Fast Curing Anticorrosion Primers for Steel Protection

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September 12, 2006

“Presented at a meeting of the Thermoset Resin Formulators Association at the Hyatt Regency Montreal in Montreal, Quebec, Canada, September 11 though 12, 2006.

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Abstract: Phenalkamine curing agents for epoxy resins provide an outstanding anti-corrosion protection, fast and low temperature curing, high surface tolerance, large overcoat window and low VOC formulations.

Introduction

Steel is the ideal material for the building of many different structures used in civil engineering and heavy duty industries. Steel remains the cheapest material to build ships. Unfortunately, steel has a major drawback, it rusts. Rusted structures or rusted ships mean poor maintenance and induce a perception of unsafety to the public.

Steel has therefore to be protected against corrosion through painting. Governments, ship builders specify the type of coating to be used guaranteeing thereby the lifetime of the steel structure without any maintenance or repair. Epoxy based coatings are most probably the standard of the industry in terms of anti-corrosion. This technology is indeed the reference for ballast tank coating, where corrosion is a huge problem. Civil engineering steel structures use almost always epoxy coatings as a mid-coat protective coating.

Albeit being excellent performing, epoxy based coatings cure very slowly and are not used when the application temperature is too low, namely close to freezing point. These main drawbacks can be easily avoided by using phenalkamine curing agents. Phenalkamines fast cure epoxy resins even at temperatures below 0°C without sacrificing the anti-corrosion properties.

Important production cost savings can therefore be obtained by using these curing agents. Phenalkamines allow formulations with very low VOC content totally complying with the future new environmental regulations.

Together with these outstanding properties, using phenalkanines provide the applicator with additional advantages like water resistance, surface tolerance.

Finally, phenalkamines are chemical compounds derived from the Cashew Nutshell Liquid (CNSL), a renewable raw material.

Phenalkamine Hardener

Phenalkamines are products derived from cardanol, a natural C_{15} substituted phenol (figure 1). Cardanol is found in the shell of the cashew nut. Cashew nutshell liquid (CNSL) contains 4 main chemicals (figure 2). The main constituent is anacardic acid which transforms in cardanol through heating by decarboxylation.
As shown in figure 1, this particular molecule provides many interesting properties to the coating:

- It enhances the reactivity with epoxy functions through its phenolic function. This OH radical provides especially good adhesion with both metallic substrates and with polyurethane top-coat;
- Its aromatic ring brings chemical resistance;
• Its long aliphatic water repellent chain provides outstanding corrosion resistance and offers some flexibility.

Phenalkamine Technology – A Proven Technology in Civil Engineering

The phenalkamine technology has already been approved for protective coatings throughout the world as illustrated by figures 3. Coating manufacturers that have chosen this technology recognized its fast cure and low temperature cure properties and its outstanding anti-corrosion properties. These properties will be demonstrated further in this paper together with many other advantages.

Figure 3. Proven Technology

Emssperwerk - Germany
Tsing Ma Bridge - China

Middleborough Soccer Stadium - UK
Windmills - Germany
Phenalkamines are widely used in the marine industry for ballast tank coatings mainly. This evidences already their outstanding anti-corrosion properties. When compared to polyamide curing agents, phenalkamines exhibit a similar excellent corrosion resistance as illustrated by salt spray tests (according to ASTM B117) (figure 4).

**Figure 4. Anti-Corrosion Properties**

Phenalkamine based epoxy 2K does not need anti-corrosive pigment to perform well as it is illustrated by salt spray test results in figure 5.

**Curing Properties**
Epoxy 2K based coating are slow curing and require a curing temperature above 10 °C (50 °F). The consequence of this poor curing efficiency is low productivity and an inability to coat outside during winter season in cold climate countries. This inconvenience can be avoided by using phenalkamine curing agents. Epoxy resins, liquid, semi-solid or solid, cure quickly even at relatively cold temperature while keeping a reasonable pot life as illustrated by figure 6.

Cure time is determined by means of a ICI apparatus (ASTM D1640) and corresponds to the time when the needle does not penetrate anymore into the coating.

The pot life is the time required to double the Brookfield viscosity after mixing the components of the paint (ASTM D 2196).
Figure 5. Use of Anti-Corrosive Pigments

Phenalkamine non-chromate

Conventional non-chromate

Conventional zinc-chromate

Figure 6. Curing Properties of Phenalkamine

<table>
<thead>
<tr>
<th>Curing (hour)</th>
<th>Solid Epoxy</th>
<th>Semi-Solid Epoxy</th>
<th>Liquid Epoxy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curing 25°C</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
</tr>
<tr>
<td>Curing 5°C</td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
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<tr>
<td>Curing -5°C</td>
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<td><img src="image8" alt="Graph" /></td>
<td><img src="image9" alt="Graph" /></td>
</tr>
<tr>
<td>Pot Life 25°C</td>
<td><img src="image10" alt="Graph" /></td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
</tr>
</tbody>
</table>
Phenalkamines even outperform polyamide amine adducts in curing speed (figure 7).

**Figure 7. Comparison with PAAad (Cured with liquid epoxy)**

![Comparison graph](image)

**Surface Tolerance**

Even if the surface is prepared as specified by the coating manufacturer, it can always happen that some imperfections remain on part of that surface. Some rust or condensation humidity can be present even if not recommended. Phenalkamine based coatings can tolerate such defects on the surface and therefore allow a margin of error for the applicator. A lightly rusted half damp panel was coated with a phenalkamine based clear coat. This coating still adhere perfectly after 4 months as illustrated by cross cut tape adhesion test (ASTM D 3359) (figure 8).

**Overcoat Window**

A metallic structure may be primed and kept as such for a long period before a top-coat is applied. This is not recommended by some coating manufacturers as the intercoat adhesion between the epoxy 2K and the acrylic-urethane top coat can be totally lost. This time lapse is not an issue when using phenalkamine curing agents. A panel coated with an solid epoxy 2K cured with a phenalkamine curing agent was exposed for 180 days outside (New Jersey). This panel was cleaned with a damp cloth and then top-
coated with an acrylic-urethane. Intercoat adhesion (according to ASTM D 3359) was significantly better than with a bench-mark polyamide curing agent (figure 9).

Figure 8 . Surface Tolerance

Rusted panels, half wet

Coating (200 µm)

Adhesion after 4 months

Figure 9 . Overcoat Window

Primer : solid epoxy - Top coat : Acrylic Urethane
Primer exposed 180 days outside
Top-coated after exposure

Polyamide
Phenalkamine
Low VOC

VOC emission will become increasingly restricted in the future and the use of high solids will be mandatory. Phenalkamine curing agents can be seen as a technology of the future because they allow the formulation of high solid coatings and moreover, are based on a renewable raw material. Commercial phenalkamines are available for formulating medium to high solids and new phenalkamines in development are reducing further the VOC emissions (figure 10). The end target (figure 11) is a solvent free technology. Phenalkamines are also compatible with non HAPS solvents, therefore complying with North American VOC regulations.

Figure 10. Low VOC Formulation
Phenalkamine cured epoxy resins are an alternative choice to conventional epoxy 2k systems used in the protective coating of steel structures. It is now a proven technology and provides outstanding anti-corrosion properties as well as:

- Fast cure which may increase productivity;
- Low temperature curing allows coating in all seasons;
- Surface tolerance brings some margin of error to the applicator;
- Overcoat window allows top-coating after a long period of storage;
- Low VOC formulations comply with current and future regulations;
- Phenalkamines are renewable chemicals.

The paint manufacturers that integrate this technology of the future will benefit from increased market share.