New Rheology Modifier Delivers Widespread Sustainability Value to Protective Coatings

Edward M. Petrie
EMP Solutions
Cary, NC

Defining sustainable paints and coatings

Sustainable paints and coatings are those that reduce harm to the environment throughout the product's entire lifecycle without sacrificing cost or performance. This includes the use of safe and environmentally responsive materials in the paint formulation. However, sustainability aspects have expanded well beyond just reducing volatile organic compounds (VOCs) and other environmentally harmful components. The definition of sustainability now also encompasses all aspects of the lifecycle (e.g., formulation, manufacturing, application, and disposal). One must also consider improvements in performance and durability to reduce maintenance and replacement costs.

Sustainability efforts often make good business sense, promising to deliver revenue gains, cost savings, and other benefits that lift enterprise value.[1] For most paint suppliers, sustainability has become an essential part of their marketing strategy. For example, sustainable certifications allow suppliers to differentiate themselves by proving that their products meet key environmental factors.

Ways to bring sustainability to the paints and coatings industry

There are many ways of bringing sustainability to the paints and coatings industry. A simple change in one minor additive in a paint formulation can promote sustainability downstream, all the way from the paint formulator to end-user. A rheology modifier is a good example of this. The amount usually introduced is very small, often less than 1%, however the impact on

[1] *How Companies Capture the Value of Sustainability: Survey Findings*, McKinsey and Company, April 2021.

properties and sustainability can be huge. Rheology modifiers are important to the overall success of a paint formulation. These additives impact leveling and control the paint's stability, application properties, open-time, and sag resistance.

A new generation of diamide rheology modifiers

A new generation of diamide rheology modifiers from Elements (THIXATROL® products) can achieve sustainable results from the formulator to the end-user. These organic thickeners have been developed for high performance industrial coatings. They are designed for use in solvent borne, high solids, and solventless paint formulations.

THIXATROL® rheology modifiers are diamide based organic thixotropes in powder form (Table 1). They enable the formulation of high-performance industrial coatings systems including epoxy and polyurethane.

THIXATROL® rheology modifiers provide the following benefits versus traditional rheological additives (fumed silica, organoclays, micronized waxes, etc.):

Benefits of THIXATROL® rheology modifiers versus traditional rheological additives

- Easier (much less dust) and safer handling versus fumed silica
- Quicker incorporation to paint
- Compared to fumed silica, 20 times higher density allowing less volume in transport and storage space
- Enhanced spray application due to strong pseudo-plastic flow
- Perfect leveling even at low film thickness
- High efficiency resulting in excellent sag resistance
- Improved viscosity stability on storage
- Labeling-free and based on renewable raw material sources.

Table 1 Organic Thixotropes as Rheology Modifiers for High Performance Protective Coatings

Product	***Suggested Systems***			***Description***	***Recommended Concentration, % of Total Weight****
	Solvent	***High Solids Content***	***Solvent-less***		
THIXATROL® AS 8053	**√**	**√**	**√**	Broad solvent compatibility	0.5-2.0
THIXATROL® PM 8054	**√**	**√**	**√**	Broad solvent compatibility including low polarity systems	1.0-2.5

THIXATROL® PM 8056	√	√	√	Broad solvent compatibility	0.5-2.0
THIXATROL® PM 8058	√	√		Broad solvent compatibility including polar solvents (e.g., alcohols)	0.5-2.0
THIXATROL® MAX	√	√	√	Broad solvent compatibility	0.5-2.0

*For optimal sag resistance. If only anti-settling properties require improvement, 0.2% to 0.5% may be sufficient.

Formulators of protective coatings face both performance and application challenges when using conventional organic thixotropes. Several drawbacks occur with the legacy castor wax or older diamide wax thixotropes.

