Bulletin 12-31

Bonding And Coating Applications of PQ® Soluble Silicates

INTRODUCTION

Sodium and potassium silicates in aqueous solutions have physical and chemical properties that are useful in bonding and coating applications. When applied as a thin layer on or between surfaces of other materials, the silicate solution dries to form a tough, tightly adhering inorganic bond or film which can exhibit the following characteristics:

- Low cost
- Non-flammable
- Resistant to temperatures up to 3000°F
- Odorless and non-toxic
- Bondable to metals, particles (e.g., refractory materials), fibrous materials (e.g., paper, fiberglass), glass, ceramics
- Strong and rigid

Because of the low cost and versatile properties of PQ® sodium and potassium silicates as coatings and binders, they are useful in a broad range of applications. Typical applications include:

- Adhesive for corrugated board, spiral or convolute paper tubing and fiber drums
- Foil-to-paper lamination adhesive
- Masonry coating/sealing
- Binders for forming fibrous materials into building products (e.g., ceiling insulating materials, wallboard)
- Binders for briquetting, pelletizing, or agglomerating (e.g., detergents)
- Binders for ceramics or powdered metals for high-temperature coating applications and welding rod coatings
- Paint vehicle

CHARACTERISTICS OF PQ® SOLUBLE SILICATES

Liquid sodium silicates are solutions of glasses which are made by fusing varying proportions of sand (SiO_2) and soda ash (Na_2CO_3). These proportions are usually defined by the specific product's SiO_2/Na_2O weight ratio. PQ also offers KASIL® liquid potassium silicates in several SiO_2/K_2O weight ratios. The potassium silicates are similar to sodium silicate but have properties that are better suited to some applications, e.g., when greater electrical resistance is required.

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PQ Corporation is a leading producer of silicate, zeolite, and other performance materials serving the detergent, pulp and paper, chemical, petroleum, catalyst, water treatment, construction, and beverage markets. It is a global enterprise, operating in 19 countries on five continents, and along with its chemical businesses, includes Potters Industries, a wholly owned subsidiary, which is a leading producer of engineered glass materials serving the highway safety, polymer additive, metal finishing, and conductive particle markets.

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The properties of the PQ liquid soluble silicates are summarized in Table I. Liquid silicates range in viscosity from very fluid, slightly sticky consistencies to thick substances that barely flow. As a general rule, the higher SiO_2/Na_2O ratio products (2.8 to 3.22) are used for adhesive and coating applications.

Table II describes the properties of various powdered forms of PQ soluble silicates used in dry mix adhesive and coating systems.

MECHANICS OF SILICATE FILM AND BOND FORMATION

Silicates are converted to solid films or bonds by two methods: (1) evaporation of water (dehydration) or (2) chemical setting mechanism. These can be used separately or in combination. Chemical setting is often used to improve film moisture resistance, to reduce setting time, and to increase ultimate bond strength as needed.

EVAPORATION DRYING

As water evaporates, liquid silicates become progressively tackier and more viscous. As shown in Table III, PQ's N® sodium silicate, for example, has an initial water content of 62.4% and a viscosity (at 20ºC) of 1.8 poises. With a weight loss of 6% by evaporation the viscosity increases to 20 poises, and after 12% weight loss, to 2,300 poises. When evaporation approaches 14%, the viscosity is approximately 40,000 poises, at which point the silicate has in effect set. Further dehydration brings it to a final hardened condition.

Soluble silicates with higher SiO_2/Na_2O or SiO_2/K_2O ratios, such as N, O®, and KASIL #1, are more desirable for applications employing evaporation drying than are more alkaline, lower ratio grades. The higher ratio silicates change from an almost waterlike condition to a semi-solid state when only a small amount of water is evaporated.

Lower ratio silicates, such as K® and RU® sodium silicates, dehydrate more slowly, because their higher alkali content creates a greater affinity for water. They may require heat for drying or treatment with chemical setting agents to achieve the desired set.

