

V

VAPOR

Vapor is the gaseous state of matter that normally exists in a liquid or solid state. It also applies to gas close to the liquid state, e.g., water in the atmosphere. The terms gas and vapor are often used interchangeably.

VAPOR BARRIER

A vapor barrier is a coating or layer that prevents the passage of vapor or moisture into a material or structure.

VAPOR CORROSION

Contaminants in the atmosphere such as sulfur dioxide, nitrogen-containing compounds, hydrogen chloride, phenol, hydrogen sulfide, nitric acid, ammonia, and other, similar materials act as stimulants to atmospheric corrosion. This acceleration to corrosion is known as vapor corrosion. Refer to "[Atmospheric Corrosion](#)."

VAPOR PHASE CORROSION INHIBITORS

Vapor phase corrosion inhibitors are solid or liquid volatile organic compounds with corrosion-inhibitive behaviors. These compounds have a significantly high vapor pressure at room temperature. They are used within sealed enclosures to protect metallic articles. The most common organic compounds used are dicyclohexylamine nitrite and cyclohexylamine carbonate. Refer to "[Corrosion Inhibitors](#)."

VERDIGRIS

Verdigris is the green patina of basic copper salts formed on copper due to atmospheric corrosion. The basic copper salts are primarily basic carbonate, basic sulfate, and in some cases the basic chloride. Refer to "[Copper and Copper Alloys](#)."

VINYL ESTER RESINS

Also see "[Polymers](#)" and "[Thermoset Polymers](#)." There are a wide variety of vinyl ester resins. As a result, there can be a difference in the compatibility of formulations between manufacturers. When checking compatibility tables, it must be kept in mind that all formulations may not act as shown. An indication that vinyl ester is compatible

generally means that at least one formulation is compatible. The resin manufacturer must be checked to verify the resistance.

In general vinyl esters can be used to handle most hot, highly chlorinated, and acidic mixtures at elevated temperatures. They also provide excellent resistance to strong mineral acids and bleaching solutions. The vinyl esters excel in alkaline and bleach environments and are used extensively in the very corrosive conditions found in the pulp and paper industry. Refer to Table V.1 for the compatibility of the vinyl esters with a wide range of selected corrodents. Reference 1 provides a wider range of compatibilities.

See also Refs. 2–4.

Table V.1 Compatibility of Vinyl Ester with Selected Corrodents^a

Chemical	Maximum temp.		Chemical	Maximum temp.	
	°F	°C		°F	°C
Acetaldehyde	x	x	Ammonium sulfate 10–40%	220	104
Acetamide			Ammonium sulfide	120	49
Acetic acid 10%	200	93	Ammonium sulfite	220	104
Acetic acid 50%	180	82	Amyl acetate	110	43
Acetic acid 80%	150	66	Amyl alcohol	210	99
Acetic acid, glacial	150	66	Amyl chloride	120	49
Acetic anhydride	100	38	Aniline	x	x
Acetone	x	x	Antimony trichloride	160	71
Acetyl chloride	x	x	Aqua regia 3:1	x	x
Acrylic acid	100	38	Barium carbonate	260	127
Acrylonitrile	x	x	Barium chloride	200	93
Adipic acid	180	82	Barium hydroxide	150	66
Allyl alcohol	90	32	Barium sulfate	200	93
Allyl chloride	90	32	Barium sulfide	180	82
Alum	240	116	Benzaldehyde	x	x
Aluminum acetate	210	99	Benzene	x	x
Aluminum chloride, aqueous	260	127	Benzene sulfonic acid 10%	200	93
Aluminum chloride, dry	140	60	Benzoic acid	180	82
Aluminum fluoride	100	38	Benzyl alcohol	100	38
Aluminum hydroxide	200	93	Benzyl chloride	90	32
Aluminum nitrate	200	93	Borax	210	99
Aluminum oxychloride			Boric acid	200	93
Aluminum sulfate	250	121	Bromine gas, dry	100	38
Ammonia gas	100	38	Bromine gas, moist	100	38
Ammonium bifluoride	150	66	Bromine liquid	x	x
Ammonium carbonate	150	66	Butadiene		
Ammonium chloride 10%	200	93	Butyl acetate	80	27
Ammonium chloride 50%	200	93	Butyl alcohol	120	49
Ammonium chloride, sat.	200	93	<i>n</i> -Butylamine	x	x
Ammonium fluoride 10%	140	60	Butyl phthalate	200	93
Ammonium fluoride 25%	140	60	Butyric acid	130	54
Ammonium hydroxide 25%	100	38	Calcium bisulfide		
Ammonium hydroxide, sat.	130	54	Calcium bisulfite	180	82
Ammonium nitrate	250	121	Calcium carbonate	180	82
Ammonium persulfate	180	82	Calcium chlorate	260	127
Ammonium phosphate	200	93	Calcium chloride	180	82

