Silquest* Silanes

products and potential applications

Product Description

Silquest silanes are versatile products that react with a wide variety of organic and inorganic materials. Their unique ability as coupling agents, crosslinking agents, and surface modifiers has been proven in an ever-increasing number of applications, ranging from fuel-saving silica tires, adhesives to coatings to fiberglass reinforced composites. The benefits that Silquest silanes may impart to these end-use applications are highlighted on page 2.

Application Guidelines

The choice of a Silquest silane is specific to resin type and application. We recommend that you contact the nearest Momentive Performance Materials sales office for assistance before selecting a silane for your end-use application. The following selection guide is provided to help you select a Silquest silane for various polymer (resin) systems. It should be considered merely a starting point. The selection of the preferred silane for a specific end-use application will require specific experimentation.

Momentive Performance Materials provides versatile materials as the starting point for our creative approach to ideas that help enable new developments across hundreds of industrial and consumer applications. We are helping customers solve product, process, and performance problems; our silanes, fluids, elastomers, sealants, resins, adhesives, urethane additives, and other specialty products are delivering innovation in everything from car engines to biomedical devices. From helping to develop safer tires and keeping electronics cooler, to improving the feel of lipstick and ensuring the reliability of adhesives, our technologies and enabling solutions are at the frontline of innovation.

Potential Applications	Typical Benefits
Adhesives	Moisture-initiated crosslinking of resins, improved wet adhesion, primerless adhesion to many materials, improved chemical resistance, weatherability and durability
Coatings / Inks	Moisture-initiated crosslinking of resins, improved adhesion, chemical and corrosion resistance, weatherability, pigment dispersion and scrub resistance
Fiber Reinforced Composites and Glass Insulation	Coupling of resins with fibers for improved resiliency of insulation batts, better wet strength retention and electrical properties of FRP composites, and improved fiber strand integrity, protection and handling
Filler Treatment	Improved coupling of resins with fillers, better filler dispersion and processing ease in thermoset and thermoplastic resins
Polymer Modification	Moisture-cure crosslinking for improved environmental and chemical resistance
Rubber and Elastomers	Coupling of resins with minerals for improved composite strength, toughness, abrasion resistance, rolling resistance, wet electrical properties and rheology control, fewer mixing steps and better silica dispersion
Sealants	Moisture-initiated crosslinking of resins, improved adhesion, chemical resistance, filler dispersion and weatherability
Thermoplastics	Moisture-curable crosslinked polyethylene for wire & cable and polyethylene crosslinked (PEX) pipe, mineral and pigment treatment for dispersibility and coupling of resins with fillers in high performance thermoplastics
Tires	Coupling silica in tire compounds to improve the rolling resistance, traction and wear. New generation silanes may facilitate higher-efficiency tire manufacturing while enhancing tire performance.

Silanes make performance possible, and here is why.

The following pages outline how silanes work, and how they are added to systems.

How they work

Silanes have four main functions:

- **Crosslinking**

Once attached to a polymer backbone, silanes can link polymer molecules together via the formation of siloxane bonds, creating a three-dimensional network. This “crosslinking” is activated by ambient moisture and can take place at ambient temperature. Silanes can provide improved thermal stability, creep resistance, hardness and chemical resistance to coatings, adhesives and sealants.

- **Adhesion Promotion**

Silanes can provide improved substrate adhesion in adhesives, sealants and coatings, especially under hot and humid conditions. Silanes are commonly used to improve adhesion to glass and metals, but they can also be beneficial with difficult substrates like polyamide, SMC, acrylics, PVC and others.

- **Coupling**

Silanes can couple inorganic pigments and fillers to organic resins. Coupling typically improves the moisture and chemical resistance of the coating or adhesive.

- **Dispersion**

Silanes can aid in the dispersion of inorganic pigments and fillers in coatings and sealants. This can lead to lower viscosity in the formulated product and can improve the hiding power of a coating.

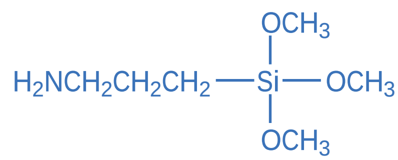
Chemistry

Organofunctional silanes are bi-functional molecules in that they usually have two types of reactivity built into their structures - organic and inorganic. Figure 1 shows the common elements of a typical organofunctional silane.

Figure 1: Anatomy of a Typical Organofunctional Silane

Y	— R	— Si	— X_3
Reactive Organic Group	Link	Silicon Atom	Hydrolyzable Groups

For example:



gamma-Aminopropyltrimethoxysilane
Silquest A-1110 silane

- **Reactions at the Organic End of a Silane**

The organic end (Y) is designed for reactivity with an organic resin. Reactive organic groups that are available include primary and substituted amino, epoxy, methacryl, vinyl, mercapto, urea and isocyanate. The organic group is selected either to react with or co-polymerize into a resin or to take part in the cure reaction of the resin system.

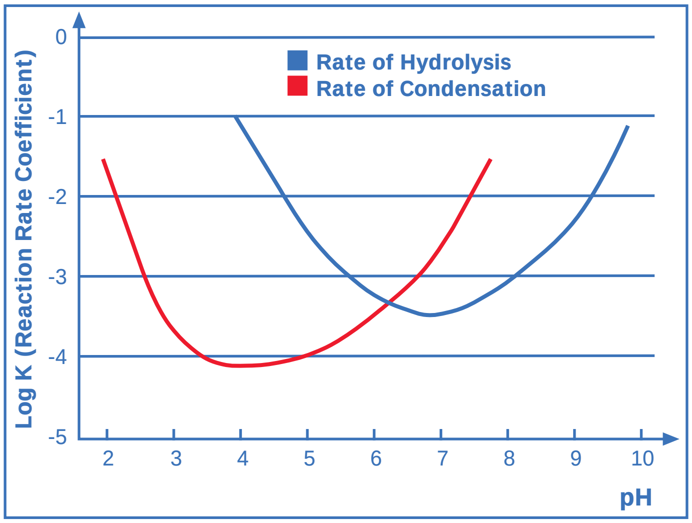
- **Linking Group in the Center of a Silane**

Between the organic group and the silicon atom is a linking group, commonly, a “trimethylene chain.” The silicon-carbon bond of the linking group is stable to most environmental conditions. The inorganic end of the molecule reacts through hydrolyzable groups attached to silicon (X). The hydrolyzable groups are usually alkoxy groups such as methoxy, ethoxy or isopropoxy. Each hydrolyzes at a different rate and releases a different alcohol upon reaction with ambient moisture. In some cases only two hydrolyzable groups are present, although a three-group configuration is more convenient synthetically and usually gives more moisture-resistant bonds. Most coupling agents have only one silicon atom, but some silanes are available with multiple silicons.

- **Reactions at the Silicon End of a Silane**

Silane reactivity is dictated by the initial reaction, with water, of the "X" groups on the silicon atom. The "X" groups hydrolyze to form silanols that then go on to condense with other silanols or other hydroxyl groups. These condensation reactions liberate water. The speed of both hydrolysis and condensation is controlled by pH [Figure 2-effect of pH]. We will focus on each of these reactions separately, below.

Figure 2: Effect of pH



- **Hydrolysis**

In order to become "active" the silane must first hydrolyze. The reaction of the silicon end of the molecule, as depicted in Figure 3, is initiated by hydrolysis of the alkoxy group, usually after exposure to ambient moisture but sometimes by the purposeful addition of water. This reaction releases an alcohol and forms a silanol. The speed with which hydrolysis occurs depends on the pH of the formulation (slowest at pH 7) and upon the steric bulk and polarity of the alcohol residue (methoxy > ethoxy > 2-methoxyethoxy > isopropoxy >> t-butoxy). Both bases (such as organic amines) and acids (such as tin compounds) will catalyze the reaction.

