THE COATINGS EXPERT

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Meeting global regulatory drivers

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TEGO® Glide Recoatable

Cure-2-Go: Anquamine® 728 curing agent

ACEMATT® 3400 New high-performance matting agent

Evonik
POWER TO CREATE
Dear Readers,

New market trends, the shift to digital technologies, and increasing demands on products and applications – the coatings market constantly confronts us with formidable new challenges. At Evonik, we gladly accept those challenges.

As a front runner in innovation, we know that the hunt for truly innovative solutions is something like a brain teaser. Lateral thinking and persistence help solve even the most daunting tasks. But thanks to our broad knowledge of the market and close cooperation with our customers, we can help coatings manufacturers enhance their formulations to improve performance and effectiveness.

Resource preservation, durability and flexibility in coatings for metal objects, long-lasting protection against biological growth, and new binders for heat-seal applications are just a few of the issues we address.

We offer numerous solutions to meet existing and emerging environmental regulations while boosting applicator productivity and coating performance. These include Anquamine® 728 waterborne curing agent for epoxy flooring primers and topcoats, as well as Ancaminde® 2769 for excellent corrosion resistance performance. Furthermore we offer TEGO® AddBond LTW for additional adhesion in can coatings, VISIOMER® Methacrylates for crosslinking solutions, and Direct-to-Metal (DTM) coatings for metals. In this issue you will learn more about these and many other exciting topics for the global challenges of our time.

We hope you enjoy reading the new journal!

Yours,

Dr. Claus Rettig
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CURE-2-GO: ANQUAMINE® 728 CURING AGENT NEW EPOXY FLOOR COATINGS WITH UNRIVALLED FAST CURE AND IMPROVED AESTHETICS
“WHAT PROBLEMS KEEP YOU UP AT NIGHT?”

A simple question to customers that displayed unmet needs in today’s industry floor coatings: – “I need to reduce my floor system cost … I want coatings with improved robustness under adverse cure condition … And also, I need good aesthetics and an epoxy system that meets stringent VOC/emission requirements”. In the application of epoxy industry floors, a maximum of four hours is acceptable to wait in between applying the primer and the topcoat, irrespective of cure conditions. Customers confirmed: “Anything longer than four hours and we will [have to] send the application team home, only to come back the next day again.” Challenging targets. Especially given the fact that fast-cure epoxy systems require 8-12 hours at low temperature cure (10°C / 50°F) before receiving a second coat and generally these systems suffer from carbamation.
Evonik Crosslinkers answers these unmet needs with the commercialization of Anquamine® 728. The new product is a waterborne amine curing agent that offers fast cure and good aesthetics, for use in epoxy primers and topcoats on concrete substrates. Combined with Ancarez® AR-555 solid epoxy resin dispersion, it yields a primer with recoat times of less than four hours at 10 °C / 50 °F and excellent adhesion to damp concrete. Topcoats are best formulated with diluted liquid epoxy resins for excellent aesthetics and good compatibility with pigment pastes. Anquamine® 728 based coatings have a low tendency to carbamation and waterspotting and can be applied up to 500 g/m² / 20 mils wet film thickness. Two coats per day and next day back-in-service enables applicators to improve productivity and save cost/m². The end-user receives a floor system that comes with excellent aesthetics and has potential to meet stringent emission requirements. That’s Cure-2-Go with Anquamine® 728!
Figure 1
Recoat time of epoxy coatings to damp concrete at low temperature cure condition. Comparison of Anquamine® 728 (Anq 728) versus a fast-cure mannich base epoxy system.

<table>
<thead>
<tr>
<th>Recoat time of epoxy coatings (h)</th>
<th>Damp concrete, 9.5°C, 2–4% moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anq 728 400 g/m²</td>
<td>3</td>
</tr>
<tr>
<td>Anq 728 600 g/m²</td>
<td>4</td>
</tr>
<tr>
<td>Mannich base</td>
<td>10</td>
</tr>
</tbody>
</table>

Figure 2
Comparison of Delta-E as a function of hours of UV-A exposure: White epoxy coating based on Anquamine® 728 versus an equivalent coating based on solvent-free epoxy technology.

Contact
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Evonik presents its new ACEMATT® 3400. It is the new matting agent in the ACEMATT® product family of Evonik Resource Efficiency GmbH, specially developed for high-transparency clear coatings and soft-touch coatings with smooth surfaces.

ACEMATT® 3400 is a surface-treated, thermal silica with medium particle size of 7.5 µm. The improved grind performance results in a smooth surface finish with outstanding optical and haptic properties.

In regards to rheology, the special after-treatment of ACEMATT® 3300 and ACEMATT® 3400 prevents the adsorption of associative thickeners in water-based systems. When formulated with particular polyurethane binders, it can also improve the soft-touch feel.

ACEMATT® matting agents are high-performance silica developed for gloss reduction in a vast range of applications in the paints and coatings industry.

This highly efficient silica is intended for use in clear coatings, water-based and solvent-based coatings. Typical application fields include wood coatings, plastics, and automotive coatings. In addition, this new type of matting agent can be used in high solids and low-VOC formulations.

Our best recommendations for high-quality coatings with excellent transparency are the family of thermal silica ACEMATT® TS 100, ACEMATT® 3300, and ACEMATT® 3400.
FAMILY OF EVONIK THERMAL SILICA MATTING AGENTS

**ACEMATT® TS 100**
- No surface treatment
- Particle size $d_{50} = 9.5 \ \mu m$
- Excellent matting efficiency
- Highest transparency

**ACEMATT® 3300**
- Organic surface treatment
- Particle size $d_{50} = 10.0 \ \mu m$
- Highest matting efficiency
- High transparency
- Soft-touch effect

**ACEMATT® 3400**
- Organic surface treatment
- Particle size $d_{50} = 7.5 \ \mu m$
- High matting efficiency
- High transparency
- Soft-touch effect
- Higher smoothness than ACEMATT® 3300

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THE COATINGS EXPERT 2019

EPOXY CURING AGENTS FOR CHEMICAL RESISTANT APPLICATIONS

Two-component epoxy systems provide excellent mechanical properties, chemical resistance, and adhesion to a wide range of substrates. Therefore, they are frequently chosen over other technologies, especially when chemical resistance is an important attribute. Chemical resistance is required in a variety of applications from construction and infrastructure to protective metal coatings. In the construction and infrastructure sector, epoxy systems are often utilized to improve chemical resistance in flooring, wastewater treatment plants, sewer, power plants, secondary containment, mortars, and grouts. For flooring applications, chemical resistance is critical in areas where the concrete flooring is regularly exposed to various chemicals, for example food and beverage preparation and service areas, meat packaging plants, dairy farms, paper and pulp plants, and chemical and pharmaceutical facilities.

There are a number of key factors to be considered when selecting the right epoxy system for chemical resistance. These
factors encompass the type of application, substrate, classes of chemicals to which resistance is required, duration of resistance, degree of resistance, and processing and application requirements. In addition to chemical resistance, many applications require other important attributes such as low-temperature cure, rapid development of hardness, carbamation resistance, or low color. Epoxy curing agents impart significant influence on chemical resistance and other properties of the cured epoxy systems. Evonik offers a portfolio of products to help epoxy formulators meet their evolving needs for improved chemical resistance epoxy systems.

For ambient-cure epoxy systems, amine curing agents for chemical resistant applications can be separated into two basic categories, aliphatic amine and cycloaliphatic amine curing agents. Cycloaliphatic amine-cured systems offer good resistance to aqueous solutions, solvents, and inorganic acids. Aliphatic amine curing agents provide fast cure speed and high crosslinking density. For grout
and mortar applications where water cleanability is needed, formulated amidoamine curing agents are often selected. For instance, Ancamide® 2886 curing agent is a newly developed curing agent for tile grout application. It provides chemical resistance to hot oleic acid in food preparation areas where high-temperature cooking oil is present. Although cycloaliphatic amine curing agents can also be used in combination with external surfactants to achieve water cleanability, the presence of surfactants would negatively affect the chemical resistance. Table 1 lists the characteristics of selected amine curing agents that offer good chemical resistance. Each of these curing agents offers distinct handling or performance advantages over the others. In many cases, the optimal performance advantages can be obtained by blending the curing agents. For example, a cycloaliphatic amine can be blended with 10% to 30% by weight of a modified aliphatic amine, such as Ancamine® 2432 curing agent.