Flexibility increases in lower-ratio silicates because of their tendency to hold onto water more tenaciously than higher ratio silicates and thus have some degree of internal plasticization of the film by the residual water. Because the low-ratio silicates tend to retain more water, they are less brittle than the higher ratio silicates.

Silicate films are subject to moisture pick-up and degradation. However, this process can be slowed if water is completely removed from the silicate. Air drying alone usually is not adequate for films or bonds that will be exposed to weather or high moisture conditions. For such applications, heat is usually recommended. Initially, the temperature should be increased gradually to 200-210ºF to slowly remove excess water. Then final curing can be done at least 350-700ºF. Heating too quickly may cause steam to form within the film, resulting in blistering or puffing when the steam is released. For some applications, where an insulated coating is desired, this intumescent property can be useful. Infrared and microwave heating have been used successfully for hardening silicate systems.

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CHEMICAL SETTING

For relatively insoluble bonds or films, liquid sodium and potassium silicates can be reacted with a variety of acidic or soluble metal compounds.

Neutralizing an alkali silicate with acidic materials polymerizes the silica and forms a gel. Chemical setting agents that can be used in this manner include: mineral and organic acids, carbon dioxide (CO_2) gas, and acid salts such as sodium bicarbonate and monosodium phosphate (NaH_2PO_4).

Multivalent metal compounds react with silicate solutions to form coatings or bonds by precipitation of insoluble metal silicate compounds.

Chemical setting reactions generally occur rapidly, and these materials frequently are applied as an after-treatment. Calcium chloride, magnesium sulfate, aluminum sulfate, borax, and sodium metaborate used in this manner are generally applied as 5 to 10% solutions.

Chemical setting agents that dissolve slowly in water, such as finely divided zinc oxide or sodium silico fluoride, can be used for silicate binders or coatings that exhibit longer working lives. These agents usually are used at a level of approximately 7% by weight based on the weight of liquid silicate. Silico fluoride is particularly effective for ambient temperature curing procedures.

Some chemical setting agents will only react with the silicate at elevated temperatures. Kaolinitic clays and minerals, which decompose at 400 to 500ºF into acidic compounds, are examples of this type of setting agent.

PROPERTIES OF SILICATE BONDS AND FILMS

Moisture Resistance

Silicate films are usually moisture sensitive. They can be made somewhat impermeable to moisture and weathering when proper drying or setting procedures are used. The use of clay and zinc oxide as chemical setting agents at high temperatures are especially desirable since, after curing at 1300ºF, it produces films capable of actually shedding water.

Heat Resistance

When silicate films are completely dehydrated, they provide excellent resistance to high temperature. Most silicates used for coatings or binders have softening points of approximately 1200ºF and flow points of 1500 to 1600ºF (see Table IV).

Resistance to higher temperatures can be achieved by adding clay to the formulation. Depending on the aluminum or magnesium content of the clay, service temperatures up to 3200 to 3400ºF are possible due to the formation of a ceramic bond.

Mixtures of copper, nickel, chromium and stainless steel powders in the silicate vehicle provide high temperature-resistant coatings for metals.

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TABLE 1. Typical Properties of PQ® Liquid Sodium and Potassium Silicates

SODIUM SILICATES

PRODUCT	WT. RATIO SiO_2/Na_2O	% Na_2O	% SiO_2	VISCOSITY AT 20°C (Poises)	DENSITY		CHARACTERISTICS
					°Be	lb./gal	
N®	3.22	8.90	28.7	1.8	41.0	11.6	Syrupy liquid
O®	3.22	9.15	29.5	4.0	42.2	11.8	Thick liquid
STIXSO® RR	3.25	9.22	30.0	8.3	42.7	11.8	Thick liquid
K®	2.88	11.00	31.7	9.6	47.0	12.3	Sticky, heavy liquid
RU®	2.40	13.85	33.2	21.0	52.0	13.0	Heavy syrup
D®	2.00	14.70	29.4	4.0	50.5	12.8	Syrupy, alkaline liquid