Table V.1 Compatibility of Vinyl Ester with Selected Corrodents^a (Continued)

Chemical	Maximum temp.		Chemical	Maximum temp.	
	°F	°C		°F	°C
Calcium hydroxide 10%	180	82	Fluorine gas, moist	x	x
Calcium hydroxide, sat.	180	82	Hydrobromic acid, dilute	180	82
Calcium hypochlorite	180	82	Hydrobromic acid 20%	180	82
Calcium nitrate	210	99	Hydrobromic acid 50%	200	93
Calcium oxide	160	71	Hydrochloric acid 20%	220	104
Calcium sulfate	250	116	Hydrochloric acid 38%	180	82
Caprylic acid	220	104	Hydrocyanic acid 10%	160	71
Carbon bisulfide	x	x	Hydrofluoric acid 30%	x	x
Carbon dioxide, dry	200	93	Hydrofluoric acid 70%	x	x
Carbon dioxide, wet	220	104	Hydrofluoric acid 100%	x	x
Carbon disulfide	x	x	Hypochlorous acid	150	66
Carbon monoxide	350	177	Iodine solution 10%	150	66
Carbon tetrachloride	180	82	Ketones, general	x	x
Carbonic acid	120	49	Lactic acid 25%	210	99
Cellosolve	140	60	Lactic acid, concentrated	200	93
Chloroacetic acid	200	93	Magnesium chloride	260	127
Chloroacetic acid, 50% water	150	66	Malic acid 10%	140	60
Chlorine gas, dry	250	121	Manganese chloride	210	99
Chlorine gas, wet	250	121	Methyl chloride		
Chlorine liquid	x	x	Methyl ethyl ketone	x	x
Chlorobenzene	110	43	Methyl isobutyl ketone	x	x
Chloroform	x	x	Muriatic acid	180	82
Chlorosulfonic acid	x	x	Nitric acid 5%	180	82
Chromic acid 10%	150	66	Nitric acid 20%	150	66
Chromic acid 50%	x	x	Nitric acid 70%	x	x
Chromyl chloride	210	99	Nitric acid, anhydrous	x	x
Citric acid 15%	210	99	Nitrous acid 10%	150	66
Citric acid, concentrated	210	99	Oleum	x	x
Copper acetate	210	99	Perchloric acid 10%	150	66
Copper carbonate			Perchloric acid 70%	x	x
Copper chloride	220	104	Phenol	x	x
Copper cyanide	210	99	Phosphoric acid 50–80%	210	99
Copper sulfate	240	116	Picric acid	200	93
Cresol	x	x	Potassium bromide 30%	160	71
Cupric chloride 5%	260	127	Salicylic acid	150	66
Cupric chloride 50%	220	104	Silver bromide 10%		
Cyclohexane	150	66	Sodium carbonate	180	82
Cyclohexanol	150	66	Sodium chloride	180	82
Dichloroacetic acid	100	38	Sodium hydroxide 10%	170	77
Dichloroethane (ethylene dichloride)	110	43	Sodium hydroxide 50%	220	104
Ethylene glycol	210	99	Sodium hydroxide, concentrated		
Ferric chloride	210	99	Sodium hypochlorite 20%	180	82
Ferric chloride 50% in water	210	99	Sodium hypochlorite, concentrated	100	38
Ferric nitrate 10–50%	200	93	Sodium sulfide to 50%	220	104
Ferrous chloride	200	93	Stannic chloride	210	99
Ferrous nitrate	200	93	Stannous chloride	200	93
Fluorine gas, dry	x	x	Sulfuric acid 10%	200	93