### Table 1
Characteristics of the curing agents formulated with standard bisphenol-A based liquid epoxy resin at 25 °C.

<table>
<thead>
<tr>
<th>Curing agent</th>
<th>Curing agent viscosity (cP)</th>
<th>Gel time (min.) (150 g mass)</th>
<th>Thin film set time¹ (h)</th>
<th>phr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancamine® 1693</td>
<td>100</td>
<td>52</td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>Ancamine® 2280</td>
<td>450</td>
<td>50</td>
<td>6</td>
<td>58</td>
</tr>
<tr>
<td>Ancamine® 2334</td>
<td>1180</td>
<td>42</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Ancamine® 2422</td>
<td>2000</td>
<td>26</td>
<td>NA²</td>
<td>26</td>
</tr>
<tr>
<td>Ancamine® 2423</td>
<td>1200</td>
<td>17</td>
<td>3.5</td>
<td>60</td>
</tr>
<tr>
<td>Ancamine® 2432</td>
<td>300</td>
<td>46</td>
<td>2</td>
<td>46</td>
</tr>
<tr>
<td>Ancamine® 2748</td>
<td>2275</td>
<td>50</td>
<td>7</td>
<td>50</td>
</tr>
<tr>
<td>Ancamine® 2749</td>
<td>275</td>
<td>49</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Ancamide® 2886</td>
<td>450</td>
<td>83</td>
<td>11</td>
<td>50</td>
</tr>
</tbody>
</table>

¹ BK Drying Recorder, phase 3; 2. Not available.
agent, for faster cure and improved solvent resistance. Table 2 provides the examples of specific chemicals to which the resistance is required and recommended curing agents.

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### Table 2
Specific chemicals to which resistance is required and corresponding curing agents.

<table>
<thead>
<tr>
<th>Specific chemicals</th>
<th>Curing agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aliphatic hydrocarbons, gasohol (10% ethanol)</td>
<td>Ancamine® 2432, Ancamine® 1693</td>
</tr>
<tr>
<td>Aromatic hydrocarbons (toluene, xylene)</td>
<td>Ancamine® 2422</td>
</tr>
<tr>
<td>Phenol</td>
<td>Ancamine® 2422</td>
</tr>
<tr>
<td>Ethanol</td>
<td>Ancamine® 2432</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>Ancamine® 2422</td>
</tr>
<tr>
<td>Citric acid</td>
<td>Ancamine® 2432, Ancamine® 2423</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>Ancamine® 2432, Ancamine® 2423</td>
</tr>
<tr>
<td>Acetic acid (low concentration)</td>
<td>Ancamine® 2432</td>
</tr>
<tr>
<td>Acetic acid (high concentration)</td>
<td>Ancamine® 2422</td>
</tr>
<tr>
<td>Hot oleic acid for coatings</td>
<td>Ancamine® 2334</td>
</tr>
<tr>
<td>Hot oleic acid for grout</td>
<td>Ancamide® 2886</td>
</tr>
<tr>
<td>Phosphoric acid (low and high concentration)</td>
<td>Ancamine® 2432</td>
</tr>
<tr>
<td>Hydrochloric acid (low and high concentration)</td>
<td>Ancamine® 2432</td>
</tr>
<tr>
<td>Nitric acid (low concentration)</td>
<td>Ancamine® 2432</td>
</tr>
<tr>
<td>Nitric acid (high concentration)</td>
<td>Ancamine® 2748, Ancamine® 2749</td>
</tr>
<tr>
<td>Sulfuric acid (low concentration)</td>
<td>Ancamine® 2432</td>
</tr>
<tr>
<td>Sulfuric acid (high concentration)</td>
<td>Ancamine® 2748, Ancamine® 2749</td>
</tr>
</tbody>
</table>
Evonik Resource Efficiency has established the Smart Surface Solutions R&D competence center in order to develop effective solutions for previously unresolved issues in the paint industry. At several locations – Essen (Germany) and Singapore – more than 25 experts with diverse education and industry backgrounds are working on the development of advanced corrosion protection coatings, anti-fouling concepts, anti-microbial surfaces, and coatings that repel dirt and ice.

The Smart Surface Solutions R&D competence center combines expertise in the fields of coatings, particles, and specialty polymers in order to selectively improve surface properties. All opportunities share a common holistic system approach, which is not limited to the development of new components for existing coating systems.

Technology-wise, the R&D competence center has access to the full spectrum of knowledge and technology platforms of Resource Efficiency. The internal experts are supported and broadened by external cooperation with customers, universities, research institutes, and start-ups.

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HIGH-PERFORMANCE WATERBORNE EPOXY FORMULATION FOR SELF-LEVELING CEMENTITIOUS COATING FOR CONCRETE
Self-leveling overlay systems for concrete floors offer numerous benefits. They can correct uneven floors, repair damaged concrete, and provide a smooth and durable new surface for decorative and functional treatments. Non-modified cement-based overlays typically used for this application can provide durability, long life, and low-maintenance cost coatings. Some of their disadvantages, however, include delayed hardening, low tensile strength, poor thermal shock and low chemical resistance. To mitigate these disadvantages, the cement can be modified with various types of organic polymers. One such advanced composition is an epoxy modified cement (EMC), using Evonik’s waterborne epoxy thermoset technology based on Anquamine® 287 curing agent and an epoxy resin.

Anquamine® 287-based EMC has a low odor and can be formulated free of volatile organic compounds (VOC), thus allowing for application in areas such as schools, offices or hospitals, that need to remain occupied during application.

Table 1
Epoxy-modified cement formulation based on Anquamine® 287 curing agent and epoxy resin.

<table>
<thead>
<tr>
<th>3K-Formulation</th>
<th>Components</th>
<th>Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part A</td>
<td>Liquid epoxy resin/emulsion</td>
<td>5 - 15</td>
</tr>
<tr>
<td></td>
<td>Defoamer</td>
<td>0.05 - 0.10</td>
</tr>
<tr>
<td>Part B</td>
<td>Anquamine® 287</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td>Water</td>
<td>0 - 10</td>
</tr>
<tr>
<td>Part C</td>
<td>Portland cement</td>
<td>15 - 35</td>
</tr>
<tr>
<td></td>
<td>Quartz sand (various particle size)</td>
<td>15 - 35</td>
</tr>
<tr>
<td></td>
<td>Superplasticizer (powder)</td>
<td>0 - 0.20</td>
</tr>
</tbody>
</table>
A typical 3-component cementitious concrete formulation based on Anquamine® 287 is shown in Table 1. The extensive latitude with varying the binder levels in the formulation provides flexibility in tailoring the performance properties in terms of cure speed, thermal properties, chemical resistance, and tensile strength. Evonik’s EMC formulation using Anquamine® 287 shows significant performance benefits over standard polymer modified cements (PMC), including a much higher compressive strength and better adhesion to concrete (Table 2).

**Table 2**

Epoxy modified cementitious coating (5% binder content) vs. commercial polymer modified cement self-leveler coatings.

<table>
<thead>
<tr>
<th>Test item (22 / 50% RH)</th>
<th>Commercial PMC self-leveler (1)</th>
<th>Commercial PMC self-leveler (2)</th>
<th>EMC 5% organic binder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond strength to concrete (ASTM D7234), 7d</td>
<td>502 psi (coating failure)</td>
<td>552 psi (concrete failure)</td>
<td>651 psi (Cohesive failure)</td>
</tr>
<tr>
<td>1 day</td>
<td>942</td>
<td>2,859</td>
<td>1,678</td>
</tr>
<tr>
<td>3 days</td>
<td>1,105</td>
<td>3,144</td>
<td>6,700</td>
</tr>
<tr>
<td>7 days</td>
<td>1,246</td>
<td>3,146</td>
<td>10,200</td>
</tr>
<tr>
<td>28 days</td>
<td>2,214</td>
<td>5,037</td>
<td>13,600</td>
</tr>
<tr>
<td>Compressive strength – psi (ASTM C579)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile strength (ASTM C307), 28d - psi</td>
<td>114</td>
<td>398</td>
<td>1,005</td>
</tr>
<tr>
<td>Flexural (ASTM C580), 28d - psi</td>
<td>311</td>
<td>1,145</td>
<td>2,337</td>
</tr>
<tr>
<td>Impact resistance (ASTM D7294) (In.lbs)</td>
<td>140</td>
<td>140</td>
<td>90</td>
</tr>
<tr>
<td>Abrasion resistance (ASTM D6037) (mg)</td>
<td>&gt; 500</td>
<td>&gt; 500</td>
<td>300</td>
</tr>
</tbody>
</table>

**CONTACT**

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Paints and coatings continue to offer one of the most efficient and cost-effective means of protecting and decorating valuable property, equipment and structures, regardless of end-use or environment. Formulators continue to innovate new ways to enhance coating properties while meeting increasing environmental and legislative demands. Adhesion failure continues to be one of the most common reasons for the loss of coating performance and some of the most catastrophic coating failures. Adhesion failures can appear as blistering, flaking, scaling, peeling or delamination, but the consequence is inevitably damage to the substrate under protection.

Adhesion occurs at the interface of two similar or dissimilar materials; in coatings, this is the interface between the dried or cured coating and its substrate. The main adhesive mechanisms are either mechanical – via diffusion, adsorption and/or mechanical interlocking – or chemical – through formation of chemical bonds between the two interfaces. The latter mechanism is dependent on the chemical nature of both the coating material and substrate, but both mechanisms require intimate contact between the two layers to ensure maximum adhesion. It is essential that the coating in its liquid or melt state can fully wet the substrate to ensure the maximum contact; therefore, good cleaning and surface preparation are essential steps to ensure good adhesion. Roughening the surface increases the surface area available for adhesive interactions to occur.

