“FEVE Fluoropolymer Resins for High-Performance, Long-Life Coatings on Roof Surfaces”

Bob Parker
“International Roof Coatings Conference”
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Outline:

- Explanation of FEVE polyol technology
- Summary of FEVE resins and their properties
- Exposure testing of FEVE resin formulations
- FEVE resin-based coatings for roofs
- 1-component water-based FEVE coatings
- FEVE resin modification for white “Cool Roof” coatings
What is an FEVE Fluoropolymer???

1) A *hybrid* fluoropolymer polyol resin with the ability to be used in standard coatings formulations like any other conventional polyol resin

2) A high performance resin that can withstand severe ultraviolet light exposure 2-3 times longer than conventional polyol resins
FEVE Resins for Roof Coatings

**Fluoroethylene Vinyl Ether (FEVE) Resins**

- Fluoro Ethylene
- Vinyl Ether

**FLUORINATED SEGMENTS:** Weatherability, chemical resistance

**VINYL ETHER SEGMENTS:** Gloss, solubility, crosslinking
Advantages of FEVE Fluoropolymer Resins:

• Ambient Cure
  – Allows field applications at ambient temperatures
  – Permits the formulation of 1-component coatings

• OH Functionality
  - Crosslinkable with isocyanates and amino resins

• Solvent Soluble
  – Conventional application techniques (airless spray)
  – Wide range of gloss (maximum is 90 @ 60º)

• Fluoropolymer Segments
  – UV Resistance
  – Corrosion resistance
  – Chemical and solvent resistance
Markets for FEVE resin-containing coatings:

1) Architectural Coatings for commercial buildings
2) Industrial Maintenance Coatings for water towers, bridges, and assorted metal and concrete structures
3) Aerospace coatings
4) Applications in Solar energy markets
Commercial Types of “FEVE” Polyol Resins:

1) *Solvent soluble resins* –
   uses organic solvents for viscosity reduction;
   predominantly cured with isocyanates;
   available as resin solutions or as 100% solid resins

2) *Water-based dispersion* –
   carboxyl modification of FEVE resin to obtain
   stable dispersion in water
Commercial Types of “FEVE” Polyol Resins:

3) Water-based emulsions –
use vinyl ether macromonomers containing polyoxyethylene (EO) units to create stable emulsion
Solvent Soluble FEVE resins – Properties

- Hydroxyl Equivalent weights range from 330 to 1800
- Tg ranges from 20°C to 35°C
- VOC compliant formulations are attainable
- Can be blended with many acrylic and polyester polyols
- Solid resins can be dissolved in a wide variety of solvents, including exempt solvents
Water-based Dispersion – Properties

- Equivalent weight of dispersion solution is 1650 (40% weight solids in H₂O)
- MFFT = 27°C.
- Particle Diameter range is 0.05 – 0.3 μm
- Appearance is translucent liquid
- Can achieve “0” VOC formulations
- Does not have shear stability for pigment dispersion
Water-based FEVE Emulsion – Properties

- Equivalent Weight of emulsion solution is 2290 (50% weight solids in H₂O)
- MFFT = 55°C.
- Particle Diameter range is 0.1-0.2 μm
- Appearance is milky-white
- Needs coalescing solvents to form film
- Does not have shear stability for pigment dispersion
FEVE Resins for Roof Coatings

**Water-based FEVE Emulsion – Properties**

- MFFT = 35° C.
- Particle Diameter range is 0.1-0.2 μm
- Appearance is milky-white
- Needs coalescing solvents to form film
- Does not have shear stability for pigment dispersion
- Intended for use in 1-component systems
QUV Weatherometer Exposure Testing

Gloss Retention (%) vs. Hours of QUV Exposure (UVA-340 Bulbs)

- FEVE Coating
- Polysiloxane Coating
- Acrylic Urethane Coating
EMMAQUA Testing  (Outside Test Fence – Arizona)

- FEVE coating
- PVDF coating
- Acrylic Urethane coating
South Florida Test Fence Exposure

Gloss retention (%)

Years of Exposure

- FEVE Yellow Coating
- FEVE Clearcoat
### 3 Types of FEVE Coating Systems for Roofs:

