Dispersants –
An overview on their purpose, value, and application

Tony Moy, September 11, 2018
Agenda

- What are dispersants?
- Why use dispersants?
- How do dispersants work?
- Dispersant types, associated pigment applications, and considerations
- Optimizing dispersant concentration/level in a formulation
- Process considerations
- Examples of dispersant applications
- Questions?
What are Dispersants
What are Dispersants?

- **Dispersants** are chemical substances that serve to **stabilize** solids/particles (pigments) in a liquid **dispersion/suspension**

- In the coatings industry these are in the form of: surface actives (surfactants) and polymers
Making a Dispersion

Raw Materials
- Water/solvent
- Dispersant
- Other Additives
- Resin

Pre-Mix

Favored Energy States

Dispersant
Pigment

Favored Properties

agglomerates
aggregates
crystals; primary particles

Finished Dispersion

Raw Materials

• Water/solvent
• Dispersant
• Other Additives
• Resin

Pre-Mix

Favored Energy States

Dispersant
Pigment

Favored Properties

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crystals; primary particles

Finished Dispersion
Why use Dispersants?
Value of Dispersants

- Minimize interaction of pigments
  - Reduce viscosity
  - Enhance stability of pigment and dispersion
  - Reduced settling and kick out
  - Maximize performance contribution of pigments (color, protection, etc.)
  - Minimize the amount of pigment required to do the job ($$$)

- More formulation latitude: ability to load more (solids) into formulation
  - Introduce filler/extender pigments
  - Use less resin to achieve mechanical properties
  - Use less primary pigment ($$$)

- Productivity ($$$)
  - Shorter dispersion time
  - Transfer product with less energy and time
How do Dispersants work?
Dispersant Mechanisms

- **Electrostatic**
  - Dispersant attaches to pigment and establishes electric double layer causing repulsive forces

- **Steric**
  - Dispersant attaches to pigment and has segments which stand out from pigment surface to provide mechanical repulsive forces

- **Electrosteric**
  - A combination of both

- Ultimately the force of repulsion created by dispersant must overcome the attractive forces of the pigment particles to realize a stable state
Types of Dispersants
Types of Dispersants

Low Molecular Weight
- Surfactant Types
  - Ionic and Non-ionic
    - MW \(<\ 1000"

Examples:
- Sulfates/sulfonates
- Phosphate esters
- Fatty acids
- Quaternary ammonium/Imidazolium salts

Oligomeric Medium Molecular Weight
- Fatty Acid Modified Ester
  - Anionic
    - MW: \(1000\ -\ 3000\)

High Molecular Weight
- Polyacrylic Acid
- Polycarboxylic Copolymers
- Polyacrylates
- Polyurethanes
  - MW \(>\ 5000\)
Types of Dispersants

- Advanced High Molecular Weight
  - Star Shaped Polymers
  - Block Copolymers via Controlled Free Radical Polymerization (CFRP)

  MW > 5000
Selecting a Dispersant
Selecting a Dispersant

Key Questions to consider when selecting/using dispersants

1. What is being dispersed?
2. What is it dispersed in?
3. How is it dispersed?
4. What is the objective?

Dispersant(s) to trial
Consideration No. 1: What is being dispersed?

- **Pigments**
  - Inorganic, Organic, or both together?
  - Type, Grade, Color Index
  - Surface Treated?!

- **Clay**
  - Ceramics, e.g. via “slip casting”

- **Calcium Carbonate**
  - Recovery from waste water

- **Catalysts**
  - For further processing as slurry
Consideration No. 2: What is it dispersed in?

- Water
  - What is the pH? Is it neutralized?

- Solvent (blend)
  - What is the polarity?

- 100% System
  - What’s the Chemistry (EP, PU, …)?

The dispersant must be compatible with the medium in which it is dispersed!
Consideration No. 3: How is it dispersed?

Typically, the type of pigment will dictate what is required
Consideration No. 4: What is the objective?