Evonik’s TEGO® AddBond adhesion promoters are a family of modified polyester resins that can partially replace the main coating binder in a formulation to enhance its adhesion to difficult substrates. These resins have multiple functional groups that can
interact with various surfaces, while the polyester binder is compatible with many different resin chemistries to ensure good performance in many different types of coatings (Figure 1). TEGO® AddBond adhesion promoters can also help improve the corrosion resistance of coatings by preventing or slowing the adhesion failure that leads to film delamination as corrosion develops.

Typically, adhesion promoter resins are relatively high in viscosity and require solvent dilution to achieve a workable viscosity. However, increasingly stringent environmental regulations limit the amount of volatile solvents that can be used in coatings, and this limits a formulator’s freedom to use these adhesion promoters as low viscosity and low solvent content are typically mutually exclusive. Evonik has developed two new solvent-free, liquid polyester adhesion resins that have been designed to improve adhesion to critical substrates and between coating layers. These adhesion resins can help decrease formulation viscosity and provide excellent adhesion to various substrates in high solids, solvent-free, and UV
formulations. TEGO® AddBond LP 1600 gives the best flowability and strongest reduction of formulation VOC content, while LP 1611 has negligible impact on film hardness and good reduction of formulation VOC content. The performance of these new products was demonstrated in four different, high solids formulations – a 1K alkyd metal topcoat, a 1K melamine cured polyester stoving enamel, a 2K white PU topcoat, and a 2K epoxy primer. Improvements in adhesion were demonstrated by replacing 5% of the main binder in each formulation with the new adhesion promoters and applying the formulation on various substrates, curing the coating for seven days and then measuring the cross-cut adhesion (0 – 5 scale where 0 is best). The improvements with the 1K alkyd topcoat are shown in Table 1, but similar results were also seen in the other formulations.

Table 1
Adhesion of alkyd metal topcoats to various substrates. All data measured using 5% (by solids content) liquid adhesion resin in place of main resin except where stated.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Without adhesion promoter</th>
<th>With TEGO® AddBond LP 1600</th>
<th>With TEGO® AddBond LP 1611</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>GT 4</td>
<td>GT 3</td>
<td>GT 3-4</td>
</tr>
<tr>
<td>Al-Alloy</td>
<td>GT 1</td>
<td>GT 1</td>
<td>GT 1</td>
</tr>
<tr>
<td>Steel</td>
<td>GT 1</td>
<td>GT 1</td>
<td>GT 1</td>
</tr>
<tr>
<td>Phosphated</td>
<td>GT 1</td>
<td>GT 1</td>
<td>GT 1</td>
</tr>
<tr>
<td>Zinc</td>
<td>GT 4-5</td>
<td>GT 3</td>
<td>GT 3</td>
</tr>
<tr>
<td>EDC</td>
<td>GT 1</td>
<td>GT 1</td>
<td>GT 1</td>
</tr>
<tr>
<td>ABS</td>
<td>GT 5</td>
<td>GT 0 (3%)</td>
<td>GT 0 (3%)</td>
</tr>
<tr>
<td>PA</td>
<td>GT 5</td>
<td>GT 1 (10%)</td>
<td>GT 1 (10%)</td>
</tr>
<tr>
<td>AlMn1Cu</td>
<td>GT 4</td>
<td>GT 4</td>
<td>GT 2</td>
</tr>
<tr>
<td>Steel</td>
<td>GT 2</td>
<td>GT 1</td>
<td>GT 0-1</td>
</tr>
</tbody>
</table>
Improvements in adhesion also correlate with improvements in corrosion resistance, where film delamination after salt spray testing was significantly reduced. Polyester adhesion resins also impart excellent elasticity that results in superior deformability and impact resistance. VOC-compliant coatings are often sensitive to raw material incompatibilities and this can often reduce optical appearance. These new liquid adhesion resins are very compatible with most binders and solvents, ensuring consistent and attractive finishes. The resins are also light stable and do not affect the color and gloss stability of the final coating, in both QUV and oven stability tests.

Chemists developing environmentally friendly, high solids coatings often struggle with obtaining a suitable application viscosity while simultaneously meeting Volatile Organic Content (VOC) limitations. These new liquid adhesion resins reduce viscosity without changing the rheological behavior of the coating, so leveling, sag control, and application properties are not affected. This effect is more

![Figure 2](viscosity_reduction.png)

**Figure 2**
Viscosity reduction in high solids, 2K polyurethane topcoat formulations.
visibly evident as the solids content of the formulation increases. Figure 2 shows how the new adhesion resins lower the viscosity of a 2K polyurethane topcoat with 5% replacement of main binder. Similar results are seen in the other formulations tested.

The new TEGO® AddBond LP 1600 and LP 1611 adhesion resins are soluble in most common solvents and provide benefits in many water-based formulations when they are formulated with wetting agents in order to ensure consistent substrate wet-out.

Ensuring excellent coating adhesion to an increasing number of difficult substrates while meeting modern VOC requirements remains a challenge for many coatings formulators. Polyester adhesion resins are a valuable formulation tool for improving both adhesion and inter-coat adhesion of many different coatings. TEGO® AddBond LP 1600 and LP 1611 are new generation, liquid polyester adhesion resins that are suitable for ultra high-solids and water-based formulations without compromising other critical performance attributes of the coating.

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Recent material developments in long-chain polyamide and PEEK powders as well as in novel coating technologies could open up new opportunities for protective or tribological coating applications. In addition to offering the well-known properties of polyamide 12, which include excellent durability and chemical resistance, Evonik’s new long-chain polymer powders also provide increased temperature resistance. Improving performance in this way could help fulfill unmet coating needs in various industrial applications.

Long-chain polyamides such as polyamide 12 (PA 12) powders have been used in applications such as wire and pipe coatings for many years, where they deliver valuable physical and chemical protection for metal. Besides long-chain polyamides, Evonik offers polyether ether ketone (PEEK) powders that are particularly suitable for coating applications that are subject to extreme mechanical, thermal, and chemical demands. The coating material can withstand consistent operating temperatures of up to 250 °C and is characterized by its unique ability to resist abrasion and chemicals.

A trend has recently emerged toward long-chain polyamides with increased temperature resistance—and Evonik is responding to that trend by introducing newly developed polyamide powders for applications with higher temperature requirements. Coatings based on high-performance polymer powders could optimize the efficiency and service life of engines, bearings, and gears, as well as protect pipes and wind turbines from corrosion.
Coatings made of VESTAKEEP® PEEK could reduce friction in the planetary gearbox of a wind turbine, transferring power even more efficiently and extending the life of the gearbox.

Evonik coated steel substrates using two long-chain polyamide powder grades (VESTOSINT® 1111 polyamide 12 powder and a development grade with increased temperature resistance) and two PEEK powder grades (VESTAKEEP® 2000 UFP20 and a development grade for tribological coatings).

**PRETREATING THE STEEL SUBSTRATES**

Pretreating parts before coating is absolutely essential for removing any adhering grease, oxide layers, and dust particles. Grease residues can crack during preheating and contaminate the surface of the part and therefore the coating. Oxide layers and dust particles result in poor adhesion. We therefore subjected the parts to alkaline degreasing, roughened the parts by sandblasting them with clean grit, and then performed an additional degreasing step.
PREHEATING THE STEEL SUBSTRATES
Evonik preheated the parts in an oven, maintaining a uniform temperature profile and varying oven temperatures between 360°C and 400°C for polyamide coatings and between 380°C and 450°C for PEEK coatings.

COATING THE STEEL SUBSTRATES
Evonik used the fluidized bed coating process for coating parts with long-chain polyamides, dipping the preheated parts into the fluidized bed basin with little heat loss. The coating powder in the basin was uniformly fluidized with air from the air chamber through the fine-pored base plate. We used oil-free air (humidity between 50% and 70%) for fluidizing, dipping parts for 3–5 seconds before allowing them to cool to room temperature under air exposure.

Electrostatic spraying technology was employed for coating parts with PEEK. Using an Optiflex 2S system from the GEMA company of Switzerland, we electrostatically charged the powder by applying a voltage of 100 kV and then placed the powder-coated parts in an oven for 10 minutes to generate a dense and adherent coating. We then allowed the parts to cool.

Laser-based technology for coating parts with PEEK was also applied by our partner Fraunhofer-Institut für Lasertechnik in Aachen (Germany).