Drawbacks with legacy castor wax or older diamide wax thixotropes as rheology modifiers

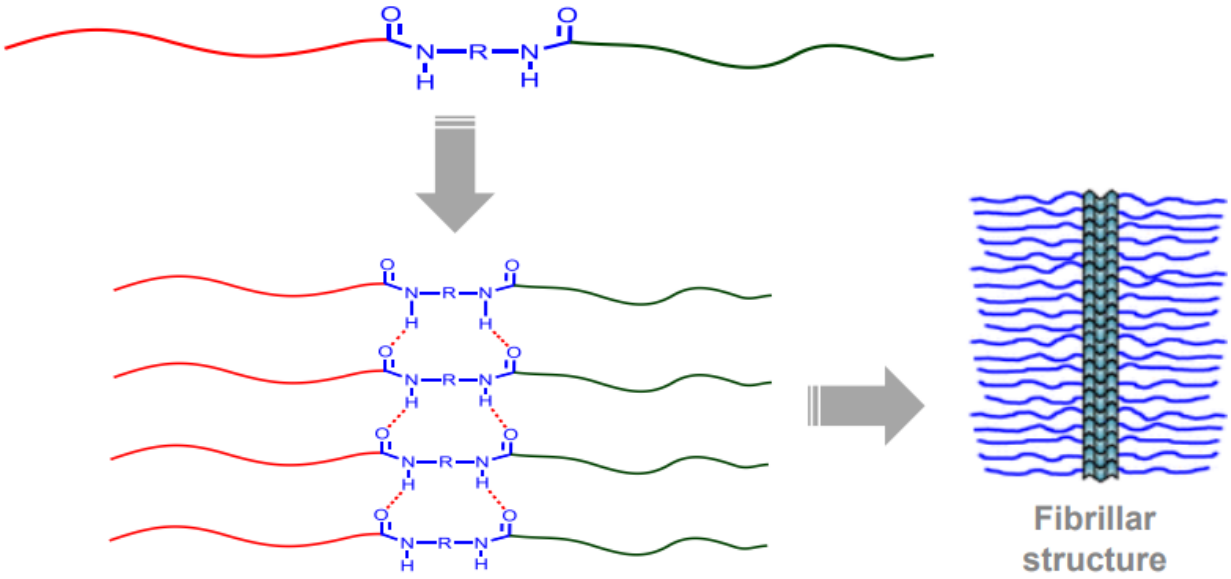
- They need to be carefully dispersed with an appropriate amount of solvent. They lose effectiveness (thickening) in highly polar solvents such as alcohol
- They require a specific temperature activation range and control of shear when processing
- They are prone to undesirable "seeding" or "false-bodying" effects due to over-processing or elevated storage temperatures.

The novel THIXATROL® rheology modifiers reduce these problems and allow for enhanced manufacturing efficiencies, storage stability, and improved process control. As a result, they are very efficient, sustainable rheology modifiers that outperform other thickeners in solvent based, and solventless systems. The high share (greater than 75%) of bio-based raw material in THIXATROL® additives also contributes to meet high sustainability demands.

Mechanism of Activation

The primary types of organic thixotropes are those that are based on castor waxes and those that are based on diamide. Once properly activated, castor waxes increase the viscosity, structure, and yield points of the formulated systems by intermolecular interactions and associations with solvents and polymer forming bridging micelles. The diamide waxes consist of a different molecular structure (Figure 1, top). Due to the nature of the amide functionality, the molecules orient themselves to each other forming a fibrillar structure by intermolecular interaction (Figure 1, bottom).

Figure 1 Thickening mechanism of THIXATROL® diamide molecules.



Like other organic thickeners, THIXATROL® products have specific processing temperature and dwell time requirements in order to develop optimum properties. For complete activation, the additive should be introduced at the beginning of the manufacturing process to obtain sufficient wetting and dwell time. The thixotropic properties benefit from the temperature developed during the pigment dispersion phase.

Binder Versatility

THIXATROL® additives offer great compatibility with a wide range of solvents and binders. The THIXATROL® products consist of inert polyamides, with low amine and acid functionality. As a result, they are suitable for epoxy, urethanes, and other reactive systems.

THIXATROL® thickeners are especially well-adapted to epoxy coatings which have the largest share of the protection coatings market. Because the rheology comes from the building of a fibrillar structure, THIXATROL® additives are more effective in formulations with high-filler loading.

The selection of a suitable organic thixotrope must be done by considering both the chemistry of the solvent and the temperature required for activation. The new THIXATROL PM & AS grades products represent a new class of diamide rheology modifiers developed to be provide proper activation at markedly lower temperatures than traditional organic thickeners based on similar chemistries. This is especially important in solvent-free systems where the activation temperatures are normally high. The main advantage of such low temperature activation is cost saving in the manufacturing process. The process can be carried out without external heating and can generate shorter batch times.

