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Last year we reintroduced a print issue designed to travel onto the show floor or be passed along to a colleague, and we are proud to bring you our second annual Print Showcase edition.

Inside this year's issue, researchers examine attapulgite thixotropic thickeners for dispersion, viscosity and sag control in paint formulations, as well as PVDF water-based resins for exterior coatings performance. We also explore artificial intelligence in chemical and coatings operations, low-bake powder coatings and a comparison of polyurea and polyurethane chemistries for concrete waterproofing.

Technical articles like these remain at the center of PCI's coverage, supported by expanding online resour-

ces including our raw materials and equipment directories, daily news coverage and market reports. Those same technical conversations continue throughout the year at industry events, including our Coatings Trends & Technologies (CTT) Summit every Fall, which again brings technical leaders together to discuss emerging formulation challenges and materials innovation.

Wherever you encounter PCI this year, whether at a conference, through an article or on the Coat It! podcast, we hope you will connect with us. Stop by at events, send us a note or share what you are working on. Many of our best ideas start with those conversations, and we are always looking for new voices to help move the industry forward. **PCI**



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Attapulgite Thixotropic Thickeners

for Improved Rheology and Sag Control in Paint Formulations

By **Dr. Bo Wang**, Vice President, Research and Development, Active Minerals, Houston, TX

Natural attapulgite, also known as palygorskite, is a hydrous magnesium aluminosilicate clay mineral with a chain crystal lattice that is structurally different from other clays such as montmorillonite or bentonite. The tetrahedral sheets of attapulgite are divided into ribbons by inversion, as adjacent bands of tetrahedra within one tetrahedral sheet point in opposite directions rather than in a single

direction. This structure creates ribbons of 2:1 layers joined at their edges, while the octahedral sheets are continuous in only two dimensions (Figure 1). Unlike the layered crystal structures found in montmorillonite or bentonite, where water molecules can easily infiltrate between

layers and cause swelling, the ribbon-like crystal structure of attapulgite remains stable in water with no swelling.

This article highlights the performance of a new attapulgite-based thixotropic thickener



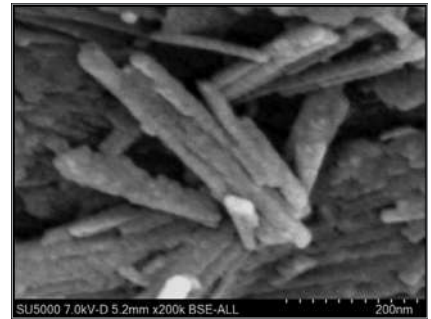
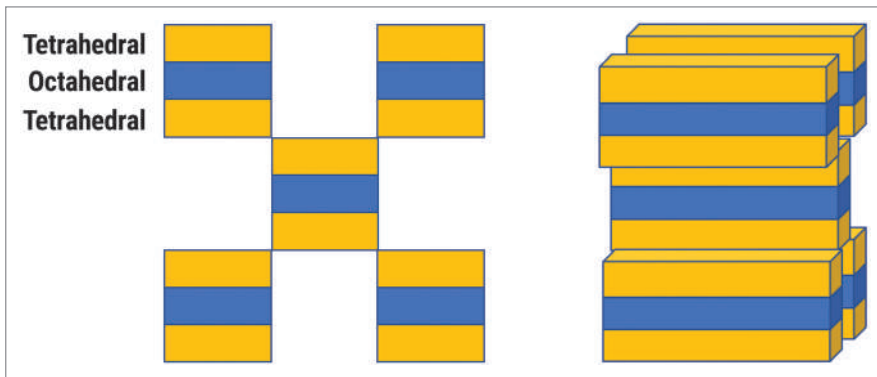


Figure 1 (above, left). Attapulgite chain crystal lattice formed with tetrahedral and octahedral sheets.

Figure 2 (above, right). Scanning electron microscope image of attapulgite at 200k magnification.

product, Min-U-Gel® 500+, developed by Active Minerals International for use in paint and coatings applications.

The unique nanorod structure (Figure 2) and weak surface electrical charges enable the formation of a colloidal gelling structure. In paint and coating formulations, gel-grade attapulgite functions as an effective rheology modifier

and suspending agent, enhancing flow and leveling while minimizing settling and sagging. Versatile performance in both aqueous and solvent systems is desirable for broad formulation applicability. The new attapulgite thickener was developed from natural attapulgite using a proprietary process designed to improve the efficiency of the three-dimensional chain colloidal gelling structure, thereby enhancing thixotropic thickener performance.

Development Performance Testing

Real-time viscosity during dispersion was measured by placing both a viscometer and mixer in a vessel containing either a 5.4% attapulgite water slurry or a 20% attapulgite solvent slurry. Syneresis over time was measured by recording the percentage of clear liquid volume relative to the total volume of the 5.4% attapulgite water slurry or the 20% attapulgite solvent slurry. Performance in paint was evaluated us-

ing a water-reducible alkyd baking enamel paint formulation (Table 1, page 10) and a solvent-based high-solids baking enamel paint formulation (Table 2, page 10). Sag resistance was measured using the ASTM D4400 test method.

Results and Discussion

As shown in Figure 3 (page 10) and Figure 4, the new attapulgite thixotropic thickener can be easily dispersed in both aqueous and solvent systems. This behavior is attributed to the smaller attapulgite particle size and the proprietary process, which facilitates formation of a three-dimensional attapulgite colloidal gel structure. When tested alongside a competitive, commercially available, high-performance attapulgite product, the new thickener exhibits higher viscosity in water and comparable viscosity in solvent systems. The new product also demonstrates a significant improvement in viscosity compared with the existing commercial product Min-U-Gel® 400.



Raw Material	%	Chemical
Grind		
Aroplaz 4097 WG4-55	12.00	Water-dispersible acrylic resin
Butyl cellosolve	0.75	Glycol
Ti-Pure® R-900	24.35	TiO ₂
<i>Premix for 5 minutes</i>		
Water	4.50	
Attapulgate	0.27	
Cowles to 7 Hegman		
Letdown		
Aroplaz 4097 WG4-55	27.63	Water-dispersible acrylic resin
Cymel® 303	7.64	Crosslinker
Water	22.86	
Total	100.00	

Table 1. Water-reducible alkyd baking enamel paint formulation.

Raw Material	%	Chemical
Grind		
Joncryl 500	21.00	Acrylic resin
n-Butanol	3.50	Solvent
Tomamine PA-14 acetate	0.03	Cationic surfactant
Attapulgate	0.30	
<i>Mix at high speed for 5 minutes</i>		
Ti-Pure R-900	34.85	TiO ₂
Cowles to 7 Hegman		
Letdown		
Joncryl 500	17.84	
Cymel 303	12.20	Crosslinking agent
MIBK (methyl isobutyl ketone)	9.30	Solvent
p-Toluenesulfonic acid	0.63	Catalyst
Defoamer	0.35	
Total	100.00	

Table 2. High-solids baking enamel paint formulation.

The testing confirms that the new attapulgate thickener exhibits superior suspension and syneresis control characteristics in both aqueous and solvent systems. As shown in Figure 5, syneresis in mineral

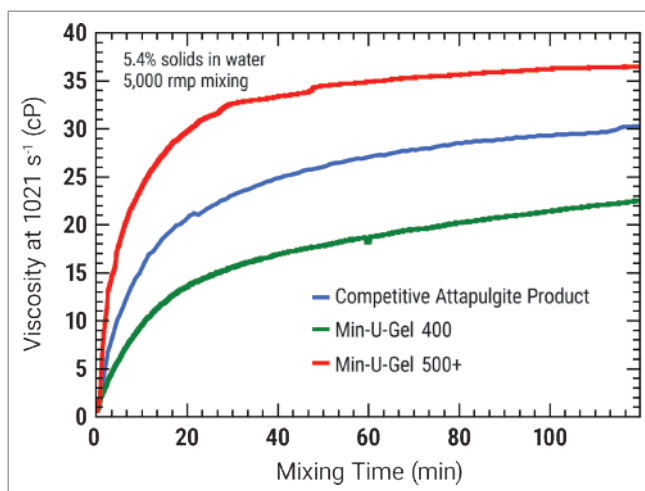


Figure 3. In-situ real-time viscosity measurement during dispersion in water.