TESTING
Polyamide coatings peeled off of the steel substrate underwent a tensile test to determine their mechanical properties. The melting point of the polyamide coatings was determined by DSC as directed in DIN EN ISO 11357. A Taber test (CS17, 500 g) for performing tribological tests on the polyamide coatings was used, and a pin-on-disc setup for the PEEK coatings (8 MPa, 0.5 m/s, 5000 m). Adhesion of the PEEK coatings was determined by a cross-cut test according to DIN EN ISO 2409.
RESULTS FOR LONG-CHAIN POLYAMIDE COATINGS

The melting point of the coatings made with the new long chain powder was 195°C; 20°C higher than that of coatings made from polyamide 12. Despite the higher melting point of the new long-chain polyamide powder, the processing parameters for fluidized bed coating were similar to those used for PA 12, and the fluidizing behavior of the new powder was as good as that of polyamide 12. Evonik was able to generate coatings with thicknesses in the range of 250 µm. The results of the tensile test show that the novel coatings are also highly durable, with yield stress and strain values of 37 MPa and 15%, respectively. The abrasion resistance of the new long-chain polyamide coatings determined by the Taber test was comparable to that of polyamide 12, and weight loss was less than 1 mg/100 cycles.

RESULTS FOR PEEK COATINGS

Evonik was able to apply both PEEK powder grades easily via electrostatic spray coating to yield coating thicknesses in the range of 60 µm. The coefficients of friction of both PEEK coatings were in the range of 0.28; the wear coefficients were in the range of $5.8 \times 10^{-7} \text{mm}^3/\text{Nm}$.

Using laser melting technology allowed to generate dense, adherent PEEK coatings in a very short time period: the minimum laser interaction time for generating dense coatings is approximately 7 seconds. The coating thickness was adjusted to 30, 45, and 60 µm, achieving excellent adhesion to the substrate with a cross-cut classification of 0, depending on substrate pretreatment and laser-melting parameters.
Evonik’s recent material developments in novel coating technologies and in long-chain polyamide and PEEK powders could open up new opportunities in demanding coating applications in the oil and gas, industrial, and automotive sectors. The latter market seems to be very promising, especially for tribological coatings. The excellent tribological performance of coatings made from specially developed VESTAKEEP® powders significantly reduces the friction between sliding surfaces, which in turn makes operation more efficient and economical. Examples of the benefits include lower fuel consumption and lower CO₂ emissions in combustion engines, extended service life for bearings, and higher turbine speeds. These special VESTAKEEP® coatings also allow manufacturers to employ more cost-efficient substrate materials for components used in applications with sliding friction.


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Consumers are becoming increasingly aware of the importance of protecting our environment. This has had a major impact on the coatings industry, with the demand for low- to no-VOC coatings increasing. To meet this demand, those who formulate these low-VOC products have invested considerable resources into developing their waterborne technologies. From a technical perspective, many waterborne formulations still suffer from application limitations – in particular, poor substrate wetting, edge retraction, pinholing, and other defects – that result in high product failure rates, which can be costly to the manufacturer. Fortunately, high-performance wetting agents, defoamers, and other additives can solve these issues and produce consistently flawless waterborne coatings.

Waterborne coatings use a combination of water-based resins and additives to achieve the desired coating performance; water replaces typical organic solvents. Water has a drying speed that is usually much slower than organic solvents. However, end-users still require quick drying speed and film formation in their water-based formulations. The drying speed can be amended by using modified resin systems, compact printing processes, and other methods. However, these methods can still display pinholing issues; these issues are especially evident in formulations with the following characteristics / properties:

- High temperature baking process
- Wet-on-wet process
- High wet film thickness, e.g. for mono coat

To address this issue, strong defoamers and deaerators – e.g. hydrocarbon-based – have been used to eliminate pinholes within the dried film. There may be compatibility issues due to the nature of hydrocar-
bon-based chemicals in water-based formulations, which results in lower gloss, poor leveling and DOI, and even sometimes cratering issues. This paper describes a new additive based on a new pinhole elimination mechanism; the additive also shows excellent compatibility in water-based formulations.

**MOLECULAR DEFOAMER FOR MICRO-FOAM IN WATER-BASED FORMULATIONS**

Molecular defoamers are surfactants with specific Gemini structures that are designed to compete with and replace foam-stabilizing surfactants at the surface of the foam bubble. These specially designed surfactants do not stabilize foam and allow normal liquid flow so the bubbles can break naturally.

Molecular defoamers are also effective at controlling micro-foam, small bubbles trapped within the liquid, which will result in pinhole issue especially after baking process. Molecular defoamers are partly soluble in water and are able to move to bubbles below the liquid surface to de-stabilize micro-foam. This leads to the coalescence of micro-foam into larger bubbles which rise to the surface much faster and burst more easily.

Many conventional defoamers, e.g. oil based defoamers, are not effective at controlling micro-foam because the
oil is insoluble and remains at the liquid surface. Molecular defoamers are also more dynamic than most foam stabilizing surfactants; therefore, they can reach new bubble surfaces more quickly and prevent new foam bubbles forming. As surfactants, molecular defoamers are compatible with most systems and do not cause incompatibility problems like oil-based defoamers. Due to their excellent compatibility in both liquid paints and also cured coating films, molecular defoamers will not migrate to the surface of the cured coating film and will not cause issues associated with this, such as poor recoatability (especially after high-temperature baking processes). Molecular defoamers can also provide additional dynamic wetting properties to the formulation. “Gemini” based surfactants simultaneously act as surfactants (and thus enhance compatibility) and defoamers; they have been used for many years by the paint and coatings industry.

**Figure 2**
Film formation mechanism in 4 stages of water-based coatings, and T2 shows the packing time of solid particles within wet paint.
**Figure 3**
Effect of additive containing different number of EO on the time of T2 during drying process. (Temperature: 24 °C, Humidity: 32%, Wet film thickness: 60um)

**USE OF HYDROPHILIC SURFAC-TANTS TO LOWER DRYING SPEED**
Although fast drying water-based formulations are required by end coating process, sometimes having slower drying speeds help give micro-foam more time to move out of water-based paints and break, thus eliminating pinholes. Proper hydrophilic surfactants will show balanced performances, including pinhole eliminations, drying speed, water resistance, and so on. It is well known that humectants can capture moisture very well; a humectant is a substance with several hydrophilic groups, most often hydroxyl groups, and also, ethoxylates, amines, carboxyl groups, or it is esterified.
These groups show excellent affinity to form hydrogen bonds with molecules of water and keep things moist. However, water-based coatings, especially for those coatings with requirement of water and corrosion resistance, can not use traditional the humectant; otherwise the water resistance will be drastically affected. Experiments shows that hydrophilic surfactants containing less than 10 alkoxylates will show very limited impact on water resistance (here focusing on alkoxylates as hydrophilic group), and the effect of number of alkoxylate on drying speed is illustrated in Fig. 2 and Fig. 3. The drying speed is evaluated by “Diffusing-Wave Spectroscopy”. “Speckle Rate” is recognized as particle moving rate in wet paint; faster the drying speed, the quick the particle’s movement rate. Pinhole elimination will be affected by Stage II shown in Fig. 2, during which

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**Figure 4**

Minimum film thickness (um) when pinhole appears in water-based mono coat for truck coating.

![Bar chart showing minimum film thickness (um) for different surfactant combinations](image-url)
the high concentration in solid induces a packing process. This stage appears as a disturbed area on the drying kinetics, showing accelerations and decelerations of the particles as they get in contact together around time T2. It is believed that before T2, solid particles can move in wet paint and micro-foam can also move freely up to wet paint surface and break. If an additive can prolong T2 during drying process, the pinhole will be easily eliminated. Fig. 3 shows the effect on the T2 of hydrophilic surfactant containing different number of ethoxylates. The result shows that additive containing ethoxylate will get T2 little prolonged, and when the number of ethoxylate increased to 10, the T2 has been prolonged about 105s, which will get pinhole having longer time to move out.

When the longer or stronger hydrophilic group is attached to the surfactant, benefits for pinhole elimination will be evident; however, there will also be a higher tendency for foam to appear in the paint. Therefore, the hydrophobic part of the surfactant needs to be paired with a structure that will compromise the issue caused by foam tendency.

**COMBINATION OF MOLECULAR DEFOMER AND HYDROPHILIC SURFACANT FOR PINHOLE ELIMINATION**

Water-based one-coat formulations for truck coatings have been selected for evaluation of pinhole elimination using different additives. The wedge spray has been applied with gradient wet film thickness, checking the film thickness when the pinhole appears after baking. As indicated in Fig. 4, the purely hydrophilic surfactant actually shows negative for the pinhole elimination. However, when combining the molecular defoamer and the hydrophilic surfactant (which provide significant synergy for pinhole elimination), the formulation benefits from the faster movement of micro-foam to the wet film surface (by molecular defoamer) and still little wet paint film (by hydrophilic surfactant). Compared to the conventional additives based on low-compatibility chemicals for pinhole elimination, the additives with new mechanism show excellent compatibility in water-based formulations. As shown in Fig. 5, a perfect coating film appearance can be achieved with the new additives, while there will be poor leveling, lower DOI, and lower gloss using the conventional additives.
CONCLUSION

With the increasing demand for water-based coating formulation development, pinholing issues are always of importance to formulators, especially those with specific requirements for compatibility, wet-on-wet processes, fast-dry baking systems, and high wet film thickness. This paper describes a new additive mechanism for elimination of pinholes, combined with excellent compatibility in water-based formulations.

