LUFOX® Colloidal Silica in Coatings
Lithium Polysilicate in Coatings

Introduction
LUFOX® colloidal silicas are aqueous dispersions of very small silica particles in the low nanometer size range. Many grades are offered in this family, giving broad flexibility for specific performance targets. This bulletin aims to inform the formulator about the unique properties of LUFOX® colloidal silica and to offer starting points for applications such as anticorrosive coatings and architectural paints.

Colloidal silica particles are roughly spherical, non-porous and dispersed in water. They have a dense silica core and a surface covered by silanol (Si-OH) groups.

Because of their small particle size and high surface area, these silanol groups interact strongly with metal substrates, metal oxide fillers commonly found in coatings, and with many polymeric and latex binders. These interactions result in strong binding properties to various substrates, giving the coating higher strength and durability.

Larger particle grades may also be used to modify coatings surface properties such as surface roughness.

LUFOX® Colloidal Silica Grades

<table>
<thead>
<tr>
<th>APS (nm)</th>
<th>SSA (m²/g SiO₂)</th>
<th>Sodium Counter Ion</th>
<th>Ammonium Counter Ion</th>
<th>pH Stable</th>
<th>Chloride Counter Ion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Grade % SiO₂ pH</td>
<td>Grade % SiO₂ pH</td>
<td>Grade % SiO₂ pH</td>
<td>Grade % Solids pH</td>
</tr>
<tr>
<td><strong>Monodisperse Grades</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>425</td>
<td>FM 15 10</td>
<td>SM 30 10</td>
<td>SM-AS 25 9.5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>350</td>
<td>SM-AS 25 9.5</td>
<td>AS-30 30 9.6</td>
<td>AM 30 9</td>
<td>CL 30 4</td>
</tr>
<tr>
<td>12</td>
<td>220</td>
<td>HS-30 30 9.7</td>
<td>HS-40 40 9.7</td>
<td>HSA 30 4</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>140</td>
<td>HS-40 40 9.7</td>
<td>LM 30 8</td>
<td>AS-40 40 9.2</td>
<td>TMA 34 4-7</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td>LM 30 8</td>
<td>AS-40 40 9.2</td>
<td>TMA 34 4-7</td>
</tr>
<tr>
<td><strong>Polydisperse Grades</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>260</td>
<td>PX-30 30 10</td>
<td>P X-30 30 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>155</td>
<td>PT-40 40 10</td>
<td>P T-40 40 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>80</td>
<td>PW-50 50 10</td>
<td>PW-50 50 10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1

APS = Average Particle Size (diameter) / SSA = Specific Surface Area

LUFOX® Colloidal Silica Grade Description
LUFOX® colloidal silica grades are distinguished by average particle size and stabilization method. In practice, the specific surface area (i.e., surface area per gram of silica) instead of average particle size is used as a specification property in most grades, because of its inverse relationship to average particle size, and because it is more easily measured.

Particle Size
Based on proprietary manufacturing processes, LUFOX® colloidal silica grades offer a wide range of particle sizes from 5 nm (or 425 m²/g SiO₂) to 60 nm (or 90 m²/g SiO₂). Please refer to Table 1 for the particle size/specific surface area range offered.

Most of the grades are “monodisperse” with relatively narrow particle size distribution. Grades designated with the letter “P” (e.g., LUFOX® P X-30) are “polydisperse” and have broader particle size distribution.
Stabilization
Because of their chemical reactivity, the colloidal silica particles must be prevented from reacting with themselves after manufacturing. Colloidal silica products must remain stable during storage, formulation, and until the final coating is applied. All grades within the LUDOX® colloidal silica family are charge stabilized to keep the particles from aggregating and gelling. The following describes the three approaches used to impart charge to the silica surface. Please refer to the figures to visualize the surface structure for each approach.

