

INDUSTRIAL
CHEMICALS
DIVISION



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PQ Corporation is a privately held global enterprise operating in 20 countries, with annual revenues in excess of \$500 million. PQ 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.

Potters Industries, PQ's wholly owned subsidiary, is a leading producer of engineered glass materials serving the highway safety, polymer additive, fine abrasive, and conductive product markets.

Bulletin 24-1

PQ[®] Soluble Silicates in Refractory and Chemical-Resistant Cements

INTRODUCTION

PQ Soluble Silicates are used effectively as binders where heat stability or resistance to chemicals is required. Silicate binders develop high green strength by air-setting without heat. They also impart increased fired strength, are easy and safe to handle, low in price, non-corrosive, form no fumes or fire hazards and resist deterioration after placement. Consequently, air-setting specialties containing soluble silicates are used in refractory mortars and ramming, gunning and patching mixes in practically all refractory or chemical-resistant construction and in their maintenance. Some examples include:

boilers	heat treating furnaces
incinerators	ladle linings
cupolas	catalytic cracking chambers
smelting furnaces	sewage works
coke ovens	chimney construction
blast furnaces	sulfite digesters
open-hearths	electrolytic cells
electric steel furnaces	acid manufacturing
oxygen converters	soaking pits

The liquid sodium silicates are solutions of water soluble glasses manufactured from varied proportions of Na_2CO_3 and SiO_2 . They are available in a variety of $\text{SiO}_2/\text{Na}_2\text{O}$ weight ratios ranging from 1.6 (highly alkaline) to 3.22 (highly siliceous). In addition to the liquid sodium silicates, PQ produces a wide variety of solid products to meet the needs of different formulations. They range from highly soluble powders to lumps of transparent glass.

The potassium silicates are solutions manufactured from varied proportions of K_2CO_3 and SiO_2 . They are available in $\text{SiO}_2 : \text{K}_2\text{O}$ weight ratios of 2.5 and 2.1. Table 1 lists the compositions and properties of the PQ sodium and potassium silicates used in refractory and chemical resistant cements.

EFFECTS OF SILICATE COMPOSITION

The highly siliceous (high $\text{SiO}_2/\text{Na}_2\text{O}$ ratio) sodium silicates tend to air dry rapidly. They are the most refractory of the sodium silicates as well as the most resistant to acids. Because the total solids of these high ratio silicate solutions are relatively low, compared to the lower ratio solutions, a cement containing a high ratio solution will necessarily contain more water.

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**TABLE 1. PQ® Soluble Silicates For Refractory and Chemical-Resistant Cements
SODIUM SILICATE SOLUTIONS**

PRODUCT NAME	WT. RATIO SiO ₂ /Na ₂ O	% Na ₂ O	% SiO ₂	ALL VALUES DETERMINED AT 68°F (20°C)			VISCOSITY CENTIPOISES
				Density			
				°Be	lb./gal	g/cm ³	
N®	3.22	8.9	28.7	41.0	11.6	1.38	180
O®	3.22	9.2	29.5	42.2	11.8	1.41	400
N 38®	3.22	8.2	26.4	38.0	11.3	1.35	60
K®	2.88	11.0	31.7	47.0	12.3	1.47	960
RU®	2.40	13.8	33.2	52.0	13.0	1.55	2,100
D®	2.00	14.7	29.4	50.5	12.8	1.53	400
C®	2.00	18.0	36.0	59.3	14.1	1.68	70,000
B-W®	1.60	19.7	31.5	58.5	14.0	1.67	700

POTASSIUM SILICATE SOLUTIONS

PRODUCT	WT. RATIO SiO ₂ /K ₂ O	% K ₂ O	% SiO ₂	ALL VALUES DETERMINED AT 68°F (20°C)			VISCOSITY CENTIPOISES	pH
				Density				
				°Be	lb./gal	g/cm ³		
KASIL® #1	2.50	8.3	20.8	29.8	10.5	1.24	40	11.3
KASIL® #6	2.10	12.6	26.5	40.0	11.5	1.36	1,050	11.7

