
<tr>
<th>Segment</th>
<th>Products</th>
<th>Driven by</th>
<th>Examples</th>
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</thead>
<tbody>
<tr>
<td>Monumental Buildings</td>
<td>AAMA 2605</td>
<td>Specification Driven</td>
<td>![Monumental Building Image]</td>
</tr>
<tr>
<td>Light Commercial</td>
<td>AAMA 2604 &amp; 2605</td>
<td>Specification Driven</td>
<td>![Light Commercial Image]</td>
</tr>
<tr>
<td>Institutional/ Education/ Small Office</td>
<td>AAMA 2604 &amp; 2605</td>
<td>Specification Driven</td>
<td>![Institutional/ Small Office Image]</td>
</tr>
<tr>
<td>Residential Windows</td>
<td>AAMA 2603 &amp; 2604</td>
<td>Manufacturer and Architect Driven</td>
<td>![Residential Window Image]</td>
</tr>
<tr>
<td>Other Applications</td>
<td>AAMA 2603, 2604, 2605</td>
<td>Manufacturer and Architect Driven</td>
<td>![Other Applications Image]</td>
</tr>
</tbody>
</table>

Powder is only available on aluminum extrusions and cannot be applied on a coil line.
What is Liquid Paint?

Four Primary Components of Liquid Paint:

Liquid Technologies
- **AAMA 2603**
  - Acrylic
  - Polyester Hi Solids
- **AAMA 2604**
  - Polyester
  - 50% PVDF Fluoropolymer
- **AAMA 2605**
  - 70% PVDF Fluoropolymer
Liquid Manufacturing Process

- Exact quantity
- Accurate color
- Reduce lead-time
- Eliminate waste
- Reduce inventory
Liquid Dispense Cell
What are Powder Coatings?

Three Primary Components of Powder Paint

Powder Technologies

- **AAMA 2603**
  - Standard Polyesters
- **AAMA 2604**
  - Ultra Durable Polyesters
- **AAMA 2605**
  - PVDF & FEVE Fluoropolymers
Bonded Powder

- Micas and metallics can be dry blended or bonded into the powder formula
- High content micas and metallics need bonding for proper application, recycling and appearance
  - Bonding attaches mica or metallic to resin for improved transfer but requires a separate manufacturing process
  - Micas & metallics will settle or fallout of the mixture if not bonded properly
  - Spray to waste versus recycling will effect transfer efficiency
Paint Application Systems For Architectural Extrusions

Electrostatic Spray
- Powder – Allows powder to adhere to the metal substrate
- Liquid – Transfer efficiency

- Line Design
  - Horizontal Line
  - Vertical Line
Basic Powder Application Equipment
Application

Powder coating is a one coat application market. Primers can be used but with some difficulty.

- Primers can be difficult and costly to apply
  - **Liquid Primer** – Spray and flash primer for five minutes and then apply powder topcoat and bake
  - **Powder Primer** – Spray and fuse the powder then apply topcoat and bake. Requires two ovens.
  - **Powder Primer** – Spray primer and bake then apply topcoat and bake. Inefficient and expensive.

Liquid fluoropolymers have utilized primers for the last 50 years. Primers improve adhesion and corrosion resistance
Fluoropolymer Liquid & Powder Coatings
Raw Materials - Resin

Resin provides primary paint properties

- Hardness
- Flexibility
- Adhesion
- Gloss
- Chemical Resistance
- Corrosion Resistance
- Humidity Resistance
- Abrasion Resistance
- Impact Resistance
- Heat Resistance
- Stain Resistance

Fluoropolymer Trade Names
- PVDF – Kynar 500®, Hylar® 5000
  - Chinese resins
- FEVE – Lumiflon (Japan)

Generic Terms
- Fluorocarbon Polymer
- Fluoropolymer
- PVDF - Polyvinylidene Fluoride
- FEVE – Fluoronate Ethylene Vinyl Ether
PVDF is 70% of the resin system, 30% is acrylic.
FEVE resin is purchased as one component.
Fluoropolymer Coatings
Gloss ranges