Figure 3: Hydrolysis and Condensation Reactions of Organofunctional Silanes

Hydrolysis:

$$Y–R–Si(OCH_3)_3 \xrightarrow{H_2O} Y–R–Si(OH)_3 + 3\ CH_3OH$$

Silanol Condensation on a Surface (Adhesion/Coupling):

$$Y–R–Si(OH)_3 + HO–Si–Surface \longrightarrow Y–R–Si–O–Si–Surface + H_2O$$

Condensation with another Silane - (Crosslinking):

$$2\ Polymer–Y–R–Si(OH)_3 \longrightarrow Polymer–Y–R–Si–O–Si–R–Y–Polymer + H_2O$$

The naturally occurring acidity or alkalinity of most inorganic surfaces is usually sufficient to catalyze silane hydrolysis. The adsorbed water found on these surfaces is generally adequate to complete hydrolysis of the silane.

☐ *Silanol Condensation on a Surface (Adhesion/Coupling)*

Once in the silanol state, the silane can condense with a mineral or substrate surface. This is the first step in the actual coupling process. The silane migrates to the surface, hydrolyzes, hydrogen bonds with the surface and upon release of water forms a direct covalent bond with the surface.

Condensation proceeds slowest at pH 4-5 and is catalyzed by both acids and bases. Each silicon atom has up to three hydrolyzable sites but it is unlikely that all three sites will bond with the surface. Many of the silanols that do not react with the surface can condense with each other to form an Si-O-Si network on the substrate surface. To complete the adhesion process, the reactive organic group on the silane reacts with the resin or binder of the coating, adhesive or sealant.

☐ *Silane Condensation for Polymer Crosslinking*

The most common method for silane crosslinking involves attachment of the silane to a polymer backbone through reaction with the "Y" group. This "silylation" process can involve co-polymerizing a methacrylate silane during the production of an acrylic co-polymer, end-capping a polyurethane with amino or mercapto silanes, or capping diols with isocyanato silanes.

Introducing Silanes into Polymer-based Systems

There are basically three ways to use a silane in a polymer matrix.

- Polymer modification
- Integral blending
- Filler and surface pre-treatment

The optimum method is governed by the benefits sought, variables of the chemistry, nature of the application and cost. Like any moisture-reactive system, silane reaction rates depend on availability of water, the moisture diffusion rate, pH, catalysts and the system's overall hydrophobicity.

- **Polymer Modification**

The organic functionality of silanes can be used to silylate polymers by grafting, endcapping or co-polymerization. This can be accomplished with most polymers: acrylics, polyesters, epoxies, urethanes, polyolefins, etc.

Silylated copolymers offer coupling or crosslinking reactions through the grafted silicon group, without requiring high temperature cure. The result is a moisture-cured, self-crosslinking system generally curable at room temperature. Coupling and crosslinking typically give significant improvements in polymer properties including:

- ☐ *Durability*
- ☐ *Water and chemical resistance*
- ☐ *Higher tensile strength and elongation*
- ☐ *Tear and crack resistance*
- ☐ *Toughness and abrasion resistance*
- ☐ *Thermal stability*
- ☐ *Creep resistance*

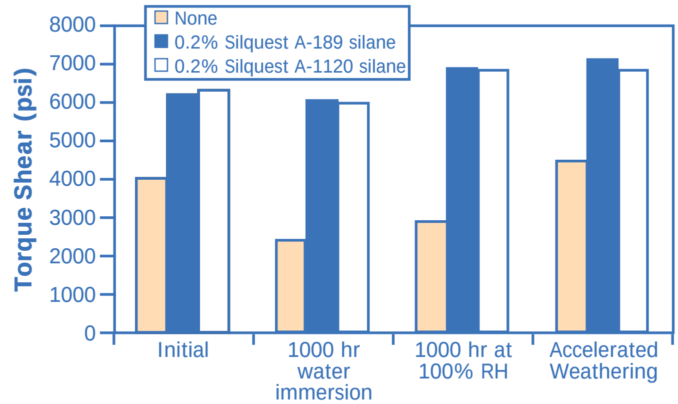
- **Integral Blending**

Integral blending is often the easiest method for using silanes because it avoids a separate polymer modification or surface pre-treatment step.

Silquest silanes can be mixed with the polymer component of most systems or formulations by any convenient method. For good dispersion of the small amounts usually involved, it is advisable to prepare a pre-dispersion containing a high silane concentration to add to the bulk of the polymer. In solvent-containing systems, the silane can be pre-dispersed in a small amount of the solvent. In latex systems, it can be added to the coalescing solvent.

The chosen silane should have reactivity with the resin; there is enough variety in silane functionalities to make this possible. Figure 4 shows the adhesion obtained between an epoxy paint and aluminum metal using a mercapto and an amino silane. Generally, the biggest increase in adhesion is achieved after exposure to moisture or humidity.

Figure 4: Improved Wet and Dry Adhesion of Epoxy Paint to Aluminum



Note: Test results. Actual results may vary.

- **Filler and Surface Pre-treatment**

Silane coupling agents may be applied as primers or pre-treatments to aid bonding of polymers to organic and inorganic surfaces. Silane primers typically are applied as "wash" coats – very thin layers with no "body". A simple primer formulation is given in Table 1. Primers may contain more than one silane. A small amount of water is added to hydrolyze the silane and bring it into its active state. For most silanes (except aminosilanes) some organic solvent is needed; formulation in an alcohol helps minimize silane condensation prior to use of the primer. The primer can be applied by spraying, dipping or brushing. It is typically dried at 100-125°C for 10-60 minutes to complete reaction with the surface prior to application of the coating. Some applications require only room temperature drying.

Table 1: Typical Silane Primer Recipe

Parts by Weight	Ingredient
5	Organofunctional silane
40	SDA - alcohol
5	Distilled water
40	Xylene
5	n-butanol
4	2-butoxyethanol

Product formulations are included as illustrative examples only. Momentive makes no representation or warranty of any kind with respect to any such formulations, including, without limitation, concerning the efficacy or safety of any product manufactured using such formulations.

Primers offer excellent technology for improving adhesion in coatings. They do require extra steps, labor and care that rule them out of many applications. Even if a primer is not used for the final version of a product, it is worthwhile to experiment with primers to observe the possible benefits.

Reactive Resins	Silquest Silanes		
Resin System	**Aqueous**	**Non-Aqueous**	
Acrylics with carboxy or hydroxyl groups	A-187*, WetLink* 78, CoatOSil* 1770	A-1100*, A-1110, A-1120 A-1637, A-Link* 15	
Epoxy	A-187, A-1106, WetLink 78	A-187, A-1100, A-1110, A-1120 A-1637, A-Link 15	
Melamine	–	A-1100, A-1110, A-1120, A-1637	
Phenolic	A-187, A-1106, WetLink 78	A-1100, A-1110, A-1120, A-1524, A-1637	
Unsaturated polyesters	–	A-174*NT	
SPUR⁺* prepolymer	–	A-1100, A-1110, A-1120, A-1637, A-Link 15, A-Link 597	
Polysulfide	–	A-187	
Polyurethane	A-187, WetLink 78, CoatOSil 1770	**One Pack** A-187, A-1524	**Two Pack** A-1100, A-1170, A-Link 15
Silicone	–	**Addition Cure** A-171*, A-174NT	**Condensation Cure** A-1100, A-1110, A-1120, A-Link 15, A-Link 597

Thermoplastic Resins	Silquest Silanes
Polyamide	A-187, A-1100, A-1120
Polyester	A-186, A-187, A-1100, A-1524
Polyolefin	A-151, A-171
PVC / PVB	A-187, A-1100, A-1160, A-1637

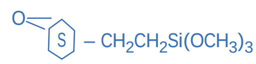
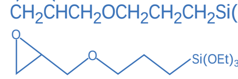
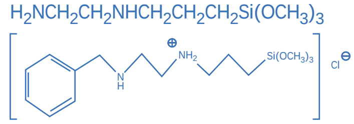
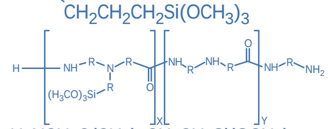
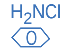
Elastomers	Silquest Silanes
Butyl	A-174NT, A-189
Neoprene	A-189, A-Link 599
Nitrile	A-187, A-189
Silicone	A-171, A-174NT
SBR	A-1100, A-1110, A-1120, A-189, A-Link 599

Silane Selection Decision Tree for Coatings Adhesives and Sealants

Resin System (Waterbased?)