Increasing sustainability through choice of raw material

Sustainable paints and coatings are gaining importance in the market. Low VOC and high bio-content contribute to the rating of a paint as "sustainable". The motivation to paint producers is that they can offer products to contractors and manufacturers who want to maximize sustainability credits for their project.

THIXATROL® organic rheological additives are free of VOCs and are readily used in solventless and VOC compliant solvent-based systems. THIXATROL® rheology modifiers are derived from renewable, bio-based material (castor). The bio-content is greater than 75%. In addition, THIXATROL® additives are labeling- free. THIXATROL® raw materials provide other properties that can increase the sustainability of paints and coatings:

- They are cost effective powders that are highly efficient at low loading levels

- They are easily handled powders (5 µm max) with much less dust and safer handling compared to fumed silica
- They have 20 times the density of fumed silica, allowing less volume in transportation and storage space at the paint manufacturer
- They provide paint systems with stable viscosity
- They have long shelf-life (four years from date of manufacture).

Sustainability through formulation and manufacturing

Within the world of sustainable options, formulation and manufacturing processes need to be considered. Two of the most important factors are formulation cost and complexity. The elements that must be studied include:

- Materials cost and availability
- Reduction in the number of materials that must be inventoried (through improved material compatibility and multifunctionality of additives)
- Reduction in the processing steps required, time consumed, and cost of manufacture
- Savings in overall energy and transportation costs, e.g. by shortening production time
- Processing and product reproducibility through minimal sensitivity to uncontrolled manufacturing variables
- Waste minimization.