**Process Aid**
- Improved pigment wetting
- Increased mill efficiency
- Viscosity control

**Performance**
- Increased color strength
- Improved compatibility
- Higher gloss
- Stability

**Formulation Effect**
- Higher pigment loading
- Improved color stability
- Improved rheology control
- Improved economics

Typically, coatings must be a balance of several objectives; Dispersant types and level of usage must be chosen accordingly!
Selecting a Dispersant: General Guidelines – Pigments & Benefits

- **Ionic Dispersants:**
  - Fillers, extenders, TiO₂
  - Economic solutions
  - Combined with resin

- **LMW dispersants:**
  - Fillers, extenders, TiO₂
  - Economic solutions with less demand for performance
  - Combined with resin or HMWD
  - Solvent and water borne

- **Medium MW dispersants and smart blends:**
  - Brodest compatibility
  - Universal application

- **HMW dispersants:**
  - For organic and inorganic pigments
  - Lowest viscosities
  - Highest color strength
  - Highest gloss
Dispersants – Pigments – Applications
Water-based

- Primers
- Deco paints
- High performance Applications e.g. OEM
- Pigment concentrates
- Surfactants
- Fatty Acid Modified High MW PA
- Fatty Acid Modified
- High MW PA
- Adv High MW PA
- Stoving enamels
- Industrial paints
- Pigment concentrates
- TiO2 Fillers Oxides
- Organic Pigments
- Water-based TiO2
- Fillers Oxides
- Organic Pigments
- 10-Sept-2018
Primers
Alkyd paints
High performance Applications e.g. OEM
Pigment concentrates

TiO2 Fillers Oxides

Organic Pigments

Fatty Acid Modified
High MW PU
Adv High MW PA

Stoving enamels Industrial paints

Fatty Acid Modified
High MW PU
Adv High MW PA

High performance Applications e.g. OEM Pigment concentrates

Solvent-based

Dispersants – Pigments – Applications
# Dispersant Application Recommendations by Market/Industry

<table>
<thead>
<tr>
<th>Application Markets</th>
<th>Recommended Products for Given Application Types</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Architectural / Deco</strong></td>
<td></td>
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<tr>
<td>Interior decorative coatings (WB)</td>
<td>- High MW Polyacrylic Acids</td>
</tr>
<tr>
<td>Exterior decorative coatings (WB)</td>
<td>- High MW Copolyacrylates</td>
</tr>
<tr>
<td><strong>Trim paints (SB)</strong></td>
<td>Fatty Acid Modified</td>
</tr>
<tr>
<td><strong>Trim paints (WB)</strong></td>
<td>- Adv High MW Polyacrylates</td>
</tr>
<tr>
<td></td>
<td>- Adv High MW Block Copolymer</td>
</tr>
<tr>
<td><strong>Industrial Coatings</strong></td>
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<tr>
<td>Can &amp; Coil Coatings (SB)</td>
<td>- High MW Polyacrylates</td>
</tr>
<tr>
<td></td>
<td>- Adv High MW Polyacrylates</td>
</tr>
<tr>
<td>Furniture &amp; Flooring Coatings (WB/SB)</td>
<td>- Fatty Acid Modified</td>
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<tr>
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<td>- Adv High MW Polyacrylates</td>
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<td></td>
<td>- Adv High MW Block Copolymer</td>
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<tr>
<td><strong>Industrial Maintenance (WB/SB)</strong></td>
<td>- High MW Polyacrylates</td>
</tr>
<tr>
<td></td>
<td>- High MW Polyurethanes</td>
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<tr>
<td></td>
<td>- Adv High MW Polyacrylates</td>
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<td></td>
<td>- Adv High MW Block Copolymer</td>
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<tr>
<td><strong>Marine Coatings (SB)</strong></td>
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<tr>
<td></td>
<td>- Fatty Acid Modified</td>
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<td></td>
<td>- Adv High MW Polyacrylates</td>
</tr>
<tr>
<td></td>
<td>- Adv High MW Block Copolymer</td>
</tr>
<tr>
<td><strong>Industrial Mixing Systems</strong></td>
<td>- Adv High MW Polyacrylates</td>
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<tr>
<td></td>
<td>- Adv High MW Block Copolymer</td>
</tr>
<tr>
<td></td>
<td>- Grind Resins</td>
</tr>
<tr>
<td><strong>Automotive OEM</strong></td>
<td>To achieve best jetness and blue undertone with carbon black pigments (WB/SB)</td>
</tr>
<tr>
<td></td>
<td>- Adv High MW Polyacrylates</td>
</tr>
<tr>
<td></td>
<td>- Adv High MW Block Copolymer</td>
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<tr>
<td><strong>Printing &amp; Packaging</strong></td>
<td></td>
</tr>
<tr>
<td>WB pigment concentrates and inks</td>
<td>- High MW Polyacrylates</td>
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<tr>
<td></td>
<td>- High MW Polyurethanes</td>
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<td></td>
<td>- Adv High MW Polyacrylates</td>
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<td></td>
<td>- Adv High MW Block Copolymer</td>
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<td>- Wetting Agents</td>
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<tr>
<td><strong>SB ink formulations</strong></td>
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<td>- Adv High MW Polyacrylates</td>
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<td></td>
<td>- Adv High MW Block Copolymer</td>
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<tr>
<td></td>
<td>- Grind Resins</td>
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<tr>
<td><strong>UV curable inks (SF)</strong></td>
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<td></td>
<td>- Adv High MW Polyacrylates</td>
</tr>
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<td></td>
<td>- Adv High MW Block Copolymer</td>
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### BASF Dispersant – Pigment Reference