- **Yes**
  - **ACRYLIC**
    - Silquest A-174NT silane
    - Silquest A-187 silane
    - Silquest A-1106 silane
    - CoatOSil 1770 silane
    - Silquest WetLink 78 silane
    - CoatOSil 1757 silane
  - **PUD**
    - Silquest A-1106 silane
    - Silquest A-1120 silane
    - Silquest A-1170 silane
    - CoatOSil 1770 silane
    - Silquest A-187 silane
    - Silquest WetLink 78 silane
- **No**
  - **ACRYLIC**
    - Silquest A-174*NT silane
    - CoatOSil* 1757 silane
    - Silquest A-11878 silane
    - Silquest A-1100* silane
    - Silquest A-1170 silane
    - Silquest A-2120 silane
    - Silquest A-1110 silane
    - Silquest A-1120 silane
    - Silquest A-1130 silane
    - CoatOSil 1770 silane
    - Silquest WetLink* 78 silane
  - **PUR**
    - **1K**
      - Silquest A-1170 silane
      - Silquest A-187 silane
      - Silquest A-Link 25 silane
      - Silquest A-1637 silane
      - CoatOSil 1770 silane
    - **2K**
      - Silquest A-1120 silane
      - Silquest A-1170 silane
      - Silquest A-1524 silane
      - Silquest A-1110 silane
      - Silquest A-1637 silane
      - Silquest A-187 silane
      - CoatOSil 1770 silane
      - Silquest Y-9669 silane
      - Silquest A-Link 15 silane
  - **EPOXY**
    - Silquest A-187* silane
    - CoatOSil 1770 silane
    - Silquest WetLink 78 silane
    - Silquest A-1100 silane
    - Silquest A-1120 silane
    - Silquest Y-9669 silane
    - Silquest A-Link* 597 silane
    - Silquest A-1170 silane
  - **HYBRID**
    - Silquest A-Link 35 silane
    - Silquest A-171* silane
    - Silquest A-1120 silane
    - Silquest A-1637 silane
  - **RTV SILICONE**
    - **FILLED**
      - Silquest A-1120 silane
      - Silquest A-1170 silane
      - Silquest A-1100 silane
    - **CLEAR**
      - Silquest A-1524 silane
      - Silquest A-Link 597 silane
      - Silquest A-1120 silane
      - Silquest A-151 silane
  - **POLY SULFIDE**
    - Silquest A-187 silane
    - Silquest A-189 silane
    - Silquest A-1100 silane
    - CoatOSil 1770 silane
    - Silquest A-1891 silane

Chemical Structures and Typical Physical Properties

Silquest	Chemical Name	Formula	Formula Molecular Weight
SILANE ESTERS			
A-137	Octyltriethoxysilane	$CH_3(CH_2)_7Si(OCH_2CH_3)_3$	276.6
A-138	Propyltriethoxysilane	$CH_3(CH_2)_2Si(OCH_2CH_3)_3$	206.4
A-162	Methyltriethoxysilane	$CH_3Si(OCH_2CH_3)_3$	178.3
A-1230	Proprietary nonionic silane dispersing agent	—	Proprietary
A-1630A	Methyltrimethoxysilane	$CH_3Si(OCH_3)_3$	136.3
A-Link* 597	*tris*-[3-(Trimethoxysilyl)propyl] isocyanurate	—	615.4
HDTMS	Hexadecyltrimethoxysilane	$CH_3(CH_2)_{15}Si(OCH_3)_3$	346.6
SILANES			
Vinyl			
RC-1	Coupling agent - proprietary	—	—
A-151NT	Vinyltriethoxysilane	$CH_2{=}CHSi(OCH_2CH_3)_3$	190.4
A-171*	Vinyltrimethoxysilane	$CH_2{=}CHSi(OCH_3)_3$	148.2
A-172NT	Vinyl-*tris*-(2-methoxyethoxy) silane	$CH_2{=}CHSi(OCH_2CH_2OCH_3)_3$	280.4
A-2171	Vinylmethyldimethoxysilane	$CH_2{=}CHSiCH_3(OCH_3)_2$	132.3
Methacryloxy			
A-174*NT	*gamma*-Methacryloxypropyltrimethoxysilane	$CH_2{=}C(CH_3)CO_2CH_2CH_2CH_2Si(OCH_3)_3$	248.4
Epoxy			
A-186	*beta*-(3,4-Epoxycyclohexyl)ethyltrimethoxysilane		246.1
A-187*	*gamma*-glycidoxypropyltrimethoxysilane	$CH_2CHCH_2OCH_2CH_2CH_2Si(OCH_3)_3$ (O bridging CH_2CH)	236.1
A-1871	*gamma*-glycidoxypropyltriethoxysilane		278.1
WetLink* 78	3-glycidoxypropylmethyldiethoxysilane		248.4
CoatOSil* 1770	*beta*-(3,4-epoxycyclohexyl)ethyltriethoxysilane		288.1
Sulfur			
A-189	*gamma*-mercaptopropyltrimethoxysilane	$HSCH_2CH_2CH_2Si(OCH_3)_3$	196.4
A-1891	*gamma*-mercaptopropyltriethoxysilane	$HSCH_2CH_2CH_2Si(OCH_2CH_3)_3$	238.4
A-Link 599	3-octanoylthio-1-propyltriethoxysilane	$CH_3(CH_2)_6C({=}O)SCH_2CH_2CH_2Si(OCH_2CH_3)_3$	364.6
Amino			
A-1100*	*gamma*-Aminopropyltriethoxysilane	$H_2NCH_2CH_2CH_2Si(OCH_2CH_3)_3$	221.4
A-1102	*gamma*-Aminopropyltriethoxysilane (Technical Grade)	$H_2NCH_2CH_2CH_2Si(OCH_2CH_3)_3$	221.4
A-1106	*gamma*-Aminopropylsilsesquioxane (aqueous solution)	$(H_2NCH_2CH_2CH_2SiO_{1.5})n$	Oligomer
A-1110	*gamma*-Aminopropyltrimethoxysilane	$H_2NCH_2CH_2CH_2Si(OCH_3)_3$	179.3
A-1120	N-*beta*-(Aminoethyl)-*gamma*-aminopropyltrimethoxysilane	$H_2NCH_2CH_2NHCH_2CH_2CH_2Si(OCH_3)_3$	222.4
A-1128	Benzylamino-silane		—
A-1130	Triaminofunctional silane	$H_2NCH_2CH_2NHCH_2CH_2NHCH_2CH_2CH_2Si(OCH_3)_3$	265.4
A-1170/Y-9627	*bis*-(*gamma*-Trimethoxysilylpropyl)amine	H-N($CH_2CH_2CH_2Si(OCH_3)_3$)($CH_2CH_2CH_2Si(OCH_3)_3$)	342.6
A-1387	Polyazamide silane (50% actives in methanol)		—
A-1637	Delta-aminoneohexyltrimethoxysilane	$H_2NCH_2C(CH_3)_2CH_2CH_2Si(OCH_3)_3$	221.4
A-2120	N-*beta*-(aminoethyl)-*gamma*-aminopropylmethyldimethoxysilane	$H_2NCH_2CH_2NHCH_2CH_2CH_2SiCH_3(OCH_3)_2$	206.4
A-2639	Delta-aminoneohexylmethyldimethoxysilane	$H_2NCH_2C(CH_3)_2CH_2CH_2SiCH_3(OCH_3)_2$	205.4
Y-9669	N-Phenyl-*gamma*-aminopropyltrimethoxysilane	 $– NH\text{-}CH_2CH_2CH_2Si(OCH_3)_3$	255.4
A-Link 15	N-ethyl-3-trimethoxysilyl-methylpropamine		222.1
Ureido			
A-1160	*gamma*-Ureidopropyltrialkoxysilane (50% in methanol)	$H_2NC({=}O)NHCH_2CH_2CH_2Si(OCH_3)_x(OCH_2CH_3)_{3-x}$	Mixture
A-1524	*gamma*-Ureidopropyltrimethoxysilane	$H_2N\,C({=}O)NHCH_2CH_2CH_2Si(OCH_3)_3$	222.4
Isocyanate			
A-Link 25	*gamma*-Isocyanatopropyltriethoxysilane	$O{=}C{=}NCH_2CH_2CH_2Si(OCH_2CH_3)_3$	247.3
A-Link 35	*gamma*-Isocyanatopropyltrimethoxysilane	$O{=}C{=}NCH_2CH_2CH_2Si(OCH_3)_3$	205.2

