“FEVE Fluoropolymer Emulsions for Performance Improvement in Architectural Coatings”

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Outline

- Overview of “FEVE” resin technology
- Introduction of water-based “FEVE” emulsions
- Formulations using “FEVE” emulsions as blending resins:
  1) Semi-Gloss House Paints
     a. White
     b. Dark Red
  2) DTM Industrial Hi-Gloss Coatings
     a. White
     b. Black
     c. Dark Green
     d. Safety Yellow
FEVE Fluoropolymer Resins

- “FEVE” is abbreviation for “Fluoroethylene Vinyl Ether” resins for coatings

- Known for their high performance properties:
  1) Exceptional resistance to UV degradation
  2) Superior Chemical Resistance
  3) Excellent Thermal Resistance

- Known for their unique formulation properties:
  1) Solvent soluble
  2) Can be cured at ambient temperature with isocyanates
  3) Can achieve high gloss formulations
Fluoroethylene Vinyl Ether (FEVE) Resins

Fluoro Ethylene

Vinyl Ether

FLUORINATED SEGMENTS: Weatherability, durability, chemical resistance
VINYL ETHER SEGMENTS: Gloss, solubility, crosslinking
Commercial Types of “FEVE” 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 emulsions** –
   use vinyl ether macromonomers containing polyoxyethylene (EO) units to create stable emulsions
<table>
<thead>
<tr>
<th></th>
<th>FE-4300</th>
<th>FE-4500</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solids (Wt.)</strong></td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>7 to 9</td>
<td>7 to 9</td>
</tr>
<tr>
<td><strong>Specific Gravity</strong></td>
<td>1.13</td>
<td>1.17</td>
</tr>
<tr>
<td><strong>MFT</strong></td>
<td>35°C.</td>
<td>28°C.</td>
</tr>
<tr>
<td><strong>Hydroxyl Value</strong></td>
<td>10</td>
<td>13</td>
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### White House Paint Formulation Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solids (Volume)</strong></td>
<td>32%</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>9.0 to 9.5</td>
</tr>
<tr>
<td><strong>TiO₂ Choice</strong></td>
<td>TiPure R-706</td>
</tr>
<tr>
<td><strong>PVC</strong></td>
<td>22</td>
</tr>
<tr>
<td><strong>Thickeners</strong></td>
<td>both cellulosic and associative</td>
</tr>
<tr>
<td><strong>60° Gloss Range</strong></td>
<td>50-65</td>
</tr>
<tr>
<td><strong>VOC</strong></td>
<td>150 g/liter</td>
</tr>
</tbody>
</table>
**Testing procedure #1:**

1) Blending of FEVE emulsions and 4 different acrylic emulsions to evaluate stability (3 weeks in 140°F. oven)

2) Manufacture of 3 *White House Paint* formulations for each acrylic emulsion:
   a. Binder = 100% Acrylic Emulsion
   b. Binder = 50% Acrylic Emulsion + 50% FE-4300 (FEVE Emulsion)
   c. Binder = 50% Acrylic Emulsion + 50% FE-4500 (FEVE Emulsion)

3) Stability testing of all formulations (6 weeks in 120°F. oven)

4) Preparation of test panels (primed Al panels coated with 4 wet mils of coating)

5) QUV Weatherometer Exposure (UVA 340 Bulbs used)
   a. Test Cycle = 8 hours UV light @ 60°C. + 4 hours condensation @ 50°C.
Gloss Decrease - Acrylic #1 and 50/50 Blends

Hours in QUV Weatherometer

- 100% Acrylic
- 50/50 w/ FE-4300
- 50/50 w/ FE-4500
Gloss Decrease - Acrylic #2 and 50/50 Blends

**Hours in QUV Weatherometer**

- 100% Acrylic
- 50/50 w/ FE-4300
- 50/50 w/ FE-4500
Gloss Decrease - Acrylic #3 and 50/50 Blends

