CHEMICAL RESISTANCE AND CHEMICAL APPLICATIONS FOR CPVC PIPE AND FITTINGS

By Michelle Knight

Chlorinated polyvinyl chloride (CPVC) has become an important engineering thermoplastic due to its relatively low cost, high heat deflection temperature, chemical inertness and outstanding mechanical, dielectric, and flame and smoke properties. First commercialized in 1959 by Lubrizol Advanced Materials, Inc. (formerly BFGoodrich Performance Materials), it has proven over nearly five decades of use to be a viable piping alternative for a variety of industrial applications in which a high use temperature and excellent resistance to corrosive chemicals are required.

The purpose of this document is to present a more detailed analysis of the chemical resistance capabilities of CPVC. It will provide specifiers and installers with information about those applications in which CPVC performs the best, as well as those in which its use may be limited or not recommended at all.

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Variables that can affect chemical resistance include chemical concentration, temperature, pressure, external stress and final product quality. Since the number of possible use conditions is so large, the final decision regarding material suitability often must be based on in-service testing and direct communications with the piping manufacturer. This paper addresses capabilities and limitations that will provide general guidelines for an end-use application.

CPVC – An Overview

At its most basic level, CPVC is a PVC homopolymer that has been subjected to a chlorination reaction. In PVC, a chlorine atom occupies 25 percent of the bonding sites on the backbone, while the remaining sites are filled by hydrogen. CPVC differs from PVC in that approximately 40 percent of the bonding sites on the backbone are filled with strategically placed chlorine atoms, while the remaining 60 percent of available sites are filled with hydrogen. The chlorine atoms surrounding the carbon backbone of CPVC are large atoms which protect the chain from attack. Access to the CPVC carbon chain is restricted by the chlorine on the molecule. It is the additional chlorine that provides CPVC with its superior temperature and chemical resistance.

Industry-Accepted Standards for Evaluating Chemical Resistance

In addition to nearly 50 years of proven experience in the field, the chemical resistance capabilities of CPVC have been confirmed through work with numerous outside testing laboratories around the world. Equally important is the fact that chemical resistance has been determined, and confirmed, using two widely-accepted standards – ISO 22088 and ASTM D543.

Part of ISO 22088 specifies methods for the determination of Environmental Stress Cracking (ESC) of thermoplastics when subjected to a constant tensile load in the presence of chemical agents. Under this standard, materials are fully immersed in the chemical agent. If the chemical is highly viscous at the test temperature, the specimen is covered by a coating that is at least 2mm thick. During immersion, a constant tensile load is applied parallel to the longitudinal axis. In general, the maximum amount of stress to be applied is determined as being that which produces an elongation of 2 percent after one hour.

The ISO test can be conducted using two different approaches. The first approach utilizes a series of tests that increase the amount of stress until the material sample ruptures. In the second approach, the goal is to identify the amount of time it takes to rupture the material sample when subjected to a single stress load. In either case, the test is run multiple times to ensure accurate results.

ASTM International has also developed standard practices for evaluating the resistance of plastics to chemical reagents. Standard D543 covers all plastic materials and provides specific guidelines as to how to administer the testing. This includes requirements on preparing the samples, conducting the actual tests, and reporting the results.

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Similar to the ISO testing standard, there are two approaches that can be taken under ASTM D543. In the Immersion Test, the sample is totally immersed for a minimum of seven days. At the completion of the test, the sample is re-weighed and re-measured and compared against its weight and measurements prior to immersion. The pipe surface is also observed for possible changes in texture, discoloration, swelling, clouding, tackiness, bubbling or cracking.

In the Mechanical Test, the sample is also exposed to the chemical reagent for a minimum time period, but during exposure, an external stress is applied (similar to ISO testing).

Even though both internationally accepted standards have proven reliable in their ability to determine a product’s chemical resistance, many pipe manufacturers still recommend that a test be conducted to replicate a plant’s process conditions. This will help to validate the expected reliability of the pipe in the presence of a specific chemical.

Suitable Chemical Applications

One of the most attractive features of CPVC piping is its resistance to corrosive chemicals – the same chemicals that can degrade and reduce the service life of many metals, potentially causing expensive maintenance, disruption of operations and property-damaging leaks in these systems.