Alkaline Grades
The easiest method of inducing a charge is by taking advantage of acidic silanol groups on the silica particle surface. By reacting these groups with alkali, the particles become charged. The alkaline compounds of commercial interest are sodium hydroxide and ammonium hydroxide. Chemically, the interaction can be written as:

\[ (\text{SiOH}) + \text{NaOH} \rightarrow (\text{SiO}^\ominus) + \text{Na}^\oplus + \text{H}_2\text{O} \]

or

\[ (\text{SiOH}) + \text{NH}_4\text{OH} \rightarrow (\text{SiO}^\ominus) + \text{NH}_4^\oplus + \text{H}_2\text{O} \]

where (SiOH) and (SiO\(^\ominus\)) denote uncharged and charged silanol groups on the particle surface.

Important features:
- Typically, grades stabilized this way will be offered at or above pH 8, more commonly at pH 9-10. More alkali is needed for smaller particle sizes. If a grade with sodium counter ions is used in a coating formulation, the sodium will remain in the coating after it is applied and dried. On the other hand, ammonium hydroxide is volatile and will evaporate from the coating during dry down.
- Below about pH 8 the colloidal silica particles do not have sufficient charge density to remain stable at concentrations ≥10% silica. These grades may still be used in acidic or neutral formulations if process throughput is relatively short.

pH Stable Grades
In some cases, the coating formulation must be maintained in the acidic to neutral pH region for various reasons. The alkaline grades discussed above may be unsuitable due to long process throughput.

Important features:
- In alkaline LUDOX® colloidal silica grades, the particles are negatively charged. For this reason, these grades are often termed anionic.
- The sodium (Na\(^\ominus\)) or ammonium (NH\(_4^\ominus\)) ions are usually called counter ions and balance the charge induced on the silica particles.
Grades are available in which a small amount of the silica surface is modified with an aluminate compound. The aluminate maintains charge density such that the stability range is extended to about pH 4-10.5.

Important features:
- Since a small amount of the particle surface is modified, the particle chemistry is predominantly that of the silica surface.
- These grades are anionic. The particles are negatively charged.
- The counter ion may be sodium, as in the case of LUDOX® AM, which is offered at about pH 9. For applications in which sodium is not desired, acidic grades are offered in which the counter ion is the acid or hydronium ion.
- Acidic or alkaline grades stabilized in this manner may be added to coating formulations adjusted to the pH 4-10.5 range with good stability.
- Acidic grades are especially compatible with water-soluble polymers such as polyvinyl alcohol and with formulations containing polar organic solvents.

Cationic Grades

In these grades, the silica particles are fully coated with an aluminium hydroxide compound (different from the pH stable grades) such that the net particle charge is positive.

Important features:
- These grades are cationic. The particles are positively charged.
- Particle chemistry is dictated by the aluminium hydroxide surface rather than silica.
- The counter ion is chloride.
- pH stability is in the range pH 3.5-6.

Lithium Polysilicate

Although not strictly a colloidal silica, Lithium Polysilicate is a companion grade to our colloidal silica line and was developed specifically for inorganic coating applications.

Lithium Polysilicate is a “high ratio silicate.” Typically, silicate grades are characterized by the molar ratio of silica to metal oxide. In the case of sodium silicate, grades with SiO₂:Na₂O ratios above 3.5 are uncommon due to low water solubility. Low ratio sodium silicate grades tend to contain relatively high levels of water that can have deleterious aging effects.

With a proprietary process, Grace can make Lithium Polysilicate at any SiO₂:Li₂O ratio up to 40, at which point the product becomes a true colloidal silica. Commercial experience has focused on Lithium Polysilicate with a molar ratio of 4.8.

Features to note:
- pH ~11. Similar handling to sodium silicate.
- Very compatible with powdered zinc for zinc-rich primers.
- High ratio results in lower levels of water in coatings.
Formulation Guidelines

Because of their small size, colloidal silica particles can play a unique role in many waterborne coating formulations. Grades with smaller particles can be used as binders or co-binders for added strength and durability to the coating. This is due to silica surface reactivity with other silica particles, metal surfaces, fillers or organic polymers. Larger particle grades are mainly used as surface modifiers.