Table V.1 Compatibility of Vinyl Ester with Selected Corrodents^a (Continued)

Chemical	Maximum temp.		Chemical	Maximum temp.	
	°F	°C		°F	°C
Sulfuric acid 50%	210	99	Sulfurous acid 10%	120	49
Sulfuric acid 70%	180	82	Thionyl chloride	x	x
Sulfuric acid 90%	x	x	Toluene	120	49
Sulfuric acid 98%	x	x	Trichloroacetic acid 50%	210	99
Sulfuric acid 100%	x	x	White liquor	180	82
Sulfuric acid, fuming	x	x	Zinc chloride	180	82

^aThe chemicals listed are in the pure state or in a saturated solution unless otherwise indicated. Compatibility is shown to the maximum allowable temperature for which data are available. Incompatibility is shown by an x. A blank space indicates that data are unavailable.

Source: PA Schweitzer. *Corrosion Resistance Tables*, Vols 1 and 2. New York: Marcel Dekker, 1991.

VINYLIDENE FLUORIDE ELASTOMERS (HFP, PVDF)

Polyvinylidene fluoride (PVDF) is a homopolymer of 1,1-difluorethene with alternating CH₂ and CF₂ groups along the polymer chain. These groups impart a unique polarity that influences its solubility and electrical properties. The polymer has the characteristic stability of fluoropolymers when exposed to aggressive thermal, chemical, and ultraviolet conditions.

In general, PVDF is one of the easiest fluoropolymers to process, and it can be easily recycled without affecting its physical and chemical properties. As with other elastomeric materials, compounding can be used to improve certain specific properties. Cross-linking of the polymer chain and control of the molecular weight are also done to improve particular properties.

PVDF possesses mechanical strength and toughness, high abrasion resistance, high thermal stability, high dielectric strength, high purity, resistance to most chemicals and solvents, resistance to ultraviolet and nuclear radiation, resistance to weathering, and resistance to fungi. It can be used in applications intended for repeated contact with food per Title 21, Code of Federal Regulations, Chapter 1, Part 177.2520. PVDF is also permitted for use in processing or storage areas in contact with meat or poultry food products prepared under federal inspection according to the U.S. Department of Agriculture (USDA). Use is also permitted under "3-A Sanitary Standards for Multiple-Use Plastic Materials Used as Product Contact Surfaces for Dairy Equipment Serial No. 2000." This material has the ASTM designation of MFP.

Physical and Mechanical Properties

PVDF elastomers have high tensile and impact strengths. The ambient-temperature tensile strength at yield of 4000–7000 psi (28–48 MPa) and the unnotched impact strength, 15–80 ft-lb/in. (800–4270 kJ/m), indicate that all grades of this polymer are strong and tough. These properties are retained over a wide temperature range.

Excellent resistance to creep and fatigue are also exhibited by PVDF, while thin sections such as films, filament, and tubing are flexible and transparent. PVDF wire insulation has excellent resistance to cut-through. Where load bearing is important, these polymers are rigid and resistant to creep under mechanical load. Resistance to deformation under load is extremely good over the temperature range of –112 to 302°F (–80 to 150°C).

PVDF finds application as thin-wall primary insulation and as a jacket for control wiring as a result of its high dielectric strength and good mechanical properties. Because of its high dissipation factor, PVDF has limited use at high frequencies. However, this property becomes an advantage in components utilizing dielectric heating techniques.

In order for PVDF to burn, it is necessary to have a 44% oxygen environment. The Underwriters Laboratories give PVDF a vertical burn rating of 94-V-O. PVDF is fire resistant and self-extinguishing.