CONTACT

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MEETING GLOBAL REGULATORY DRIVERS WHILE BOOSTING APPLICATOR PRODUCTIVITY
Demands within the global coatings market are always increasing. The performance envelope is expanding, while the need to improve worker safety and minimize environmental impact is at the forefront of new developments. Ancamine® 2878 epoxy curing agent has recently been developed to meet the requirement for fast return to service, offering safer handling and regulatory compliance in most global regions.

The key properties of fast cure at both ambient and low temperature with excellent carbamation and high-corrosion resistance makes Ancamine® 2878 ideally suited to meet performance demands within the protective coating and marine markets. Systems based on Ancamine® 2878 can also be formulated into high-build coatings offering fast property development for quicker turnaround of applications.

Ancamine® 2878 has been formulated to be low-viscosity and highly reactive without the use of alkyl phenols or solvents, providing an improved EH&S profile and safer handling. It has been specifically developed to meet performance requirements for medium-duty corrosion-resistance application within the marine and protective coating markets and due to the fast-cure properties can also find further applications in other areas including civil engineering. The combination of high-performance and a good EH&S profile means Ancamine® 2878 will continue to meet the emerging demands within the coatings market for years to come.

CONTACT
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Moisture related problems with floor coverings and coatings applied over concrete slabs have created significant problems over the years for formulators, specifiers, contractors, and owners in the construction industry. Concrete is one of the most commonly used materials in the construction industry due to its strength, durability, resilience, safety, and low cost. However, concrete is a permeable material and allows moisture contained below the slab, or trapped in the concrete itself, to migrate as a vapor phase to the concrete surface. This moisture transfer phenomenon accounts for many flooring failures with millions of dollars lost annually; and, the construction team from manufacturers, installers and project architects have to bear the liability.

Over the years, there have been various methods that the industry employed to mitigate moisture problems when installing flooring over concrete in new and existing construction. One of the methods includes the use of vapor retarder films under the concrete to prevent moisture migration from the soil. This approach is only effective, however, in new construction jobs as the film needs to be laid down before the concrete is poured. It also does not address any migration from moisture contained within the concrete itself. Another technique is to use reactive silicates to reduce moisture and soluble alkali transfer to the concrete surface by combining them with hydroxides within the cement paste. When used properly and in the right amounts, reactive silicates can be beneficial to concrete, improving its density and reducing permeability. Nonetheless, if these materials are over-applied, they can be more deleterious to concrete as water soluble cations (K+, Li+, Na+) from the silicates can promote salt formation in the top layer of the concrete. This formed layer can cause osmotic pressure to
occur which could potentially lead to blistering or disbondment of the surface coating or floor covering.

The most common means to address flooring failures due to moisture vapor is to apply moisture mitigation coatings on the surface of the concrete slab. A moisture mitigating coating can be a very effective solution to address moisture vapor originating from either the ground soil or concrete itself as water is one of its ingredients. Applicators can use this method for both existing and new construction jobs since it is the final step before applying the floor covering, such as tile, wood, carpet, laminate etc. or a seamless flooring system consisting of multiple coating layers such as broadcast floors, Terrazzo, etc.

There are two types of moisture mitigation coatings; (1) moisture vapor permeable or “breathable” (MVP) and (2) moisture vapor blocking or barrier coatings (MVB). A MVP coating system is typically preferred where
there is a significant possibility of osmosis to occur due to high alkaline salts and moisture presence in the concrete. As the osmotic pressure is considered to be more severe, compared to other moisture transmittance mechanisms such as hydrostatic and capillary pressure, a moisture breathable system could be the best choice assuming that the top layer is also breathable. A MVB prevents a moisture vapor from migrating to the surface of the concrete slab due to hydrostatic pressure or capillary flow and is preferred when a non-permeable floor covering or seamless coating is applied on top of the moisture mitigating layer. If no MVB is applied, over time even a small amount of moisture collected under the non-permeable floor covering can lead to adhesive failures between concrete and a top floor coating or covering. The moisture vapor transmission difference between moisture vapor permeable coating systems such as Anquamine® 701 and moisture vapor barrier system such as Ancamine® 2800 is shown in Figure 1. These results were obtained by ASTM E96 wet cup method and demonstrate well a significant difference in the rate of moisture migration through the different type of moisture mitigating coatings.

Evonik offers products for both MVP and MVB applications. Evonik can provide curing agents to formulate a complete breathable flooring system including primers, self-leveling floors and cementitious concrete floors. Our waterborne curing agents such as Anquamine® 701 and 731 can be formulated as overlays which cure at > 3 mm thickness to give a porous morphology that allows moisture vapor to transmit while preventing soluble salts within a concrete layer to move to the surface and therefore avoid osmotic blistering or delamination (Figure 2). Another Evonik curing agent, Anquamine® 287 can be formulated with cement, aggregates and additives in a low binder-to-cement ratio to provide a high-performance, breathable coating that can avoid floor failures due to moisture.

For MVB applications, Evonik provides a number of curing agents, including Ancamine® 2739 and 2800. The MVB coatings are 100% solids epoxy systems applied directly to surface of prepared concrete at >10 mils (0.25 mm) to suppress moisture transmission down to ≤ 0.1 perms. Ancamine® 2739 and 2800 employ Evonik’s patented “very low emission technology” that allows the coating to
Figure 1
Moisture vapor transmission of Anquamine® 701 (moisture vapor permeable) and Ancamine® 2800 (moisture vapor barrier) coating as tested using ASTM E96 wet cup method.

![Moisture Vapor Transmission (MVT)
ASTM E96 (wet cup)](image)

- **Anquamine® 701**
- **Ancamine® 2800**

Figure 2
Blister formation in coatings due to osmotic pressure from the concrete slab.

![Blister formation in coatings](image)
cure without the use of non-reactive diluent such as benzyl alcohol. Benzyl alcohol, a common diluent used in most conventional epoxy floor coatings, emits out of the coating over time leaving voids in the film. This could allow moisture vapor to pass through, or if the voids occurs at the interface of the coating-concrete layer, it could cause blistering or delamination as the epoxy coating would start peeling off from the substrate. Ancamine® 2739 and 2800 do exceed the new moisture mitigation systems standard ASTM F3010 -13 as certified by third party testing. This is a standard practice for two-component resin based membrane-forming moisture mitigation systems for use under resilient floor coverings. One of the main requirements to meet the compliance is that MVB coating should not exceed permeance greater than 0.1 grains/h/ft²/in. Hg (perm) when tested in accordance with Test Method ASTM E96 when applied at the recommended thickness designated by its manufacturer. The handling properties and third party testing results of Ancamine® 2739 and 2800 are shown in Table 1.

Table 1
The handling properties and third parting testing results of Ancamine® 2739 and 2800.

<table>
<thead>
<tr>
<th></th>
<th>Ancamine® 2739*</th>
<th>Ancamine® 2800*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curing agent viscosity @25°C (cPs)</td>
<td>350</td>
<td>500</td>
</tr>
<tr>
<td>Mix viscosity @25°C; (cPs)</td>
<td>500</td>
<td>594</td>
</tr>
<tr>
<td>Gel time, 150 g mass @25°C ; (min)</td>
<td>85</td>
<td>41</td>
</tr>
<tr>
<td>Thin film set time, phase 3 (hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM D5895</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Adhesion to concrete**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM D7234</td>
<td>360 psi</td>
<td>380 psi</td>
</tr>
<tr>
<td>Bulk concrete failure</td>
<td>Bulk concrete failure</td>
<td></td>
</tr>
<tr>
<td>Permeance; (grains/hr/ft²/in.Hg)</td>
<td>0.064 (16 mils)</td>
<td>0.051 (16 mils)</td>
</tr>
<tr>
<td>ASTM E96 wet method at specified thickness (mils)**</td>
<td>0.062 (14 mils)</td>
<td>0.10 (10 mils)</td>
</tr>
</tbody>
</table>

* Used with resin blend consisting of liquid epoxy resin (LER), Epodil® 748 and Epodil® 749 (80:10:10)
** Results from third party testing (CTL Group)
In summary, preventing moisture related failures is becoming one of the most critical demands in the flooring industry and Evonik’s epoxy curing agents can help to mitigate these problems. Anquamine® 701, 731 and 287 are excellent choices for a moisture mitigation system where there is a need for permeability. Ancamine® 2739 and 2800 would be the products of choice when a moisture barrier is required. All these curing agents have outstanding adhesion to dry and damp concrete which is also an important requirement for this type of application (Figure 3). In addition to having excellent performance in moisture mitigation application, all the mentioned epoxy curing agents are eco-friendly and do not use volatile organic components (VOC), or other harmful materials such as nonyl phenol. They are proven technology that has been used in the construction industry for quite some time and continues to grow due to the new requirements and market drivers.