To decide which of the available grades to evaluate, we recommend the following selection process:

1. For alkaline coatings formulations, the alkaline LUDOX® colloidal silica grades are natural fits.
   1.1 If sodium poses no problems in the formulation, evaluate a medium particle grade such as HS-40 as a starting point.
      1.1.1 If better binding performance is required, try a smaller particle grade such as SM.
      1.1.2 If better surface effect or formulation stability is required, try a larger particle grade such as TM-50.
   1.2 If sodium poses problems in the formulation, consider a medium particle, ammonia-stabilized grade such as AS-30 as a starting point.
      1.2.1 If better binding performance is required, try the smaller particle grade SM-AS.
      1.2.2 If better surface effect or formulation stability is required, try a larger particle grade such as AS-40.

2. For acidic coating formulations, the pH stable LUDOX® colloidal silica grades are natural fits.
   2.1 Decide whether the colloidal silica concentration in the formulation and process times will allow the use of alkaline grades with pH adjustment. This is often the more cost effective choice. If so, the same evaluation process for alkaline formulations can be used as described under 1.
   2.2 If greater pH stability is required, evaluate a medium particle size, pH stabilized grade.
      2.2.1 If sodium poses no problem in the formulation, evaluate the medium particle grade AM (with pH adjustment).
      2.2.2 If sodium poses a problem, try HSA colloidal silica (with perhaps minor pH adjustment).
   2.3 If better surface effect or formulation stability is required, try the larger particle TMA grade (with perhaps minor pH adjustment).
   2.4 If the formulation contains significant levels of positively charged cations (from, for example, surfactants, polymers or metal ions) or if greater modification to a substrate surface is desired, evaluate CL-P.
      2.4.1 If better performance is required, try the medium particle grade CL.

Lithium Polysilicate may be used as a replacement for sodium silicate in metal pretreatments, zinc-rich primers and silicate paints.
Some applications require the development of special grades. Please contact a Grace Davison representative if you have needs that our current portfolio of grades does not satisfy.

Key Coatings Applications

Architectural Emulsion (Latex) Paints and Parquet Hardcoats

Colloidal silica may be added to many water-borne coating systems to significantly improve durability and anti-soil properties (especially dust retention). Colloidal silica may improve hardness and abrasion resistance in parquet formulations.

The colloidal silica grade must be chosen to be compatible with the other components of the formulation. Anionic grades are compatible with most latex emulsions, nonionic and anionic surfactants and polymers. They are not compatible with cationic surfactants and polymers.

Zinc-Rich Silicate Primers

Zinc-rich silicate primers provide very hard, anti-corrosive coatings on steel and are often used in marine applications. Sodium, potassium, lithium silicates and combinations may be used. These coatings are markedly weather resistant, do not chalk, are resistant to many organic solvents and are used in a broad temperature range.

High ratio silicates are necessary to fill these requirements and to provide good film forming characteristics and faster drying times. With a molar ratio of 4.8, Grace’s Lithium Polysilicate ratio is higher than commonly available sodium and potassium silicates. In addition, Lithium Polysilicate coating systems exhibit excellent compatibility with powdered zinc and typically have a longer pot life than sodium and potassium silicates.

A simple zinc-rich primer formulation containing lithium polysilicate consists of:

<table>
<thead>
<tr>
<th>Component</th>
<th>Parts (by Mass)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium Polysilicate</td>
<td>100</td>
</tr>
<tr>
<td>Zinc Powder</td>
<td>290</td>
</tr>
</tbody>
</table>

Masonry Silicate Coatings

As with zinc-rich silicate primers, sodium, potassium and lithium silicates are used to make waterborne masonry paints. Silicate paints are suitable for indoor and outdoor applications and have excellent adhesion to masonry and cementitious substrates.

Colloidal silica may be added to silicate formulations for faster development of water resistance and faster overall drying times.

Because these coating formulations also favor high ratio silicates, Grace Lithium Polysilicate may offer significant advantages in terms of durability and chemical resistance, either as the principal binder or as a co-binder with sodium and potassium silicates.