Thermoplastic Dispersion

PVDF Medium Gloss Coating
Cured at 475° F
Gloss – 30-40%

Thermoset Solution

FEVE High Gloss Coating
Cured at 475° F
Gloss – 20-80%
### PVDF vs. FEVE Comparison

<table>
<thead>
<tr>
<th></th>
<th>PVDF</th>
<th>FEVE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gloss</strong></td>
<td>Liquid - 10 – 40% gloss</td>
<td>Liquid - 20 – 80% gloss</td>
</tr>
<tr>
<td></td>
<td>Powder – 10 – 40% gloss</td>
<td>Powder - 20 - 70% gloss</td>
</tr>
<tr>
<td><strong>Hardness</strong></td>
<td>Softer films</td>
<td>Harder films</td>
</tr>
<tr>
<td></td>
<td>Powder Versions – Both technologies have harder films</td>
<td></td>
</tr>
<tr>
<td><strong>Layers of Coating</strong></td>
<td>primer/topcoat systems</td>
<td>one or two coat systems</td>
</tr>
</tbody>
</table>
Pigmentation & Appearance
Pigments: As important as the resin system

Liquid & powder utilize the same pigmentation

- Pigments provide color, corrosion resistance, gloss control
- Inorganic pigments are generally more durable (color fade)
  - Ceramic pigments are the standard
    - Finite set of formulated pigments
    - 50 years of durability testing in Florida
- Organic pigments provide bright colors but can be less durable
- A good resin with a weak pigment
  = Poor coating system
Pigment Durability
3 Years of Florida Exposure
Metallic & Mica Capability

- Metallics are metal flakes and have high reflection and sparkle
  - Liquid has capability to formulate with metallics
    • Requires a clear coat for color control
  - Powder metallics for AAMA 2604 environments are now being introduced into the market.
    • Clears coats are rare in powder.

- Metal-oxide coated micas give pearlescent appearance
  - Micas are a mineral, available in both liquid and powder coatings and don’t require a clear coat
Pigmentation – Color Matching Liquid & Powder Colors

- **Application** – Can be difficult to match liquid and powder coatings
  - Solid colors are consistent
  - Liquid is smoother, powder has more orange peel
  - Micas orient differently in paint film based on application and film thickness

- **Formulation**
  - Micas in powder give different appearance than liquid based on pigment load

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**Thickness**

- **3 mils**
- **1 mil**

**Powder**

**Liquid**
Standard Two Coat Liquid System

- Substrate:
  - Aluminum
  - Steel

- Pretreatment

- Primer coat – 0.2 mils

- Liquid Topcoat – 0.8 to 1.0 mil

*Hexavalent / Trivalent chrome / Non-chrome
Three and Four Coat Liquid Systems

- **Substrate**
- **Pretreatment**
- **Primer Coat** - 0.2 mils
- **Topcoat** - 1.0 mils
- **Clearcoat** - 0.4 mils

*Barrier coat*
- 0.8 mils
- Protects primer
- Color consistency

*Barrier coat required with transparent colors
One and Two Coat Powder Systems

- **Substrate**
- **Pretreatment**
  - Primer coat – 0.2 mils liquid or 1.5 mils powder
- **Powder Topcoat** – 3.0 mils

Powder can be a one coat or two-coat systems
Specialty Coating Capabilities

- **Liquid**
  - Metallic flake size
  - Clear coats
  - Mica in the clear coat
  - Textures – aggregate

- **Powder**
  - Speckle-Coats – Blends of powder colors
  - Textures – Utilize large powder particles
Textured / Multi-Color Powder for Metal Roofing

Paint Process
1. Coil coat primer & PVDF topcoat
2. Roll form roofing shingles or wall panels
3. Powder coat components

Powder Texture
• Supply multiple color bases
• Intermix powders to desired color
• Salt and pepper textured appearance
Performance
Types of Corrosion vs. Market Forces

- Filiform
- Aluminum Pitting
- Galvanic
- Cut Edge
- Film Erosion
- Sealant Attack
- Low Grade Aluminum