Some suggestions/starting points

<table>
<thead>
<tr>
<th>Pigment Type</th>
<th>Water</th>
<th>Solvent</th>
<th>Solvent-free</th>
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<tbody>
<tr>
<td>White</td>
<td>Dispex AA 4144</td>
<td>Efka FA 4608/4609/4620</td>
<td>Efka FA 4608/4620</td>
</tr>
<tr>
<td></td>
<td>Dispex CX 4230/4320</td>
<td>Efka PU 4010/4047</td>
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<tr>
<td></td>
<td>Dispex Ultra PX 4585</td>
<td>Efka PX 4330</td>
<td></td>
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<tr>
<td>Inorganic Fillers</td>
<td>Dispex Ultra FA 4420/4431/4483</td>
<td>Efka FA 4609/4620/4642</td>
<td>Efka FA 4620/4642</td>
</tr>
<tr>
<td></td>
<td>Dispex AA 4135/4140/4144</td>
<td>Efka PU 4046</td>
<td>Efka PU 4046</td>
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<tr>
<td>Aluminum, Pearls (Mica)</td>
<td>Efka FA 4620</td>
<td>Efka FA 4609/4620</td>
<td>Efka FA 4620/4665</td>
</tr>
<tr>
<td></td>
<td>Dispex Ultra FA 4437</td>
<td>Efka PU 4047</td>
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</tr>
<tr>
<td>Black (Organic)</td>
<td>Dispex Ultra PX 4585</td>
<td>Efka PX 4310/4320</td>
<td></td>
</tr>
<tr>
<td>Blue (Phthalo)</td>
<td>Dispex Ultra PX 4585</td>
<td>Efka PX 4350/4751+Efka MI 6745</td>
<td>Efka PX 4731 / 4732 / 4733 / 4751+Efka MI 6745</td>
</tr>
<tr>
<td>Violet (Quinacridone)</td>
<td>Dispex Ultra PX 4585</td>
<td>Efka PX 4310</td>
<td></td>
</tr>
<tr>
<td>Red (DPP)</td>
<td>Dispex Ultra PX 4585</td>
<td>Efka PX 4310</td>
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<tr>
<td>Red (Quinacridone)</td>
<td>Dispex Ultra PX 4585</td>
<td>Efka PX 4310</td>
<td></td>
</tr>
<tr>
<td>Green (Phthalo)</td>
<td>Dispex Ultra PX 4585</td>
<td>Efka PX 4350/4751+Efka MI 6745</td>
<td></td>
</tr>
<tr>
<td>Yellow (Isoindoline)</td>
<td>Dispex Ultra PX 4550 (B, BV) / 4585 (I, B)</td>
<td>Efka PA 4401 (I, B)</td>
<td>Efka PX 47** series (I,B)</td>
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<tr>
<td>(Benzimidazalone) (Bizmuth Vanadate)</td>
<td></td>
<td>Efka PX 4330 (I, B, BV)</td>
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<tr>
<td>Trans Iron Oxide (Red, Yellow)</td>
<td>Dispex Ultra PX 4550/4575</td>
<td>Efka FA 4608/4609/4620</td>
<td>Efka 4608/4620</td>
</tr>
</tbody>
</table>
## Pigment Grinding Reference

<table>
<thead>
<tr>
<th>Pigment Type</th>
<th>Grind</th>
<th>Grind Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>Easy</td>
<td>HSD or Sandmill</td>
</tr>
<tr>
<td>Inorganic Fillers</td>
<td>Easy</td>
<td>HSD</td>
</tr>
<tr>
<td>Aluminum, Pearls (Mica) – Effect Pigments</td>
<td>Don’t grind</td>
<td>Paddle mixer</td>
</tr>
<tr>
<td>Black (Organic)</td>
<td>Difficult</td>
<td>HSD Premix + High Energy Mill</td>
</tr>
<tr>
<td>Blue (Phthalo)</td>
<td>Difficult</td>
<td>HSD Premix + High Energy Mill</td>
</tr>
<tr>
<td>Violet (Quinacridone)</td>
<td>Difficult</td>
<td>HSD Premix + High Energy Mill</td>
</tr>
<tr>
<td>Red (DPP)</td>
<td>Difficult</td>
<td>HSD Premix + High Energy Mill</td>
</tr>
<tr>
<td>Red (Quinacridone)</td>
<td>Moderate to Difficult</td>
<td>HSD Premix + High Energy Mill</td>
</tr>
<tr>
<td>Green (Phthalato)</td>
<td>Difficult</td>
<td></td>
</tr>
<tr>
<td>Yellow (Isoindoline)</td>
<td>Moderate</td>
<td>Sandmill</td>
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<td>(Benzimidazalone) (Bizmuth Vanadate)</td>
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<tr>
<td>Trans Iron Oxide (Red, Yellow)</td>
<td>Moderate to Difficult</td>
<td>HSD Premix + High Energy Mill</td>
</tr>
</tbody>
</table>
Optimizing Dispersant Level in a Formulation
Some Best Practices after a dispersant has been selected