- 100% Acrylic
- 50/50 w/ FE-4300
- 50/50 w/ FE-4500

Hours in QUV Weatherometer

60° Gloss Decrease (%)
Gloss Decrease - Acrylic #4 and 50/50 Blends

60° Gloss Decrease (%)

Hours in QUV Weatherometer

- 100% Acrylic
- 50/50 w/ FE-4300
- 50/50 w/ FE-4500
## Red House Paint Formulation Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solids (Volume)</strong></td>
<td>36%</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>9.0 to 9.5</td>
</tr>
<tr>
<td><strong>Pigment Choice</strong></td>
<td>Organic Red + Phthalo Blue (trace)</td>
</tr>
<tr>
<td><strong>PVC</strong></td>
<td>6.5</td>
</tr>
<tr>
<td><strong>Thickeners</strong></td>
<td>both cellulosic and associative</td>
</tr>
<tr>
<td><strong>60° Gloss Range</strong></td>
<td>50-65</td>
</tr>
<tr>
<td><strong>VOC</strong></td>
<td>150 g/liter</td>
</tr>
</tbody>
</table>
Testing procedure # 2 :

1) Choose Acrylic Emulsion #3 as blending resin for Red HP formulation.

2) Manufacture of 6 Red House Paint formulations:
   a. Binder = 100% Acrylic Emulsion
   b. Binder = 50% Acrylic Emulsion + 50% FE-4500 (FEVE Emulsion)
   c. Binder = 60% Acrylic Emulsion + 40% FE-4500 (FEVE Emulsion)
   d. Binder = 70% Acrylic Emulsion + 30% FE-4500 (FEVE Emulsion)
   e. Binder = 80% Acrylic Emulsion + 20% FE-4500 (FEVE Emulsion)
   f. Binder = 90% Acrylic Emulsion + 10% FE-4500 (FEVE Emulsion)

3) Preparation of test panels (primed Al panels coated with 4 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 Acrylic #3 and FE-4500 Blends

60° Gloss Decrease (%)

0 10 20 30 40 50 60 70 80
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000

Hours in QUV Weatherometer

- 100% Acrylic
- 10% FE-4500
- 20% FE-4500
- 30% FE-4500
Gloss Decrease of Acrylic #3 and FE-4500 Blends

60° Gloss Decrease (%)

Hours in QUV Weatherometer

- 100% Acrylic
- 40% FE-4500
- 50% FE-4500
## White DTM I/M Paint Formulation Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Solids (Volume)</td>
<td>38%</td>
</tr>
<tr>
<td>FEVE Emulsion</td>
<td>FE-4300</td>
</tr>
<tr>
<td>pH</td>
<td>9.0 to 9.5</td>
</tr>
<tr>
<td>TiO₂ Choice</td>
<td>TiPure R-706</td>
</tr>
<tr>
<td>PVC</td>
<td>18</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 # 3:

1) Choose 3 different acrylic emulsions from 2 manufacturers as blending resins for White DTM I/M Formulation. Blend these acrylic emulsions with the FE emulsions and run oven stability tests.

2) Manufacture of 2 White DTM I/M Paint formulations:
   a. Binder = 100% Acrylic Emulsion
   b. Binder = 50% Acrylic Emulsion + 50% FE-4300 (FEVE Emulsion)

3) Preparation of test panels (primed Al panels coated with 4 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 Acrylic #5 and FE-4300 Blend

Hours in QUV Weatherometer

- 100% Acrylic
- 50/50 BLEND w/ FE-4300
Gloss Decrease of Acrylic #6 & FE-4300 Blend

Hours in QUV Weatherometer

- 100% Acrylic
- 50/50 BLEND w/ FE-4300
Gloss Decrease of Acrylic # 7 and FE-4300 Blend

60° Gloss Decrease (%)

Hours in QUV Weatherometer

- 100% Acrylic
- 50/50 BLEND w/ FE-4300
## Black DTM I/M 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 and FE-4500</td>
</tr>
<tr>
<td>pH</td>
<td>9.0 to 9.5</td>
</tr>
<tr>
<td>Pigment Choice</td>
<td>Tint-Ayd CW5331 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 # 4:

1) Choose Acrylic Emulsion # 5 and Acrylic Emulsion # 6 as blending resins for Black DTM I/M Formulation.