POTASSIUM SILICATES

PRODUCT	WT. RATIO SiO_2/K_2O	% K_2O	% SiO_2	VISCOSITY AT 20°C (Poises)	DENSITY		CHARACTERISTICS
					°Be	lb./gal	
KASIL® #1	2.50	8.30	20.8	0.4	29.8	10.5	Thin syrup
KASIL® #6	2.10	12.65	26.5	10.5	40.3	11.6	Syrupy liquid

The properties shown are typical values, not manufacturing specifications

TABLE II. Typical Properties of PQ® Powdered Sodium Silicates

PRODUCT	WT. RATIO SiO_2/Na_2O	% Na_2O	% SiO_2	% H_2O	DENSITY lb./ft³	CHARACTERISTICS
SS® 65 Pwd.	3.22	23.1	74.4	0.0	88	Through 65 mesh
G®	3.22	19.2	61.8	18.5	44	Through 100 mesh
GA®	2.40	23.8	57.2	17.5	38	Through 100 mesh
GD®	2.00	27.0	54.0	18.0	46	Through 100 mesh

The properties shown are typical values, not manufacturing specifications

TABLE III. Effects of Evaporation on Viscosities of PQ® Liquid Sodium Silicates

PRODUCT NAME	WT. RATIO SiO_2/Na_2O	Viscosities at 20°C (Poises)			APPROXIMATE WT. LOSS FOR INITIAL SET- %
		INITIAL	6% WT. LOSS	12% WT. LOSS	
N®	3.22	1.8	20	2,300	13.6
O®	3.22	4.0	120	20,000	11.2
K®	2.88	9.6	150	10,000	12.0

TABLE IV. High Temperature Properties of Soluble Silicates in Anhydrous State

PQ® PRODUCTS	APPROXIMATE SOFTENING POINT[1] °F(°C)	APPROXIMATE FLOW POINT[2] °F(°C)
N, O, N 38, G, SS 65 Pwd.	1200(649)	1545(840)
K	1185(640)	1520(827)
RU	1140(615)	1455(790)
D, GD, SS-C Pwd.	1095(590)	1400(760)
B-W 50	1050(565)	1345(729)
KASIL #1	est. 1280/1360(693/738)	1660(904)
KASIL #6	est. 1280/1360(693/738)	1635(890)

[1]Viscosity reaches 4 x 10^7 poises
[2]Viscosity reaches 10^5 poises

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Electrical Properties

When completely dehydrated, sodium and potassium silicates exhibit good dielectric properties. PQ's N sodium silicate (3.22 SiO_2/Na_2O ratio), when dehydrated, has a specific resistance of approximately 3 x 10^{10} ohm-centimeters - about the same as common plate glass. Electrical resistance is lower when more alkaline (lower SiO_2/Na_2O ratio) sodium silicates are used.

Potassium silicates, when fully dehydrated, exhibit greater electrical resistance than sodium silicates. Maximum resistance is obtained by combining selected proportions of potassium and sodium silicates.

UV Transmission

Silicate films are generally stable to UV light exposure. Specially clarified sodium silicate solutions, such as PQ's E® silicate, transmit 92 to 98% of light in wave lengths ranging from 430 to 700 millimicrons. Below 400 millimicrons transmission drops off rapidly, exhibiting a value of approximately 40% at 325 millimicrons.

UV absorption is usually a function of the type of filler or pigment used in a silicate film or adhesive. A potassium silicate coating pigmented with zinc oxide proved satisfactory for use on space vehicles requiring solar radiation absorption and infrared emittance.

Opacity and Color

Silicate films can be made opaque by the use of titanium dioxide or aluminum pigments. Fillers such as clay are used for semi-opaque films. Alkali-resistant pigments are necessary for use with silicate vehicles. The following are suggested: white—titanium dioxide; red—lime-free iron oxide; blue—ultramarine; green—chrome oxide; yellow—ochre; brown—umbers or siennas; black—grease-free carbon black.

When silicate coatings are used on paper or other materials, the coating's alkalinity may darken the material's color. The addition of 0.5 to 5.0% hydrogen peroxide, based on the weight of the silicate, may be helpful.