- Avoid mixing pigment types in a single dispersion *if possible*

- Use of a single, universal dispersant for pigments can be advantageous if compatibility is important
  - Note that these types of dispersants may not give best dispersing results for all pigments; compromise for compatibility

- Confirm compatibility of dispersant with key liquid ingredients in formulation

- If replacing an existing dispersant with a new one, account for substitution based on **active solids**

- Run a Dispersant Demand Ladder Experiment to determine optimal concentration

- Once an optimal dispersant level is chosen, run grind experiments

- Correlate property development vs grind time to determine optimal grind time

- Perform 2 week accelerated aging study (120 °F) to confirm dispersion stability
  - Test properties before and after aging

- If other pigmented dispersions will be mixed then check for compatibility
  - Flood, float, color acceptance
  - May need a fatty acid (compatibilizer/emulsifier) or controlled flocculation type of dispersant
Dispersant Demand Curves

- For a given formulation with: Fixed pigment, resin, solvent/water concentrations
- Run ladder experiment varying dispersant concentration
  - Low to High
  - Refer to supplier TDS for recommended range or
  - Use rough rule of thumb for center point:
    
    \[
    \text{Active dispersant amt} = \frac{\text{Pigment Surface area}}{4}\text{ on pigment (\%)}
    \]
  - Measure key property of interest
  - Plot measured Property vs Dispersant Concentration
  - Identify Dispersant Concentration which matches most positive Property value
  - May need to balance a variety of Properties
Dispersant Demand Curve – Viscosity Example

- For a given formulation with:
  - Fixed pigment, resin, solvent/water concentrations
- Run ladder experiment varying dispersant concentration
  - Low to High
  - Refer to supplier TDS for recommended range or
  - Use rough rule of thumb for center point:
    Active dispersant amt = Pigment Surface area/4 on pigment (%)
  - Measure low shear viscosity
    (e.g., Brookfield at fixed RPM)
  - Plot measured viscosity vs Dispersant Concentration
  - Low point on curve corresponds to optimal dispersant concentration for viscosity suppression

Active dispersant amt on pigment (%) = Pigment Surface area/4 on pigment (%)
Processing Considerations
Processing considerations

1. Determine grind/processing requirements based on pigment type
   - For easy to grind pigments a simple high shear mixing operation is sufficient
   - For hard to grind pigments a premix followed by milling is required

2. Add liquid ingredients first*

3. Add solids (pigments) slowly
   - Allow time to fully wet pigment

4. *May need to hold back some solvent/water to increase solids/viscosity
   - Increase energy of mixing to help break pigment down to primary size

5. Pull samples during grind to track property (color, degree of grind, visc.) as a function of grind time

6. Add back liquid hold out as a letdown to create final dispersion

---

**Raw Materials**
1. Water/solvent
2. Dispersant
3. Other Additives
4. Grind Resin*
5. Pigment

**Post Add**
- Held
  - Water/solvent
- Latex*
- Biocide

**Notes:**
* Latex emulsions are typically not shear stable
These would be added as a post add

---

**Pre-Mix**

**Favored Energy States**
- Dispersant
- Pigment
- Crystals; primary particles

**Finished Dispersion**

**Favored Properties**

---

May not be required for easy to grind pigments
Case Examples of Applications
Case Example: W-210 Microspheres with Efka® FA 4620

Efka FA 4620 Demand for W-210 in Bis A Epoxy

- DER 332 Control
- DER 332 w/ 50% wt. 210
- w/ Efka FA 4620 at 0.2%
- w/ Efka FA 4620 at 2% wt.