Many of the same chemicals that cause the greatest damage to metal piping, including acids, caustics and salts, can be handled well by a properly installed CPVC piping system. In addition, CPVC piping is not pH limited. It can accommodate wide pH swings in the fluids it transports.

As a result of its superior corrosion resistance, CPVC is proven acceptable for use with many different chemicals used in a wide array of industrial operations. Industries that have already successfully installed CPVC piping systems include metal finishing (chrome plating), chlor-alkali, wastewater treatment, pulp and paper, and food and beverage.

In the metal finishing/plating industry, there are numerous reasons why CPVC has proven to be a viable alternative to metal – primarily because of the strong acids used, including sulfuric acid for chrome and nickel stripping and the use of nickel sulfate and nickel chloride. In addition, the industry utilizes a many high pH caustics. These corrosive chemicals, especially when used in high-temperature environments, can quickly create major corrosion problems. CPVC not only offers the necessary chemical- and temperature-resistance, but it also possesses the required impact and tensile strength.

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Similarly, the chlor-alkali industry frequently transports a number of highly corrosive chemicals, including sulfuric acid, sodium hydroxide (caustic soda), cell liquor (brine, sodium hydroxide), sodium chloride (brine), sodium hypochlorite, hydrochloric acid, and demineralized/deionized water. All of these have proven to be compatible with CPVC for use in steam condensate/evaporator systems, chlorine drying towers, and chlorine headers/manifolds, to name just a few applications.

In wastewater treatment applications, harsh chemicals are a problem for many materials but can be handled easily and safely with CPVC piping. So whether a plant is using acids such as sulfuric, hydrochloric, nitric or phosphoric acid, or bases including caustic (NaOH), magnesium hydroxide and calcium hydroxide (lime), CPVC has proven to be compatible. It can even handle those chemicals that are used in conjunction with today’s treatment technologies, including ferric chloride, sodium hydroxide and sodium hypochlorite.

In the pulp and paper industry, CPVC piping is ideal for use with pulp or bleaching operations, as well as for weak black liquor and green liquor in various storage and unit operations.

Since most food and beverage plants require meticulous cleaning to meet strict health standards, process equipment is frequently cleaned using harsh chemicals or cleaning agents at high temperatures. These conditions can corrode most metals and make many plastics unsuitable, due to the extreme temperatures. But CPVC possesses both the corrosion and temperature resistance needed to perform reliably and cost effectively.

Refer to Appendix A for a full listing of chemicals that are both recommended and not recommended for use with CPVC piping. Again, remember that chemical compatibility can be ultimately affected by many factors, including temperature, pressure and design of the system. Some piping manufacturers offer technical assistance and will actually test specific chemical formulations to determine chemical compatibility. It is always recommended to work with the specific pipe and fitting manufacturer in determining material suitability.

It should further be noted that CPVC products are made with base resins having different molecular weights and chlorine content, as well as different compound additives. Therefore, it is always recommended to check with a specific pipe and fitting manufacturer before confirming actual chemical resistance capabilities and compatibility.

Caution Areas and Indications of Chemical Compatibility Problems

Chemical resistance issues can show up in a number of ways, with the most common problems being softening, degradation and cracking. If CPVC pipe has been incorrectly specified for a particular chemical application, or if it is unintentionally coming into contact with an incompatible material, several modes of failure can result.

MODES OF FAILURE

Softening

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Although there are several causes of softening (a type of pipe failure characterized by a swollen and/or distorted appearance which eventually causes a failure by ballooning and ductile rupture, or by distortion of the system), one primary cause is the absorption of solvents or plasticizers, either from the process fluid itself or from the external environment. CPVC, generally, is not recommended for use with most solvents—soluble or insoluble – including ketones, ethers, furans, esters, alcohols and aromatics. Some water-soluble solvents may be suitable at low concentrations. However, water-insoluble solvents may be absorbed out of process fluid even if present at low concentrations.

Chemical contamination can arise from a variety of sources. Oils can leak from pumps or other mechanical devices; plasticizers can leach from gaskets, hoses or tank linings; or the process fluids inside may not be as clean or as well defined as had been thought.
Solvents or plasticizers may also be absorbed from the environment external to the piping system. Gasketing materials, caulks, rubber padding or lining materials may all contain plasticizers that can migrate into the rigid vinyl over time, leading to softening and eventual rupture under pressure. While the design engineer must be aware of these limitations, proper system design and specification of ancillary materials can prevent these types of compatibility issues.