Anticorrosive Metal Pretreatments

Metals may be “pretreated” with a formulation to protect the metal against corrosion and to improve adhesion of subsequent organic layers for better film formation. The pretreatment formula typically contains alkaline oxides, chromates and/or phosphates and is used to convert the metal surface to a mixed oxide to “passivate” the metal.

In efforts to replace hexavalent chromium formulations with trivalent chromium, colloidal silica and Lithium Polysilicate have been found to improve trivalent chromium adsorption and to help film formation. Furthermore, colloidal silica’s high surface area helps control rheology.

The table below gives a typical formulation used for the treatment of galvanized steel:

<table>
<thead>
<tr>
<th>Component</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphoric acid</td>
<td>15 – 20</td>
</tr>
<tr>
<td>Aluminum hydroxide Al(OH)₃</td>
<td>3 – 6</td>
</tr>
<tr>
<td>LUDOX® HS-40, AM or AS-40</td>
<td>40 – 50</td>
</tr>
<tr>
<td>Chromic acid</td>
<td>2 – 4</td>
</tr>
<tr>
<td>Water</td>
<td>Balance</td>
</tr>
</tbody>
</table>

Electroplating/Galvanization

In this application, a layer of zinc metal is electrodeposited onto a metal substrate. The zinc is then treated with a passivating formula similar to the metal pretreatment formula given above for added corrosion protection and to promote adhesion for subsequent paint applications. If needed, a sealant formula, also containing colloidal silica, may be coated on top of the passivating layer to seal defects and increase protection further.
Lithium Polysilicate Zinc-Rich Paint Vehicle

Introduction
Lithium Polysilicate is an aqueous, self-curing, inorganic binder developed and tailored for use with metallic zinc powder. The polysilicate paint vehicle and zinc make up a two-component, zinc-rich paint system designed for marine and industrial applications. Extensive laboratory and field testing have proved these systems to be technically competitive with the most popular commercial systems available. Polysilicate zinc-rich primers offer the following advantages:

- Rapid self-cure
- Superior salt-fog and immersion performance
- Impact and abrasion resistance
- Wide latitude of film thickness
- Resistance to jet fuels and many other organic materials
- Compatibility with organic top coatings
- Economy (long-term performance at competitive initial cost)
- No flash point (completely inorganic)

In order to demonstrate the performance of the polysilicate as a zinc-rich paint vehicle, much of the data presented in this bulletin is based on “formulated” systems. Table 1 lists the approximate chemical compositions and the physical properties of Lithium Polysilicate.

Table 1: Lithium Polysilicate Solution – Composition and Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Lithium Polysilicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica (SiO₂), approx. wt%</td>
<td>20.2</td>
</tr>
<tr>
<td>Lithium Oxide (Li₂O) approx.</td>
<td>2.1</td>
</tr>
<tr>
<td>Viscosity, cP</td>
<td>10</td>
</tr>
<tr>
<td>Flash Point</td>
<td>nonflammable</td>
</tr>
<tr>
<td>Freezing Point*</td>
<td>0°C (32°F)</td>
</tr>
<tr>
<td>Density, lb/gal</td>
<td>9.9</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.18</td>
</tr>
<tr>
<td>pH</td>
<td>11</td>
</tr>
<tr>
<td>Shelf Life, month at 24°C (75°F)</td>
<td>&gt;12</td>
</tr>
<tr>
<td>month at 49°C (120°F)</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Total Solids, wt%</td>
<td>22.1</td>
</tr>
<tr>
<td>vol%</td>
<td>10.9</td>
</tr>
</tbody>
</table>

*Although the Lithium Polysilicate solution freezes at approximately 0°C (32°F) it is “freeze-stable,” and if elevated to room temperature and thoroughly mixed, retains all normal properties.