SODIUM SILICATE POWDERS

PRODUCT	WT. RATIO SiO ₂ /Na ₂ O	% Na ₂ O	% SiO ₂	% H ₂ O	APPROX. DENSITY		PARTICLE SIZE CHARACTERISTICS (TYLER SCREEN)
					lb./ft ³	g/cm ³	
SS® 65 Pwd.	3.22	23.1	74.4	—	54	0.86	Thru 65 mesh
G®	3.22	19.2	61.8	18.5	44	0.70	80% thru 100 mesh
SS-C® Pwd.	2.00	32.7	65.4	—	45	0.72	Thru 65 mesh
GD®	2.00	27.0	54.0	18.5	46	0.73	80% thru 100 mesh

SODIUM METASILICATES

PRODUCT	MOL RATIO Na ₂ O/SiO ₂	% Na ₂ O	% SiO ₂	% H ₂ O	APPROX. DENSITY		PARTICLE SIZE CHARACTERISTICS (TYLER SCREEN)
					lb./ft ³	g/cm ³	
METSO PENTABEAD® 20	1:1	29.3	28.4	41.6	55	0.88	Bet. 20 & 48 mesh
METSO BEADS® 2048	1:1	51.0	47.0	—	68	1.09	Bet. 20 & 48 mesh

POTASSIUM SILICATE POWDER

PRODUCT	Wt RATIO	% K ₂ O	% SiO ₂	% H ₂ O	APPROX. DENSITY		PARTICLE SIZE CHARACTERISTICS (TYLER SCREEN)
					lb./ft ³	g/cm ³	
KASIL® SS Pwd	2.50	28.4	71.0	—	57.4	0.92	95% thru 48 mesh

The more alkaline silicates impart greater plasticity to cement structures and may result in higher green strength. Concentrated wet mixes may be somewhat sticky. The tendency of a low ratio silicate to fuse at high temperatures may be offset in practice by the fact that less of it is needed to obtain good strength. At a given consistency, a refractory cement made from a more highly alkaline silicate will contain less water, making for a denser structure with less shrinkage.

In many refractory applications RU® sodium silicate gives the best results. In certain other formulations, because of working characteristics or special conditions of application, silicates such as D® or K® may be indicated. Formulas for chemical-resistant cements are likely to call for N®38 or N.

LIQUIDS

The liquid soluble silicates usually are more economical than the dry forms for the manufacture of wet cements. They are easy to handle and convenient to store in bulk. The many types available offer a choice of concentration and, therefore, of viscosity and density of the solutions.

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POWDERS

Powdered silicates differ in solution rate according to ratio, particle size, and degree of hydration.

High alkalinity, large surface area through small individual particles, and some water content all help to increase speed of solution. The hydrated powders GD[®] and G[®] sodium silicate have been developed to dissolve at a satisfactory rate in room temperature water. Because of their affinity for moisture, they should be kept in dry storage. A comparison of typical solution rates of the different PQ[®] silicate powders is shown in Table 2. Raising the temperature of the water will speed the solution rate; water near the freezing point has a strong retarding effect over room temperature conditions.

TABLE 2: SOLUTION RATES OF PQ[®] SILICATE POWDERS
1 part of silicate powder in 3 parts water

	TIME NEEDED TO DISSOLVE	
	50% Dissolved	75% Dissolved
At 7°C (45°F)		
GD	14 minutes	48 minutes
G		
Kasil SS	Only a few percent dissolved in one hour	
SS-C PWD.		
SS 65 PWD.		
At 25°C (77°F)		
GD	27 seconds	54 seconds
G	19 minutes	45 minutes
Kasil SS	2 hours	8 hours
SS-C PWD.	10 hours	70 hours
SS 65 PWD.	60 hours	N.D.
At 50°C (122°F)		
GD	15 seconds	22 seconds
G	54 seconds	76 seconds
Kasil SS	12 minutes	N.D.
SS-C PWD.	17 minutes	N.D.
SS 65 PWD.	15% dissolved in 30 minutes	
N.D.—Not Determined		

On sudden exposure to heat, G[®] and GD[®] silicates will fuse in their water of hydration near 400°F. The temporary tackiness developed is helpful in the adhesion of gunning compounds.