<table>
<thead>
<tr>
<th>TYPE OF COATING</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2- COMPONENT SOLVENT-BASED</td>
<td>• CAN BE 100% FEVE POLYOL IN FORMULATION</td>
<td>• LIMITED POT LIFE</td>
</tr>
<tr>
<td></td>
<td>• HIGHLY CROSSLINKED FILM</td>
<td>• DIFFICULT TO OBTAIN LOW “VOC” LEVELS</td>
</tr>
<tr>
<td></td>
<td>• FAST CURE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• EXCELLENT ADHESION TO PREVIOUSLY COATED SURACES</td>
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<tr>
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<td>• CAN BE BLENDED WITH ACRYLIC &amp; POLYESTER POLYOLS</td>
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### 3 Types of FEVE Coating Systems for Roofs:

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| 1- COMPONENT WATER-BASED| • LOW “VOC” ATTAINABLE  
• NO APPLICATOR MIXING  
• NO ISOCYANATE PRESENCE  
• CAN BE BLENDED WITH ACRYLIC EMULSIONS | • NO CROSSLINKING; SOFTER, MORE PERMEABLE FILMS  
• APPLICATION MORE SENSITIVE TO ATMOSPHERIC CONDITIONS  
• SURFACE CLEANLINESS HIGHLY IMPORTANT  
• PERCENTAGE OF FEVE RESIN LIMITED DUE TO ADHESION ISSUES |
# Black Hi-Gloss Paint Formulation Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids (Volume)</td>
<td>36%</td>
</tr>
<tr>
<td>FEVE Emulsions</td>
<td>FE-4300</td>
</tr>
<tr>
<td>pH</td>
<td>9.0 to 9.5</td>
</tr>
<tr>
<td>Pigment Choice</td>
<td>Tint-Ayd CW5331</td>
</tr>
<tr>
<td></td>
<td>Masstone Black</td>
</tr>
<tr>
<td>PVC</td>
<td>2.7</td>
</tr>
<tr>
<td>Thickeners</td>
<td>associative-type</td>
</tr>
<tr>
<td>60° Gloss Range</td>
<td>60-80</td>
</tr>
<tr>
<td>VOC</td>
<td>100 g/liter</td>
</tr>
</tbody>
</table>
Testing procedure # 1:

1) Choose Acrylic Emulsion # 5, #8, and #9 as blending resins for High Gloss Black Formulation.

2) Manufacture of 2 Black Paint formulations for each Acrylic:
   a. Binder = 100% Acrylic Emulsion
   b. Binder = 80% Acrylic Emulsion + 20% FE-4300 (FEVE Emulsion)

3) Preparation of test panels (primed Al panels coated with 8 wet mils of coating)

4) QUV Weatherometer Exposure (UVA 340 Bulbs used)
   a. Test Cycle = 8 hours UV light @ 60° C.
      4 hours condensation @ 50° C.
FEVE Resins for Roof Coatings

Gloss Decrease of Acrylic #5 and FE-4300 Blend (HIGH GLOSS BLACK FORMULATION)

- 100% Acrylic
- 20% FE-4300

Hours in QUV Weatherometer

Gloss Decrease (°)

500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10,000
Gloss Decrease of Acrylic #8 and FE Emulsion Blend
(HIGH GLOSS BLACK FORMULATION)

60° Gloss Decrease (%)

0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0

Hours in QUV Weatherometer

100% Acrylic
80/20 w/ FE-4300
Gloss Decrease of Acrylic # 9 and FE4300 Emulsion Blend (HIGH GLOSS BLACK FORMULATION)

- **Gloss Decrease (%):**
  - 0.0%
  - 10.0%
  - 20.0%
  - 30.0%
  - 40.0%
  - 50.0%
  - 60.0%
  - 70.0%
  - 80.0%
  - 90.0%

- **60°**:
  - 0.0
  - 10.0
  - 20.0
  - 30.0
  - 40.0
  - 50.0
  - 60.0

- **Hours in QUV Weatherometer**

  - 500
  - 1000
  - 1500
  - 2000
  - 2500
  - 3000
  - 3500
  - 4000
  - 4500
  - 5000
  - 5500
  - 6000
  - 6500
  - 7000
  - 7500
  - 8000
  - 8500
  - 9300
  - 10,000