Comparison of Zinc-Rich Primers
Lithium Polysilicate zinc-rich primers applied on metal substrates to give dry film thicknesses from 1.5 to 8 mil (38 to 200 μm) show consistent high performance. The dry-film thickness normally preferred is 3 mil (75 μm). Such a paint film exhibits an excellent balance of properties, including a rapid cure rate (see “Cure Rates of Polysilicate Zinc-Rich Primer Coats”) and over 2,000 hr resistance to salt fog (Federal Test Method 141-6061).

Laboratory tests have shown the Lithium Polysilicate zinc-rich coatings to be fully competitive with other leading commercial zinc-rich paint systems. Table 2 summarizes the test data.

Above photo shows condition of Lithium Polysilicate coated panels following 24-month exposure in a marine tidal zone test station. The panel shows no evidence of underfilm corrosion in either the scribed area (center of panel) or adjacent to the uncoated triangular control area. Areas of welds and weld spatter are likewise free of any sign of pinhole corrosion, blistering, or peeling.

Fig 1: Panel coated with 93% zinc (dry film) formulation with Lithium Polysilicate.
Table 2: Film Properties of Zinc-Rich Primers

<table>
<thead>
<tr>
<th>Property</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pencil Hardness after 12 Days</td>
<td>H</td>
<td>H</td>
<td>5-B</td>
<td>5-H</td>
</tr>
<tr>
<td>Abrasion Resistance, Indexb</td>
<td>1.0</td>
<td>1.0</td>
<td>14.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Immersion Performancec</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Cathodic Protectiond</td>
<td>+</td>
<td>G</td>
<td>+</td>
<td>G</td>
</tr>
<tr>
<td>5% Salt Fog Test, 2000 hr14d</td>
<td>+</td>
<td>G</td>
<td>G</td>
<td>G</td>
</tr>
</tbody>
</table>

Table 3: Field-Test Performance of Zinc-Rich Primer Coats Without Topcoating

<table>
<thead>
<tr>
<th>Grade of Zinc-Rich Paint</th>
<th>Formulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium Polysilicate Paint</td>
<td></td>
</tr>
</tbody>
</table>

Among the outstanding qualities of the Lithium Polysilicate vehicle is its ability to carry wide variations of zinc loading, as high as 95% by weight in the dry film, if desired. Based on results of comprehensive field and laboratory tests, several typical suggested formulations are listed in Table 5.

Table 4: Field-Test Performance of Zinc-Rich Primer Coats Without Polyamide-Epoxy Topcoat

Field-test panels, each coated with one of the six systems in Table 5, have been exposed 24 months at five test stations in widely separated atmospheric and marine tidal zones, at a steel mill, and at industrial salt and acid sites. The data in Table 3 and 4 show the Lithium Polysilicate zinc-rich primers to be consistently among the best performers. (Competitive systems A, B, C, D, and E were not duplicated in all test areas, and are reported only where included.)

Table 5: Preparation of Polysilicate Paint Vehicles

<table>
<thead>
<tr>
<th>Grade of Zinc-Rich Paint</th>
<th>Formulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium Polysilicate Paint</td>
<td></td>
</tr>
</tbody>
</table>

The two-component formulations suggested in Table 5 are as easy to modify, make up, and apply as described below.

Alternative Suspending Agents

The suspending agents listed in Table 5 are those that have been used most frequently in test work.

Specification of proprietary products does not imply an unqualified recommendation by Grace; a variety of alternative suspending agents (see Table 6) have been found compatible in polysilicate systems with varying degrees of effectiveness. Grace recommends that the user evaluates the concentration and effectiveness of suspending agents of his/her choice in the user's own polysilicate system.

As Lithium Polysilicate is partially colloidal in nature, so it is subject to gelation on contact with most salts. Therefore, use care when selecting additives.