(1) estimated (2) ELINCS Dossier: 436-680-4

Chemical Structures and Typical Physical Properties

Silquest	Physical Form CL=Clear Liquid	Viscosity at 25°C, cSt	Apparent Specific Gravity, 25°C	Refractive Index, 25°C	Flash Point, °C (°F)	Boiling Point, °C	CAS #	EINECS #
SILANE ESTERS								
A-137	CL	—	0.876	—	82 (180)	250[1]	2943-75-1	220-941-2
A-138	CL	—	0.891	1.395		180	2550-02-9	219-842-7
A-162	CL	—	0.915	1.382	29 (85)	143	2031-67-6	217-983-9
A-1230	CL	37	1.080	—	87 (190)	>150	Proprietary	Proprietary
A-1630A	CL	0.50	0.953	1.369	12 (54)	101	1185-55-3	214-685-0
A-Link* 597	CL	~95	1.170	—	102 (216)	>250	26115-70-8	247-465-8
HDTMS	CL	—	0.886	—	104 (219)	>350	16415-12-6	240-464-3
SILANES								
Vinyl								
RC-1	CL	—	0.950	—	47 (116)	>160	Proprietary	Proprietary
A-151NT	CL	0.70	0.905	1.397	44 (111)	160	78-08-0	201-081-7
A-171*	CL	—	0.967	1.390	28 (82)	122	2768-02-7	220-449-8
A-172NT	CL	1-2	1.040	1.427	92 (198)	285	1067-53-4	213-934-0
A-2171	CL	—	0.888	—	8 (46)	106	16753-62-1	240-816-6
Methacryloxy								
A-174*NT	CL	2	1.045	1.429	108 (226)	255	2530-85-0	219-785-8
Epoxy								
A-186	CL	5	1.065	1.448	112 (235)	310	3388-04-3	222-217-1
A-187*	CL	3	1.069	1.427	110 (230)	290	2530-83-8	219-784-2
A-1871	CL	—	1.003	–	118 (244)	>300	2602-34-8	—
WetLink* 78			0.980		104 (219)	290	2897-60-1	220-780-8
CoatOSil* 1770			1.004		129 (264)	>300	10217-34-2	425-050-4
Sulfur								
A-189	CL	—	1.0500	1.440	88 (190)	212	4420-74-0	224-588-5
A-1891	CL	—	0.990		88 (190)	>200	14814-09-6	—
A-Link 599	CL	—	0.9686	—	110 (230)	>400	220727-26-4	436-690-9
Amino								
A-1100*	CL	2	0.950	1.420	96 (205)	220	919-30-2	213-048-4
A-1102	CL	—	0.9500	—	49 (120)	217	919-30-2	213-048-4
A-1106	CL	4	1.076	—	>66 (>150)	>100	58160-99-9	261-145-5
A-1110	CL	1.68	1.014	—	82 (180)	210	13822-56-5	237-511-5
A-1120	CL	6	1.030	1.448	138 (280)	259	1760-24-3	212-164-2
A-1128	CL	—	0.942	—	9 (48)	>65	42965-91-3	256-023-3
A-1130	CL	—	1.030	—	125 (257)	>250	35141-30-1	252-390-9
A-1170/Y-9627	CL	—	1.040	—	113 (235) (at 0.4 mmHg)	152	82985-35-1	280-084-5
A-1387	CL	—	0.969	—	8 (46)	>65	—	—
A-1637	CL	—	0.976	—	97 (207)	230	157923-74-5	(2)
A-2120	CL	—	0.980	—	>93 (>200) (at 0.8 mmHg)	85	3069-29-2	221-336-6
A-2639	CL	—	0.925	—	100 (212)		156849-43-3	—
Y-9669	CL	—	1.070	—	146 (295)	310	3068-76-6	221-328-2
A-Link 15			0.952		91 (196)		>100	227085-51-0
Ureido								
A-1160	CL	2.2	0.920	1.386	14 (58)	>65	116912-64-2	—
A-1524	CL	—	1.150	1.386	99 (210)	250	23843-64-3	245-904-8
Isocyanate								
A-Link 25	CL	1.5	0.999	1.420	77 (171)	238	24801-88-5	246-467-6
A-Link 35	CL	1.4	1.073	1.420	99 (210)	210	15396-00-6	239-415-9

(1) estimated (2) ELINCS Dossier: 436-680-4

Tips For Success With Silanes

General Tips

- For good dispersion of silanes in solvents or polymer-based formulations, the unhydrolyzed silane should be dispersed as well as possible. Intensive agitation and adding solvent are two useful recommendations in case of difficulties. As a rule, pH should be controlled prior to adding silanes, and adjusted as necessary throughout the process.

- As the hydrolysis reaction takes place in the presence of water, no silane condensation is expected in dry, tight containers.

- Ambient humidity is often sufficient for silanes to fully hydrolyze and therefore to activate silanes for subsequent condensation.

- It can take time for complete hydrolysis to occur. To ensure a reaction, silanes can be left to react with moisture one hour prior to use, if needed.

Tips for Water-Based Systems

- Some silanes are not water-soluble. However, once hydrolyzed, most of these become water-soluble.

- For most silanes, high concentrations in solutions are not possible because competitive condensation results in oligomerization and precipitation. Stable solutions can be obtained at concentrations not exceeding 5-8% depending on the silane used.

- Hydrolysis is ideally run under acidic or basic conditions. Neutral water reacts slowly. Acid hydrolysis at pH 4-6 in diluted solutions optimizes hydrolysis of most silanes (except aminosilanes) without premature formation of oligomers and insoluble polymers.

- Condensation of hydrolyzed silanes is slowest at slightly acidic pH. But it does occur under all conditions and is promoted at elevated temperatures.

- When reacting silanes with a hydroxylated surface, surface pH and catalytic activity should be considered to be important parameters. Neutral surface (quartz, silica, mica) will not react readily. Acidic surfaces (such as kaolin) react quickly. Basic surfaces (glass, aluminum, magnesium hydroxides) react almost instantly. Solid surfaces in normal atmospheric conditions are usually exposed to enough moisture to promote the reaction without additional water.

Guidelines for Handling Silanes

Organofunctional silanes are highly reactive materials, requiring special handling precautions for safe use. As the world's leading supplier of high quality organofunctional silanes, Momentive Performance Materials is presenting the following information to customers as part of our continuing effort and commitment to Product Stewardship. This document contains general safety guidelines only and should in no way be viewed as a substitute for your exercise of all appropriate safety measures.

This information is being provided to you in good faith by Momentive Performance Materials in the spirit of Product Stewardship. The information contained herein applies only to Momentive's products. Competitive materials may not necessarily be chemical equivalents and, as such, may pose different safety issues and hazards.