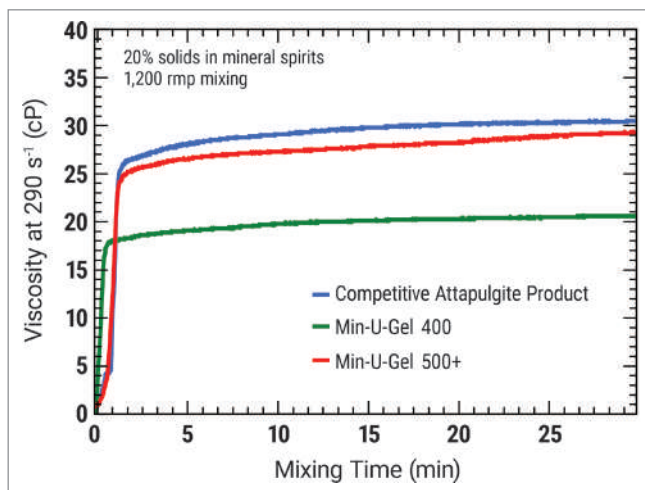
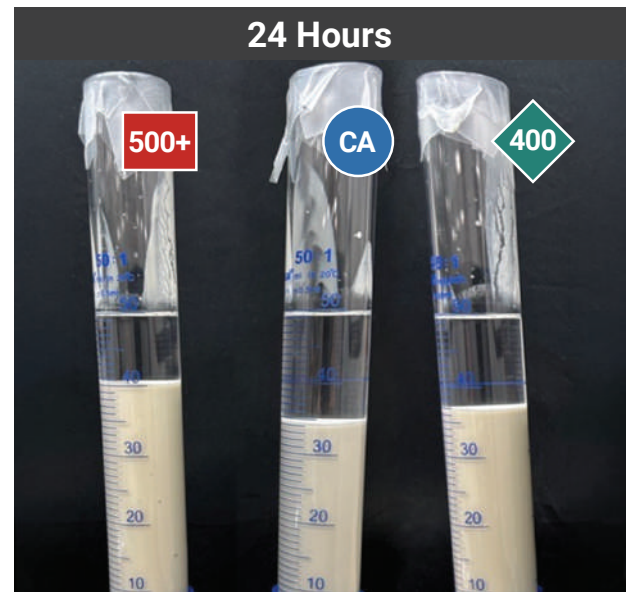
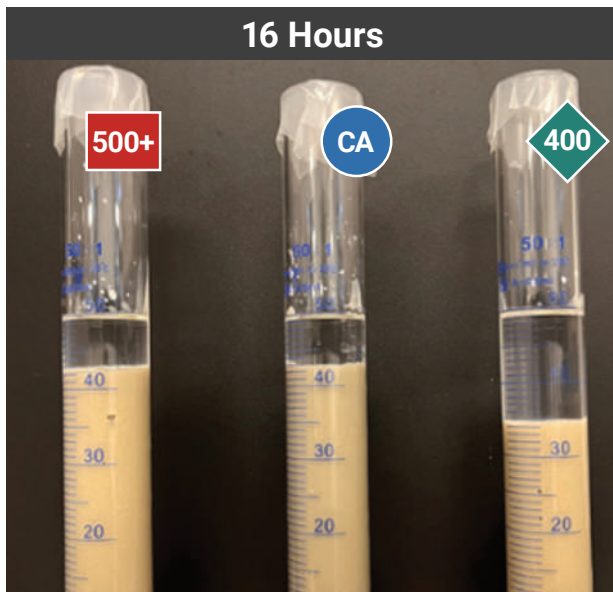
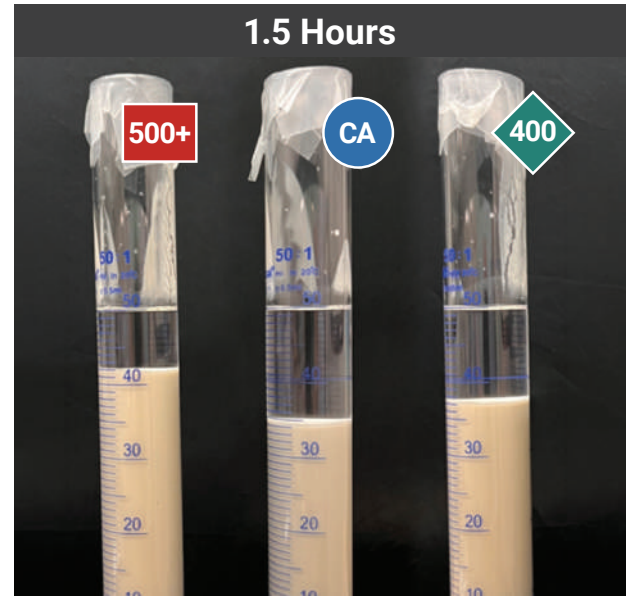
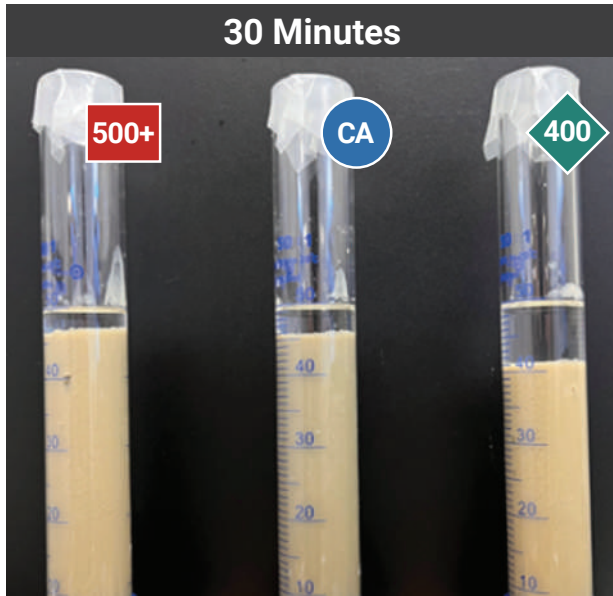
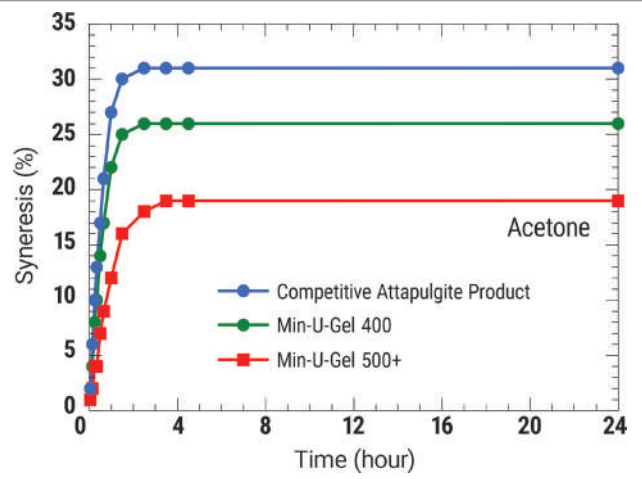
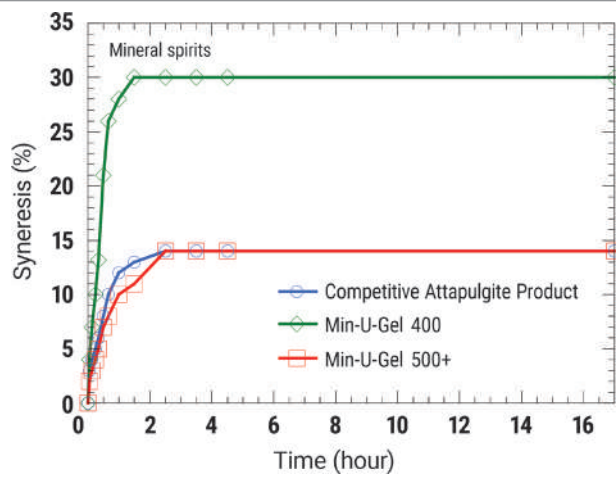


Figure 4. In-situ real-time viscosity measurement during dispersion in solvent (mineral spirits).

spirits is similar to that of the competitive attapulgate product and represents a significant performance improvement over the earlier-generation commercial grade. In acetone, the new product exhibits markedly lower syneresis than both the competitive attapulgate product and the company's previous standard-grade benchmark (Figure 6). All three products demonstrate the expected high performance in water, with no syneresis observed after 24 hours.

As shown in Figure 7 (page 12), in the water-reducible alkyd baking enamel paint formulation, the new attapulgate thickener exhibits higher viscosity than both the competitive attapulgate product and the earlier-generation commercial grade. Even at 10% lower loading,



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Figure 5. Syneresis in mineral spirits.

Figure 6. Syneresis in acetone.

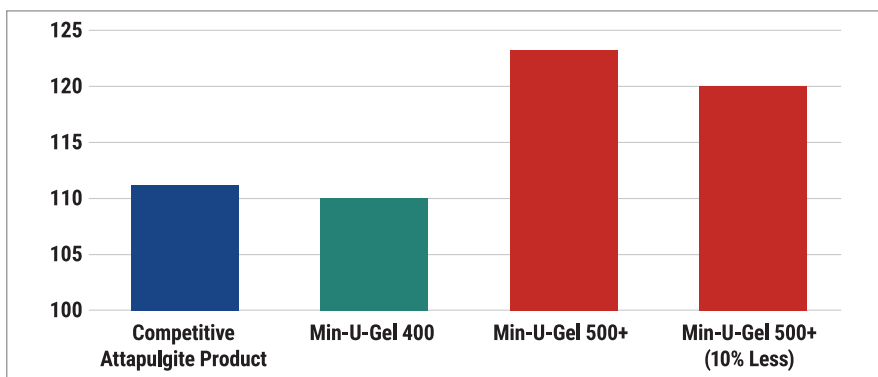


Figure 7. Krebs viscosity in water-reducible alkyd baking enamel paint.

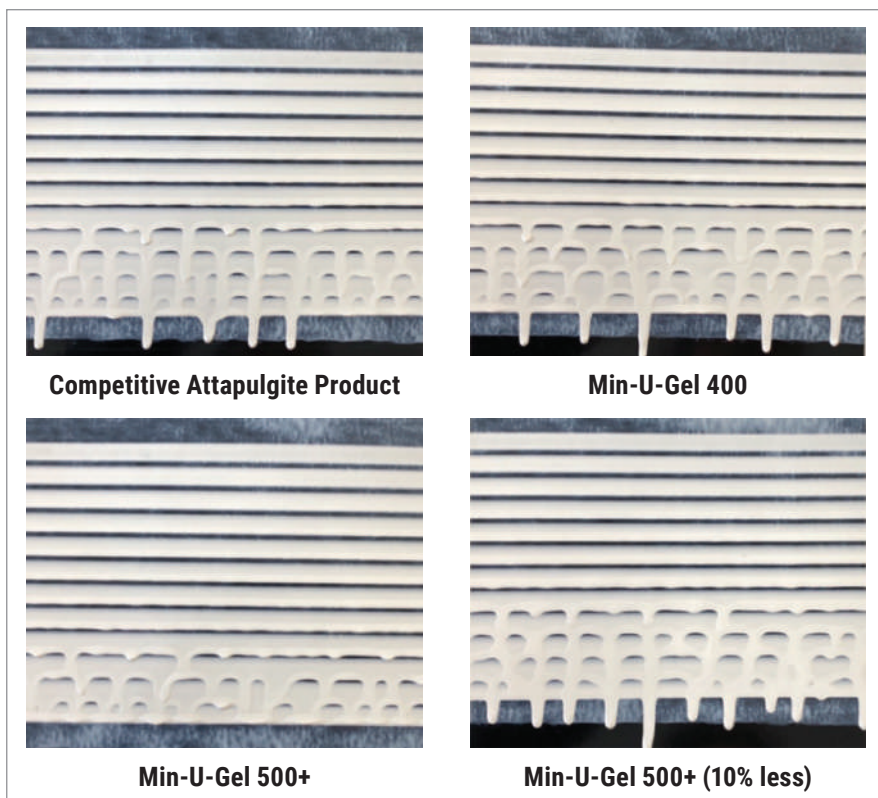


Figure 8. Sag-resistance drawdowns in water-reducible alkyd baking enamel paint.

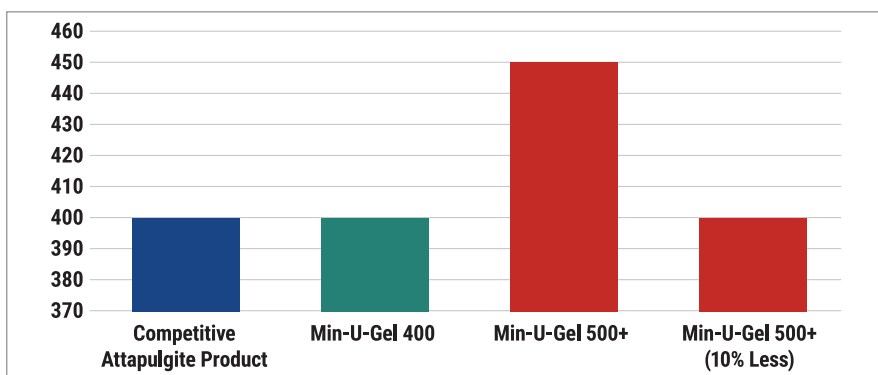


Figure 9. Anti-sag index in water-reducible alkyd baking enamel paint.

the new product maintains higher viscosity. This result is consistent with the higher viscosity measured during dispersion in water.

As shown in Figure 8 and Figure 9, the new attapulgite thixotropic thickener exhibits better sag resistance than both the competitive attapulgite product and the existing commercial product. Even at 10% lower loading, sag resistance of the new product is comparable to that of the competitive attapulgite product. This improved performance is achieved with no significant differences in other paint properties, including color, opacity and gloss. These paint test results indicate improved performance in the water-reducible alkyd baking enamel formulation with the potential for lower loading levels.

Similar to the results observed in the water-reducible alkyd baking enamel paint, the new attapulgite thickener exhibits higher viscosity and improved sag resistance compared with the competitive attapulgite product in the solvent-based high-solids baking enamel paint (Figure 10 and Figure 11 on page 14). Consistent with the other tested system, no significant differences were observed in other paint properties, including color, opacity and gloss.