Mixing Polysilicate and Additives

Depending on the zinc mixture used, it is possible to incorporate Benagel® or Benaqua® by dryblending into the zinc portion or by addition to the vehicle using high-shear agitation.
Table 5: Suggested Two-Component Formulations

<table>
<thead>
<tr>
<th>Component 1</th>
<th>Zinc Content of Dried Film [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>95</td>
</tr>
<tr>
<td>Lithium Polysilicate, parts (wt)</td>
<td>100</td>
</tr>
<tr>
<td>Potassium Dichromate (K₂Cr₂O₇), parts (wt)</td>
<td>0.05</td>
</tr>
<tr>
<td>Suspending Agentb, parts (wt)</td>
<td>Carbopol® 941</td>
</tr>
<tr>
<td>Benagel® or Benaque®</td>
<td>–</td>
</tr>
<tr>
<td>Zinc Powderc, parts (wt)</td>
<td>420</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids (wt film/dry film), vol%</td>
</tr>
<tr>
<td>Theoretical coverage, ft²/gal</td>
</tr>
<tr>
<td>Pot life at 21°C (70°F), hr</td>
</tr>
<tr>
<td>38°C (100°F), hr</td>
</tr>
</tbody>
</table>

| Pot life at 38°C (100°F), hr | >16 | >16 | >16 | >16 |

Table 6: Some Compatible Suspending Agents for Polysilicate Systems

<table>
<thead>
<tr>
<th>Suspending Agents</th>
<th>Compatibility</th>
<th>Mfr.a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrysol® A2695</td>
<td>polymeric acrylic derivativel</td>
<td>Yes</td>
</tr>
<tr>
<td>Attage® 40 atapulguis clay</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Avibest™ C microcrystalline magnesium silicate</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Benagle® beneficiated hector clay</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Benaque® gelling and suspending agent</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Carbopol® 941</td>
<td>water-soluble resin</td>
<td>Yes</td>
</tr>
<tr>
<td>Gantrez® AN 169</td>
<td>water-soluble copolymer</td>
<td>Yes</td>
</tr>
</tbody>
</table>

a Suggested for welding primers. / b See text, “Alternative Suspending Agents,” and Table 6.

Carbopol® 941 is a dry, acid-base copolymer that should be introduced using a turbine-type mixer such as an Eppenbach® Mixer or a Barrington Mixer. The Carbopol® 941 should be added slowly to the vortex while the agitator is running. Complete dispersion will take 20 to 60 minutes, depending on the degree of agitation.

Potassium dichromate, used as a pot-life extender, may be in crystalline form or in solution in a small amount of water. The addition needed to give 0.05% concentration level can be made either before or after adding the suspending agent to the polysilicate.

Suggestions for Tinted (Colored) Coatings

All formulations listed in Table 5 produce a matte gray coating. These are sometimes difficult to work with in bright sunshine or shaded areas due to similarity of the coating with the sandblasted surface.

Pigments such as chrome green oxide, red iron oxide, and lead oxide may be added to the zinc portion to produce a tinting effect to ease application problems. Following is one formulation that is recommended:

100 parts Lithium Polysilicate Vehicle (containing 0.05 parts K₂Cr₂O₇) plus 290 parts zinc powder mixture (284 parts zinc powder plus 6 parts chrome green oxide dryblend-together). This gives a coating of 93% total pigment weight concentration in the dry film, a coating of greater abrasion resistance, and a formulation that requires no separate suspending agent.

Avoid additions of metallic oxide pigments in excess of 2 to 3%, because greater additions can lead to “mudcracking” problems in thicker film applications.
Choice of Zinc Dust
Medium particle zinc dusts, in the range of 5 to 9 μm, have been most generally used. Due to the high rate of reactivity between polysilicate and large surface area (small particle size) zinc, avoid exclusive use of very small particle size zinc. Excessive gassing may occur, accompanied by reduced pot life and premature gelation of the vehicle, which can lead to poor wetting and excessive mud-cracking at higher film thicknesses.

Recent laboratory results, however, indicate that mixtures of medium and fine zinc particles, in the range of 1-to-1, produce coatings of higher early wet abrasion resistance.

Avoid dust containing calcium oxide (frequently added to organic systems), because even very low levels of calcium oxide will prematurely “gel” the vehicle, causing some of the same problems mentioned above.