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Evonik presents two optimised siloxane superwetting surfactants – DYNOL™ 960 and DYNOL™ 980 – based on unique chemistry to meet the growing need for high-performance waterborne coatings.

DYNOL™ superwetters are designed to achieve exceptional wetting of difficult-to-wet substrates by providing a superior balance of properties, including both equilibrium and dynamic wetting, system compatibility and low foam. DYNOL™ 960 and DYNOL™ 980 especially enhance flow and levelling properties and help in eliminating marks left by brush or roller. The figure below shows a comparison of the performance obtained with DYNOL™ 980 compared to modified siloxane surfactants in an acrylic water-based wood coating. DYNOL™ 980 works to smooth the surface of the spray applied coating, helps wetting the pores of the wood, leaves no surface defects and no foam (Figure 1).

Both DYNOL™ products improve the overall performances of waterborne coatings and present multiple benefits to wood coating formulators.
Figure 1
Comparison of superwetters in an acrylic water-based wood coating applied by spray.

Blank
Polyether modified siloxane 1
Polyether modified siloxane 2
DYNOL™ 980

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Evonik has a long-standing history as a supplier of glide additives to improve the flow/leveling and surface properties of various coating systems. For solvent-based wood coatings for kitchen cabinets or furniture, the challenge is that additives which provide good haptic (feel/touch) properties are not recoatable – and vice versa. Being able to use one additive that provides both of these properties is desirable in these situations. Through comparison with commercial benchmarks, Evonik Resource Efficiency GmbH has developed a product to meet this demand: TEGO® Glide 496 satisfies the need for advanced solutions (see Figure 1 and Table 1).

Table 1 shows that the blank formulation has not only a poor appearance but also a very high slip value and corresponding poor touch (hand feeling). All of the benchmark additives provide an improved slip and touch but their recoatability is deficient. The new TEGO® Glide 496 improves all performance attributes.

**Figure 1**
TEGO® Glide 496 provides excellent recoatability in a 2K solvent-based polyester clear lacquer.
Application work has shown that the new TEGO® Glide 496 is suitable for both solvent- and water-based formulations, has excellent compatibility, and demonstrated scratch-resistance improvement in various systems. Furthermore the additive is globally registered and complies with various food contact regulations.

Besides wood lacquers, the coatings industry has a growing interest for such a new additive in plastic, industrial, and transportation coatings as well as printing inks.

Table 1
Application testing results for 2K solvent-based polyester clear lacquer on cherry wood.

<table>
<thead>
<tr>
<th></th>
<th>Visual appearance</th>
<th>Adhesion</th>
<th>Slip [cN]</th>
<th>Touch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank</td>
<td>Turbulent</td>
<td>GT 0</td>
<td>182</td>
<td>-</td>
</tr>
<tr>
<td>Benchmark A</td>
<td>Good</td>
<td>GT 5</td>
<td>45</td>
<td>+</td>
</tr>
<tr>
<td>Benchmark B</td>
<td>Good</td>
<td>GT 1</td>
<td>55</td>
<td>+</td>
</tr>
<tr>
<td>Benchmark C</td>
<td>Craters</td>
<td>GT 5</td>
<td>48</td>
<td>+</td>
</tr>
<tr>
<td>TEGO® Glide 496</td>
<td>Good</td>
<td>GT 0</td>
<td>47</td>
<td>+</td>
</tr>
</tbody>
</table>

Adhesion: Cross-cutting test according to DIN EN ISO 2409
Slip: Measured with Instron, Bluehill, 500 g, felt coated, 12 mm/sec
Touch: Hand-feel

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DRIVING HIGHER PERFORMANCE WITH ULTRA-HIGH SOLIDS EPOXY SYSTEMS FOR LONG-TERM ASSET PROTECTION
Epoxy coatings has a successful track record in heavy duty marine and protective coatings, due to the combined offerings of excellent corrosion and chemical resistance. As global environmental drivers become firmly established, the coating industry is faced with the constant challenge of providing solutions which can comply with emerging VOC regulations. One trend for compliance is to migrate traditional solvent based to high solids coatings. In addition, the overall performance attributes associated with current epoxy systems need to be improved to meet emerging industrial application needs. Many competitive high solid epoxy systems typically use non-reactive plasticizers such as benzyl alcohol or alkyl phenols to enable full chemical conversion of the polymer matrix.

While this approach allows for reduced solvent demand, this approach does not always address the market need for long-term, in service performance. Under certain conditions, these modifiers have the potential to migrate out of the coating over time, potentially negatively impacting the mechanical properties of the coating leading to reduced flexibility and an increase in the stress build. Consequently, the potential for a coating to deteriorate in performance is increased depending upon in-service conditions, a factor which needs to be addressed when formulating coatings based on such technologies.
Evonik leveraged its understanding of amine chemistry and developed a new platform in which the plasticizer is bonded within the amine backbone. Incorporation of this amine technology into Ancamide® 2769 curing agent enables 0 g/l VOC coatings to be formulated where additional non-reactive plasticizers are no longer required. Epoxy coatings based on this curing agent deliver excellent corrosion protection as well as providing long-term conservation of the mechanical properties of the coating, the latter ensuring the predictable performance necessary for delivering long-term asset protection (Table 1).

Figure 1 shows the storage modulus of clear coatings based on Ancamide® 2769 vs a conventional high solid curing agent as a function of temperature. The initial DMA scans have been obtained after 2 weeks ambient cure.

**Figure 1**
DMA (dynamical mechanical analysis) evaluation of the mechanical properties of polyamide clear coats.
For the second scans the coatings have been cured for 2 weeks at 25°C followed by 2 hrs at 150°C in an air circulation oven.

The glass transition temperature (Tg) of the coating based on conventional curing agent demonstrates a significant increase (ca. 60°C) between the initial and second scan. At the same time the initial effective molecular weight between cross-links, Mc, of 1020 g/mol decreases to 930 g/mol. This behavior illustrates the potential shortfall of conventional epoxy systems. Non-reactive plasticizers are liberated from the coating with the consequent danger of stress accumulation. In comparison the Ancamide® 2769 coating shows no such shortfall. The changes in Tg between initial and second scan are within error margins at a similar decrease of Mc.

### Table 1
Comparison of Ancamide® 2769 vs solvent based and conventional high solid curing agents.

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Ancamide® 2769</th>
<th>Solvent based polyamide</th>
<th>Conventional high solid polyamide</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHEW</td>
<td>g/eqv</td>
<td>150</td>
<td>270</td>
<td>150</td>
</tr>
<tr>
<td>Viscosity @25°C</td>
<td>mPa.s</td>
<td>100 – 150</td>
<td>2000 – 2500</td>
<td>2000 – 5000</td>
</tr>
<tr>
<td>Level of fugitive plasticizer</td>
<td>%</td>
<td>0</td>
<td>0</td>
<td>20 – 35</td>
</tr>
<tr>
<td>Level of solvent</td>
<td>%</td>
<td>0</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Degree of cure, 7d @25°C</td>
<td>%</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>VOC for the curing agent only</td>
<td>g/L</td>
<td>0</td>
<td>282</td>
<td>306</td>
</tr>
<tr>
<td>VOC for curing agent plus epoxy resin</td>
<td>g/L</td>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>480&lt;sup&gt;b&lt;/sup&gt;</td>
<td>145&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Formulated with liquid epoxy resin (EEW 190)  
<sup>b</sup> Formulated with solid epoxy resin (EEW 500)
Thanks to an innovation in the production process for AEROSIL® fumed oxides from Evonik Resource Efficiency GmbH, these fumed silicas can now undergo wetting and dispersion – processes that previously had to be carried out in two separate systems (dissolver, bead mill) – in a single dissolver step.

The feasibility of the idea was confirmed four years ago when a laboratory-scale setup produced the first product samples, which were named “easy-to-disperse” (or “E2D” for short), a term that describes the unique properties of these products (i.e. readily dispersible in a dissolver). A pilot plant constructed and commissioned at the Hanau (Germany) site two years ago has now generated the first pilot-scale product samples.

<table>
<thead>
<tr>
<th></th>
<th>d_{50} (\mu\text{m})</th>
<th>d_{100} (\mu\text{m})</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEROSIL® R 9200</td>
<td>8</td>
<td>250</td>
</tr>
<tr>
<td>VP RS 920</td>
<td>0.25</td>
<td>3</td>
</tr>
</tbody>
</table>
**Figure 1**
Particle size distribution of VP RS 920.
The experimental products that are available for sampling are VP RS 92, VP RS 82, VP RS 85 and VP RS 920 which are the E2D versions of AEROSIL® R 972, AEROSIL® R 812, AEROSIL® R 805, and AEROSIL® R 9200.