Purpose of this document

This document is intended to provide an overview of the special safety issues and resultant storage and use considerations for organofunctional silanes. **This document is not intended to replace, or act as a substitute for, the material safety data sheet (MSDS), or to identify all generally accepted industry standards for chemical handling that may be relevant to the use of all potentially hazardous chemicals.** Accordingly, Momentive Performance Materials recommends that all laboratory and manufacturing/operations personnel who use or handle organofunctional silanes be well acquainted with the MSDS and other company literature for each specific silane, and also appropriate industry safety practices and standards for chemical management.

If further background is needed regarding the toxicology, safe use, or handling of Momentive Performance Materials organo-functional silanes, we recommend calling our Product Safety and Regulatory Affairs group at 304.652.8155.

Process Safety Reviews and Inspections

Before using organofunctional silanes at your location, a thorough safety review of all equipment and operational facilities should be conducted. Aspects of facility electrical/hazard classification, equipment operation, operational procedures, personal protective equipment, personnel training, fire safety, emergency equipment, emergency procedures and disposal issues, etc., should be covered in these reviews. Periodic safety inspections are important in maintaining safe operations and should be conducted as deemed appropriate.

Understanding the Reactivity of Silanes

The reactivity of each specific silane is outlined in its MSDS in Section 10, subtitled "Stability and Reactivity." However, reactions that are common to all alkoxy silanes [silanes which contain groups suchas methoxy-, ethoxy-, or isopropoxy- attached to the silicon atom(s)] include hydrolysis and condensation, as described below. In addition to hydrolysis and condensation, each organofunctionality imparts its own specific reactivity characteristics. Momentive Performance Materials manufactures a wide variety of organofunctional silanes, each tailored with different reactivity characteristics. A discussion of each silane with its unique reactivity is beyond the scope of this document. However, additional reactivity information and assistance with the proper silane selection for your specific application(s) can be obtained by contacting your Technical Sales representative or our Customer Service Department at 800.523.5862.

Guidelines for Handling Silanes (continued)

The Alkoxy Silane Group: Hydrolysis/Condensation and Liberation of Alcohol

Organofunctional alkoxy silanes, by nature, react with water (hydrolyze) from humid air, moisture, or from water contamination within process chemicals or equipment. Hydrolysis and condensation are necessary for organofunctional silanes to work effectively. However, premature hydrolysis that occurs as a result of careless handling or moisture contamination will reduce product quality, possibly resulting in reduced downstream performance. Therefore, it is important to keep silanes free from moisture contamination throughout storage.

Amino-functional alkoxysilanes are readily soluble in water and hydrolyze very rapidly with noticeable heat generation (exotherm) and the liberation of alcohol. Other silanes hydrolyze more slowly depending upon the organic functionality, the specific alkoxy group attached to silicon, the product's solubility in water, and the pH of the water. Upon hydrolysis, the alkoxy groups of all alkoxysilanes [most typically in the form of "methoxy" ($-OCH_3$) or "ethoxy" ($-OCH_2CH_3$)] are liberated as the corresponding alcohol (methanol or ethanol, respectively). The amount of alcohol liberated upon hydrolysis can be as high as 70% by weight of the initial silane charge. During hydrolysis, the resulting silane is converted to a silanol (-Si-OH) group. The formation of silanol is key to the function of silane coupling or condensation with inorganic substrates. Within a short period of time, silanols condense with other silanols and hydroxylated substrates to form siloxanes and silicate-like structures (-Si-O-Si- or –Si-O-[metal atom]). This reaction is referred to as the "condensation" of silanols. The liberation of alcohol from alkoxysilane hydrolysis has an impact on flammability, personnel exposure, and environmental issues:

a) Flammability: The flammability of the resulting silane mixture will increase following hydrolysis according to the amount of water present. In the simplest case, the flash point of an alkoxysilane is reduced significantly following moisture contamination. On the other extreme, with an intentional hydrolysis step during which most of the alcohol by-product is released, an explosive mixture could develop within equipment headspaces assuming sufficient oxygen/air is present.

b) Personnel Exposure: For methoxy-silane hydrolysis, by-product methanol is toxic and can be absorbed through the skin. In addition, the OSHA and ACGIH occupational exposure limit for methanol by inhalation is 200 ppm TWA. For ethoxy-silanes, ethanol is liberated upon hydrolysis. Although ethanol is significantly less toxic than methanol, the MSDS carries the associated warnings appropriate for ethanol exposure. For either methoxy or ethoxy silane esters, additional effects would be observed based on the specific organofunctionality of each silane product.

c) Environmental: Since up to 70% by weight of the silane charge is converted to alcohol (depending on the silane structure and hydrolysis conditions), the environmental release reporting and permitting requirements must be taken into consideration.

The Alkoxy Silane Group: Adventitious Moisture

A nuisance in handling some alkoxysilanes is the undesirable formation of hydrolyzate, or build-up of solids due to premature hydrolysis and condensation of the product. Silane hydrolyzate may appear crystalline or gummy depending upon the original silane and hydrolysis conditions. The solids are actually condensed, crosslinked amorphous polymers of the silane. A typical problem in handling laboratory quantities of alkoxysilanes is the opening of sealed bottles if the caps appear 'frozen'. Leather gloves and extra precautions are recommended when opening glass containers of organofunctional silanes.

Silane hydrolyzate is avoidable or can be minimized with the proper use of a dry nitrogen purge, desiccants, and solvent flushing of equipment and lines.

Hydrolysis and condensation reactions and kinetics for organofunctional silanes have been studied in depth by F. D. Osterholtz and E. R. Pohl,[1] of Momentive Performance Materials.

Guidelines for Handling Silanes (continued)

The Alkoxy Silane Group: Avoiding Hydrolyzate Formation

a) Use of Desiccants: To avoid premature hydrolysis of silanes during storage and use, desiccants can be utilized. Various disposable desiccating units are currently available from independent distributors and chemical supply companies.

b) Use of an Inert Gas (*e.g.,* dry nitrogen):
The use of dry nitrogen to blanket the headspaces of silane drums and storage vessels is advantageous for maintaining silane integrity and for minimizing handling problems caused by silane hydrolyzate.

Exception: Do not blanket or purge methacryloxysilanes with pure nitrogen since oxygen necessary for stabilization would be removed – see discussion below entitled "Dissolved Oxygen Requirement."

Note: Do not pressurize drums or other non-rated vessels/containers with nitrogen or any other gas; the container could rupture. Nitrogen gas can be dangerous due to the displacement of oxygen in the work area, which can potentially cause asphyxiation. In any operating area where nitrogen is used, adequate ventilation must be ensured. The atmosphere of the work area should be checked periodically to be certain adequate oxygen is present. Be aware of potential "confined spaces" and use proper testing and entry procedures, if applicable.

c) Solvent Flushing Techniques:
Hydrolyzate build-up can be a particular problem at equipment nozzles and valves, and in transfer lines, pipes and tubing. Lines, valves and nozzles should be dry and pre-purged with nitrogen before introducing silanes. The appropriate solvent should be used to flush equipment after shutting down a processing line or operation. Selection of solvent is important. It should be non-reactive, free from water contamination, and compatible with the specific process.

The Organofunctional Group: Reactivity

The organofunctional portion of the silane molecule is designed to react/interact with an organic phase, for example, in polymeric resins or with polymerizable organic media. The proper silane is matched with the organic/polymeric medium to maximize the compatibility and effectiveness for optimum coupling and product performance. The reactivity of silanes at the organofunctional end varies among silanes. Therefore, refer to the MSDS, Section 10 ("Stability and Reactivity") for warnings of incompatibility and specific conditions to avoid.

The Organofunctional Group: Polymerization

An organofunctional silane may be susceptible to polymerization and may require extra care during temporary and longer term storage. The polymerization potential is described within the MSDS (Section 10). Examples are products containing methacrylate-, epoxy-, and vinyl- functionality.