Steel drums and pails or tinplate cans are satisfactory containers for the formulated paint vehicles. The presence of potassium dichromate, although not essential, improves compatibility with tinplate containers in addition to extending pot life.

The shelf life of properly formulated paint vehicles containing potassium dichromate and a suspending agent is about the same as that of the Lithium Polysilicate used (see Table 1). The formulations should be protected from freezing temperatures and from temperatures above 43°C (110°F). Stocks of the packaged formulations should preferably be turned over on a “first in, first out” basis.

Preparation and Application of Primer
Zinc-rich paint systems based on Lithium Polysilicate can be applied using conventional surface preparation and equipment techniques.

Surface Preparation
Wipe the surface of the metal substrate with a cloth or apply a suitable solvent to remove any grease or oil. Sand-, grit-, or shot-blast the surface to a nearwhite condition (profile of 1 to 1.5 mil [25–38 μm]).

Paint Preparation
Add zinc powder to the polysilicate paint vehicle while vigorously stirring the mixture in an agitating pot.

Spray-Gun Application
Use pot gauge pressures of 20 to 30 psi (1.4 to 2.1 kg/cm2) and atomizer gauge pressures of 50 to 60 psi (3.5 to 4.2 kg/cm2) for routine application with conventional spray equipment such as the Binks Model 18 gun5 with No. 65 fluid nozzle, size 65 needle, and No. 66 PE air nozzle (required air volume for gauge pressure at 50 psi [3.5 kg/cm2] is 13.9 cfm [-400 L/min]).

Coating Thickness
A single 2.5- to 3-mil (63–75 μm) dry coat of polysilicate zinc-rich primer gives the metal long term cathodic corrosion protection. On the other hand, polysilicate zincrich primers do not mud crack or lose adhesion when applied allowing a high film buildup. Primer application is easier and overspray in corners, angles, and crevices less critical than with conventional primer formulations. Dry film thicknesses from 1.5 to 8 mil (38–200 μm) show consistent high performance.

Cleaning Equipment
Polysilicate dries rapidly to a water-insoluble film. For best results, equipment should be promptly cleaned with hot soapy water following use. A weak solution of caustic soda will remove zinc-rich paint primer that has dried completely.

Application of Topcoating

Organic Topcoats
Polysilicate zinc-rich primers are compatible with such conventional organic topcoatings as the vinyls, polyamide epoxies, amine epoxies, and coal-tar epoxies. Applying a “mist” coat of the topcoating immediately prior to building up the final coat is an effective means of obtaining tightly adherent, pinhole-free coatings.

Tie-coats such as vinyl red lead are frequently used where alkalinity of the zinc coating may be in conflict with certain topcoats. This is particularly true in the case of silicone alkyls in seawater exposure.

Zinc-on-Zinc
Polysilicate zinc-rich primers show excellent adaptability to repair or buildup following prolonged weathering. Washing, scraping, or wire-brushing to remove surface corrosion and salt products leaves a surface suitable for overcoating with additional polysilicate zinc-rich primer. Applying the primer as described above gives a tightly adhering, high performance film. Mandrel tests have shown the zinc-to-zinc bond between the old and new coats to be every bit as strong as the zinc-to-metal bond.

Cure Rates of Polysilicate Zinc-Rich Primer Coats
Polysilicate films cure by forming a basic zinc silicate and polymerized silica matrix as water is released from the coating. Initial cure occurs through reaction between lithium silicate and zinc particles, with ultimate hardness achieved through polymerization of silicate particles with time.

The cure rates of zinc-rich paint systems vary according to their composition. Like other waterbased paint systems, polysilicate zinc-rich primers cure rapidly at high temperatures and low humidities, more slowly at lower temperatures and higher humidities.
During evaluation studies on polysilicate zinc-rich primer formulations, a test procedure was developed that shows the relationship between the ambient temperature/humidity and the initial cure time of the primer coat, the time required for it to harden to maximum dry abrasion resistance, the additional time needed to ready the coat for topcoating, and the overall or absolute cure rate of the primer coat. The test was applied to multiple sets of panels that were coated and placed in a Tenney Environmental Cabinet to cure the coatings at regulated temperatures and humidities. (No attempt was made to simulate the effects of wind or sunlight, both of which would tend to improve cure rates.) Panel coatings were tested at periodic intervals for residual water content, adhesion, and hardness to establish the timetable of the cure according to the following criteria:

1. Initial Cure: Panel removed from cabinet, tilted 45°, exposed to a jet of water to simulate the resistance of the coat to an early rainfall. The coating must not lift, peel, crack, or blister.