Market Forces

Chrome Free
One Coat Powder
Eliminate Clears
Red List
LEED

Seacoast Failures
Under Eve Failures
AAMA
- G85 Cyclic Test
- Seacoast Spec
- Filiform Test
## ISO 12944-2 (Exterior & Interior)

| Type of Environment or Location* (Based on ISO 12944-2 atmospheric-corrosivity categories) | Warranty in years |
|---|---|---|
| **Residential** |
| C1 - very low |
| C2 – low - Atmospheres with low level of pollution. Mostly rural areas. |
| C3 – medium - Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity. |
| **Industrial** |
| C4 - high – Industrial areas and coastal areas with moderate salinity. |
| C5-I - very high (industrial) – Industrial areas with high humidity and aggressive atmosphere. |
| ***** Severe Marine** |
| C5-M - very high marine – Coastal and offshore areas with high salinity |

<table>
<thead>
<tr>
<th>Film Integrity</th>
<th>Color $\Delta E \leq 5.0$</th>
<th>Chalking $\geq 8$ Rating</th>
</tr>
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<td>Chalking $\geq 8$ Rating</td>
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- Iso corrosivity classification based on time of wetness and levels of corrosive impurities (sulfur dioxide/chloride)
- Metal weight loss measurements determine corrosivity categories.
Florida Materials Research Facility (FMRF)

An Atmospheric Testing Site one of the world’s most corrosive sites

WEIGHT LOSS ON 6061 ALUMINUM IN OUTDOOR BASE ENVIRONMENTS; CY 98-99; START AUG 98
Salt Concentration

Sodium ion concentration, 2011

Sites not pictured:
- Alaska 01  27 µg/ha
- Alaska 03  25 µg/ha
- Alaska 06  26 µg/ha
- Puerto Rico 20  1345 µg/ha
- Virgin Islands 01  1537 µg/ha

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu
Performance Considerations

Corrosion risk increases with humidity, salt, wind, sand and other factors

- Most powder systems come as one coat finishes.
- High performance liquid systems have always demanded a primer.
- Two coat systems should always be considered for harsh environments like seacoast or industrial locations.
- Chromium pretreatments and primer systems have historically provided the most effective protection of aluminum in seacoast environments.
- Clear coats provide another barrier and clean easier.
One Coat vs Two Coat Powder
Non-chrome pretreatment

7 years Daytona Beach Exposure
One Coat Powder Field Failure
2 years Seacoast

Edges  Recesses  Punch Holes

Moisture gets trapped under the paint film based on high film build and does not have the protection of a primer or chrome.
Ft. Lauderdale Exposure Site
(Topcoat Evaluations)

Exposure in Miami at 45 from vertical facing south, open backing
Fluoropolymer - 40 Years Exposure
FEVE Powder – 12 years Exposure Florida
## Powder Product Lines

<table>
<thead>
<tr>
<th>Product</th>
<th>Residential &amp; Interior</th>
<th>Residential &amp; Light Commercial</th>
<th>High Performance Commercial</th>
<th>High Performance Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology</strong></td>
<td>Polyester</td>
<td>Ultra-Durable Polyester</td>
<td>FEVE</td>
<td>PVDF</td>
</tr>
<tr>
<td><strong>AAMA Spec</strong></td>
<td>2603</td>
<td>2604</td>
<td>2605</td>
<td>2605</td>
</tr>
<tr>
<td><strong>Coating Layers</strong></td>
<td>One coat</td>
<td>One coat</td>
<td>One coat/Two coat</td>
<td>Two coat</td>
</tr>
<tr>
<td><strong>Warranty</strong></td>
<td>5 years</td>
<td>10 years</td>
<td>20 years</td>
<td>20 years</td>
</tr>
<tr>
<td><strong>Seacoast</strong></td>
<td>No</td>
<td>No</td>
<td>No/Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Gloss</strong></td>
<td>20 - 80</td>
<td>20 - 80</td>
<td>20 - 80</td>
<td>10 - 40</td>
</tr>
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## Liquid Spray Product Lines