In order to prevent unwanted polymerization, certain contaminants must be avoided with methacryloxy-silanes (*e.g.,* Silquest A-174* and Silquest Y-9936 silanes). Peroxides and other free radical initiators, oxidants, reducing agents, and transition metal salts or their oxides (even rust) should be avoided. Avoid direct exposure to UV light and excessive heat. Follow storage and handling procedures as dictated in standard vinyl ester and acrylate/methacrylate ester product safety brochures. Do not attempt to remove polymerization inhibitors or treat these products with adsorption media that could lower the concentration of contained inhibitors.

Dissolved Oxygen Requirement:
The presence of dissolved oxygen is important in maintaining the stability of methacrylate silanes. Therefore, for methacryloxy-silanes do not purge the headspace of drums or storage containers or sparge the liquid with an inert gas such as pure nitrogen, unless the storage period is very short and at, or below, ambient temperature.

The Organofunctional Group: Vinyl Silane Reactivity

The potential exists for self-heating reactions of vinyl silanes, especially at elevated temperatures and if peroxides or other free radical initiators are present. The primary examples of vinyl silanes are Silquest A-151 and Silquest A-171* silanes. Follow the precautions specified in the MSDS.

The Organofunctional Group: Vinyl Silane/Peroxide Blends

The Momentive Performance Materials silanes portfolio includes a series of vinyl silane/peroxide blends (*e.g.,* Silcat* and XL-PEarl* blends) available for a number of specific applications. These blends are prepared under carefully controlled conditions in order to prevent runaway reactions. Most simple vinyl silane/peroxide blends have the potential to undergo uncontrolled self-accelerating decomposition (SADT) reaction if heated beyond moderate temperatures (*i.e.,* the SADT may be as low as 50˚C/122˚F).

SADT Definition (summarized): A self-accelerating decompositon temperature is the lowest ambient air temperature at which a self-reactive substance underwent (or is predicted to have undergone) an exothermic reaction, in a specified commercial package, within a period of seven days or less, from which the container was damaged excessively.

Guidelines for Handling Silanes (continued)

The SADT is the basis for deciding whether a self-reactive substance should be subject to temperature control during transport. The SADT value of a reactive liquid within a container is inversely proportional to the total mass (a larger container has a lower SADT). It is also highly dependent on the configuration and heat transfer properties of the container. The SADT is therefore container-specific. For this reason and because of DOT restrictions, Momentive Performance Materials generally does not supply vinyl silane/peroxide blends in containers larger than drum size. As a result, Momentive Performance Materials cautions against storing most vinyl silane/peroxide blends in quantities larger than one drum. Likewise, Momentive Performance Materials recommends extra caution to those customers who choose to do their own silane blending with peroxides or other polymerization agents. For a vinyl silane/peroxide blend sold by Momentive Performance Materials, the SADT specifications for the container in which it is sold has been determined to be no lower than 60˚C (the legal limit is 50˚C).

The Organofunctional Group: Epoxy Silane Reactivity

Silquest A-186, Silquest A-187*, Silquest A-1871, CoatOSil* 1770, and Silquest WetLink* 78 silanes are common epoxy-functional silanes which have reactivities similar to epoxy monomers. The epoxysilanes are not monomers in the usual sense, but polymeric materials may be produced under certain conditions of catalyzed partial hydrolysis. Hydrolysis can occur at both the silyl ester group as well as the epoxy group. Epoxy ring opening can occur when exposed to contaminants such as acids and bases, amines, and ionic chloride. Silquest A-186 silane and CoatOSil 1770 silane are more prone to acid catalyzed ring opening; Silquest A-187, Silquest A-1871 and Silquest WetLink 78 silanes are susceptible to base catalyzed ring opening. Polymerization can occur depending upon the specific reagents and conditions. Generally, product degradation or shelf life concerns are not significant provided care is taken to avoid product contamination.

Polysiloxanes are produced by hydrolysis and condensation of the silyl ester group in the presence of controlled amounts of water and alkali or acid catalyst at ambient temperatures. At slightly higher temperatures (~50˚C), polyglycols or polyglycol ethers are produced via the epoxy functional group under the same conditions of water concentration and alkali or acid catalyst. These reactions are exothermic. Furthermore, the heat evolved may be cumulative and greatly accelerate the rate of continued reactions.

Note: It is imperative, therefore, that unintentional contamination of the epoxysilanes with water be avoided, and that intentional hydrolysis be properly controlled to avoid hazardous consequences.

The Organofunctional Group: Amino Silane Reactivity

Silquest A-1100*, Silquest A-1102, Silquest A-1110, Silquest A-1120, Silquest A-1130, Silquest A-1170 silanes are common examples of aminofunctional silanes. Aminosilanes are unique in that the rate of hydrolysis is rapid without pH adjustment of the water used in the aqueous premixes. Therefore, aminosilanes are readily soluble in water and the subsequent hydrolysis occurs almost instantaneously. When hydrolysis occurs with these silanes, heat may be noticeable and the alcohol by-product is rapidly generated (methanol or ethanol, depending upon whether the silane contains methoxy- or ethoxy- substituents on the silicon atom).

Note: Certain weight ratios of silane and water can lead to the generation of enough heat that the mixture may boil, thereby liberating significant amounts of alcohol.

Due to the inherent affinity of amino-functional silanes with water, extra care should be taken to ensure that moisture contamination does not occur within original containers and temporary storage tanks prior to their intended use. Unintentional water contamination can lead to gels or solids which can cause plugging of equipment and lines. Therefore, nitrogen blanketing and purging of equipment and containers is strongly encouraged for eliminating equipment fouling and for maintaining the integrity of these silanes.

Flammability Considerations: Specialty Blending and Mixing Operations

Blenders, mixers, and compounding operations may present varying inherent hazards when introducing silanes. In addition to the mechanical hazards associated with mixing units, there are recommended precautionary steps to avoid flammable atmospheres during or following the mixing of silanes with other chemicals, solvents, polymers, mineral fillers, or inorganic substrates.

Operations personnel should be aware of the inherent generation of free alcohol when organofunctional silanes are exposed to water or moisture. Hydrolysis is an inherent characteristic of silanes, and in most applications is intended for the optimum performance of the silane. As noted earlier, hydrolysis occurs when alkoxysilanes react with free water. The water may be 1) a separate ingredient within the mixture, or 2) atmospheric moisture, or 3) present on the surface of the inorganic filler, such as the clay, calcium carbonate, silica, etc. This reaction involves the conversion of alkoxysilanes to silanols and is a necessary step in promoting the chemical bonding of the silane to inorganic substrates. Most silanes will liberate either methanol or ethanol during the intentional silane coupling process in which inorganic fillers are bonded to a polymeric resin. The potential, therefore, exists for flammable vapors to develop within or around mixing units, unless adequate precautions are taken to exclude oxygen and ignition sources. Explosion of air/vapor mixtures can result.

Guidelines for Handling Silanes (continued)

Static

Often, static can be generated in mixing vessels and compounding operations. Although all mechanical equipment should be properly grounded, static discharges may not be completely eliminated, especially in certain intensive mixing operations. Another consideration is the conductivity of the medium being mixed. Since the fuel source (alcohol) and an ignition source (static) might be unavoidable in some cases, the only controllable factor is the elimination of oxygen. The blanketing of mixing and compounding units with an inert gas, such as nitrogen, is one of the most effective options in the removal of the remaining (third) side of the "fire triangle" (see "Grounding and Purging...").

EPDM, a non-polar rubber compound, is particularly prone to the generation of static sparks, especially during compounding. This is often the case when a Banbury mixer (or equivalent) is undercharged, which is sometimes standard procedure in second stage mix cycles. Wire- and cable-grade EPDM compositions often generate static sparks during compounding because they typically contain low levels of plasticizing oils and use calcined (anhydrous) clays.