Degradation

Degradation of CPVC piping materials occurs when the vinyl resin or other compounding ingredients in the material are altered or destroyed. Degradation, which can manifest itself in many ways, including blackening and blistering, can be caused by prolonged exposure to conditions in excess of the recommended temperature, pressure and chemical concentration (TPC). Often, degradation is due to exposure to chemicals capable of reacting with and destroying the base polymer of the compounding additives. Some of the most common problem chemicals include amines and ammonia.

As previously stated, CPVC offers superior resistance to many strong acids and caustics, and this is the reason it is often selected for use in a number of aggressive chemical environments, including industrial-strength bleach applications or metal pickling and plating baths. However, no material is without its limitations. In excess of its recommended TPC limits, hot concentrated sulfuric acid may cause blackening and blistering, while hot concentrated nitric acid may cause whitening and surface etching.

A key difference between PVC and CPVC chemical resistance is in the area of ammonia and amine chemistries. In most cases, CPVC will outperform PVC in both its chemical and temperature resistance. However, PVC exhibits generally good resistance to ammonia and some amines, even at somewhat elevated temperatures. CPVC, on the other hand, has extremely poor resistance to ammonia or ammonium hydroxide, and limited resistance to most amines, even at ambient temperatures. This is due to the extremely high reactivity of amines and chlorine, the higher availability of chlorine on the CPVC, and the lower carbon-chlorine bond strength of CPVC compared with PVC. Even at fairly low concentrations and temperatures, ammonia and many amines are capable of rapid dehydrochlorination of CPVC.

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Environmental Stress Cracking

Environmental stress cracking, also referred to as ESC, is a mechanism by which an organic chemical (possibly a weak solvent or even a non-solvent) achieves an extremely localized weakening at the surface of the material which permits propagation of a crack.

Environmental stress cracking generally presents itself as a crack with glossy fracture surfaces that occur in regions of high mechanical stresses. ESC is dependent on both the presence of the chemical and a significant level of mechanical stress. Therefore, it may occur in some installations or certain parts of a system, while the system performs well in other areas. Many problems can, as a result, be avoided by proper design and installation. Potential ESC agents for CPVC include natural or synthetic ester oils, nonionic surfactants, alcohols and glycols.

Solvent Cement Joints – Reliable Even When Handling Harsh Chemicals

Chemical resistance capabilities are important to understand because they directly affect the reliability and long-term performance of the entire piping system. In addition to the chemical and mechanical properties of the pipe and fittings, however, it is also important to consider the integrity of the joint. In many piping systems – metallic as well as non-metallic – the joint is often the most vulnerable point in the system, the most likely to fail, and the point at which most leaks will occur. This is not the case with CPVC. In fact, over its nearly 50-year history in the field, CPVC piping joints have proven to be the strongest part of the system – stronger than either the pipe or fitting alone. This is due to the unique chemical bonding process of the solvent cement weld.

Although there are a number of methods for joining a CPVC piping system, in most operations CPVC pipe is joined with solvent cement. Despite the fact that some people liken solvent cement to adhesive glue, it is very different, inasmuch as the solvent cement creates a welded, permanent bond. The solvents in the cement are designed to intentionally soften the surfaces of the pipe and fitting socket. Since the socket is tapered, the softened surfaces bond once they are pushed together. CPVC resin in the solvent cement fills in any gaps that might otherwise exist in the joint. As the joint cures, the solvents flash off.

As a result, the CPVC solvent cemented joint is permanent and reliable. For exceptionally harsh chemical environments, special solvent cements are available and recommended. These have proven to be highly successful in even the most aggressive environments and compare favorably in mechanical performance to traditional solvent cements. In fact, years ago some plants experienced joint failures as a result of the CPVC solvent cement used. The fillers contained in the solvent material had dissolved from the effects of the harsh chemicals, and leaks occurred at the joint. These problems have since been remedied and proven reliable with newer formulations. The designer should always consult with the pipe and fitting or solvent cement manufacturer to ensure the proper solvent cement is specified.

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Conclusion

Chemical compatibility is critical when designing and installing an industrial piping system. Consideration must be given to the chemical makeup of all process fluids, as well as any other materials that are in contact with the CPVC pipe and fittings.