PVDF will not support the growth of fungi. However, if additives that will support the growth of fungi are used in compounding, then fungicides should also be added to overcome this problem.

Because of its extremely low weight loss when exposed to high vacuum, PVDF can be used in high-vacuum applications. At 212°F (100°C) and a pressure of 5×10^{-6} torr, the measured rate of weight loss is 13×10^{-11} g/cm²-s.

PVDF can also be pigmented.

The physical and mechanical properties of PVDF are given in Table V.2.

Table V.2 Physical and Mechanical Properties of Vinylidene Fluoride (PVDF) Elastomer^a

Specific gravity	1.76–1.78
Refractive index	1.42
Specific heat, Btu/lb-°F	0.30–0.34
Brittle point	–80°F (–62°C)
Coefficient of linear expansion	
per °F	7.8×10^{-5}
per °C	1.4×10^{-4}
Thermal conductivity	
Btu-in/h-ft ² °F	0.70–0.87
cal/cm ² -s-°C	3×10^{-4}
Dielectric strength, kV/mm	63–67
Dielectric constant at 77°F (23°C)	
at 100 Hz, ohm-cm	9.9
at 1 kHz, ohm-cm	9.3
at 100 kHz, ohm-cm	8.5
Tensile strength, psi	4000–7000
Elongation, % at break	25–650
Hardness, Shore A	77–83
Abrasion resistance, Armstrong	0.3
(ASTM D 1242) 30-lb load volume loss, cm ³	
Maximum temperature, continuous use	302°F (150°C)
Impact resistance, Izod notched, ft-lb/in.	3–18
Compression set	Good
Machining qualities	Excellent
Resistance to sunlight	Excellent
Effect of aging	Nil
Resistance to heat	Good

^aThese are representative values since they may be altered by compounding.

PVDF is suitable for applications where load-bearing characteristics are important, particularly at elevated temperatures. Long-term deflections at 140°F (60°C) with a load of 172 psi vary from 0.8% to 119%, while at 194°F (90°C) with a load of 530 psi the deflection ranges from 1.2% to 3.6%.

PVDF has a wide useful temperature range with a brittle point at -80°F (-62°C) and a maximum continuous operating temperature of 302°F (150°C). Over this entire range its properties remain virtually unaffected.

Special formulations are available for use in plenum cable applications. These formulations produce products having impact strengths of 12–18 ft-lb/in. and elongations of 400–650%. They also have improved stress crack resistance.

Resistance to Sun, Weather, and Ozone

PVDF is highly resistant to the effects of sun, weather, and ozone. Its mechanical properties are retained while the percent elongation to break decreases to a lower level and then remains constant.

Chemical Resistance

In general, PVDF is completely resistant to chlorinated solvents, aliphatic solvents, weak bases and salts, strong acids, halogens, strong oxidants, and aromatic solvents. Strong bases will attack the material.

The broader molecular weight of PVDF gives it a greater resistance to stress cracking than many other materials, but it is subject to stress cracking in the presence of sodium hydroxide.

PVDF also exhibits excellent resistance to nuclear radiation. The original tensile strength is essentially unchanged after exposure to 1000 Mrad of gamma irradiation from a cobalt-60 source at 122°F (50°C) and in high vacuum (10^{-6} torr). Because of crosslinking, the impact strength and elongation are slightly reduced. This resistance makes PVDF useful in plutonium reclamation operations.

Applications

PVDF finds many applications where its corrosion resistance, wide allowable operating temperature range, mechanical strength and toughness, high abrasion resistance, high dielectric strength, and resistance to weathering, ultraviolet light, radiation, and fungi are useful.

In the electrical and electronics fields PVDF is used for multi-wire jacketing, plenum cables, heat-shrinkable tubing, anode lead wire, computer wiring, and cable and cable ties. Because of its acceptance in the handling of foods and pharmaceuticals, transfer hoses are lined with PVDF. Its corrosion resistance is also a factor in these applications.

In fluid-handling systems PVDF finds applications as gasketing material, valve diaphragms, and membranes for microporous filters and ultrafiltration.