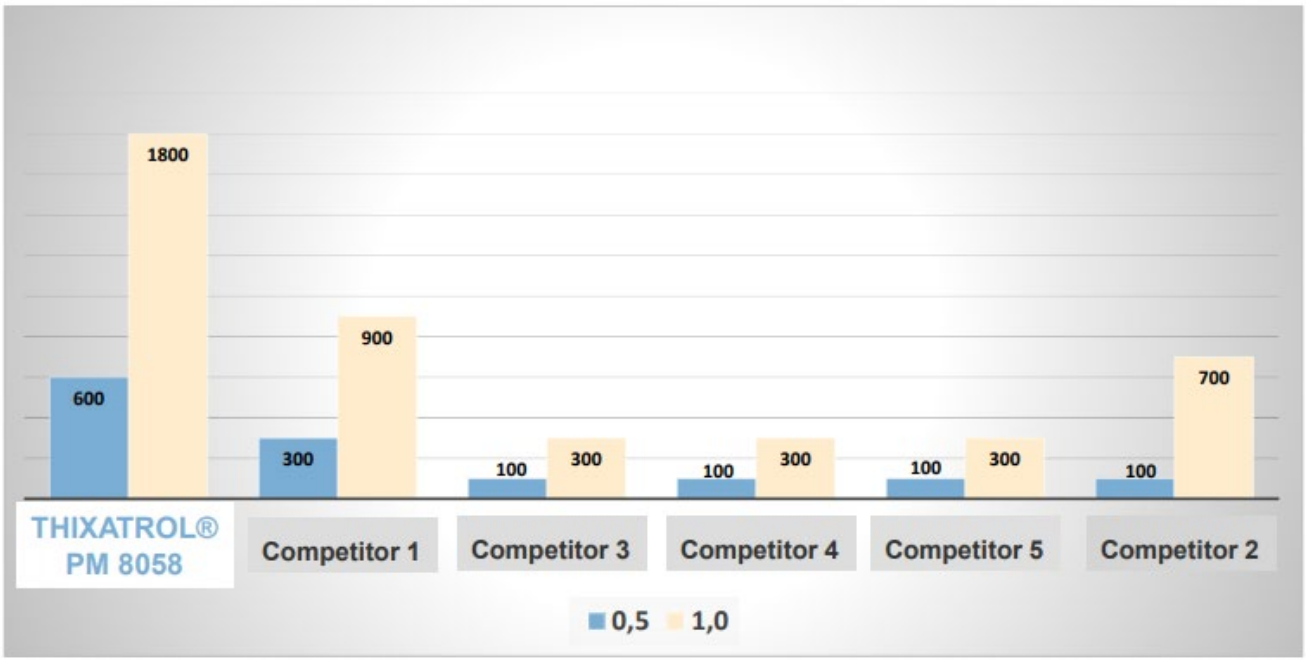
Reduced Additive Demand

THIXATROL® additives provide up to 50% higher efficiency than other thixotropic fillers. Low loading levels (0.5% to 2.0% by total system weight, see Table 1; result in excellent slump / sag resistance and lower additive cost. Lower loading levels also have less pronounced influence on secondary properties such as substrate and intercoat adhesion.

The optimum use level will vary depending on the chemistry of the system. When formulating a new system, a loading ladder study is recommended to determine the precise level of additive needed, the optimum activation temperature and the optimum stirring conditions.

Depending on the application, sag resistance is vital for both producers and end-users of coatings. It is especially important in industrial and protective coatings, where higher builds are required in a single coating. Faster recovery and more elastic behavior provided by THIXATROL® additives leads to better sag control as shown in Figure 2.

Figure 2 Sag resistance (ASTM D4400) of THIXATROL® PM 8058 in 2K high solids epoxy coating. (Sag performance -blade measured at 0.5% and 1.0% thixotrope loading. Determined at activation temperature of 66°C at 12 m/sec blade speed).

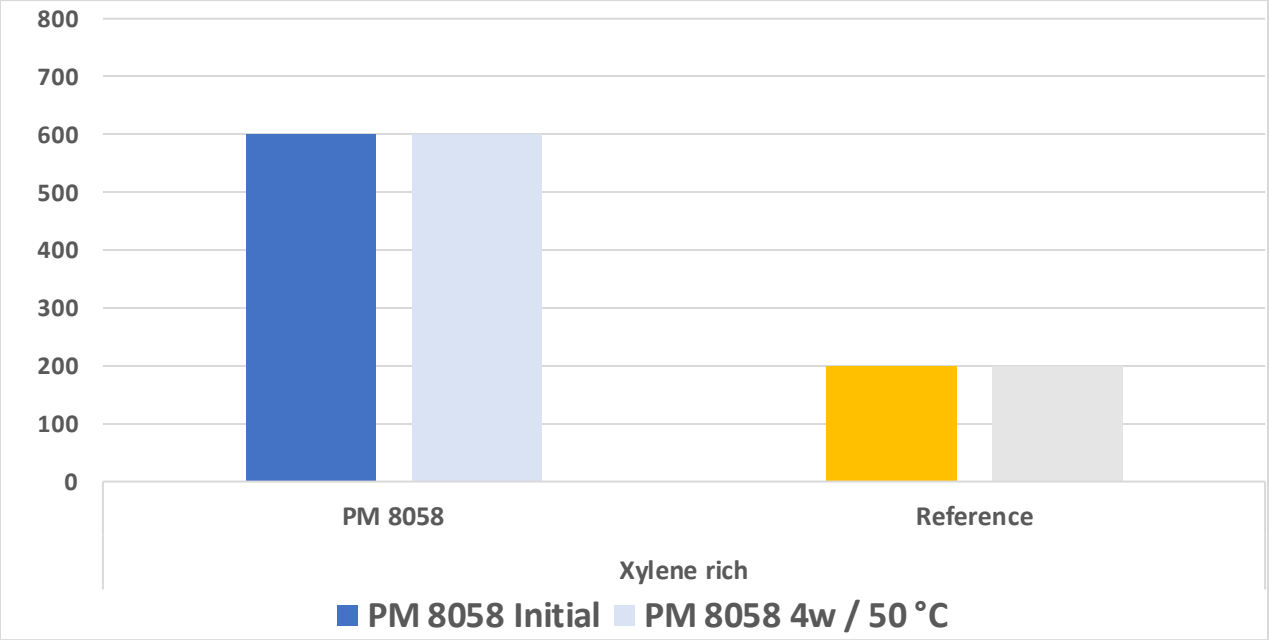


Stable Performance

The aging stability of sag resistance and viscosity is important in many paint systems. For example, protective coatings often consist of suspensions of multiple components in a continuous phase. The functionality of the final product relies on maintaining these suspended components in a dispersed state from the date of paint manufacture to final substrate application and for all the storage conditions that may be encountered.