2. Maximum Dry Abrasion Resistance: Panel removed from cabinet and coating abraded 100 cycles with Taber Abraser (CS-17 wheels at 1000g loading per wheel) to estimate the time required for the coat to acquire maximum early hardness in the absence of direct water contact.

3. Ready for Topcoat: Panel coating tested for residual water content. The primer is not considered ready for topcoating until 99% of free water is evaporated. (Some researchers recommend that where top coatings are to be subjected to sea-water, inorganic zinc primers should be weathered up to 7 days before topcoating. Decisions should be based on conditions and time available.)

4. Absolute Cure: Panel removed from cabinet, partially immersed 1 hr in 24°C (75°F) tap water, air-dried 2 hr, and abraded as in (2) above to estimate absolute cure time following severe exposure. Coating must remain hard after the combined exposures to water immersion and varying temperature/humidity conditions.

Note: The tap-water immersion test represents most severe curing conditions and should not be confused with normal curing conditions. Intimate contact of the primer coat with fresh water decreases the rate of polymerization, and the fresh water leaches out the unpolymerized silicates from the coating, weakening the zinc-to-silicate bonds. This increases the cure time. (Contact with salt water has the opposite effect. Salts tend to “set” silicate coatings, thus decreasing cure time.)

Figure 2 shows a typical time profile obtained in the cure-evaluation testing of polysilicate zinc-rich primer coats. Table 7 lists the cure rates of a typical primer coat for different ambient conditions. The numerical values are for the midpoint of the respective temperature/humidity ranges and thus are indicative of expected performance at these intermediate conditions.

### Materials of Construction

Lithium Polysilicate can be handled and stored in equipment constructed of mild steel or stainless steel. Among the plastic materials suitable for handling polysilicates are polyvinyl chloride and polyethylene. Phenolic resin coatings such as Lithcote® LC-34® or coatings of the plastics cited can be used to protect construction materials that are sensitive to alkaline solutions.

The storage areas or tanks should be protected from freezing temperatures and from temperatures above 43°C (110°F).

### Safe Handling

Since Lithium Polysilicate is alkaline and may cause skin and eye irritation, avoid contact with skin or eyes. Grace recommends that goggles and rubber gloves be worn when handling or mixing these materials.
In case Lithium Polysilicate is accidentally splashed in the eyes or on the skin, flush with plenty of water. A physician should be consulted for the eyes.

**Toxicology**
The character of Lithium Polysilicate is similar to that of sodium silicate. The irritant effect of silicate is limited to its alkalinity. Prolonged contact of liquid silicones with the skin would be expected to cause drying, chafing, and irritation of cuts or sores as would be the case with an alkaline detergent. Liquid silicate or dried films and powder would be irritating to the mucous membranes of the eyes, nose, and throat.

**Packages of Lithium Polysilicate**
Grace offers Lithium Polysilicate in nonreturnable polyethylene 208-L (55-gal) drums and, in North America, in tank trucks.

**Ordering Information – Product, Literature, or Samples**
To order Grace Lithium Polysilicate, additional literature or a product sample, call Customer Service toll-free at 888-659-1716. For locations outside the United States, contact the local Grace representative in your country.
We invite you to partner with us. Grace has a strong commitment to open innovation. Our research scientists strive to collaboratively develop tailored solutions to support customers’ needs. We welcome the opportunity to explore the challenges you face and how LUDOX® colloidal silica can help in catalyst applications. Contact Grace today at colloidal silica@grace.com to schedule a meeting or request a sample.

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