2) Manufacture of 3 Black DTM I/M Paint formulations for each Acrylic:
   a. Binder = 100% Acrylic Emulsion
   b. Binder = 50% Acrylic Emulsion + 50% FE-4300 (FEVE Emulsion)
   c. Binder = 50% Acrylic Emulsion + 50% FE-4500 (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.
Gloss Decrease of Acrylic #5 and 50/50 LUMIFLON Blends (BLACK FORMULA)

Hours in QUV Weatherometer

- 100% Acrylic
- 50/50 w/ FE-4300
- 50/50 w/ FE-4500
Gloss Decrease of Acrylic #6 and 50/50 FEVE Blends (BLACK FORMULA)

- 100% Acrylic
- 50/50 w/ FE-4300
- 50/50 w/ FE-4500

Hours in QUV Weatherometer
 **Testing procedure # 5:**

1) Choose Acrylic Emulsion # 5 and Acrylic Emulsion # 6 as blending resins for Black DTM I/M Formulation.

2) Manufacture of 3 *Black DTM I/M Paint* formulations for each Acrylic:
   - a. Binder = 100% Acrylic Emulsion
   - b. Binder = 80% Acrylic Emulsion + 20% FE-4300 (FEVE Emulsion)
   - c. Binder = 80% Acrylic Emulsion + 20% FE-4500 (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.
Gloss Decrease of Acrylic #5 and FE-4300 Blends
(DTM BLACK FORMULATION)

Hours in QUV Weatherometer

- 100% Acrylic
- 20% FE-4300
Gloss Decrease of Acrylic #5 and FE-4500 Blends (DTM BLACK FORMULATION)

60° Gloss Decrease (%)

Hours in QUV Weatherometer

- 100% Acrylic
- 20% FE-4500

FEVE Emulsions in Architectural Coatings
Test Formulation:
100% Acrylic Emulsion #5 as total binder
Test Formulation:
80% Acrylic emulsion #5 and 20% FE-4300 FEVE Emulsion as total binder
**Test Formulation:**
80% Acrylic emulsion #5 and 20% FE-4300 FEVE Emulsion as total binder
**Test Formulation:**
80% Acrylic emulsion #5 and 20% FE-4500 FEVE Emulsion as total binder.
FEVE Emulsions in Architectural Coatings

**Test Formulation:**
80% Acrylic emulsion #5 and 20% FE-4500 FEVE Emulsion as total binder
Gloss Decrease of Acrylic #6 and FE-4300 Blends
(DTM BLACK FORMULATION)

60° Gloss Decrease (%)

Hours in QUV Weatherometer

- 100% Acrylic
- 20% FE-4300
Gloss Decrease of Acrylic #6 and FE-4500 Blends (DTM BLACK FORMULATION)

60° Gloss Decrease (%)

Hours in QUV Weatherometer

- 100% Acrylic
- 20% FE-4500
Test Formulation: 100% Acrylic Emulsion #6 as total binder
**Test Formulation:**
80% Acrylic emulsion #6 and 20% FE-4300 FEVE Emulsion as total binder
**Test Formulation:**
80% Acrylic emulsion #6 and 20% FE-4300 FEVE Emulsion as total binder
Test Formulation:
80% Acrylic emulsion #6 and 20% FE-4500 FEVE Emulsion as total binder
Test Formulation:
80% Acrylic emulsion #6 and 20% FE-4500 FEVE Emulsion as total binder
## Dark Green DTM I/M Paint Formulation Properties