Viscosity (poise)

Shear rate 1/sec

No Dispersant
With Dispersant
Flows

32 10-Sept-2018

We create chemistry
## Case Example 2: Dispex® AA 4135

<table>
<thead>
<tr>
<th>Product</th>
<th>Dispex® AA 4135</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance Highlights</strong></td>
<td>• Offers reduced odor due to sodium hydroxide neutralization</td>
</tr>
</tbody>
</table>
| **Sustainability Highlights** | • Low VOC  
• Low odor  
• Non-APEO  
• Excellent cost performance balance |
| **Applications (Construction Market Focus)** | • Recommended for flooring adhesives, sealants, construction adhesives, for ceramic tile adhesives, flexible roof coatings and for primers/bonding aids |
| **Properties**   | • Solids(%): 35  
• VOC content (%): <0.1 |

### Dispersant effect on different grades of CaCO₃ Filler

- Dispex® 4135 provides a strong viscosity reduction
- Optimal dispersant levels depend on the filler grade
Dispersant in the colorant is adsorbed by the poorly wetted part of the TiO$_2$/extender in the paint, causing the iron oxide to flocculate

- Color strength decreases over time

**Case Example 3a: Color Acceptance with Dispex Ultra FA 4420**

- Decrease in color strength after high shear incorporation of colorant
- No change in color strength after high shear incorporation of colorant
Dispex Ultra FA 4420 (Efka 6220) added to a base paint can significantly improve the performance of the colorants in the paint.

In the example the compatibilizing effect is achieved by addition of the Dispex Ultra FA 4420. This effectively “tunes” the polarity of the base paint and improves compatibility towards the tested colorants.
Case 4a: Surfactants as Co-Dispersants for High PVC Arch Coating

- Evaluated surfactants as co-dispersants.
- Hydropalat WE 3320 was most efficient of items tested.
- Increased dosing of Dispex AA 4144 did not show any further benefit.
Case 4b: Surfactants as Co-Dispersants for High PVC Arch Coating

- Differences exist in low shear region of viscosity curve.
- Hydropalat WE 3320 most effective keeping viscosity low.
Addressing settling
Pigment Physical Phenomena and Thermodynamics

Viscosity

- Pigment surface interactions cause resistance to flow
- Dispersants minimize pigment interactions → results in lower viscosity
- Pros: Obtain desired film properties from pigment and lower handling viscosity for productivity and increased formulation latitude

Undesired Properties

- Less color saturation
- Higher handling viscosity
- Inefficient/inconsistent pigment coverage in coatings
- Separation and settling in coatings and storage conditions

Desired Properties

- Optimal color characteristics
- Lower handling viscosity
- Efficient/consistent pigment coverage in coatings
- Enhanced dispersion stability

Favored Energy States

Dispersant
Pigment
agglomeration
aggregates
crystals; primary particles
Pigment Physical Phenomena and Thermodynamics

Settling

- Function of a variety of aspects: gravity, density of pigment and fluid, fluid viscosity, and pigment size (Stoke’s Equation)
- Dispersants minimize pigment interactions \(\rightarrow\) hence smaller effective particle size
- In low viscosity regimes, the effect of dispersants may not be enough to mitigate settling

Stoke’s Equation for Settling

\[

\nu = \frac{2(\rho_p - \rho_f)}{9 \mu} \cdot gR^2

\]

\(\nu\) – settling viscosity
\(\rho_p\) – particle density
\(\rho_f\) – fluid density
\(\mu\) – fluid (dynamic) viscosity
\(g\) – gravitational constant
\(R\) – particle radius

\(F_D\) – Drag force, function of particle diameter, viscosity, density differences

\(F_g\) – Gravitational force, function of particle diameter, viscosity, density differences
Use of Rheology Modifier to address settling
Dispex Ultra FA 4416 with 0.7% Rheovis AS 1188
Higher Pigment Loading to address settling
High Pigment Loading – Efka PX 4585

47.4% DOP
15% Pigment

Sep/Set

Sep/Set

47.5% DOP
30% Pigment
High Pigment/Dispersant Loading – Dispex Ultra FA 4480

10.4% DOP
30.3% Pigment

25.9% DOP
30.3% Pigment

35.6% DOP
30.3% Pigment

Sep/Set
Questions?
This tool provides you the best additive solution for your challenging formulation task:

- From dispersing agents, wetting agents and surface modifiers, to defoamers, rheology modifiers and film-forming agents

Explore the BASF formulation additives portfolio for the paints and coatings industry, by:

- Receiving recommendations for your formulation challenges
- Understanding the main benefits of our products by application and get technical information
- Ordering samples or contacting us for more detailed consultations

Check out our Solution Finder Tool on www.basf.com/formulation-additives
Contact Information

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Cell: (610) 764-4309 or (704) 724-7417