Sag resistance of THIXATROL® PM 8058 compared to a standard rheology modifier reference after four weeks of storage at 50°C is illustrated in Figure 3. The THIXATROL® additive shows much higher performance than the reference product in xylene with different alcohol types. Alcohols typically cause a post-increase in viscosity. However, the THIXATROL® PM 8058 in xylene rich systems shows no change in viscosity even after the four weeks of aging, providing the most stable performance in sag resistance.

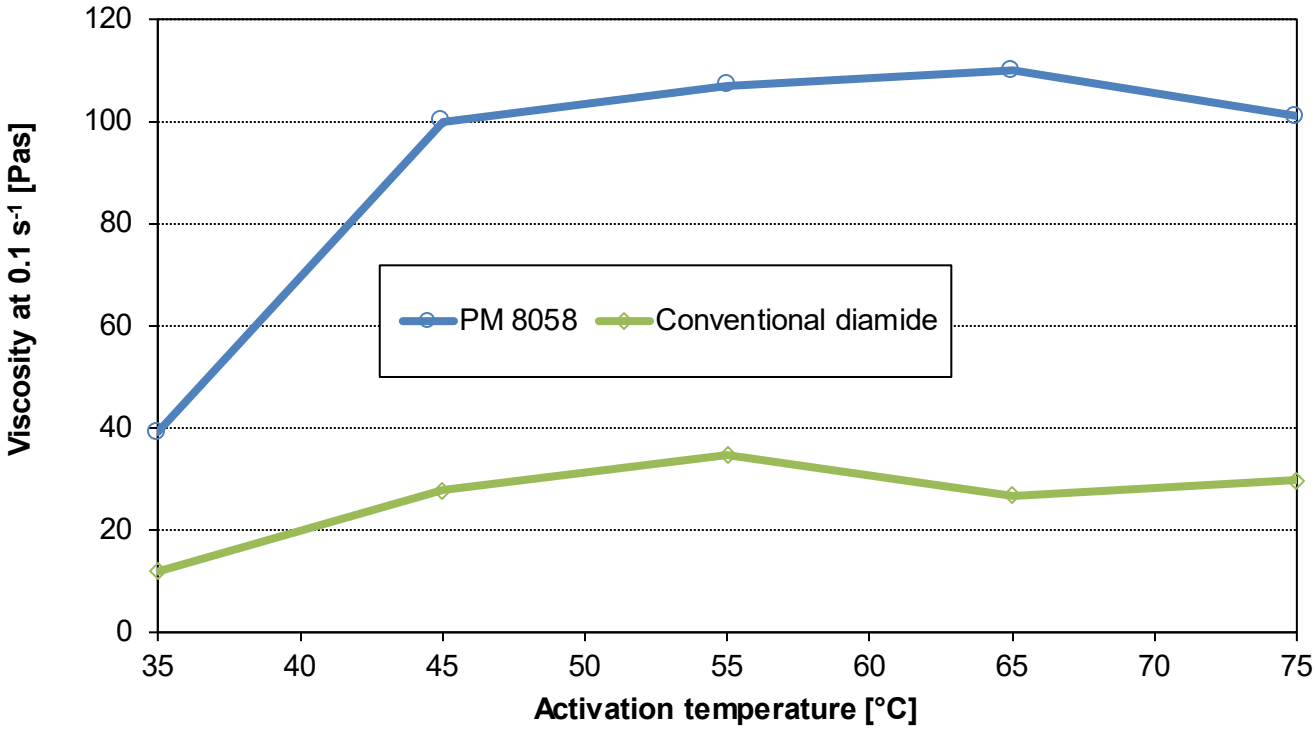
Figure 3. Sag resistance Y axis says viscosity (ASTM D4400) of THIXATROL® PM 8058 in Xylene rich solvent systems after 4 weeks aging at 50°C.



Simplified Activation Temperature and Solvent Compatibility

THIXATROL® rheology modifiers offer more simplified incorporation and activation processes. Mixing incorporation and specific temperature requirements are much broader compared to traditional organic thixotropes.