Grounding and Purging of Silanes Drums and Pails

To minimize flammability potential during transfer, mixing, compounding, and blending operations, all equipment and tanks should be properly grounded. Grounds should be periodically tested for electrical continuity. Purge and blanket all mixing, compounding, blending, and storage units and vessels with an inert gas, such as dry nitrogen, to reduce the oxygen concentration to a safe level prior to the addition of silane. The inert blanketing should be maintained throughout the entire operation and storage. As described earlier, inerting also helps to maintain a moisture-free atmosphere, and thus helps to ensure the integrity of the product against premature hydrolysis. This is especially true with aminofunctional silanes that hydrolyze rapidly in the presence of moist air.

Note: An exception to the purging/inert blanketing requirement is the (meth)acrylate functional silane group, including Silquest A-174* silane, Silquest FR-1A silane, and Silquest Y-9936 silane or any other methacryloxy silane (see MSDS for compositional information). The inhibitors in these silanes require the presence of oxygen to help retard premature polymerization. Therefore, these silanes should be maintained with a headspace of dry 3% oxygen in nitrogen, rather than pure nitrogen.

To minimize oxidation: In addition to reducing flammability concerns, inert blanketing also helps reduce air oxidation that can lead to color formation, especially with the aminosilanes (Silquest A-1100* silane, Silquest A-1102 silane, Silquest A-1120 silane, Silquest A-1130 silane and Silquest A-1170 silane). In order to maintain the quality and original integrity of the aminoalkylsilane, purge the headspace of all partial drums with nitrogen. Do not transfer unused silane back into the original drum. Do not use silane drums as mixing containers. Dispose of all empty drums properly, utilizing an environmentally responsible drum disposal company or reclaimer.

Volatile Organic Compounds (VOCs)

It is difficult to determine the volatile organic compound value for silanes using ASTM method #D2369 (EPA Method #24), due to the propensity of the alkoxysilane to hydrolyze during the test procedure. Once hydrolysis takes place, a loss of alcohol results, which affects the gravimetric determination of low boiling materials. As a result, most VOC determinations for organofunctional silanes are abnormally high. Alternative analytical procedures have been suggested.(2)

Personal Protective Equipment

The minimum recommended personal protective equipment (PPE) is outlined in the applicable MSDS. Be particularly sensitive to the potential for eye and skin contact. The correct glove must be worn if contact is likely. Safety goggles/monogoggles are mandatory when working with silanes. For inhalation concerns, use adequate ventilation, including local exhaust hoses, to minimize the need for respirators and full-face supplied-air systems (required for high vapor concentrations). Note that the use of organic vapor cartridges are not recommended for methoxy-silanes, due to the poor warning properties of methanol (by-product from hydrolysis).

Toxicity of Organofunctional Silanes

Refer to the MSDS and Toxicology Summary for each product for a review of the toxicity testing that has been conducted to date.

Fire Safety (Storage) Considerations

Refer to the Appendix for fire safety considerations, particularly if assessing design for the storage of silanes.

Materials of Construction (MOC)

The recommended material of construction for silanes in general is 316 stainless steel. For elastomers, Teflon® is recommended. For applications that require greater elasticity and flexibility, other elastomers may suffice; however, compatibility varies from one silane to another. Silanes in general have exceptionally good solvating properties. For this reason, many elastomers are not suitable for use with silanes. Contact Product Safety and Regulatory Affairs group for additional information specific to elastomer selection for a particular silane.

Teflon is a registered trademark of E.I. Du Pont de Nemours and Company

Guidelines for Handling Silanes (continued)

Transferring Organofunctional Silanes

A separate publication addresses pump, transfer piping and tubing selection for organofunctional silane transfers. Contact our Product Safety and Regulatory Affairs group and request "Pumping Systems for Silquest Silane Chemicals."[3]

Maintaining the Integrity of Partial Drums of Silanes

The purging of drum headspaces with dry nitrogen is critical to maintaining the quality integrity of alkoxysilanes. The exception to nitrogen purging is Silquest A-174*, Silquest Y-9936 or any other (meth)acryloxy functional silane (see discussion earlier).

If piped nitrogen is not available, a simple rack of exchangable nitrogen cylinders can be arranged into a regulated manifold delivery system. As a secondary approach, desiccated air lines can be used to purge the headspaces of silanes provided the silanes have a flash point greater than 150˚F.

Environmental Considerations (Including Disposal)

Clean-Up Procedures

Equipment and transfer line clean-ups are necessary to avoid hydrolyzate build-up and to reduce the potential for plugging. Due to the hydrolytic instability of most alkoxysilanes, solvent flushing at ambient temperature is recommended following silane contact, especially if inert purging is not possible. The solvent(s) selected for clean-up should be non-reactive, free of water contamination, and compatible with the rest of the process chemistry. The appropriate fire safety precautions should be taken if flammable solvents are selected. For assistance in selecting the appropriate solvent for your purposes, contact your Momentive Performance Materials Technical Service representative or our Product Safety and Regulatory Affairs group.

Spills

For spills, refer to the MSDS. Contain spills by barricading the area and use temporary diking, if possible, to avoid run-off to sewers and waterways. Be certain that clean-up or emergency personnel use the proper protective equipment as specified in the MSDS. Be aware of potential ignition sources. Remember that organofunctional silane esters readily generate the corresponding alcohol when in contact with moisture. The flash point will be lowered dramatically. For small spills, we recommend absorbant products and equipment commonly used in the chemical industry. Collect absorbed product and dispose of in accordance with federal, state, and local regulations. Large spills must be dealt with very carefully on a case-by-case basis. Immediate action must be taken to minimize the potential for fire, personnel exposure, and a threat to the environment. Contact CHEMTREC or other emergency numbers provided in the MSDS.

Disposal Issues

The proper disposal method for waste silane or silane mixtures may vary depending upon the state or province. Definitions of "hazardous waste" vary. Waste disposal firms have different capabilities and permits that may influence the mode of disposal.

Be certain that the clean-up and containment procedures for the waste are safe and appropriate. For emergency assistance, contact CHEMTREC or emergency phone numbers provided on the specific MSDS.

Consult local, municipal and state regulatory agencies for proper classification of the waste(s). Under the federal RCRA rules (40CFR 261), the following characteristic properties are indicative of hazardous wastes:

- D001: Flash point less than 140˚F (PMCC)
- D002: pH <2 or >12.5, or corrodes steel at >0.25 in. per year.
- D003: Reacts violently with water, forms potentially explosive mixtures with water, or when mixed with water generates toxic gases, vapors, or fumes, or releases over 500 ppm of sulfides/cyanides.

If the silane has been blended or reacted with another material, additional waste codes may apply. If you have questions on the regulatory status of your waste, consult your state or province environmental authorities.

Empty Containers

Under RCRA, empty containers are defined as having all contents removed by common means (pumping, pouring, etc.) and not containing more than one inch of residue in the bottom of the container or liner. For containers equal to, or less than, 110 gallons, no more than 3 wt.% of the total container capacity can remain. For containers greater than 110 gallons, no more than 0.3 wt.% of the container can remain.

Disposal of Empty Containers

Empty containers must be disposed of or reclaimed only by reputable facilities. Momentive Performance Materials recommends that contractors be audited for approval. Due to the exposure and reactivity potential of residual silanes, "empty" containers should never be given to the public, or sold for reuse by the public or by non-reputable firms.

References

1. Osterholtz, F. D., Pohl, E. R., “Kinetics of the Hydrolysis and Condensation of Organofunctional Alkoxysilanes: A Review,” Journal of Adhesion Science and Technology, Volume 6, No.1, pp.127-149 (1992).
2. Turner, S. M., “Explanation of Inherent VOC Error with Hydrolyzable Materials,” bulletin available by Momentive Performance Materials, Product Safety and Regulatory Affairs group.
3. “Pumping Systems for Silquest* Silane Chemicals,” a Momentive Performance Materials bulletin.