As a result of its resistance to fungi and its exceptional corrosion resistance, it is also used as the insulation material for underground anode bed installations.

See [Refs. 1 and 5](#).

VITON

See "[Fluoroelastomers](#)."

VITREOUS ENAMEL

See “Glass Linings.”

VITREOUS ENAMEL COATINGS

Vitreous enamels, glass linings, or porcelain enamels are all essentially glass coatings that have been fused on metals. Powdered glass is applied to a pickled or otherwise prepared metal surface and heated in a furnace at a temperature that softens the glass and permits it to bond to the metal. Several thin coats are applied to provide the required final thickness. These coatings are normally applied to steel, but some coatings can be applied to brass, aluminum, and copper.

There are many glass formulations, but those with very high silica (>96% S_1O_2), aluminosilicate, and borosilicate compositions have the highest corrosion resistance to a wide range of corrosive environments. Glass is assumed to be inert to most liquids, but in reality it slowly dissolves.

The greatest danger of failure of a glass coating comes from mechanical damage or from cracking as a result of thermal shock. Thus, care must be taken in handling glassed equipment so as not to damage the lining, and sudden temperature changes in the operation must be avoided, particularly cold shock, which poses a greater danger of failure than hot shock.

Cold shock is the sudden introduction of a cold material onto a hot glassed surface; hot shock is the reverse. Manufacturers of this type of equipment will specify the maximum allowable thermal shock. These precautions must be followed.

See “Glass Linings.”

VITRIFIED CLAY PIPE

Vitrified clay pipe is virtually impervious to every chemical except hydrofluoric acid. It was and still is used for the handling of sewage. With the advent of the problems of cleaning up toxic dumps and landfills, new applications have arisen. The primary reasons for using clay pipe in these new applications are that it

1. Is chemically inert, unaffected by sewer gases and acids
2. Is rigid and will not flatten or sag
3. Is rustproof
4. Is unaffected by harsh household cleaning compounds and solvents
5. Withstands the extra stresses of heavy backfill loads
6. Will not soften or swell under any conditions
7. Is durable, will not roughen, erode, or wear out
8. Is unaffected by gases and acids generated by ground garbage
9. Is made impervious through vitrification

Vitrified clay pipe is presently being used to conduct the leachate from Love Canal to holding tanks for processing.

Though salt-glazed pipe may be used for sanitary sewers, unglazed pipe should be employed when handling industrial wastes. Clay pipe is normally applied for gravity flow lines. However, they should be designed for heads of 5–10 feet to guard against the possibility of blockage or of the sudden or abrupt introduction of material into the line. [Table V.3](#) provides the compatibility of vitrified clay with selected corrodents.

Table V.3 Compatibility of Vitrified Clay with Selected Corrodents^a

Chemical	Maximum temperature (°F/°C)
Acetic acid 5%	150/66
Acetone	73/23
Aluminum chloride	x
Aluminum sulfate 5%	150/66
Ammonium chloride 5%	150/66
Ammonium chloride 10%	x
Ammonium chloride 25%	x
Ammonium hydroxide 5%	73/23
Ammonium hydroxide 10%	73/23
Aniline	73/23
Benzene	73/23
Borax 3%	150/66
Carbon tetrachloride	73/23
Chromic acid 40%	150/66
Citric acid 10%	150/66
Copper sulfate 3%	150/66
Ferric chloride 1%	150/66
Hydrochloric acid 10%	120/49
Hydrofluoric acid 30%	x
Hydrofluoric acid 70%	x
Hydrofluoric acid 100%	x
Nitric acid 1%	150/66
Nitric acid 10%	150/66
Nitric acid 20%	150/66
Sodium carbonate 20%	150/66
Sodium chloride 30%	150/66
Sodium hydroxide 10%	150/66
Sulfuric acid 20%	150/66
Sulfuric acid 30%	150/66
Toluene	120/49

^aThe chemicals listed are in the pure state or in a saturated solution unless otherwise indicated. Compatibility is shown to the maximum allowable temperature for which data are available. Incompatibility is shown with an x.

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