The addition of a small percentage, relative to other silicate powders present, of METSO BEADS[®] 2048 anhydrous sodium metasilicate may promote faster solution by quickly generating alkalinity in the solution water. In contrast to the amorphous silicates described, sodium metasilicate is crystalline and exhibits a true melting point, 1990°F (1088°C) for METSO BEADS[®] 2048. However, its solutions have little bonding power of their own.

REFRACTORINESS

Except for the sodium metasilicates, sodium silicates are amorphous and exhibit no sharp melting points. Depending on composition they begin to soften at approximately 1100°F (590°C) and begin to flow at about 1400°F (760°C). Commercial potassium silicates have appreciably higher flow points (See Table 3).

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**TABLE 3: HIGH TEMPERATURE BEHAVIOR OF SOLUBLE SILICATES
IN ANHYDROUS STATE**

PQ® PRODUCTS	APPROXIMATE SOFTENING POINT ¹ °F(°C)	APPROXIMATE FLOW POINT ² °F(°C)
S 35	1230(666)	1600(871)
N, O, N 38	1200(649)	1545(840)
G, SS 65 Pwd.	1200(649)	1545(840)
K	1185(640)	1520(827)
RU	1140(615)	1455(790)
D, C, GD, SS-C Pwd.	1095(590)	1400(760)
B-W	1050(565)	1345(729)
METSO BEADS 2048		1990(1088) ³
KASIL #1	est. 1280/1360(693/738)	1660(904)
KASIL SS Pwd.	est. 1280/1360(693/738)	1660(904)
KASIL #6	est. 1280/1360(693/738)	1635(890)

¹Viscosity reaches 4×10^7 poises
²Viscosity reaches 10^5 poises
³True melting point

Soluble silicates form a ceramic bond with clay-type minerals and may form forsterite (crystalline magnesium orthosilicate) upon reaction with magnesium oxide. Consequently, good performance at 3200°F (1760°C) is easily obtainable in formulations with selected refractory filler material. Generally, in mortars the filler should be more refractory than the raw material in the brick. If brick and mortar are to be equally heat resistant. For example, a higher alumina content in the mortar than in the brick will equalize the service temperatures of fire brick and bonding mortar.

POTASSIUM SILICATES

Potassium silicates soften and flow at a higher temperature than corresponding sodium silicates (See Table 3). For this reason KASIL® potassium silicates are used advantageously in various high temperature cements.

Another characteristic of mortars made with potassium silicate cement is their smoothness and lack of tack. They do not stick to the trowel, yet they retain all the desirable attributes of sodium silicate formulations. Still another special value of potassium silicate cement specialities is that efflorescence, or blooming, is less conspicuous.

Because of the greater affinity of potassium silicate for moisture, mixes containing KASIL® potassium silicate dry more slowly. Furthermore, a difference in the tendency of the potassium systems to form hydrated crystals contributes to the superiority of KASIL® in chemical-resistant mortars.

SODIUM-POTASSIUM SILICATE

Anhydrous soluble silicates containing both sodium and potassium alkali are unique in their possession of minimum softening points. These occur at a lower temperature than in either sodium or potassium silicate alone.

This phenomenon suggests the value of using a combination of sodium and potassium silicate in refractory gunning compounds or in any situation where it is desirable to more precisely control the temperature of ceramic bond formation.

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FORMULATIONS

Formulations vary with the intended application. The trend is toward proprietary products developed by extensive research and evaluation in the field. The following suggestions may be used to obtain optimum performance from the physical and chemical properties of the soluble silicates.

Density/Volume Stability/Plasticity - In addition to the choice of the silicate binder, density of the cement structure depends on the shape and size of the filler particles. High impermeability is obtained with an assortment of mesh sizes and combinations of particle shapes that will promote close packing.

On the other hand, volume stability on firing is related to water content and to the proportion of solids to liquids. Relatively alkaline silicates such as RU® will tend to hold shrinkage to a minimum. Of course, when density becomes excessive, there will be a greater tendency toward bloating. However, this can be controlled through proper procedures in initial firing.

Plasticity may be regulated through the amount of plastic ingredients (raw clay or bentonite) relative to non-plastic ingredients (calcined clay, chrome ore, or silica).