Conclusion

The new attapulgite thickener can be easily dispersed in both aqueous and solvent systems, and ex-



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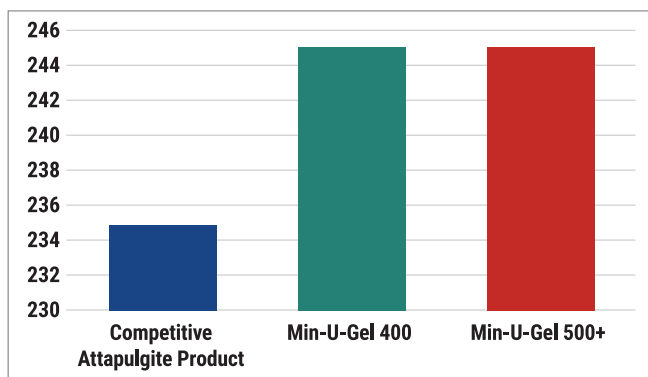
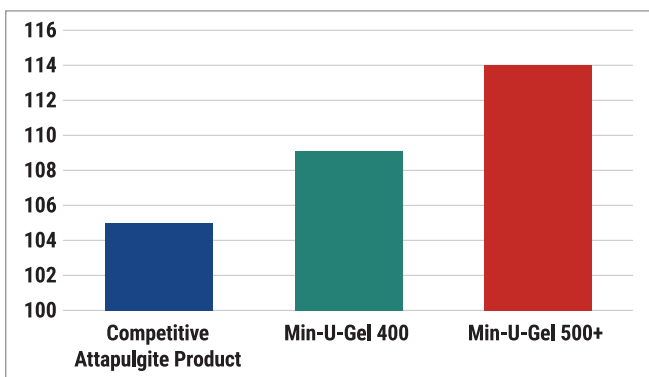


Figure 10. Krebs viscosity in solvent-based high-solids baking enamel paint.

Figure 11. Anti-sag index in solvent-based high-solids baking enamel paint.

hibits superior suspension and syneresis control characteristics. It also demonstrates higher viscosity and improved sag resistance in both water- and solvent-based paints. The enhanced performance is attributed to the smaller attapulgitic particle size and

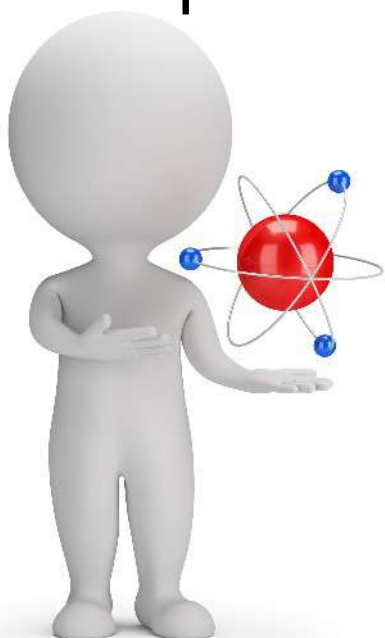
proprietary process, which facilitates and stabilizes the three-dimensional chain colloidal gelling structure. This versatile thixotropic thickener can be used in various applications, including paint and coatings, adhesives and agriculture. In aqueous and solvent paint

and coating systems, it stabilizes the media, prevents settling, controls flow and reduces syneresis.

For more information contact Active Minerals International, a Huber company. **PCI**

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Curing Smarter and Cooler with Low-Bake Powders

By **Julia Haponski**, Product Manager, Powder Coating Technology, PPG

From the finish on cell phones to shipping containers and monumental architectural structures, high-performance powder coatings are used in nearly every industry to make products look better and last longer. However, how those powders cure, the temperatures required for the ovens, and the performance of the finish are all evolving.

New developments in powder coatings that cure at lower temperatures are allowing OEMs and finishers to speed up production, increase throughput and reduce energy usage, while delivering

the durability and longevity expected of today's powder coating solutions.

The data tells the story. A 2025 Precedence Research report forecasts that the low-temperature powder coatings market will grow from approximately \$125 million today to more than \$200 million by 2034, signaling accelerating demand for energy-efficient technologies.

This momentum is driving OEMs and finishers to adopt low-cure technologies that not only meet performance expectations but also open the door to more efficient and sustainable production.

What are Low-Cure Powders?

Low-cure powders are designed to perform comparably to traditional powder coatings in terms of durability, chemical and corrosion resistance, and color retention, but with a distinct advantage in energy efficiency over standard formulations.

In general, most industrial powder coatings require thermal heat to initiate the cross-linking chemical reaction that gives them their tough, durable finish. For conventional powder coatings, this typically occurs under temperatures of 325 °F to 400 °F (163 °C to 204 °C). However, advanced low-bake pow-



Credit: PPG

der formulations can cure at temperatures as low as 250 °F (121 °C). This, in itself, is an attractive attribute for coatings operations seeking to reduce energy use.

While powder coatings have been used on metal since the 1940s, their use on higher density metal substrates is a more recent development. Products made of thicker metal naturally take longer to reach the target temperature required for a proper cure, which can create curing inconsistencies when thin and thick parts run on the same line. Low-cure powder coatings overcome this challenge by lowering the required metal temperature, making it easier to achieve uniform heating across mixed gauges.

Low-cure powder innovations are also extending the technology's applicability for new substrate types. Reduced oven temperatures have made powder

coating feasible for materials once considered unsuitable like heat-sensitive plastic, wood and wood composites. In essence, low-cure solutions are bringing the performance and sustainability advantages of powder coatings to more products and industries than ever before.

Rising Requirements for Sustainability

Generally, sustainability was not nearly as top of mind 25 years ago as it is now, and it was not a factor that drove interest in powder coatings initially. Instead, powder adoption first saw a boost when finishing operations were asking coatings suppliers for solutions that would deliver faster throughput and speedier cure times. They also needed to provide the long-lasting durability today's manufacturers expect, on par with

or exceeding the performance of traditional liquid coatings.

This led leading coatings manufacturers to prioritize the development of new resin and pigment technologies that cured faster. Over time – and as the technology improved – this allowed coaters to drop the temperatures of their ovens and reduce overall energy use. This approach maintained performance standards and strengthened the sustainability of their operations.

Fast forward to today, and the combination of sustainability and performance are standard expectations in the coatings industry, and low-cure powders are playing an increasingly important role. This shift is only accelerating with environmental regulations in the United States and Europe, which are limiting the reliance on liquid spray coatings because they con-

tain solvents that emit volatile organic compounds (VOCs).

Regulations and Why Industrial Coaters are Paying Attention

In the United States, industrial spray operations are subject to VOC and hazardous air pollutant (HAP) limits under the Environmental Protection Agency's National Emission Standards and NESHAP regulations. This falls under the Clean Air Act (CAA), an overarching federal law, and consequences for non-compliance include hefty fines, legal liabilities and facility shutdowns. Even facilities that rely heavily on allow-

able spray-applied liquid coatings face ongoing monitoring, reporting and control requirements.

Directive 2004/42/EC, the European Union's "Paint's Directive," also caps VOC content in coatings to reduce air pollution, including ground-level ozone and smog as well as restrictions on solvent use. Similarly, the Industrial Emissions Directive (2010/75/EU) sets emission limits and best-practice standards for industrial facilities, all aimed at minimizing pollution. The EU Green Deal, a strategy to make Europe the first climate-neutral continent by 2050, is driving much of this change.

Together, these regulations

and others are influencing the reduction of solvent use globally, and coaters are responding by adopting new coatings solutions like powders.

In the United States and abroad, powder coatings allow finishing operations to circumvent these barriers by eliminating the solvents present in conventional liquid sprays. Powders generate virtually no VOC emissions during application, and modern low-cure formulations further reduce oven temperatures to save energy while expanding the types of substrates that can be coated. For industrial coaters, this means better regulatory compliance, lower energy



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costs and reliable throughput.

Beyond the absence of solvents, low-cure powder formulations take sustainability advantages to the next level by reducing oven temperatures to save energy while expanding the types of substrates that can be coated.

The Future of Low-Cure

While low-cure powders solve a number of issues presented by their liquid spray counterparts, there's still more performance, efficiency and capability to unlock.

Leading coatings manufacturers continue to push the limits, identifying new methods and creating formulations designed to reduce both curing times and oven temperatures without compromising performance.

For instance, some innovators are exploring ways to shrink cure times down to less than five minutes, further boosting throughput on lines that are already optimized for speed.

Another area of advancement

within the low-cure segment is the development of wider curing windows. For most industrial finishers, especially those running continuous lines with a mix of thin and thick metal gauges, this flexibility is invaluable.

A wide cure window allows operators to set one consistent oven temperature and trust that all parts will fully cure, regardless of metal thickness or mass. It not only achieves a full cure, but meets all required mechanical and performance property criteria for modern coatings. Previously, different gauges required constant adjustments or even separate cure schedules. Today's modern low-cure powders offer wider process tolerances, reducing line disruptions and creating more stable, predictable and reliable production.

There are, however, practical considerations for coaters who may be transitioning from a standard cure schedule to a low-cure system. Low-cure powders are

typically selected for energy savings or for substrates with less strict aesthetic requirements. Some products that require an extremely smooth, minimal-fade surface, or those relied on for high-visibility applications, may still require a standard powder solution. However, industry-leading coatings manufacturers are developing products that marry low-cure qualities with high aesthetics that can be used for automotive exterior parts, architectural panels and consumer electronics.

In addition, even with wider curing windows and today's more flexible curing options, realizing the full return on investment of a low-bake line often requires a complete commitment to this type of operation. A single oven cannot efficiently run both low-cure and standard-bake powders at once. Therefore, coaters must evaluate where low cure makes the most sense and whether dedicating equipment to it is feasible.



Credit: PPG

Pushing the Boundaries

While low-cure powders hold several notable advantages over liquid coating formulations, the innovation and R&D behind these solutions haven't crossed the finish line. Leading coatings manufacturers are redefining what's possible, identifying methods and creating formulations designed to reduce both curing times and oven temperatures while delivering a high-aesthetic appearance.

Innovation in low-cure powders is a big part of the equation. When paired with a total-solutions approach from a reliable partner, coaters can streamline operations, save time and money, and exceed customer expectations for efficiency, sustainability and durability. **PCI**



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A Comprehensive Evaluation of PVDF Water-Based Resins for Exterior Coatings Performance

By **Nicholas Michael**, R&D Lab Intern, APV Engineered Coatings

Background on Resins and Water-Based Formulas

Resins are often defined by their chemical structure, which reflects their physical attributes. These polymers can be further divided into various groups, such as thermoplastic and thermoset materials. Thermoplastic polymers are those that maintain their chemical identity as they transform into the final material, whereas thermoset polymers react chemically to achieve the final product.¹ Resins can be characterized by various markers, including minimum film-forming

temperature (MFFT), gloss, chemical resistance, mechanical resistance and rheological performance.

Resins provide an important function in the coatings industry: to protect the underlying material. The protection provided by the resin is often measured by variables such as color retention, and mechanical and chemical durability.²⁻³ The variables in the environment in which the coating is used will determine the strength of durability needed from the coating. For example, an area that receives more direct sunlight will require a topcoat that can provide better UV degra-

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dation resilience than an overcast area. Further, areas near the coast will require topcoats that offer corrosion resistance due to increased salt concentration.

Recently, in the coatings industry, there has been an effort to switch from solvent-based systems to water-based systems. This is largely impacted by new regulations that classify certain solvents as volatile organic compounds (VOCs) that exhibit photochemical reactivity and create increased concentrations of ground-level ozone. This increased concentration negatively affects the environment as well as human health. Another factor influencing this switch is the movement away from petroleum-based materials, an effort that is increasingly important as the plastics industry continues to grow and the demand for petroleum products rises, requiring a shift to different material sources.