- **100% Acrylic**
- **80/20 w/ FE-4300**
<table>
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<tr>
<th>Dark Green Paint Formulation Properties</th>
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<tbody>
<tr>
<td><strong>Solids (Volume)</strong></td>
</tr>
<tr>
<td><strong>FEVE Emulsions</strong></td>
</tr>
<tr>
<td><strong>pH</strong></td>
</tr>
<tr>
<td><strong>Pigment Choice</strong></td>
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<tr>
<td><strong>PVC</strong></td>
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<tr>
<td><strong>Thickeners</strong></td>
</tr>
<tr>
<td><strong>60° Gloss Range</strong></td>
</tr>
<tr>
<td><strong>VOC</strong></td>
</tr>
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Testing procedure # 2:

1) Choose Acrylic #9 as blending resin for Hi-Gloss Dark Green Formulations (Federal 895 Color Std. 14090)

2) Manufacture of 3 formulations:
   a. Binder = 100% Acrylic Emulsion
   b. Binder = 70% Acrylic Emulsion + 30% FE-4300 (FEVE Emulsion)
   c. Binder = 55% Acrylic Emulsion + 45% FE-4300 (FEVE Emulsion)

3) Preparation of test panels (Al panels coated with 8 wet mils of coating)

4) QUV Weatherometer Exposure (UVA 340 Bulbs used)
   a. Test Cycle = 8 hours UV light @ 60° C. + 4 hours condensation @ 50° C.
Gloss Decrease of Dark Green Formulations - 100% Acrylic and FE emulsion blends

- 100% Acrylic
- w/ 30% FE4300
- w/ 45% FE4300

Hours in QUV Weatherometer

Gloss Decrease (%)

60°
FEVE Resins for Roof Coatings

Color Change ($\Delta E$) of Dark Green Formulations - 100% Acrylic and FEVE emulsion blends

- 100% Acrylic
- w/ 30% FE4300 Emulsion
- w/ 45% FE4300 Emulsion
“Cool Roof” Coating Performance Properties:

1) High Reflectivity and Low Thermal Emittance –
   these properties have to be maintained for as long as is possible during the life of the roof

2) Dirt Pick-up Resistance –
   needed to maintain high reflectivity and low thermal emittance

3) Mold and Mildew Resistance –
   needed to maintain high reflectivity and low thermal emittance

How can a hybrid fluoropolymer emulsion improve the performance of conventional “cool roof” coatings?
**Dirt Pick-up Resistance:**
slight improvement with FEVE emulsion modification;
high resistance to UV degradation may prevent premature erosion of the
additives developed to improve dirt pick-up resistance in the formulation

**Mildew and Mold Resistance:**  

*What performance properties of an acrylic elastomeric roof coating need to be retained?*

- Stability of Coating
  - Adhesion
  - Elongation
- Crack Resistance
- Ease of Application
### White “Cool Roof” Coating - Formulation Properties

<table>
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<tr>
<th>Property</th>
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<tbody>
<tr>
<td>Solids (Volume)</td>
<td>36.7%</td>
</tr>
<tr>
<td>FEVE Emulsions</td>
<td>FE-4300</td>
</tr>
<tr>
<td>pH</td>
<td>9.0-9.5</td>
</tr>
<tr>
<td>Pigment Choice</td>
<td>Ti Pure R960</td>
</tr>
<tr>
<td></td>
<td>No inert pigments added</td>
</tr>
<tr>
<td>PVC</td>
<td>20</td>
</tr>
<tr>
<td>Thickeners</td>
<td>Cellulosic &amp; associative-type</td>
</tr>
<tr>
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ASTM D2370 Elongation test

% Elongation of FEVE emulsion-modified formulas

% Elongation

% FEVE Emulsion in Formulation
Work in Progress:

1) Increasing PVC in original formulation with inert pigments
2) Exposures on test fence for dirt pick-up resistance, mildew resistance, and crack resistance over elastomeric basecoats
3) Adhesion testing on basecoats and roofing substrates
4) Adding different fluorosurfactants to improve dirt pick-up resistance.
FEVE Resins for Roof Coatings

**Summary**

FEVE resin technology will extend the lifetime of roof coatings, in both pigmented and clearcoat formulations. They can be use as 100% of the resin or as modifiers to boost the weatherability of both solvent and water-based formulations. They may also improve the performance of “cool roof” coatings.
Acknowledgements:

Kamel Fennell
Victoria Spofford