CPVC has proven through the years that it offers superior chemical resistance and a more reliable performance in a number of key chemical industries. When combined with its other benefits – including lower material costs; a faster, easier installation process; lightweight design; abrasion resistance; superior flame and smoke characteristics; weatherability and energy efficiency – it is easy to see why CPVC has become the material of choice for more and more industrial plants around the globe.

But like all other piping materials, it does have its weaknesses and should not be specified in applications for which it offers very little or no chemical resistance. This paper generically addressed the types of chemical environments in which CPVC does well and those in which its performance is less than desirable. Since there are so many factors that ultimately affect a pipe's ability to perform safely, reliably and cost effectively, it is important to thoroughly research the material and work directly with the pipe and fitting manufacturer to ensure compatibility and a high-performance system.

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APPENDIX A

Chemical Resistance Table

* Lubrizol has determined that the surface temperature of gray CPVC installed in direct sunlight can reach peak temperatures approaching 175°F. This should be taken into account when establishing the maximum operating temperature of the system.

R: Recommended
N: Not Recommended
C: Caution, further testing suggested; suspect with certain stress levels
A: Case by Case approval, contact Lubrizol Advanced Materials
-- : Incomplete data

Given percentages are by weight

Reagent	73°F (23°C)	Max. Temp. (°F)
A		
Acetaldehyde	N	N
Acetic Acid, up to 10%	R	180°F
Acetic Acid, greater than 10%	C	C
Acetic Acid, Glacial	N	N
Acetic Anhydride	N	N
Acetone, up to 5%	R	180°F
Acetone, greater than 5%	C	C
Acetone, pure	N	N
Acetyl Nitrile	N	N
Acrylic Acid	N	N
Acrylonitrile	N	N
Adipic Acid, sat'd in water	R	200°F
Alcohols	C	C
Allyl Alcohol	C	C
Allyl Chloride	N	N
Alum, all varieties	R	200°F
Aluminum Acetate	R	200°F
Aluminum Chloride	R	200°F
Aluminum Fluoride	R	200°F
Aluminum Hydroxide	R	200°F

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Aluminum Nitrate	R	200°F
Aluminum Sulfate	R	200°F
Amines	N	N
Ammonia	N	N
Ammonium Acetate	R	200°F
Ammonium Benzoate	R	200°F
Ammonium Bifluoride	R	200°F
Ammonium Carbonate	R	200°F
Ammonium Chloride	R	200°F
Ammonium Citrate	R	200°F
Ammonium Dichromate	R	200°F
Ammonium Fluoride	R	200°F
Ammonium Hydroxide, 28%	N	N
Ammonium Hydroxide, 10%	N	N
Ammonium Hydroxide, 3%	C	N
Ammonium Nitrate	R	200°F
Ammonium Persulfate	R	--
Ammonium Phosphate	R	C
Ammonium Sulfamate	R	200°F
Ammonium Sulfate	R	200°F
Ammonium Sulfide	R	200°F
Ammonium Thiocyanate	R	200°F
Ammonium Tartrate	R	200°F
Amyl Acetate	N	N
Amyl Alcohol	C	C
Amyl Chloride	N	N
Aniline	N	N
Antimony Trichloride	R	200°F
Aqua Regia	R	N
Aromatic Hydrocarbons	N	N
Arsenic Acid	R	--
B		
Barium Carbonate	R	200°F
Barium Chloride	R	200°F
Barium Hydroxide	R	200°F

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Barium Nitrate	R	200°F
Barium Sulfate	R	200°F
Barium Sulfide	R	200°F
Beer	R	200°F
Beet Sugar Liquors	R	200°F
Benzaldehyde	N	N
Benzene	N	N
Benzoic Acid, sat'd in water	R	N
Benzyl Alcohol	N	N
Benzyl Chloride	N	N
Bismuth Carbonate	R	200°F
Black Liquor	R	200°F
Bleach, household (5% Cl)	R	200°F
Bleach, industrial (15% Cl)	R	200°F
Borax	R	200°F
Boric Acid	R	200°F
Brine Acid	R	180°F
Bromine	N	N
Bromine, aqueous, sat'd	R	200°F
Bromobenzene	N	N
Bromotoluene	N	N
Butanol	C	C
Butyl Acetate	N	N
Butyl Carbitol	N	N
Butyl Cellosolve	N	N
Butyric Acid, up to 1%	R	180°F
Butyric Acid, greater than 1%	C	C
Butyric Acid, pure	N	N