In order to test its processing characteristics, rheological effects, and optical properties within a coating system, the standard product was processed using traditional bead milling procedures, while the experimental product was processed exclusively in the dissolver. The results for viscosity, gloss, haze, and jetness (depth of color) and improvement of scratch resistance (VP RS 920) were all correct within the accuracy of measurement. A significant, absolute reduction in processing time was observed as well, even as the degree of dispersion improved.

The viscosity curves at high and low shear rates were identical within the key range of rising viscosity. This showcases a key advantage of the E2D products: Because they achieve the same level of efficiency and the same optical characteristics, manufacturers do not need to adjust existing formulations, and new formulations can be created according to the same rules as earlier coatings. In addition, easy-to-disperse versions of fumed silicas are chemically identical to the corresponding AEROSIL® products. An important point to highlight here is that no additives of any kind are used in the production process, making these products just as compatible with coating systems as familiar standard products.

The use of easy-to-disperse silica decreases processing times, cleaning times, production losses, etc. Omitting the milling step reduces investment and maintenance costs – especially in varnish production. Pigment manufacturers likewise offer products that can be dispersed in dissolvers, opening up the possibility of formulating colored coatings with no need for a bead mill.

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The superwetter portfolio from Evonik Resource Efficiency GmbH has been on the market for several years and consists of the following products: DYNOL™ 604, DYNOL™ 607, DYNOL™ 360, DYNOL™ 800, DYNOL™ 810, DYNOL™ 960, and DYNOL™ 980. The latter two products are siloxane-containing, while the other products in the range are siloxane-free. DYNOL™ 360 offers the additional benefit of promoting coalescence in waterborne systems by lowering the MFFT (minimum film-forming temperature). Originally designed to promote wetting on difficult-to-wet substrates (such as plastics and contaminated metals), these products can be used to promote flow and leveling in both waterborne and solventborne coating systems. This is of particular interest for automotive coatings, because car manufacturers are constantly looking for ways to improve the appearance of their vehicles to appeal to the ever-changing demands of their customers.
As illustrated in Figure 1, superwetters offer a combination of low dynamic surface tension (DST) and low equilibrium surface tension (EST), hence providing an advantage over fluorosurfactants or traditional siloxane surfactants. This ability to lower both equilibrium and dynamic surface tension is what makes our superwetters suitable for improving flow and leveling.

This article focuses on the performance of our superwetters and the effect they have, not only in the automotive coating layer in which they are used, but also on consecutive coating layers.

Figure 1
Positioning of Evonik superwetters.
The combination of the ability to lower both EST and DST also helps to prevent what is known as telegraphing (or ghosting), i.e. the visibility of wipe marks or sanding marks in the final layer of the coating system.

Our superwetters also offer the possibility to meet the ever-increasing demands of OEM manufacturers to decrease the long- and short-wave (LW and SW, respectively) values of their coatings. As illustrated in Figure 2, DYNOL™ 960 and DYNOL™ 800 are especially effective in lowering both long-wave and short-wave values of the
2K PE clear coat applied on top of the waterborne base coat. In this experiment, the thickness of the base coat is approx. 12 microns and the thickness of the clear coat is approx. 40 microns. Another important thing to note: It is possible to effectively lower the layer thickness of the clear coat while still obtaining very good flow and leveling results and high gloss values.

The same effect is observed when adding the additives to the clear coat; by promoting wetting of the surface, flow and leveling is enhanced which enables the formulator to achieve excellent long- and short-wave values even at lower layer thicknesses. Figure 3 shows the results obtained with a 1K acrylic clear coat at a layer thickness of 35 microns. As shown, DYNOL™ 980 effectively improves flow and levelling of the clear coat.

**CONCLUSION**

The use of superwetters is a very effective way to improve flow and leveling (even at lower layer thickness) in solventborne coatings. Superwetters can be added to either the base coat or the clear coat. In both cases, the formulator will see an improvement.
Figure 3
Effect of wetting agents on LW and SW in a 1K acrylic clear coat.
Evoniks DYNAPOL® polyester resins are widely used binders in paints for pre-coated metal sheet and strip finally serving various end uses from architectural cladding and roofing via appliances housings towards metal packaging. Consistent product quality, good processability and high coating performance are key for a sustainable success of the DYNAPOL® series along these different value chains.

When it comes to formulation of metal packaging coatings for food contact applications, it is extremely important that the final coating film keeps integrity during filling, processing and storage of the food. For such purpose high molecular weight DYNAPOL® grades are the products of choice even if foodstuff containing aggressive ingredients must be preserved and packed safely. To demonstrate this, paint formulations based on DYNAPOL® were applied on metal sheets. Stamping of the coated sheets gave test can specimens that were sterilized (@ 129°C for 30 minutes) in presence food simulants to mimic the food preservation process in real packaging lines. Choice of food simulants fell on quite aggressive chemicals that could be part of real food types. No matter if lactic, tartaric, citric or even a highly concentrated acetic acid solution (8 wt.-% with pH 2) was used, the specimens look unaffected after the sterilization process. Even alkaline test solutions like aqueous sodium hydroxide with pH 10 or red tomato paste could not deteriorate respectively stain the coating film.

Formulators in search of a high quality binder resin for the development of new can coatings covering a broad spectrum of different food types or simply one demanding filling good may meet the solution with DYNAPOL®.
Above paint application test results demonstrate that coating films based on DYNAPOL® can pass the sterilization process without impairing metal adhesion nor affecting visual appearance (Figure 1).

Technical support, guide formulations and samples are available on request via www.dynapol.com.

Figure 1
Different test specimens after sterilization process in
a) 2% lactic acid,
b) 3% tartaric acid,
c) 2% citric acid,
d) 3% acetic acid,
e) 8% acetic acid,
f) tomato paste and
g) sodium hydroxide solution @ pH 10
in comparison to
h) non-sterilized reference.

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VESTAGON®:
FROM HIGH-PERFORMANCE SOLUTIONS TO FUTURE INNOVATIONS
Easy to use, environmentally friendly and cost effective: Powder coating has become extremely popular since its introduction more than 50 years ago. Evonik played a major role in the development of powder coating technology from the very beginning. Today Evonik is the world’s largest producer of internally and externally blocked crosslinkers for polyurethane powder coatings, that are used by powder coating manufacturers worldwide. Under the trade name VESTAGON® Evonik creates products for light-stable and weathering-resistant powder coating systems. The broad product range finds use in a wide range of applications, such as automotive, appliance, architectural, lawn and garden, general metal and pre-coated metal. Among others, VESTAGON® products enable full gloss control, excellent reusability and brilliant mechanical properties.

**HIGH-PERFORMANCE SOLUTIONS**

From graffiti removal to window frames: Polyurethanes provide outstanding properties to coatings. They show superior durability, weatherability, easy one-shot matte formulation and good surface smoothness. These properties make polyurethane coatings attractive for powder coating technology. One example of the many innovations that make Evonik the creative force in eco-friendly and high-performance powder coating crosslinkers is VESTAGON® B 1530: Whenever anti-graffiti properties are required, they are usually achieved by using a polyurethane coating. These coatings have a high crosslink density which is the key property to withstand graffiti and its removal. Because of its branched backbone, VESTAGON® B 1530 is the preferred grade for highly crosslinked polyurethane powders.

When it comes to unusual designs, geometric patterns or imitations of natural building materials, the sublimation printing technology is overcoming the past limitations of metal and temperature-resistant materials. Sublimation (or heat transfer) technology is a method of infusing a powder coating with ink to leave behind a design on the coated metal part. This technology made it possible to greatly improve the appearance of building components, especially components made of aluminum such as window frames, front doors, garage doors, office furniture, and aluminum kitchen cabinets. Thanks to VESTAGON® BF 1320 or VESTAGON® BF 1321, aluminum window frames can blossom in the spring, for example.
The need for matte appearances in sublimation printing quickly became another source of development: one-shot matte coatings. With liquid coatings, it is very easy to provide a matte coating by the addition of significant quantities of fillers or matting agents. Internally and externally blocked polyurethane crosslinkers (such as VESTAGON® BF 1321 and VESTAGON® B 1400) have been accepted worldwide in combination with dissimilar resins for semi-matte and even flat-matte polyurethane powder coatings and have been successfully used in both exterior and interior applications such as motor vehicle parts, fittings, bicycle frames, exterior furniture, agricultural machinery and telephone booths.

FUTURE INNOVATIONS
As a pioneer in powder coatings, Evonik also creates the basis for future innovations. Evonik’s product development activities are driven by the focus on customer requirements and market trends. The innovative solutions enable coatings formulators to develop coatings for tough demands, for example low temperature cure coatings or powder coatings for direct food contact. Coatings coming into contact with food are under severe and increasing regulatory control. Here raw material suppliers, coating formulators and applicators have to take responsibility that everything is done to protect the health of the end user. It has been shown in lab studies that current requests from the food packaging industry can be met.