Most paint producers use just the heat generated during dispersion to activate organic thixotropes. THIXATROL® additives are activated at low temperatures and over a wider temperature range, enhancing manufacturing efficiencies, storage stability, and improved process control. They also act mostly independent from potential temperature variations during processing. I would add the below figure and add some verbiage to exemplify the wider activation temperature window . For example: *PM 8058 shows a wide activation temperature window. Between 45°C and 75°C stable and predictable viscosities can be achieved. The additive provides over the entire temperature range significantly higher viscosity values than the reference rheology modifier.*



The selection of a suitable organic thixotrope must be done in accordance with the polarity of the solvents and the ability to control the activation temperature. Unlike other organic thixotropes, THIXATROL® additives have wider solvent compatibility and are not impacted by polar solvents (Table 2). They provide moderate activation temperatures and little temperature sensitivity in solventless formulations and in systems that contain aromatic solvents (e.g., xylene) and polar solvents (e.g., n-butanol, benzyl alcohol, etc.).

Table 2 Activation Temperatures of THIXATROL® Additives in Various Paint Systems Compared to Conventional Organic Thickeners

Product	***Solventless Systems***	***Solvent Based Systems***		
		Aliphatic	***Aromatic***	***Oxygenated***
Castor wax	60-70	40-55	Not recommended	Not recommended
Polyamide modified castor wax	80-95	60-75	40-55	Not recommended
THIXATROL® AS 8053	30-60			
THIXATROL® PM 8054	50-65			
THIXATROL® PM 8056	50-70			
THIXATROL® PM 8058	40-70			
THIXATROL® MAX	90-105	71-85	60-70	49-54

Add this line under the chart on page 9: Mentioned temperature ranges are general recommendations and should not replace the individual screening of activation temperature

Thixotropy will also depend on the various alcohols used in the paint system. For example, the THIXATROL® PM 8058 additive will provide better compatibility when the formulation contains high levels of iso-butanol, n-butanol or benzyl alcohol. This improved compatibility results in less viscosity drop both initially and after aging.

Reduction of Unwanted Side Effects

In the case of castor wax derivative, if the processing temperature is set too high or applied for too long, the thixotrope will solubilize during the heating process. During the cool down, the solubilized wax immediately comes out of solution and is visible as large particles, so called "seeds," and results in loss of fineness of grind. Due to the significantly higher melting point of the THIXATROL® diamide grades, the risk of classic seeding is minimized.

Another side effect, which mostly occurs with castor wax-based rheology modifiers, is the so-called "false body" effect. When activated correctly into the system but cooled down without agitation, excessively high viscosities will develop. This apparent viscosity rise can be avoided by cooling down while stirring after the activation process. However, the false-body effect can restrict the possibility of filling and packaging hot material.

Without the false body effect, THIXATROL® modified paint systems can be packaged hot, immediately after mixing, with no negative effects. The sag resistance values remain at a high-performance level after aging. Also, unwanted variations in processing (screening and grinding) conditions will not affect anti-sag performance.

The THIXATROL® additives enable reductions in processing costs and formulation complexity. The process for dispersing these rheological additives has the following advantages over conventional additives.

- Easier to incorporate with respect to process temperature control due to:
    - Easier mixing incorporation of powder than "fluffy" silica
    - Wider production operating window, and
    - Lower activation temperatures, putting less demand on equipment and energy consumption
- Throughput at the manufacturers' site can be improved. Cooling down before addition of any additional solvent or polymer is not necessary, and once mixed, the product may be packed hot

- There is less chance of seeding or formation of false body
- Compatibility with a range of solvents (oxygenated, aliphatic, aromatic) as well as with high solids and solventless paint systems.

These advantages lead to improved processability under real-life conditions and provide sustainability value to the paint formulator / manufacturer.

Sustainability through to the end-use

It is generally accepted that 10% of the environmental footprint of coatings is created during formulation, with some 50% generated upstream due to the raw material, and 40% created downstream in end-use and disposal. However, through its choice of ingredients, the industry can impact the environmental footprint of the whole supply chain. [2]

Durable, long-lasting coatings that extend asset lifecycle, while minimizing the need for replacement and maintenance, are examples of end-user sustainability. The protective coatings market segment (industrial, maintenance, and marine) is an excellent example of where sustainability efforts can produce substantial benefits.