Switching from a solvent-based system to a water-based one has its challenges. First, the resins and additives that were used in a solvent-based formula need to be soluble in water. This can occur through modifying the additive directly by creating a new version that exhibits similar properties as before but is now hydrophilic.⁴ Second, these water-based systems need to meet the same specifications as the previous solvent-based systems in order to be viable for commercial use. Third,

since the system is water-based, the energy required for film formation increases due to the evaporation rate of water compared to other organic solvents. Another issue with the water-based system is that the components of the formula are water soluble and therefore can more easily enter the ecosystem, potentially causing more difficult-to-address pollution issues since the pollutants are water soluble instead of insoluble as before.⁵

Supplier A's PVDF Latex Emulsions

Supplier A provides the three PVDF latex emulsions that are used in APV's NeverFade products. The resins for this project were chosen due to their prevalence in the marketplace and inclusion of this PVDF polymer. The current understanding of this material and its contributions is that PVDF provides good impact strength, hardness, mechanical strength and thermal stability as well as piezoelectric properties.⁶⁻⁷

Because of these reported properties, PVDF is prevalent in many fields, including sensors, energy harvesting, biomedical devices and coatings.⁷ The use of PVDF in water-based systems lowers the absorbance of UV radiation in the

Resin Name	Percent Non-Volatile	PVDF:Acrylic	MFFT (°C)
R0	50	0:100	20
R1	45	70:30	--
R2	44	70:30	27
R3	46	50:50	12

Table 1. The four resins from this experiment are shown along with their nonvolatile weight percentage, PVDF: acrylic ratio and minimum film-forming temperature (°C).

Ingredient	Percent Total Formula Weight (%)
Defoamer	0.13
Surfactant	0.38
Resin	94.30
Coalescent	3.82
HEUR thickener	1.27
Biocide	0.10

Table 2. General Formula 1 and its additives.

Ingredient	Percent Total Formula Weight (%)
Distilled water	21.25
Coalescent	8.66
HEC thickener	0.50
pH modifier	0.20
Defoamer	0.10
Resin	68.91
Surfactant	0.28
Biocide	0.10

Table 3. General Formula 2 and its additives.

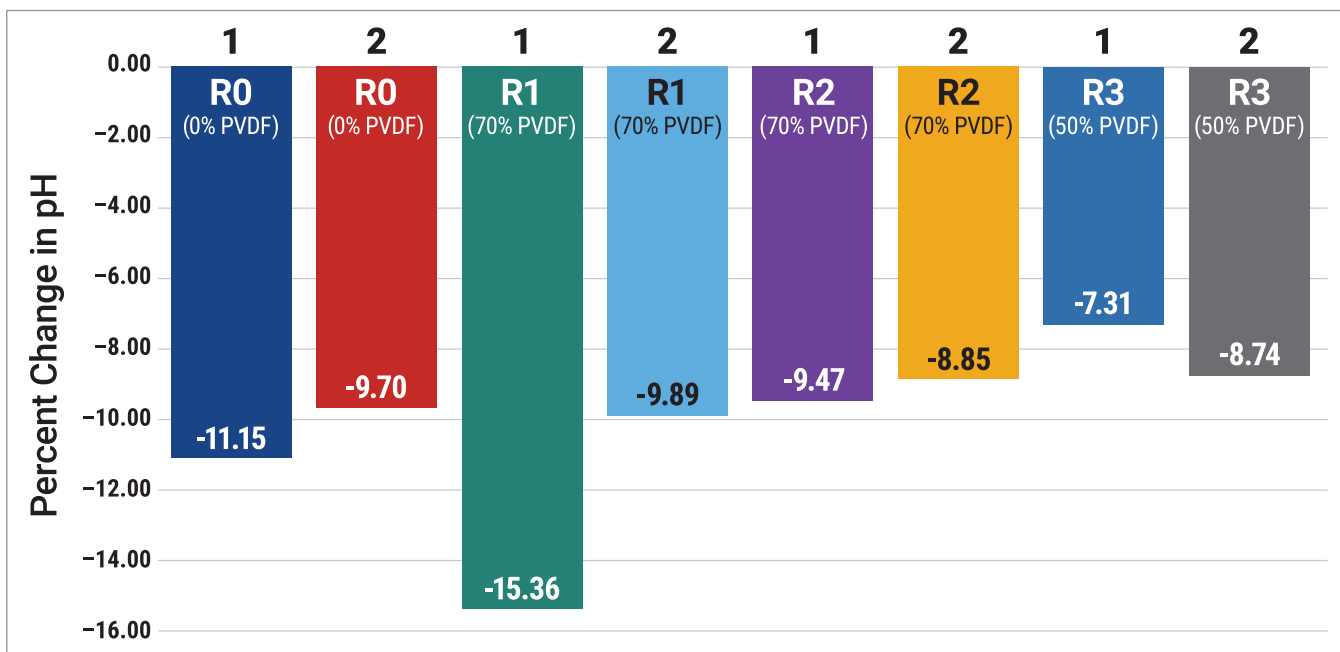


Figure 1. Percent change in pH of each sample from Formulas 1 and 2 after accelerated aging for 2,000 hours in a 50 °C oven.

200–400 nm region compared to other commercially available water-based resins. Other reported benefits of these PVDF resins include higher gloss readings and improved color retention over time.⁸

The goal of this summer research was to utilize this information regarding the industry shift to evaluate three of Supplier A's PVDF latex water-based emulsions, R1, R2 and R3, against an all-acrylic, no-PVDF resin (R0) with a similar nonvolatile weight percentage (Table 1). Through this work, a series of additives was used for initial testing and formula adjustments to observe resin qualities and changes over time between each resin. Additionally, a series of tests from the American Architectural Manufacturers Association (AAMA) was implemented to better compare

and contrast these resins and their performance under a standardized test framework.

Experimental Methods

The following four resins were tested in this project: R0, R1, R2 and R3. The first three resins were provided by Supplier A, and R0 was the all-acrylic standard.

Two different formulations were prepared using these four resins. The first formula was made using approximately 95% resin of total formula weight and utilized a hydrophobically ethoxylated urethane (HEUR) thickener along with a defoamer, surfactant, coalescing agent and biocide (Table 2).

The second formula reduced the resin weight to 31–34% of the total formula weight, changed the thickener to hydroxyethyl cellulose (HEC), increased the coalescing

agent concentration and added a pH modifier (Table 3).

The application performance of these two formulas was then tested. Aluminum Q-panels were used for this portion of the testing in accordance with AAMA for specular gloss (7.2), dry film hardness (7.3), dry film adhesion (7.4.1.1) to various substrates, gloss retention (7.9.1.4) and color retention (7.9.1.2) through simulated weathering (D). First, each panel was cleaned and coated with a white primer before application of the topcoat. The topcoat layer was then sprayed onto the primer and allowed to cure for 72 hours under ambient conditions. Formula 2 required a five-minute oven cure for the topcoat prior to testing.

The same procedure was followed for salt spray corrosion re-

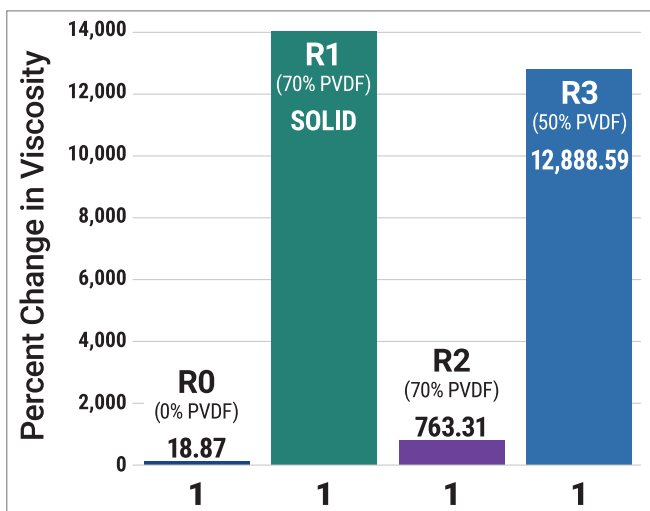


Figure 2. Percent change in viscosity of each sample from Formula 1 after accelerated aging for 2,000 hours in a 50 °C oven.

sistance testing (7.8.2), with the modification of using steel panels due to their higher oxidation affinity compared to aluminum. Only Formula 2 was used for this portion of testing, and each sample was applied to two panels.

Results

Accelerated Aging

The pH and viscosity were measured for each of the eight samples over the course of 10 weeks. All samples were held in an oven set to 50 °C and removed periodically for mixing and cooling to 77 °F prior to data collection. From Figures 1 (page 23), 2 and 3, it is shown that R1 in Formula 1, without a pH modifier, experienced the largest change in pH compared to the other resins. The point at which the pH for this sample decreased below 7 was accompanied by solidification of the sample after one week in the oven. The viscosity instability of R1 became evident during week six, when Formula 2 also experienced hardening and separation from solution.

Additionally, Figure 2 indicates some instability for R3 in Formula 1, but this behavior was not propagated in Formula 2, as the percent change in viscosity of the R3 formulation was consistent with the other samples according to Figure 3.

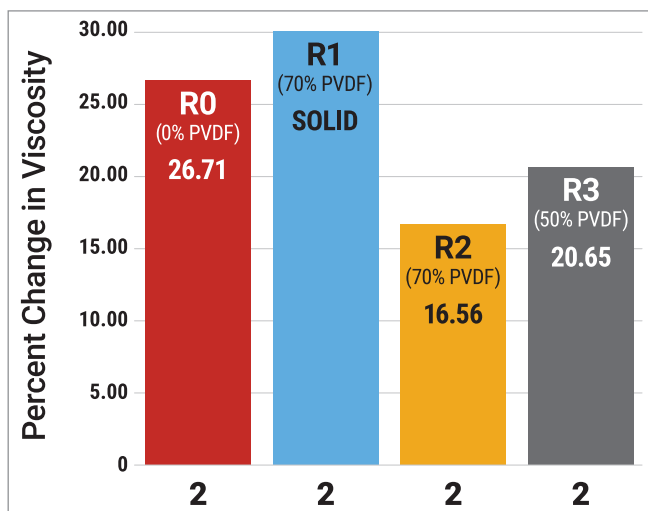


Figure 3. Percent change in viscosity of each sample from Formula 2 after accelerated aging for 2,000 hours in a 50 °C oven.

From this initial series of accelerated aging tests evaluating pH and viscosity stability over 10 weeks, R2 showed greater consistency between the two formulas used in this project and exhibited a lower percent change in viscosity compared to the other resins.

Qualitatively, Figure 4 shows yellowing of the R1 Formula 2 sample compared to the other samples. The syneresis observed in R1 was more pronounced than in the other formulations and was found to occur more frequently with the hydroxyethyl cellulose thickener.

Gloss and Color Retention

(ASTM D 523 and ASTM D 2244)

Based on Figures 4 and 5, the only two resins that showed consistent results from the Q-SUN testing were the all-acrylic standard and R2. Both R1 and R3 completed their 2,000-hour cycles with ΔE values of 1.62 and 1.37, respectively. This represents a substantial difference compared to R0, R2 and the Q-panel that was coated only with the white primer and no topcoat. Further, the gloss of R1 was also greatly impacted and showed the largest change in gloss compared to the other resin formulas. This was primarily due to the low initial gloss value of 5.5, meaning that any change had a larger effect on the percent difference. Again, R2 demonstrated more consistent performance than the other resin formulas.

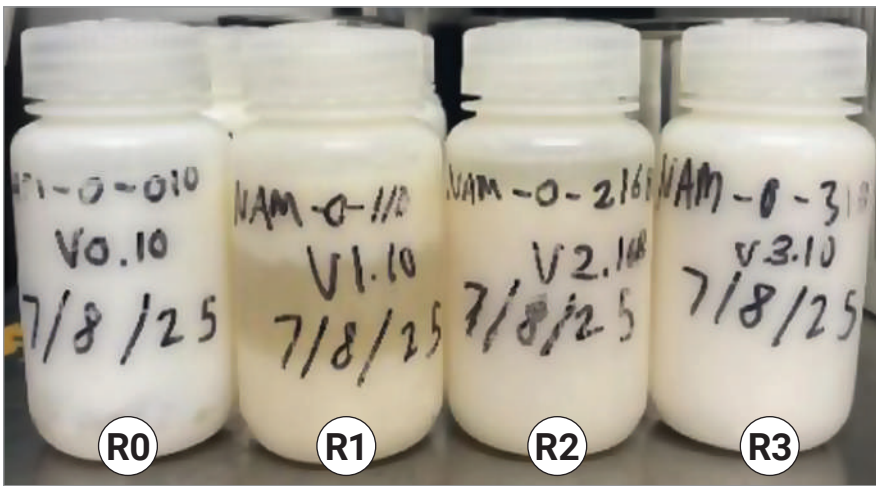


Figure 4. Samples from Formula 2 following the accelerated aging process.