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<th>High Performance Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology</strong></td>
<td>Polyester &amp; Acrylic</td>
<td>Polyester &amp; 50% PVDF</td>
<td>70% PVDF</td>
</tr>
<tr>
<td><strong>AAMA Spec</strong></td>
<td>2603</td>
<td>2604</td>
<td>2605</td>
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<td><strong>Warranty</strong></td>
<td>5 years</td>
<td>10 years</td>
<td>20 years</td>
</tr>
<tr>
<td><strong>Seacoast Coverage</strong></td>
<td>No</td>
<td>No/Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Gloss</strong></td>
<td>20 - 80</td>
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<td>10 - 40</td>
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Advantages of Liquid & Powder
Environmental Considerations

- Powder Coatings contain near 0 VOC’s
- VOC’s can be incinerated with liquid coatings, but require energy and emit CO2
- Powder Coatings use less energy in transportation
- Liquid coatings require shipping solvent in larger, heavier containers

Although environmentally preferable factory applied coatings contribute to the sustainability of a project, they do not contribute to the attainment of LEED points on a project.
## Powder versus Liquid General Comparisons

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Liquid</th>
<th>Powder</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions</td>
<td>-</td>
<td>+</td>
<td>Powder – No VOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Liquid – Incineriation</td>
</tr>
<tr>
<td>Waste/Material transfer</td>
<td>-</td>
<td>+</td>
<td>Powder 95% transfer efficiency when recycled</td>
</tr>
<tr>
<td>Film Build</td>
<td>+</td>
<td>-</td>
<td>Liquid film lower and more controllable</td>
</tr>
<tr>
<td>Surface hardness</td>
<td>-</td>
<td>+</td>
<td>Powder tends to be harder</td>
</tr>
<tr>
<td>Smooth Appearance</td>
<td>+</td>
<td>-</td>
<td>Liquid can vary solvent reductions</td>
</tr>
<tr>
<td>Mica &amp; Metallic Colors</td>
<td>++</td>
<td>-</td>
<td>Can utilize more flake in liquid spray</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>formulations</td>
</tr>
<tr>
<td>Corrosion Resistance</td>
<td>+</td>
<td>-</td>
<td>Powder single coats are susceptible to filiform on coast.</td>
</tr>
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<tr>
<td>Color Palette</td>
<td>+</td>
<td>-</td>
<td>Liquid has wider color palette</td>
</tr>
<tr>
<td>Material Cost</td>
<td>+</td>
<td>-</td>
<td>Film thickness is triple with powder</td>
</tr>
<tr>
<td>Ease of Application</td>
<td>-</td>
<td>+</td>
<td>Powder is a simpler process and lower maintenance</td>
</tr>
<tr>
<td>Fire Hazard</td>
<td>-</td>
<td>+</td>
<td>Powder Insurance costs and less fire hazard during application</td>
</tr>
<tr>
<td>Shipping</td>
<td>-</td>
<td>+</td>
<td>Powder is more concentrated and will not freeze.</td>
</tr>
<tr>
<td>Color Change</td>
<td>+</td>
<td>-</td>
<td>Liquid easier to change color on paint line</td>
</tr>
<tr>
<td>Explosion Risk</td>
<td>+</td>
<td>-</td>
<td>Powder particles can ignite in storage</td>
</tr>
<tr>
<td>Odor</td>
<td>-</td>
<td>+</td>
<td>Liquid gives off strong solvent fumes</td>
</tr>
</tbody>
</table>
Touch Up Options

- PVDF touch up should be used over factory applied liquid PVDF products
  - Adhesion is excellent
  - Other touch ups will chalk and fade prematurely

- PVDF touch up has minimal adhesion to factory applied powder products.
  - Air dry primers and topcoats will have to be tested for adhesion
  - FEVE air dry fluoropolymers offer the best adhesion
Liquid or Powder Coatings

- Liquid has been the long time coating choice in the US market
- Powder is becoming more available for aluminum extrusions as new application lines are installed
- This brings more options for coatings in architecture applications
Contact Information

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