Storage Stability - Certain clays and grogs are not very stable when stored as wet mixtures with soluble silicate. This is due to a variety of causes. If the presence of soluble calcium or magnesium as an impurity is responsible, some type of sequestering agent should be a helpful additive. Certain specific formulations of this type are patented.

Clays which prove incompatible with liquid silicates may be formulated with the readily soluble hydrated sodium silicate powders G® and GD®.

Chemical Setting Agents - Chemical set is desired primarily in chemical-resistant mortars which normally cannot be aged by exposure to high temperature. Occasionally, the technique is applied to refractory formulations. Sodium silicofluorides are most commonly employed, but recently their use has been discouraged because of possible hazards. Newer accelerators are also in use. In some cases, it is sufficient to brush dilute mineral acid on the cement or coating surface in order to neutralize its alkalinity.

TABLE 4: FILLERS USED WITH SOLUBLE SILICATES IN TYPICAL REFRACTORY AND CHEMICAL-RESISTANT SPECIALTIES

1. Air-Setting Refractory Specialties

TYPE FILLER A.

raw fire clay
calcined fire clay
kyanite
mullite
alumina

chrome ore
silica
silicon carbide
graphite

zircon

magnesite

chrome ore

ACID REFRACTORIES

high temperature bonding mortars
in wet & dry form; coke oven
cements & other gunning mixes;
patching compounds & linings.

B. NEUTRAL REFRACTORIES

plastic chrome ore
chrome mortars in wet & dry form
chrome patching & gunning compounds
air-setting silica specialties for service in
lower temperature ranges
silicon carbide & graphite products.

C. BASIC REFRACTORIES

magnesite ramming, gunning and
patching mixes
magnesite-chrome specialties

2. Chemical-Resistant Cements

silica (powdered quartz, ganister, silica flour) Chemical resistant mortars & linings

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HOW TO USE SILICATE-BASED CEMENTS

Silicate mortars may be applied by dipping or troweling and are made up accordingly with the proper amount of water. Where a powdered mixture is prepared on the job, best results are obtained when the water is not too cold and the mix stands long enough to dissolve the powdered silicate before it is placed. In chemical-resistant construction it is important to keep the mortar joints thin. Only a few courses of brick should be built at one time to maintain the minimum amount of mortar and to avoid squeezing it out.

Good wetting is the first requirement for good bonding with aqueous binders. Since water will not wet a metal surface when covered with grease or oxide films, adhesion to metal is promoted by sand blasting or alkaline cleaning.

Bloating is caused by the sudden escape of water or steam, especially through a case-hardened, surface layer of the material. It is prevented by firing up new construction gradually or by reducing the density of the filler.

STANDARDS AND TESTS

ASTM Committee C-8 on Refractories has developed a "Standard Specification for Air-Setting Refractory Mortar (Wet Type) for Boiler and Incinerator Services" known as ASTM Designation C178. Standard test methods for bonding strength and for refractoriness of wet-air-setting refractory mortars are identified under designations C198 and C199.

Chemical-resistant mortars are the concern of ASTM Committee C-3. The following designations involve formulations with soluble silicates:

- C267-01 Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacing and Polymer Concretes.
- C397-00 Standard Practice for Use of Chemically Setting Chemical-Resistant Silicate and Silica Mortars.
- C413-01 Standard Test Method for Absorption of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacing and Polymer Concretes.
- C414-99 Standard Test Method for Working, Setting and Service Strength Setting Times of Chemically Setting Chemical-Resistant Silicate and Silica Mortars.
- C466-97 Standard Specification for Chemically Setting Silicate and Silica Chemical-Resistant Mortars.
- C307-99 Standard Test Methods for Tensile Strength of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacing
- C579-01 Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes.
- C580-98 Standard Test Methods for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes.
- C905-01 Standard Test Methods for Apparent Density of Chemical-Resistant Mortars, Grouts, Monolithic Surfacing and Polymer Concretes.

SAFETY INFORMATION

Depending on their degree of alkalinity, soluble silicates may irritate or burn the skin and eyes. 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 or further assistance, contact PQ's Industrial Chemical Division. Our technical sales representative will be happy to assist you in selecting and evaluating the proper PQ brand silicate for your specific requirements.