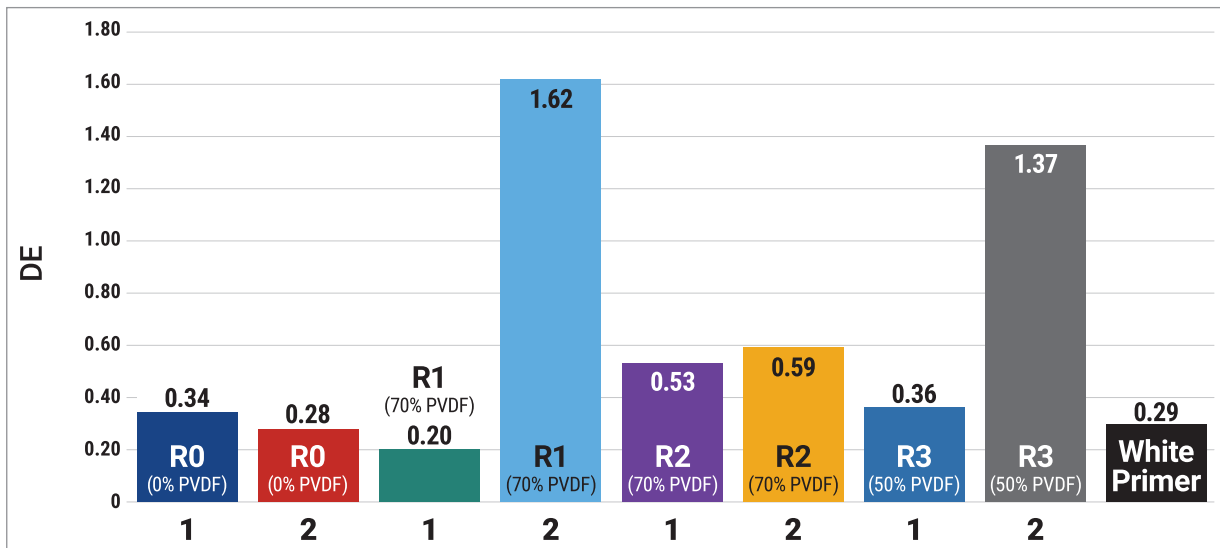


Figure 5. ΔE values for each sample at the end of the 2,000-hour cycle.

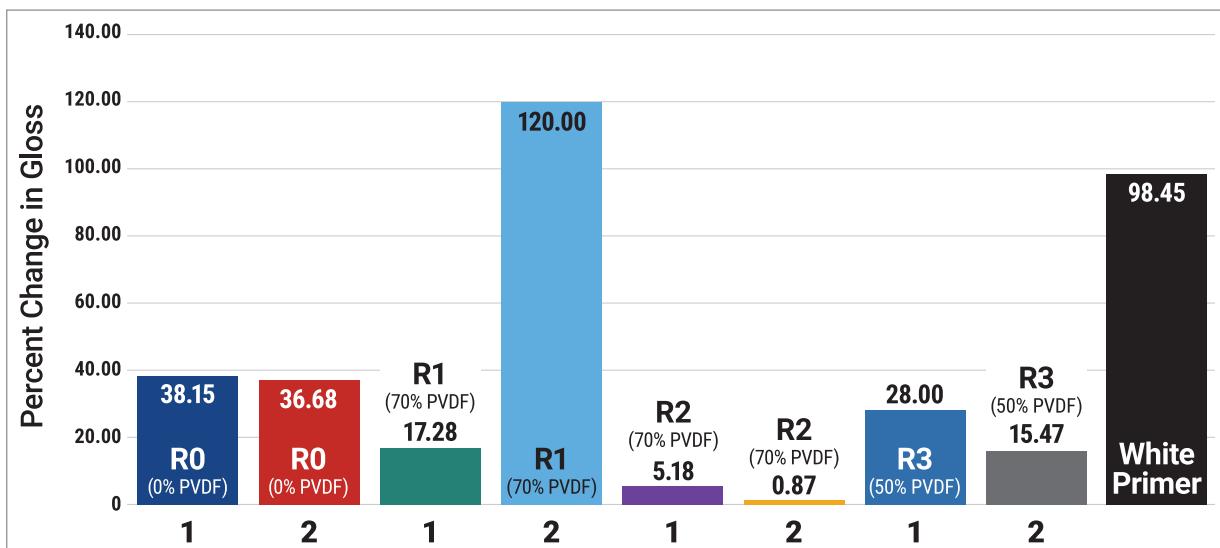


Figure 6. Percent change in gloss for each sample at the end of the 2,000-hour cycle.

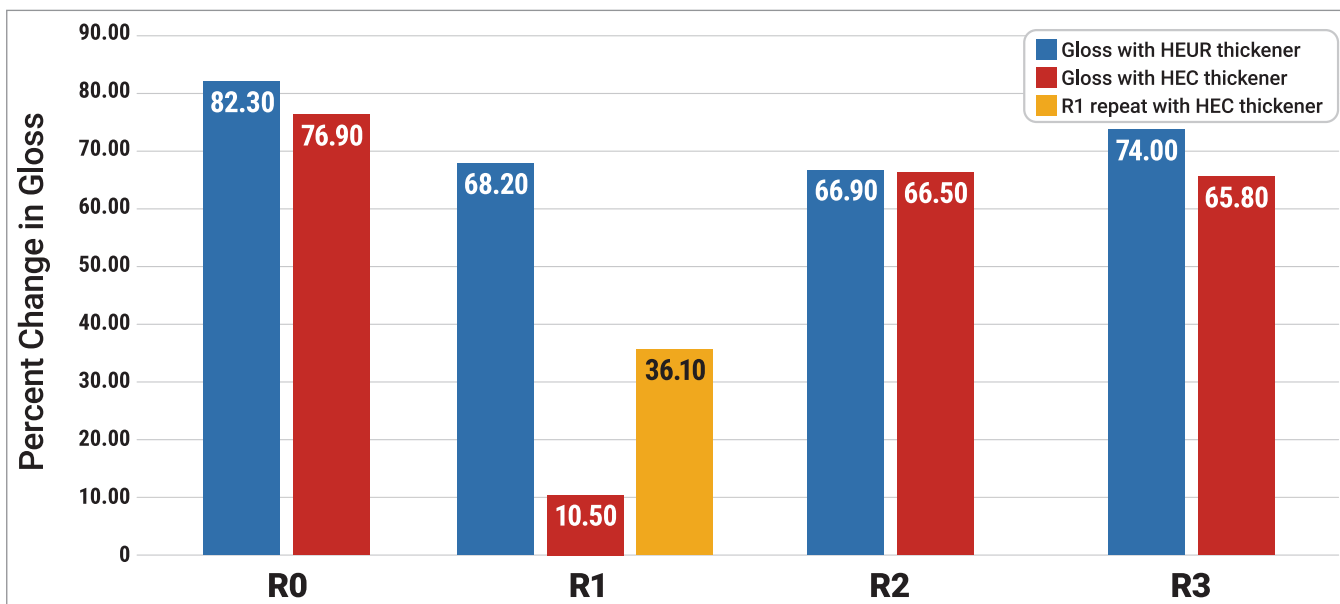


Figure 7. Effect of a hydroxyethyl cellulose thickener on the gloss of the R1 formulation.

When evaluating the Q-SUN results, the consistency of R2 was observed across both formulas, as shown in Figure 4 (page 25). Preliminary results favored R1 during week five, as ΔE values of 0.14 and 0.11 were measured for Formulas 1 and 2, respectively. However, over the final five weeks, the Formula 2 results for R1 increased substantially compared to R0 and R2, ending with a ΔE of 1.62. This increase for Formula 2 of R1 was also mirrored by Formula 2 of R3, which ended with a ΔE of 1.37. This behavior could indicate that the performance of R1 and R3 decreases significantly at lower formulation concentrations compared to R2.

Another observation regarding gloss for R1 is that when paired with the two hydroxyethyl cellulose thickeners evaluated in this project, both produced low gloss readings in the 5–10 range. During the later stages of the project, a different production batch of R1 was received and tested for this same effect. The results are shown in Figure 7.

Salt Spray Resistance (ASTM D 1654) and Degree of Blistering (ASTM D 714-02)

The results of the eight samples from the salt spray resistance testing are displayed in Figure 7 after approximately 2,100 hours of salt fog exposure. The numerical results are shown in Table 4. Through the ASTM D 714-02 test, blistering of each sample was evaluated in

addition to creep from the scribe, as the samples were approximately halfway through the 4,000-hour cycle.

The percent blister failure was evaluated using a ¼-inch grid system based on the exposed area to measure how many squares within the grid blistered. Size and frequency were determined based on the references provided in ASTM D 714-02. Size was determined on a scale of 0–10, with 10 indicating a sample with no blisters. Frequency was categorized into four options of increasing density: few (F), medium (M), medium-dense (MD) and dense (D).

From Table 4, the R2 formula shows slightly better corrosion resistance when comparing the first set of resin samples, as it exhibits both a lower blistering percentage and lower failure in the scribe test.

Dry Film Hardness (ASTM D 3363)

The dry film hardness of the four samples from Formula 2 was evaluated. This test showed that the samples containing R0 and R1 exhibited coating rupture with pencil leads of lower hardness compared to R2 and R3, which ruptured at the 4H lead level. The results are recorded in Table 5.

Substrate Adhesion (AAMA 7.4.1.1)

The substrates used for dry film adhesion testing were white primer, aluminum, steel and plastic. For the

Sample	R0 1	R0 2	R1 1	R1 2	R2 1	R2 2	R3 1	R3 2
Scribed failure rating	7	9	7	7	9	9	7	9
Percent blister failure (%)	29.0	20.4	32.1	2.5	18.5	6.2	45.7	4.3
Size and frequency	4M	6M	3MD	6F	4M	6M	4MD	5F

Formula 2 Sample	Rupture Level
R0	H
R1	2H
R2	4H
R3	4H

Table 4 (above, left). Ratings of the scribed areas on the salt spray test samples with the blister rating. A lower number indicates increased failure in the scribed sample.

Table 5 (above, right). Rupture levels for each sample from Formula 2. From softest to hardest, the H value increases.

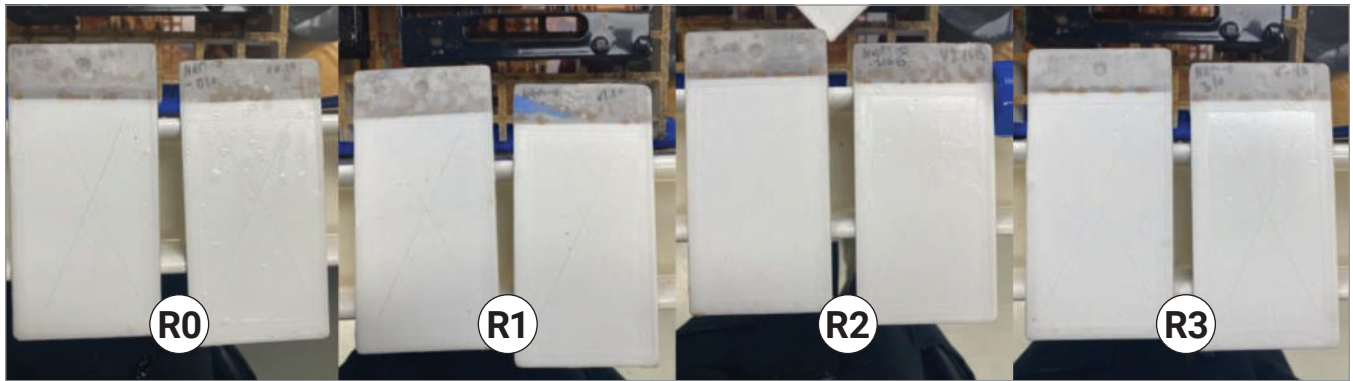


Figure 8. Samples before entering the salt spray test.