<table>
<thead>
<tr>
<th>Properties</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solids (Volume)</strong></td>
<td>32.7%</td>
</tr>
<tr>
<td><strong>FEVE Emulsions</strong></td>
<td>FE-4300, FE-4500, and FE4400</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>9.0 to 9.5</td>
</tr>
<tr>
<td><strong>Pigment Choice</strong></td>
<td>TiO$_2$ Colorant (Evonik 896 line)</td>
</tr>
<tr>
<td></td>
<td>Phthalo Green Colorant (896 line)</td>
</tr>
<tr>
<td></td>
<td>Tint-Ayd CW5317 (Elementis)</td>
</tr>
<tr>
<td><strong>PVC</strong></td>
<td>8.7</td>
</tr>
<tr>
<td><strong>Thickeners</strong></td>
<td>associative-type</td>
</tr>
<tr>
<td><strong>60° Gloss Range</strong></td>
<td>60-80</td>
</tr>
<tr>
<td><strong>VOC</strong></td>
<td>150 g/liter</td>
</tr>
<tr>
<td><strong>Solids (Wt.)</strong></td>
<td>50%</td>
</tr>
<tr>
<td>------------------</td>
<td>-----</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>7 to 9</td>
</tr>
<tr>
<td><strong>Specific Gravity</strong></td>
<td>1.13</td>
</tr>
<tr>
<td><strong>MFT</strong></td>
<td>55°C.</td>
</tr>
<tr>
<td><strong>Hydroxyl Value</strong></td>
<td>49</td>
</tr>
</tbody>
</table>
**Testing procedure # 6:**

1) Choose Acrylic Emulsion # 5 as blending resin for Dark Green DTM I/M Formulations

2) Manufacture of 4 formulations:
   a. Binder = 100% Acrylic Emulsion
   b. Binder = 80% Acrylic Emulsion + 20% FE-4300 (FEVE Emulsion)
   c. Binder = 80% Acrylic Emulsion + 20% FE-4500 (FEVE Emulsion)
   d. Binder = 80% Acrylic Emulsion + 20% FE-4400 (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.
Gloss Decrease of Avanse MV-100 and 80/20 LUMIFLON Blends (Dark Green FORMULA)

- 100% Acrylic
- w/ 20% FE-4300
- w/ 20% FE-4500
- w/ 20% FE-4400

Hours in QUV Weatherometer:
- 1000
- 2000
- 3000
- 4000
- 5000
FEVE Emulsions in Architectural Coatings

Color Change of Avanse MV-100 and 80/20 LUMIFLON Blends (Dark Green FORMULA)

Hours in QUV Weatherometer

<table>
<thead>
<tr>
<th>Color Change ΔE</th>
<th>100% Acrylic</th>
<th>w/ 20% FE-4300</th>
<th>w/ 20% FE-4500</th>
<th>w/ 20% FE-4400</th>
</tr>
</thead>
</table>
Testing procedure # 7:

1) Choose Acrylic Emulsion # 5 as blending resin for Safety Yellow DTM I/M Formulations

2) Manufacture of 3 formulations:
   a. Binder = 100% Acrylic Emulsion
   b. Binder = 80% Acrylic Emulsion + 20% FE-4300 (FEVE Emulsion)
   c. Binder = 60% Acrylic Emulsion + 40% 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.
Gloss Decrease of Acrylic #5 and LUMIFLON Blends (Safety Yellow FORMULA)

- 100% Acrylic
- w/ 20% FE
- w/ 40% FE

Hours in QUV Weatherometer:
- 1000
- 2000
- 2500
- 3905
- 5000

60° Gloss Decrease (%):
- 0.0
- 10.0
- 20.0
- 30.0
- 40.0
- 50.0
- 60.0
- 70.0
- 80.0
- 90.0
- 100.0
Color Change of Acrylic #5 and LUMIFLON Blends (Safety Yellow FORMULA)

- 100% Acrylic
- w/ 20% FE-4300
- w/ 40% FE-4300
Conclusion:

Inclusion of FEVE emulsions in architectural coating formulations can increase gloss retention, color retention, and the overall durability of the dry film. These characteristics will prolong the aesthetic properties and the protection properties of these coatings, thereby increasing the time frame between recoats.