Protective coatings include coatings used on consumer products and heavy machinery in oil and gas, petrochemical, infrastructure, power generation, and water and sewage industries. It is estimated that the global cost of corrosion is $2.5 trillion USD. The growth of the protective coatings market ($6.9 billion USD in 2020 to $8.9 billion in 2025[3]) is due to the increasing demand for sustainable products that protect against rust and the need for long-term durability.

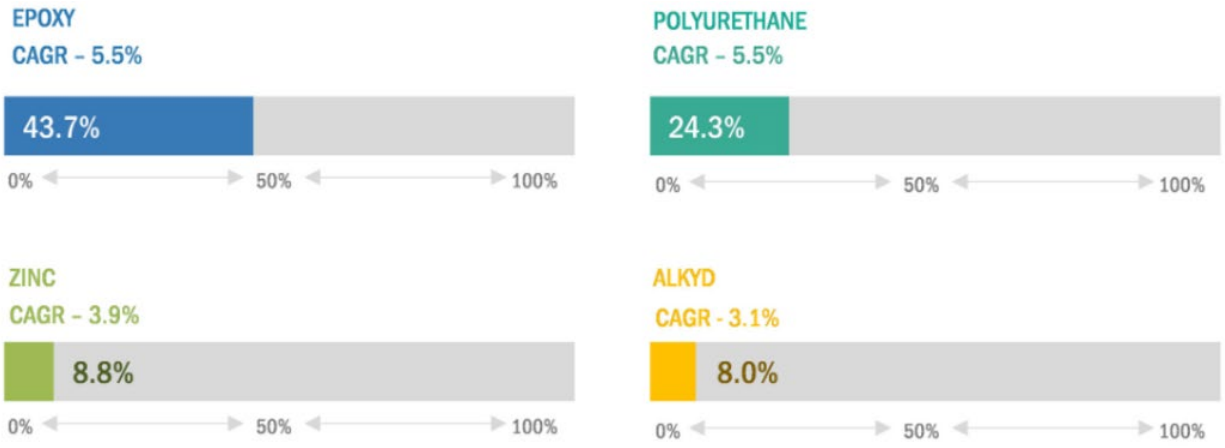
THIXATROL® additives are especially well suited for protective coating applications due to the following factors:

- The industry places high requirements on sag resistance and stability. The paint systems are typically spray applied in high layer thickness (+1000 µm) in one pass.
- The industry is primarily centered on solvent, high-build, and solventless coatings. THIXATROL® additives are capable of withstanding higher amounts of various alcohols and other highly polar solvent components.

[2] Mash, T., "Sustainability in the Coatings Industry", *Paint and Coatings Industry*, April 1, 2015.
[3] Marketsandmarkets Research Pvt Ltd. (www.marketsandmarkets.com).

- Performance properties including durability, moisture resistance, and corrosion resistance are not affected by the thixotrope.
- Intercoat adhesion (necessary with primers and maintenance coatings) is not affected by the rheology modifier.
- THIXATROL® additives are especially well-adapted to epoxy coatings, which have the largest share of the corrosion protection market (Figure 4).

Figure 4 Epoxy coatings represent the largest share of the corrosion protection coatings. (Source: MarketsandMarkets Research Pvt Ltd. (www.marketsandmarkets.com)



Conclusion

THIXATROL® organic thickeners are suitable for use in a variety of modern solvent borne, high build, and solventless paint systems. They reduce much of the complexity associated with the incorporation of other organic thickeners by activation at lower processing temperature, less sensitivity to solvent chemistry, and less sensitivity to uncontrollable process variations. Due to their excellent sag resistance and structure stability storage, they are well suited for the protective coatings market where thicker coatings are dominant.

Sustainability aspects related to THIXATROL® additives go well beyond reducing volatile organic compounds (VOCs). They include reduced additive demand, energy conservation, process efficiency enhancement, use of renewable materials, and much more. The novel THIXATROL additives allow for faster and more flexible throughput in the manufacturing process.

A simple change in rheology additive can also impact the entire value chain by considering overall sustainability effects. With 40% of the environmental footprint downstream of the paint manufacturer, the proper rheology modifier can have a significant impact on the sustainability of the entire life cycle.