Formula 2 Sample	Isopropyl Alcohol		Acetone		MEK	
	Normal	Crosslinked	Normal	Crosslinked	Normal	Crosslinked
R0	Yes	Yes	No	Yes	No	Partial
R1	Yes	Yes	Partial	Partial	No	No
R2	Yes	Yes	No	No	No	No
R3	Partial	Yes	No	Partial	No	Partial

Table 6 (left). Chemical resistance results for Formula 2 samples exposed to three solvents, comparing the standard formulation and a crosslinked version containing 2.5% carbodiimide based on sample weight.

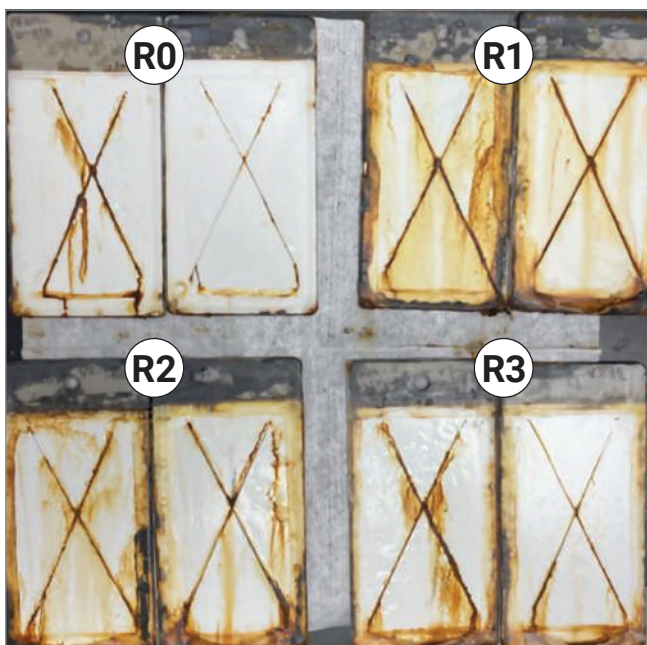


Figure 9. Samples removed for evaluation at 2,100 hours.

primer adhesion samples, all formulations showed 0% failure. This result differed significantly from the direct-to-metal applications on aluminum, steel and plastic. Each plastic adhesion sample was heat treated to improve wetting and adhesion.

All aluminum applications experienced 100% failure, and nearly all steel and plastic samples did as well. R1 Formula 2 performed better according to the dry adhesion test guidelines for steel and heat-treated plastic, with failure ratings of 0% and 4%, respectively.

Chemical Resistance and Crosslinking Effect

Another testing method used for these resins evaluated chemical resistance against three solvents: isopropyl alcohol, acetone and methyl ethyl ketone (MEK). The Formula 2 coatings were applied using a 30-draw-

down bar and cured in a 150 °C oven for five minutes. Each solvent was applied to a cloth and rubbed 50 times over the coating to determine the final result.

Additionally, each formula sample was treated with a Part B carbodiimide crosslinking additive to observe its effect on chemical resistance. Part B was added at 2.5% of the total formula weight. Only R0 and R3 showed improvements in chemical resistance following crosslinking. Overall, R3 exhibited the poorest chemical resistance, while R1 showed slightly improved resistance, with partial resistance to acetone. These results are summarized in Table 6 (page 27).

Table 6 shows that the samples of the standard Formula 2 were

relatively similar in chemical resistance. The R1 formulation showed slightly greater chemical resistance than R0 and R2, while R3 provided slightly poorer resistance. However, the crosslinked versions of samples R0 and R3 showed significant improvements in chemical resistance, reaching partial resistance to methyl ethyl ketone (MEK). A “yes” rating signifies no film alteration, a “partial” rating signifies slight film alteration and a “no” rating signifies complete removal of the film.

Conclusion

The results from this series of tests, including accelerated aging stability, UV weathering for color and gloss retention, salt spray resistance, dry film hardness, film ad-

hesion and chemical resistance, indicate that R2 has advantages over the other two PVDF water-based resins, R1 and R3. Across the scope of testing, viscosity and pH values for R2 during accelerated aging remained consistently lower than those of the other resins and were consistent between formulations. In the color and gloss retention tests, R2 also displayed lower ΔE values and smaller changes in gloss across both formulations.

During salt spray testing, R2 showed lower creep from the scribe and a lower failure rate when evaluating the degree of blistering. Additionally, all PVDF resins exhibited slightly higher hardness than the all-acrylic standard, as shown in Table 5 (page 27). In substrate adhe-



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sion testing, all samples performed with similar adhesion across the tested substrates, with the excep-

tion of R1, which also demonstrated low adhesion failure on steel and heat-treated plastic. **PCI**

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Artificial Intelligence in the Chemical and Coatings Industries

Practical Applications, Benefits and Risks

By **Eric Casebolt**, Vice President, The ChemQuest Group, Inc.

Over the last few years, the use of artificial intelligence (AI) in the chemical and coatings industries has become quite a polarizing topic. The launch of Open AI's ChatGPT in 2022, with its easy-to-use, large language model (LLM) platform, gave everyone access to the vast capabilities of AI. While the first versions

of these LLM platforms certainly had their issues and became the butt of many jokes, numerous people found practical value in them and began to use the tools daily for tasks such as online research, writing and editing articles, or data analysis.

Fast-forward to 2026, and the advancement in capabilities and breadth of use cases for AI makes

it clear that this technology will significantly change the way companies do business. However, many people still dig their heels in and refuse to embrace that change. This crowd raises legitimate concerns, a few of which will be discussed further in this article. But first, let's look at how companies are implementing AI to work more efficiently or gain a competitive advantage.

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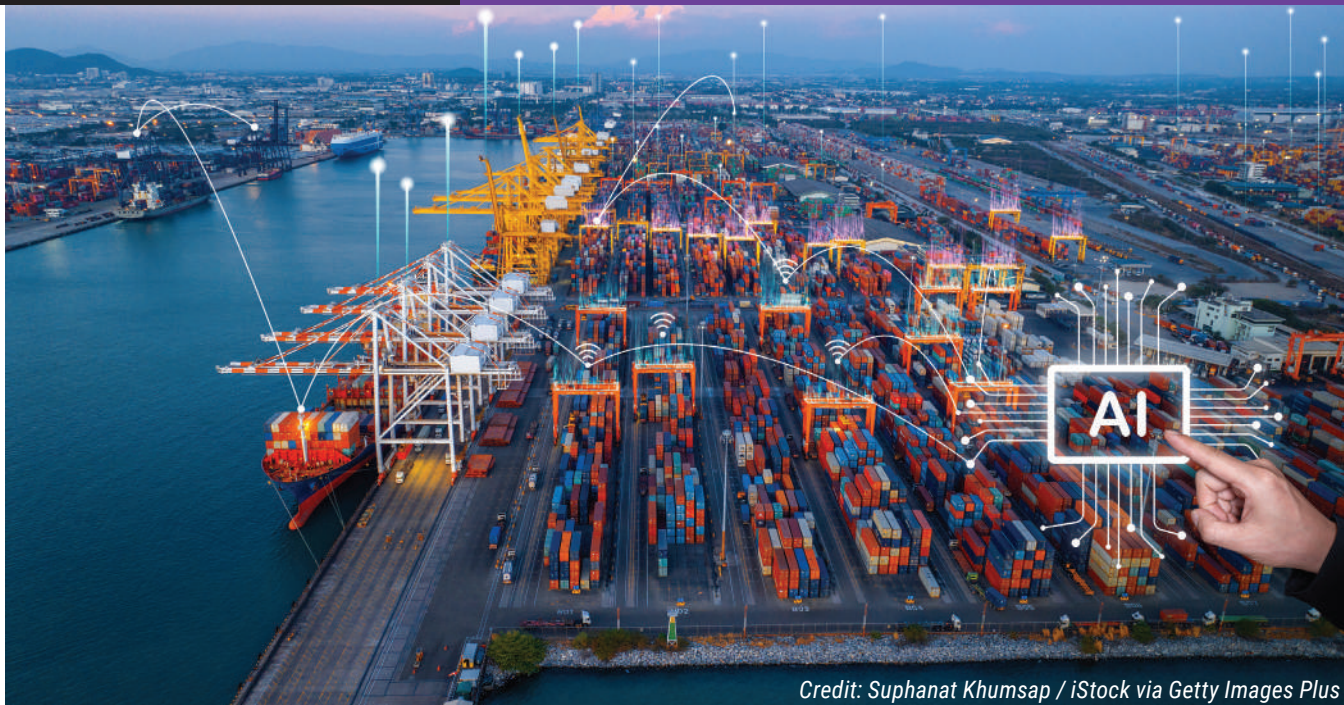
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Use Cases for AI in the Chemical and Coatings Industries

AI use cases exist across most (if not all) industries, and the chemical and coatings industries are no exception. Even when not used on a company-sanctioned basis, many employees across these industries are using LLM platforms as a “virtual assistant” at various levels. With that said, the focus of this article is on the use of AI strategically at companies to simplify internal processes and/or gain a competitive edge. While potential use cases are abundant, two that are often mentioned are in the areas of supply chain and logistics, and research and development.

Supply Chain and Logistics

While Amazon does not qualify as a chemical company, the complexity of its supply chain and logistics is well-known and parallels can be drawn from the use of AI within this forward-thinking company. In a recent message from Amazon CEO Andy Jassy to his employees, he describes AI as a once-in-a-lifetime technology development that has the ability to “completely change what’s possible for customers and businesses.”¹ In addition to various use cases that are specific to an online retailer, Jassy discusses the

use of AI across Amazon’s internal operations, which includes improved inventory placement and demand forecasting, both of which are critical for improving cost structure and delivery speed. It isn’t a major stretch to see how these improvements could benefit companies in the chemical industry.

Along similar lines, companies such as Valdera and Arkestro offer AI-powered software platforms that enable chemical companies to improve raw material sourcing and the procurement process. They boast that their systems typically save their clients 10-20% in overall costs by improving capabilities in supplier and material sourcing, negotiation and streamlining the materials procurement process.²⁻⁴ These companies leverage AI, data science and machine learning to identify and qualify new suppliers based on their ability to meet specifications, rather than just an SKU or CAS number. Additionally, they use historic pricing patterns to anticipate market changes and assist in the negotiations process.

The companies report an impressive list of chemical organizations in their client lists, collectively including BASF, Dow, Evonik, Clariant and many other well-known names in the chemicals and coatings industries. Supply chain and logistics clearly stand out as areas where AI can deliver near-term benefits.

Research & Development

Getting a bit deeper into the predictive capabilities, many companies are beginning to see the benefits of using AI in their product development work – an area where scientists have typically held a high level of skepticism. The skepticism isn't around the ability of AI to analyze a data set and determine the next set of experiments or a possible solution; after all, design of experiment (DOE) has been used for many years in this manner, and there is a clear path for AI to act as a natural extension to that process. Instead, the concern is that under certain conditions, AI can potentially "make things up" or "hallucinate," resulting in inaccuracies or baseless recommendations for follow-up experiments.