Flexibility

Silicate coatings or adhesives alone generally are not suitable where a high degree of flexibility is required. However, a moderate degree of flexibility is obtained by the addition of plasticizers to the silicate solution. Typically, 1 to 5% by weight of sugar, glycerine or other polyhydric alcohols are used. Up to 30% of sorbitol can be used, provided the silicate solution is diluted to avoid excessive thickening. Rubber latices can also be employed as plasticizers. Incorporation of finely ground clays and similar fillers will improve flexibility to some extent.

Soluble silicates have limited compatibility with alkaline aqueous emulsions (pH above 8) such as styrene-butadiene, polystyrene, neoprene, polyvinyl chloride, polyvinyl acetate, acrylonitrile copolymers, acrylic polymers and copolymers.

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BONDING AND COATING APPLICATIONS

Surface Characteristics

Since silicate coatings and adhesives are inorganic aqueous polymers they perform most effectively on hydrophilic, non-oily surfaces, where they achieve proper wetting and, hence, maximum adhesion. Generally, a thin continuous silicate film between the surfaces to be bonded provides optimum adhesion.

Coating Metals. In the coating or bonding of metals and similar rigid materials, the difference in coefficient of thermal expansion between silicate and the bonded surfaces may be a limiting factor. However, where temperatures are relatively constant and there is no mechanical strain, ultrathin silicate films which have been dehydrated by baking can hold permanently. A thin silicate film has greater elasticity and is more serviceable than a thick one for coating or bonding metal. A compatible surfactant in the amount of 0.05 - 0.1% by weight relative to the silicate will aid surface wetting. Good adhesion to metal often can be obtained after the surface has been thoroughly cleaned with alkali (e.g. with a PQ METSO® sodium metasilicate) or solvent or is degreased or sandblasted.

Typical metal coating applications are:

- Thin silicate films on lithographic plates to render the surface area hydrophilic and acceptable for further processing.
- Steel ingots coated with thin films of silicate to protect against corrosion.
- Silicate films on silver flatware to protect against scratches during manufacture.
- A thin coating of silicate - about .001" thickness - protects stainless steel colored by controlled oxidation, rendering it resistant to atmospheric con ditions, abrasion and fumes as well as to cleaning agents commonly used on architectural or decorative finishes. The silicate film does not change the color of the coated steel but rather adds a depth of color to the steel sheet. Baking at about 480^{o}F cures the silicate and considerably delays any moisture uptake. The silicate coating is smooth, glossy and resistant to scratching.
- A silicate coating to impregnate aluminum for ferrous castings by special vacuum and pressure techniques to reduce their porosity.
- Anodized aluminum surfaces sealed with sodium silicate solutions.
- Sodium or potassium silicates used as a binder for zinc dust in the appli cation of zinc-rich primers on metal surfaces exposed to moisture or weather.
- Coating of the interiors of bulk rail cars that have been cleaned or sand blasted, to act as a barrier for the metal from corrosive cargos such as salts.

Paper and Fibrous Products. Soluble silicates are ideal for bonding, laminating or impregnating cellulose and other types of fibrous materials, particularly in the manufacture of various building and insulating products. In addition to their flame-retardant qualities, silicate adhesives or coatings provide good wet strength as well as dry bond strength and excellent overall adhesion.

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Powdered or Granular Materials. For bonding powdered or granular materials a thin silicate film should envelop each particle. Depending on the particle size and density of the material, this usually requires from 2 to 5% N silicate relative to the weight of the solids to be agglomerated. Perlite wallboard or acoustical tile and colored roofing granules are examples of the successful bonding and coating of particulate materials with soluble silicates.

Safety and Handling Information

Depending on their degree of alkalinity, soluble silicates may irritate or burn the skin and eyes on contact. Precautions for handling, provided on the labels of packages, should be observed. Material Safety Data Sheets are available for all products for further guidance.

Application Assistance

For additional information and/or assistance, contact PQ's Industrial Chemicals Division. Our technical service representatives will be happy to assist you in selecting and evaluating PQ® sodium silicates for your specific application.