Appendix

Safety Considerations for Storing and Using Organosilicones and Silanes

Various criteria should be taken into consideration when assessing safety and design for chemical storage and use in industrial settings. The raw material supplier cannot specify safety standards to the customer since these standards vary with differing state and local regulations, corporate policies, and insurance carriers. The supplier can only give general guidance based on experience and knowledge of the physical properties and characteristics of the product. It is up to the customer to use this guidance, together with other appropriate information, to evaluate all the applicable safety criteria for the customer’s area and situation, including local codes, specific operating conditions, building design, equipment design, storage conditions, insurance requirements, and corporate policies. The following outline may be used as a checklist (not intended to be exhaustive) for evaluating what safety criteria should be considered when storing and using organosilicones and silanes. One of the most obvious safety concerns for chemical use and storage is fire safety, an emphasis of this outline.

Outline and Checklist of Potentially Relevant Safety Criteria

A. Building Design / Classification

- Structural design of room/building (metal, concrete, wood vs. synthetic)
- Design for flammable or combustible liquid storage/handling (NFPA-30 Code)
- Fire protection (NFPA-3, -15, -16 Codes; OSHA 29CFR1910 Subpart L)
    - Automatic Sprinkler protection (29CFR1910.159)
      Fixed vs. portable extinguishing system requirements (29CFR1910.160-.163)
      Water spray, foam, dry chemical, general or gaseous agents
      Remote spray monitors

  Electrical classification of operating area (classified vs. non-classified)
    - (See NFPA-70 National Electric Code: illustrates provisions, equipment and installation requirements for classified vs. non-classified areas.)
    - Height of non-explosion proof electrical equipment and other ignition sources off floor level Ventilation, HVAC, static air volume in building Diking, curbing, drainage, emergency containment

Appendix (continued)

- General layout of operating or storage areas / access and egress (NFPA-30 restrictions)
  - Storage [general guidance: NFPA-231 (231C covers rack storage)] based on physical properties of the materials
  - Minimum aisle space; separation between storage containers and portable tanks
  - Minimum distance between storage and use areas

Potential for ignition sources
  Temperature of equipment in vicinity
  Vehicular traffic limitations
  Explosion proof equipment requirements
  Spark producing devices or open flame in area
Grounding and inerting (purging) practices (also see procedures)
Consultation with Engineering Dept./contractor or architect knowledgeable in industrial fire codes and design classifications

B. Equipment Design / Classification
Electrical classification
Equipment electrical rating
Equipment supplier's recommendations
Engineering controls

C. Raw Material Characteristics: Physical Properties, Reactivity, etc.
Flash point of organosilicone/silane (impacts NFPA classification)
Boiling point of organosilicone/silane (impacts NFPA classification)
Reactivity of organosilicone/silane
Keeping equipment and raw materials dry
Maximum volume of material
Delivery rate of material
Open vs. closed transfer operations (hard-piped vs. temporary connections)
Materials of construction and compatibility of equipment
  Transfer equipment, reaction/treatment equipment, and storage equipment

D. Corporate Health, Safety & Environmental Policy / Procedures (*e.g.*, for design criteria)
Corporate manual/standards
Fire Safety Group/Skills Center availability within organization
  Standard Operating Procedures
  General Process Operation
  Emergency Procedures
  Life Critical Procedures
    Hazardous Work Procedures
    Confined Space Entry
  Use of Ignition Sources in Classified Areas
  Breaking or Cutting of Lines or Opening Equipment
  Facilities and Operational Change
  Review Procedures
  Grounding and Inerting Procedures
  Vessel to Vessel Transfer Procedures
  Flammable Liquid Dispensing Procedures
Administrative Controls
Process Safety Management OSHA 29CFR1910 (1910.119)
  Safety Review Process
  Process Hazard Analysis
  Risk Assessments
  Internal Audits
  Safe Operating Envelope for the Process
Personnel Safety
  Personnel Training
  Hazardous Materials: OSHA 29CFR1910, Subpart H
  Personal Electrical Safety: 29CFR1910, Subpart S (coincides with NFPA-70)
  Toxic and Hazardous Substances: 29CFR1910, Subpart Z
  IH Monitoring
Environmental Safety Issues
  Hazardous Waste Operations and Emergency Response (1910.120)
  Environmental Monitoring

E. Local / State Codes
OSHA and NFPA requirements (Note: not all states are subject to NFPA requirements)
Local laws and regulations
State laws and regulations
Fire Marshall requirements

F. Insurance Carrier Requirements
Consultation prior to design
Liability perspective
Review of hazards with local fire companies
On-site fire brigade availability SMT April 2000

Patent Status

Nothing contained herein shall be construed to imply the nonexistence of any relevant patents or to constitute the permission, inducement or recommendation to practice any invention covered by any patent, without authority from the owner of the patent.

Product Safety, Handling and Storage

Customers considering the use of this product should review the latest Material Safety Data Sheet and label for product safety information, handling instructions, personal protective equipment if necessary, and any special storage conditions required. Material Safety Data Sheets are available at www.momentive.com or, upon request, from any Momentive Performance Materials representative. Use of other materials in conjunction with Momentive Performance Materials products (for example, primers) may require additional precautions. Please review and follow the safety information provided by the manufacturer of such other materials.

Limitations

Customers must evaluate Momentive Performance Materials products and make their own determination as to fitness of use in their particular applications.

Emergency Service

Momentive Performance Materials maintains an around-the-clock emergency service for its products. The American Chemistry Council (CHEMTREC), Transport Canada (CANUTEC), and the Chemical Emergency Agency Service also maintain an around-the-clock emergency service for all chemical products:

Location	Momentive Performance Materials Products	All Chemical Products
Mainland U.S., Puerto Rico	518.233.2500	CHEMTREC: 800.424.9300
Alaska, Hawaii	518.233.2500	CHEMTREC: 800.424.9300
Canada	518.233.2500	CANUTEC: 613.996.6666 (collect) or CHEMTREC: 800.424.9300
Europe, Middle East, Africa	+32.(0)14.58.45.45 (Belgium)	CHEMTREC: +1-703.527.3887 (collect)
Latin America, Asia/Pacific, all other locations worldwide	+518.233.2500	CHEMTREC: +1-703.527.3887 (collect)
At sea	Radio U.S. Coast Guard, which can directly contact Momentive Performance Materials at 518.233.2500 or CHEMTREC at 800.424.9300.	

DO NOT WAIT. Phone if in doubt. You will be referred to a specialist for advice.

CUSTOMER SERVICE CENTERS

North America	**E** cs-na.silicones@momentive.com		
	• Specialty Fluids	**T** +1.800.523.5862	**F** +1.304.746.1654
	• UA, Silanes, Resins and Specialties	**T** +1.800.334.4674	**F** +1.304.746.1623
	• RTV Products-Elastomers	**T** +1.800.332.3390	**F** +1.304.746.1623
	• Sealants and Adhesives & Construction	**T** +1.877.943.7325	**F** +1.304.746.1654
Latin America	**E** cs-la.silicones@momentive.com		
	• Argentina & Chile	**T** +54.11.4862.9544	**F** +54.11.4862.9544
	• Brazil	**T** +55.11.4534.9650	**F** +55.11.4534.9660
	• Mexico & Central America	**T** +52.55.5899.5135	**F** +52.55.5899.5138
	• Venezuela, Ecuador, Peru Colombia & Caribbean	**T** +58.212.285.2149	**F** +58.212.285.2149
Europe, Middle East, Africa and India	**E** cs-eur.silicones@momentive.com	**T** +00.800.4321.1000 **T** +31.164.225350	
Pacific	**E** cs-ap.silicones@momentive.com	**T** +0120.975.400 **T** +0.81.276.20.6182	**F** +81.276.31.6259
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