Another concern is the complexity of the chemical and coatings formulation world – without knowing the constraints, AI may recommend combinations of materials that are not physically possible. These issues will be discussed in more detail, but first let's

examine how companies like Syensqo and Applied Molecules are leveraging AI in their product development work.

In a recent article in *Chemical Processing Magazine*, Jonathan Katz writes that Syensqo launched an AI-focused division about two years ago, focused on implementing AI initiatives across the organization and is already reaping the benefits.⁵ As an example, Syensqo's technical team successfully utilized AI to analyze data on 4 million molecules to identify a single polymer that met their desired properties for a new product. Their team of data scientists, modeling experts and experimental chemists were able to leverage internal and external databases to arrive at a solution in 18 months; they estimate the discovery would have taken five to six years using traditional methods.

Applied Molecules, a company that develops and offers energy-curable technologies for the CASE industry, has also been leveraging AI and machine

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learning to accelerate their product development.⁶ They use a platform called Albert Breakthrough, from Albert Invent, that reportedly excels at identifying non-obvious correlations within complex scientific data. This “intelligent assistant” enables them to rapidly sift through large databases of chemical and material properties to identify optimal pathways and predict performance.

Paul Snowwhite, CEO of Applied Molecules, recently stated, “Thanks to Albert Breakthrough, projects that would traditionally take three months now take as little as two days.”⁷ At a recent coatings conference, Snowwhite said that “AI is like an Ironman suit. It doesn’t replace scientists, but it gives them the tools to do science better – and as they feed in more data they keep getting better results.” Since Applied Molecules desires to remain at the forefront of technology in their markets, they believe it is critical to “integrate cutting-edge lab technology into the heart of their processes.”

Adoption of AI at Coating Manufacturers

I have spoken with many leaders in the coatings industry, and while there are many potential AI use cases for coating manufacturers, most are hesitant to give specific examples of how the technology is being implemented within their organizations. What is clear from these discussions is that all the major coating manufacturers are at the very least experimenting with AI in their processes, including supply chain and logistics, R&D, coating formulation, color matching and optimizing coating application processes.

What is unclear is how far along these companies are in their implementation efforts, as they tend to keep details a bit closer to the vest regarding information that they consider a competitive advantage or that may affect end-user perceptions. Nevertheless, one can conclude that coating manufacturers, much like raw material suppliers, are utilizing AI and will continue to adopt the technology on a broader scale to capture its benefits in their operations.

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Common Concerns Inhibiting the Adoption of AI

With all the upside potential of AI, it may seem that every company would be pushing forward to implement this technology in their business operations, but that is not the case. In fact, many are highly skeptical of the technology and believe the benefits are not worth the downside risks. What exactly is holding these people back from getting on board and reaping the benefits? In addition to the investment costs, which can be significant depending on the specific initiative, a few reasons come up repeatedly that could have clear, negative impacts if not managed properly. Among them are security of information, output accuracy and potential overreach.

Security of Information

Chemical and coatings companies are a highly secretive bunch, and rightly so, given that their proprietary information plays a major role in their ability to compete. Additionally, most people's familiarity with AI is limited to the free LLM AI platforms mentioned earlier, and it is well understood that information input into these platforms is far from confidential. In fact, that information is often used to "train" the model and

can be used by the AI as output to other users, both directly and indirectly.

Based on this knowledge, "trust me, your information is secure" is not going to be enough to convince people in the chemical and coatings industries that their information won't be shared or used in a way that is not desired. Even if the vendor is deemed trustworthy, people have seen enough data breaches to make them think twice before trusting a third party with their valuable information. Security of information remains one of the main concerns regarding the use of AI technology in the chemical and coatings industries.

Output Accuracy

Another common concern involves the accuracy of the information output from AI. If not managed properly, AI models have been known to generate and confidently present information that is not grounded in verified data, evidence, or reality. Many have experienced this issue with commonly used LLM models, but the impact of these "hallucinations" is much more significant when companies are using this information to make business decisions.

While several factors influence AI hallucinations, the issue stems from the AI model generating responses



to questions that do not have a clear answer based on its available information. When the necessary data does not exist, the AI's tendency will be to "fill in the blanks" based on patterns within the data set, causing it to draw conclusions that may be incorrect. The potential for an AI model to hallucinate creates a significant barrier to adoption, because if the AI model lacks credibility, it will not be trusted by the scientific community or with tasks that are business critical.

Potential for Overreach

The issue with AI overreach isn't the science-fiction scenarios that are the subject matter of many books and movies. Instead, the real concern is that the AI model's role may expand faster than governance — it may start deciding rather than advising in the business environment. That is an important distinction, because the consequences of those decisions sit with the company, not with the AI model, and thus human oversight is critical.

For example, an AI pilot program that was intended to help employees make product recommendations may evolve into making customer-facing responses, completely bypassing the human approval process. The concern here isn't that the AI

model becomes too powerful, but that it becomes powerful without accountability.

Risk Mitigation Strategies

When researching the use of AI within the chemical and coatings industries, there are a few common themes regarding how companies manage the potential risks:

- **Internal/private deployment** — AI models for company usage should be behind firewalls or contained within a closed environment to avoid information leakage and prevent interaction with the external environment. This is of critical importance to protect IP and data confidentiality, as well as to control the information that the AI uses in its decision-making processes.
- **Domain constraints and AI rules** — The information that the AI model has access to and the range of activities that it is allowed to undertake must be constrained to reduce the potential for hallucinations and overreach. Access to information should be limited to data that is validated and approved for use. Guardrails should be used to limit the AI to activities that are within its scope-of-use, including the type of prompts it is allowed to answer.

- **Permissions and auditing** — A tiered access system should be used to restrict data and AI access by employee role to avoid cross-project or inter-company information leakage. Additionally, prompts and logs should be recorded and auditable, creating audit trails that can be used in the event of data leaks or misuse. Outputs should be spot checked for accuracy, and the AI model should be modified as necessary.
- **Pilot deployment and oversight** — Start with a limited scope on non-critical business activities and gradually scale while evaluating risk, performance and governance.

It is highly recommended to engage a third party that is current on the latest AI technologies early in the process, as they will play a critical role in laying out a roadmap for the specific use case. In addition to building the roadmap, the selected partner should also be able to recommend specific types of software or develop a custom AI model as needed.

Educate Yourself and Make Informed Decisions

Overall, the potential benefits of AI are significant and will likely provide early adopters with a meaningful competitive advantage. While valid concerns

surround the use of AI, including those related to security, accuracy and overreach, these risks can be mitigated through the use of guardrails, governance and human oversight.

Rather than ignoring what may be a once-in-a-lifetime technological shift, companies and individuals should take the time to understand how AI works and where it can be applied responsibly within their organizations and personal life. Perhaps Amazon CEO Andy Jassy said it best in his message to employees: "... be curious about AI, educate yourself, attend workshops and take trainings, use and experiment with AI whenever you can, participate in your team's brainstorming to figure out how to invent for our customers more quickly and expansively, and how to get more done with scrappier teams."

For companies and individuals in the chemical and coatings industries, this is one of those moments where it is better to understand the technology and make informed decisions rather than dismissing it outright and being forced to play catch up at some point in the future.

To learn more, reach out to the author at ecasebolt@chemquest.com or visit <https://chemquest.com>. **PCI**

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Polyurea vs. Polyurethane Chemistry for Concrete Waterproofing

Performance Trade-Offs for Formulators

By **Oleg Maslennikov**, Co-Founder & Technical Director,
Technologies for a Better Environment

The Chemistry Decision

Continuous immersion concrete assets (clearwells, reservoirs, basins) push coatings into conflicting requirements: fast return to service, crack bridging, long-term adhesion, resistance to chlorination and pH excursions and — in potable service — NSF/ANSI/CAN 61 limits. The chemistry choice

— polyurea vs. polyurethane — sets non-negotiable boundaries: polyurea's amine-isocyanate reaction delivers near-instant gel and high hardness, while polyurethane's hydroxyl-isocyanate path provides workable pot life and a lower effective modulus. The sections below distill what those differences mean on concrete.

Cost-Performance Analysis for Formulators

Parameter	Aromatic Polyurea	Aromatic Polyurethane	Aliphatic Polyurea	Aliphatic Polyurethane
Raw material cost	\$4.00-\$5.50/lb	\$3.00-\$4.50/lb	\$5.25-\$7.00/lb	\$4.00-\$6.00/lb
Typical DFT	60-80 mils	40-60 mils	60-80 mils	40-60 mils
Material cost at 60 mils	\$4.80-\$6.60/ft ²	\$3.60-\$5.40/ft ²	\$6.30-\$8.40/ft ²	\$4.80-\$7.20/ft ²
Abrasion loss (ASTM D4060)	28-33 mg	50-80 mg	28-35 mg	45-75 mg
Shore hardness	D 50±5	A 80±10 (D 30±5 equiv)	D 45±5	A 75±10 (D 25±5 equiv)
Typical elongation	225-400%	400-600%	200-350%	400-600%
Equipment investment	\$25,000-\$45,000 (spray)	\$8,000-\$45,000 (hand to spray)	\$25,000-\$45,000 (spray)	\$8,000-\$45,000 (hand to spray)

Table 1. Raw material cost and coverage comparison.

Note: Coverage assumes 100% solids, density 8.8–9.5 lb/gal and 1 gal = 1,600 ft²-mil. "Material cost @ 60 mils" is raw materials only (no waste, consumables or labor). Installed costs are typically ~15–25% higher for polyurea (overspray) and ~5–10% for polyurethane.

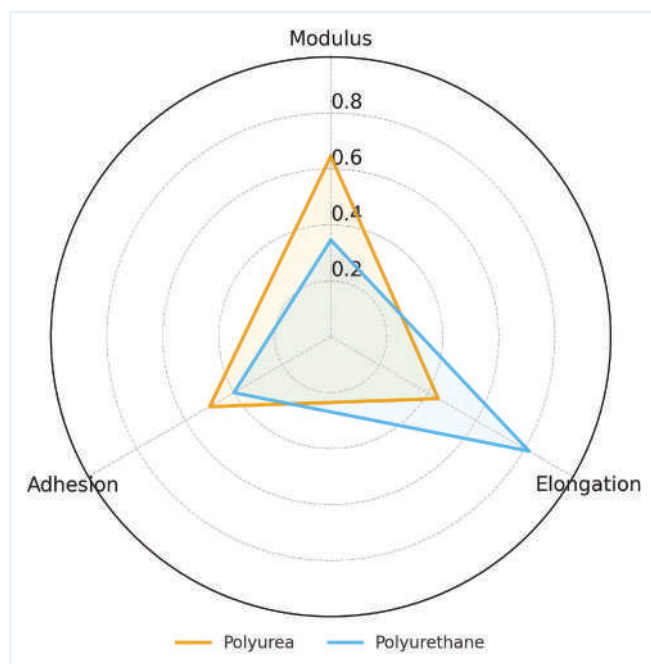


Figure 1. Modulus-elongation-adhesion triangle: Polyurea vs. polyurethane (normalized; modulus shown illustratively as an inverse proxy of elongation).

Credit: TFBE

Fundamental Chemistry Comparison

Polyurea Formation (Amine + Isocyanate → Urea)

- **Reaction:** $R-NCO + R'-NH_2 \Rightarrow R-NH-CO-NH-R'$ (urea).
- **Kinetics:** Gel 3–10 s at 150–160 °F (65–71 °C); single-pass high build with low exotherm.