Within the last few decades huge efforts were exerted to improve the cure response of all powder coatings, polyurethane powder coatings included. Often a full hour can be needed to sufficiently crosslink standard polyurethane powder coatings at 170°C. Due to recent discoveries, it has been found that the uretdione ring (internal blocked polyurethane
grades) can react at lower temperatures (130°C), but this requires a dedicated catalyst approach. Another disadvantage of such low temperature cure coatings is the limited storage stability and the necessity to keep the powder coatings in refrigerated storage. Polyurethane coatings without these disadvantages were recently developed. This next generation of low temperature cure coatings will make it possible to open completely new fields of applications like coating of temperature sensitive substrates.
“Finish first – fabricate later”, this is the short formula to which the continuous and fully automated coil coating process can be reduced and generally describes the work and ideas of many paint professionals who are in this particular business. For decades generations of chemists and engineers have constantly been busy to improve the performance properties of liquid coil coating paints and cured paint films for primers and top coats on steel and aluminum metal substrates. About 220,000 MT of paints\(^1\) are annually used just in the European coil coating industry. The resulting pre-coated metal coils go into various end application fields such as exterior and interior construction elements, domestic appliance housings, automotive parts, metal furniture but also metal packaging and numerous other end uses.

By far the biggest volumes of paints are needed for the architectural sector, for example for ceilings or wall and roof claddings which can be often seen on shopping malls, industrial warehouses and to an increasing degree also on residential buildings.

Finished paint films of just about 15–30 µm thickness provide protection of the metal substrate against mechanical damage like abrasion or scratches, corrosion and other chemical impact of aggressive environment. For visual and aesthetic reasons particular attention needs to be paid on weathering and resistance to ultraviolet radiation (UV) of the metal coating. UV radiation is one of the biggest challenges on durability of coil coatings. Depending on the region in the world, the impact of UV radiation sooner or later will lead to loss of

\(^1\) European Coil Coating Association (ECCA) Statistics 2017
gloss, color fading and chalking of the surface area, followed by other aging effects which can cause severe damage of the entire coating film (e.g. delamination, etc.). The question is, how can paint formulators and producers maximize the lifetime of metal coatings to meet the required highly demanding specifications or long lasting warranty demands of the end users?

Coil coating paints are always formulated with many different paint ingredients as there are paint binder resins, pigments, matting agents, crosslinkers and catalysts, solvents and surface-active additives as well as sometimes special effect substances. Every single component is playing its individual role in the paint formula. But without doubt, the main binder resin as major part is always of special importance. It provides the already above mentioned mechanical and chemical resistance and is mainly responsible for hardness, flexibility and substrate adhesion of the finished paint film. Commonly used binder resin technology for coil coating applications is acrylic, epoxy, PVC, polyester, polyurethane, silicone modified polyesters (SMP) and polyvinylidene fluoride (PVDF). All of these materials are well-suited as paint binders but in fact, with approximately 70%, polyester resins share the biggest volumes. In the majority of cases, modern so called “super-durable” polyesters (SDP), providing excellent UV and weathering resistance, can meet the requirements for long-lasting and durable protective and decorative architectural paint films. Typically in combination with amino-plast resins as crosslinkers. Polyester-polyurethane systems show even improved performance.

However, high-end coil coating systems for roofing, composite and building panels with very long-lasting warranties are to some extend formulated with PVDF binder systems. These are usually a blend of about 70% chemically and photo-chemically inert PVDF polymer and 30% of a polymethacrylate polymer as a co-binder and kind of a carrier for the insoluble PVDF. No doubt, this particular class of paint binders can provide outstanding durability, very good dirt-pick-up-resistance and for example also good resistance against graf-fities. Coil coating paint suppliers
around the world often do not hesitate to give warranties of 30 years and more on color stability and chalking resistance of the coated article.

But no light without shadow. Beside their superior weatherability, there are some generally known technical drawbacks of PVDF coatings, for example limitations in gloss control. It is hardly possible to formulate high-gloss (>70%) and low-gloss coatings (<10%). Further to that, paint solids and hence the yield of PVDF based systems are usually pretty much lower than compared with super-durable polyester systems. Sufficient abrasion resistance of PVDF based paint films can be problematic, because in fact, PVDF and polymethacrylate polymers are basically incompatible and many of these systems cannot be characterized by an essentially high chemical crosslinking density. Last, but not least, the price of PVDF binder systems can be prohibitive.

Trying to avoid these weaknesses of PVDF coatings and at the same time reaching their outstanding durability as close as possible, many end-users in the coil coating industry are consistently looking for highly durable paint binder systems with weathering (UV) resistance that can be classified “between PVDF and super-durable polyesters (SDP)”.

Evonik Resource Efficiency, Product Group Polyesters, has identified market potential for this kind of systems and successfully developed a new class of coil coating paint binders. These are able to close the gap in weathering performance between super-durable polyester or polyurethane systems and ultra-high resistant PVDF. In comparison to PVDF based paint formulations they provide remarkably higher paint solids. As the new binder resins are fully curable - either with aminoplast or blocked polyisocyanate crosslinking agents – they offer improved abrasion resistance. Individually adjustable gloss levels over the complete range from dead- to high-gloss finishes are possible (Table 1). Many special effect coatings (e.g. wrinkle, metallic, textured PUR/PA, etc.) can be formulated to meet end users’ requirements (Figure 1).
Table 1
Property profiles of coil coating paint systems on steel (dry film thickness appr. 20 µm).

<table>
<thead>
<tr>
<th>Paint system</th>
<th>NEW Evonik binder system</th>
<th>PVDF</th>
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</thead>
<tbody>
<tr>
<td>Durability</td>
<td>++ (+)</td>
<td>++ +</td>
</tr>
<tr>
<td>Dirt-pick-up resistance</td>
<td>+ +</td>
<td>++ (+)</td>
</tr>
<tr>
<td>Gloss control (60° angle)</td>
<td>++ + (&lt;10% – &gt;90%)</td>
<td>(20% – &lt;70%)</td>
</tr>
<tr>
<td>Abrasion resistance</td>
<td>++ +</td>
<td>+</td>
</tr>
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</table>

Figure 1
Modern decorative “wrinkle coatings” based on the new Evonik binder system.

Picture 1
Wrinkled top coat, black, on aluminum

Picture 2
Wrinkled top coat, clear, on aluminum
Numerous application tests on steel and aluminum substrates prove the practicability of the new paint binders. Accelerated weathering tests like QUV-A (Figure 2) or QUV-B examinations and xenon arc tests confirm superior gloss control, chalking resistance and color stability. Outdoor exposure tests in Florida are still running but first results are also very promising.

**Figure 2**
Gloss retention after 10,000 hours accelerated weathering test (top coat, white, gloss 30 units, PU-system on primed steel).
VISIOMER® HEMA-P 70M
A NEW ALL-ROUNDER

2-Hydroxyethyl-Methacrylate-Posphate (HEMA-P) is a well-known adhesion promoter in applications like adhesives and coating resins. With VISIOMER® HEMA-P 70M Evonik designed a highly versatile monomer that has also proved to be an effective anti-corrosion agent and reactive flame-retardant.

ADHESION PROMOTION
VISIOMER® HEMA-P 70M is a specialty methacrylate, which improves adhesion dramatically even at low concentrations. In studies the shear strength tripled at an addition of 5wt% VISIOMER® HEMA-P 70M in structural adhesives. (Figure 1)

**Figure 1**
Shear strength enhancement of a standard structural adhesive using VISIOMER® HEMA-P 70M as adhesion promoter.
CORROSION PROTECTION

Corrosion protection has always been an important requirement for coatings. The trend towards waterborne systems makes anti-corrosion properties a challenge. Our studies on acrylic emulsions with a low amount of VISIOMER® HEMA-P 70M demonstrate enhanced corrosion resistance compared to resins without any anti-corrosion agent. Panels coated with VISIOMER® HEMA-P 70M containing emulsion polymers withstood corrosion up to 168 hours in a saltwater immersion test (Figure 2).

Figure 2
Saltwater immersion test on galvanized steel substrate for emulsion coating with and without VISIOMER® HEMA-P70M.

<table>
<thead>
<tr>
<th>With VISIOMER® HEMA-P70M</th>
</tr>
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<tr>
<td>24 h</td>
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</table>

Without
FLAME-RETARDANT PROPERTIES

New regulations drive industry interest towards alternatives for conventional halogen based flame-retardant, alternatives that are non-migrating and less hazardous. Since the product acts as a reactive diluent or co-monomer which is bonded to the polymer backbone, it does not migrate like conventional flame-retardants. VISIOMER® HEMA-P 70M further improves flame-retardancy in combination with non-polymerizable flame-retardants.

VISIOMER® HEMA-P 70M contains 70% phosphate components and 30% methyl methacrylate. It is particularly easy to process because of its low viscosity of 40 – 75mPa-s in comparison to pure HEMA-P. Thanks to its low color index, the specialty monomer is particularly well-suited for optical applications in acrylate and methacrylate systems. This enables the use in applications with high demands for transparency and surface quality, such as surface coatings, plastics or adhesives.

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