- **Levers:** (1) Isocyanate functionality (~2.7 MDI) → cross-link density; (2) Amine equivalent weight → hardness (Shore D ~45–65); (3) Polyether MW (1,000–4,000) → elongation.

Polyurethane Formation (Polyol + Isocyanate → Urethane)

- **Reaction:** $R-NCO + R'-OH \Rightarrow R-NH-CO-O-R'$ (urethane).
- **Kinetics:** Pot life 20–90 min (catalyst and temperature dependent); hand or spray application.
- **Levers:** (1) Polyol type (polyether vs. polyester); (2) OH number (28–56 mg KOH/g) → softness and flexibility; (3) Catalyst (tertiary amines vs. bismuth or zinc); (4) Reactive diluents for viscosity control.

Mechanical Property Comparison

Laboratory testing per ASTM D412 (tension and elongation) and ASTM D624 (tear) shows distinct profiles (see Figure 1; Table 1).

Polyurea Performance Profile

- **Hardness:** Shore D 50 ± 5
- **Tensile:** 2,700–3,000 psi (18.6–20.7 MPa)
- **Elongation:** 225–400%
- **Tear:** 400–450 pli (70–79 kN/m)



Credit: Vladimir Zapletin / iStock via Getty Images Plus

- **Abrasion (D4060):** 28–33 mg
- **Interpretation:** High cross-link density → abrasion and impact strength; higher modulus concentrates interfacial peel stress at the concrete interface.

- **Tear:** 200–350 pli (35–61 kN/m)
- **Abrasion:** 50–80 mg loss (higher than polyurea)
- **Interpretation:** Lower modulus accommodates movement with reduced peel stress; softer films are more vulnerable to puncture and abrasion in traffic.

Formulation Insight: Hardness vs. Peel Stress

Raising hard segment content increases chemical and abrasion resistance but raises elastic modulus and interfacial peel stress during thermal cycling and movement. A Shore D ~60 polyurea film can impose ~2x the peel stress of a Shore A ~80 polyurethane at comparable strain.

Mitigations include reducing hard segment content, raising soft segment MW (2,000–4,000) or adding 5–15 phr plasticizer, with some chemical resistance trade-off.

Polyurethane Performance Profile

- **Hardness:** Shore A 70–90 (~Shore D 20–40, approximate)
- **Tensile:** 1,800–2,500 psi (12.4–17.2 MPa)
- **Elongation:** 400–600%

Application Characteristics and Field Constraints

Polyurea (Spray Only, Fast Gel)

- **Equipment:** Heated plural-component (e.g., Reactor), ≥2,000 psi, hoses 150–160 °F (65–71 °C), purge gun. Capex \$25,000–\$45,000.
- **Process sensitivities:** Component viscosities at temperature (A: 100–160 cP; B: 40–50 cP); component $\Delta T \leq 10$ °F. Moisture less critical than PU; overspray waste 15–25%.
- **Schedule:** Return to service ~4–6 h (light).

Polyurethane (Hand or Spray, Workable Pot Life)

- **Equipment:** Spray at 120–140 °F or roller (3,000–8,000 cP) or trowel (20,000–40,000 cP). Capex \$8,000–\$45,000.

- **Process sensitivities:** Moisture critical—excess moisture can generate CO₂ (foaming/pinholes); manage via dew-point control and concrete moisture testing (e.g., ASTM F2170).
- **Schedule:** Light service 24–48 h; full cure and disinfection 3–7 days.

Quick Levers to Reduce CO₂ Foaming at High RH

1. **Moisture scavenger:** p-toluenesulfonyl isocyanate 0.5–2 wt% in A side.
2. **Catalyst strategy:** Reduce amine 30–50%; bias to bismuth or zinc.
3. **Hydrophobic fillers:** Treated CaCO₃ or fumed silica 1–3%. Expect 15–40% slower cure; verify in-field mockups.

Chemical Resistance Performance (ASTM D543 Guidance)

- **pH exposure:** Polyurea excels from pH 2–13 (chalks at long acidic exposure); polyurethane

(polyether) is excellent in neutral pH 6.5–8.5 and good in alkaline, with risks above pH 12. Polyester polyurethanes are less hydrolytically stable.

- **Chlorine and oxidizers:** Municipal residuals 0.2–4.0 ppm are generally tolerated by both chemistries. Short-duration shock events can reach 4–10 ppm — aromatic polyurea may surface oxidize (shallow), while polyether polyurethane holds well; aliphatic systems avoid UV yellowing at higher cost.

Adhesion to Concrete (ASTM D7234 Pull-Off)

- **Polyurea (CSP 3–4):** Initial 500–900 psi (3.4–6.2 MPa); after 5 years immersion 400–700 psi (2.8–4.8 MPa); after thermal cycling 350–600 psi (2.4–4.1 MPa).
- **Polyurethane:** Initial 400–800 psi (2.8–5.5 MPa); 5 yr 350–650 psi (2.4–4.5 MPa); thermal cycling 300–550 psi (2.1–3.8 MPa).



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- **Formulation and installation factors:** Low-viscosity epoxy primers (200–800 cP) for pore wetting; maintain primer tack and recoat window 12–24 h for polyurea; moisture-tolerant PU can sometimes bond direct at RH <75%.
- **Decision tip:** If moisture control is difficult (tight schedules, high RH), PU with MVB primer is lower risk. Polyurea demands tighter moisture control but yields higher ultimate adhesion.

**With appropriate primers,
moisture control and
QC, both chemistries
routinely exceed
20-year service life
in immersion.**

NSF/ANSI/CAN 61 for Potable Water (Overview)

- **Polyurea:** MDI-based prepolymer, amine-terminated polyether; NSF/ANSI/CAN 61 compliance is driven by extraction testing (including high surface-area-to-volume conditions) and formulation control of potential extractables. Fast cure while meeting extractables targets requires careful amine reactivity and NCO functionality tuning.
- **Polyurethane:** Aliphatic prepolymer (HDI/IPDI) for UV; polyether polyol; bismuth or zinc catalysts; controlled free NCO. Longer pot life aids degassing, mixing and surface quality.

Final requirements depend on product category and test plan; examples above are typical, not universal.

Field Performance (Condensed Case Studies)

Case 1 – Wastewater Activated Sludge Basin (11 Years)

- **System:** Aromatic polyurea 60 mil over epoxy primer (8–10 mil); geotextile at joints; plural-component spray.
- **Service:** pH 5.8–8.2; seasonal 40–75 °F; H₂S 5–50 ppm; continuous immersion.
- **Results (10-year inspection):** Adhesion 520 psi (3.6 MPa) avg/12 pulls; cohesive concrete failure; no delamination or holidays (ASTM D4787); minor chalking above waterline; Shore D rose 50 → 55; elongation held ~380%.
- **Takeaway:** High cross-link density handled variable pH; joint reinforcement prevented stress concentration.

Case 2 – Potable Water Clearwell (7 Years)

- **System:** Aliphatic polyurethane 40 mil (NSF 61) over MVB epoxy (10–12 mil); spray walls and roller details.
- **Service:** 0.5–2.5 ppm-free chlorine; pH 7.2–8.0; underground 45–68 °F; 2.3 in differential settlement over 5 years.
- **Results (5-year inspection):** Full continuity across movement joints; adhesion 480 psi (3.3 MPa) avg/8 pulls (100% cohesive); no UV yellowing; 72 h hydrostatic test at design head (12 ft): no leakage.
- **Takeaway:** Lower modulus and high elongation accommodated settlement without adhesion loss; aliphatic premium justified for UV and appearance.

Application Labor Impact (Quick View)

- **Polyurea:** 1,500–2,500 ft²/day; higher equipment care; 15–25% waste; RTS 4–6 h.
- **Polyurethane:** 800–1,500 ft²/day (hand) or 2,000–3,000 ft²/day (spray); 5–10% waste; RTS 24–48 h; full 3–7 days.

Selection Criteria (At a Glance)

- **Favor polyurea when:** Fast RTS, high abrasion and impact, extreme pH, spray-viable scope, single-coat high build 60–125 mil needed.
- **Favor polyurethane when:** Hand work or complex details, significant movement (soft soils, seismic or thermal), longer working time, lower raw material cost, superior aliphatic color retention.
- **Hybrid approaches:** Urea-rich hybrids (~70–80% urea / 20–30% urethane) blend fast set with improved elongation and cost balance.

Future Formulation Signals (Brief)

- **Sustainability:** Bio-based polyols (10–50%), zero VOC at 100% solids; viscosity management is the challenge.
- **Regulation:** Diisocyanate training and exposure rules (EU); scrutiny of certain aromatic diamines; evolving NSF 61 extractables.
- **PFAS removal:** Reformulating wetting and leveling packages without fluorinated additives.

Conclusions

Polyurea and polyurethane each solve different concrete immersion problems. Polyurea's fast gel and higher hardness favor rapid turnarounds, high-build single passes and aggressive pH; polyurethane's workable pot life and lower modulus favor complex detailing, movement and potable water aesthetics. With appropriate primers, moisture control and QC, both chemistries routinely exceed 20-year service life in immersion.

For formulators, anchor decisions to: (1) Cure kinetics vs schedule; (2) Modulus and elongation vs. movement; (3) Chemical profile vs pH and chlorination; (4) Moisture conditions vs primer strategy, (5) Installed cost vs equipment and waste. Use Figure 1 and Table 1 (page 39) as quick proxies when aligning chemistry to service conditions. **PCI**

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- ASTM D624 – Tear strength of elastomers
- ASTM D2240 – Durometer hardness (Shore)
- ASTM D4060 – Abrasion (Taber)
- ASTM D4541/D7234 – Pull-off adhesion (including concrete)
- ASTM D4787 – Continuity verification of linings on concrete
- ASTM F2170 – In situ RH of concrete floor slabs
- ASTM D543 – Chemical reagent resistance of plastics
- NSF/ANSI/CAN 61 – Drinking water system components
- ICRI 310.2R – Concrete surface preparation (CSP)



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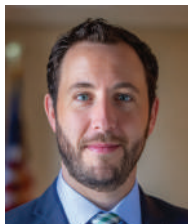
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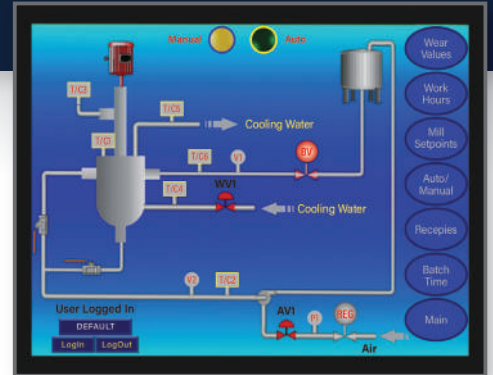
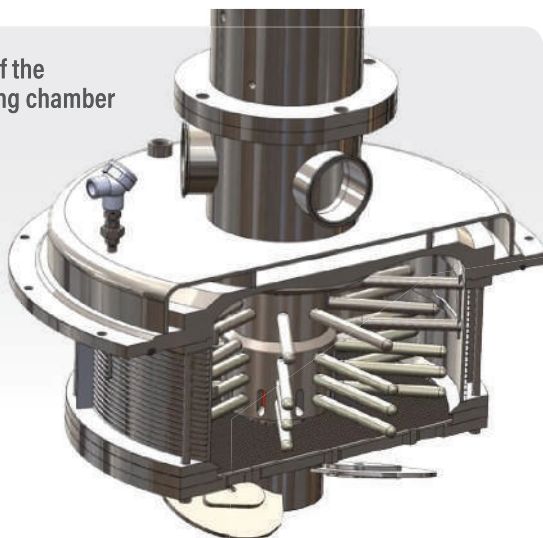
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