C

Cadmium Acetate	R	200°F
Cadmium Chloride	R	200°F
Cadmium Sulfate	R	200°F
Calcium Acetate	R	200°F
Calcium Bisulfide	R	200°F

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Calcium Bisulfite	R	200°F
Calcium Carbonate	R	200°F
Calcium Chlorate	R	200°F
Calcium Chloride	R	200°F
Calcium Hydroxide	R	200°F
Calcium Hypochlorite	R	200°F
Calcium Nitrate	R	200°F
Calcium Oxide	R	200°F
Calcium Sulfate	R	200°F
Can Sugar Liquors	R	200°F
Caprolactam	N	N
Caprolactone	N	N
Carbitol	N	N
Carbon Dioxide	R	200°F
Carbon Disulfide	N	N
Carbon Monoxide	R	200°F
Carbon Tetrachloride	N	N
Carbonic Acid	R	200°F
Castor Oil	C	C
Caustic Potash	R	180°F
Caustic Soda	A	A
Cellosolve, all types	N	N
Chloric Acid	R	180°F
Chlorinated Solvents	N	N
Chlorinated water, (hypochlorite)	R	200°F
Chlorine, dry gas	A	A
Chlorine, liquid	N	N
Chlorine, trace in air	R	200°F
Chlorine, wet gas	A	A
Chlorine dioxide, aqueous, sat'd	R	200°F
Chlorine water, sat'd	R	200°F
Chlorobenzene	N	N
Chloroform	N	N
Chromic Acid, 40% (conc.)	R	180°F

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Chromium Nitrate	R	200°F
Citric Acid	R	200°F
Citrus Oils	N	N
Coconut Oil	N	N
Copper Acetate	R	200°F
Copper Carbonate	R	200°F
Copper Chloride	R	200°F
Copper Cyanide	R	200°F
Copper Fluoride	R	200°F
Copper Nitrate	R	200°F
Copper Sulfate	R	200°F
Corn Oil	N	N
Corn Syrup	R	200°F
Cottonseed Oil	N	N
Creosote	N	N
Cresol	N	N
Crotonaldehyde	N	N
Cumene	N	N
Cupric Fluoride	R	200°F
Cupric Sulfate	R	200°F
Cuprous Chloride	R	200°F
Cyclohexane	N	N
Cyclohexanol	N	N
Cyclohexanone	N	N
D		
Detergents	C	C
Dextrin	R	200°F
Dextrose	R	200°F
Dibutyl Phthalate	N	N
Dibutyl Ethyl Phthalate	N	N
Dichlorobenzene	N	N
Dichloroethylene	N	N
Diethylamine	N	N
Diethyl Ether	N	N
Dill Oil	N	N

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Dimethylformamide	N	N
Disodium Phosphate	R	200°F
Distilled Water	R	200°F
E		
EDTA, Tetrasodium	R	200°F
Esters	N	N
Ethanol, up to 5%	R	180°F
Ethanol, greater than 5%	C	C
Ethers	N	N
Ethyl Acetate	N	N
Ethyl Acrylate	N	N
Ethyl Benzene	N	N
Ethyl Chloride	N	N
Ethyl Ether	N	N
Ethylene Bromide	N	N
Ethylene Chloride	N	N
Ethylene Diamine	N	N
Ethylene Glycol, up to 50%	R	180°F
Ethylene Glycol, greater than 50%	C	C
Ethylene Oxide	N	N
F		
Ferric Chloride	R	200°F
Ferric Hydroxide	R	200°F
Ferric Nitrate	R	200°F
Ferric Sulfate	R	200°F
Ferrous Chloride	R	200°F
Ferrous Hydroxide	R	200°F
Ferrous Sulfate	R	200°F
Fluorine gas	N	N
Fluosilicic Acid, 30%	R	180°F
Formaldehyde	N	N
Formic Acid, up to 25%	R	180°F
Formic Acid, greater than 25%	C	N
Freons	C	C

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Fructose	R	200°F
G		
Gasoline	N	N
Glucose	R	200°F
Glycerine	R	200°F
Glycol Ethers	N	N
Green Liquor	R	200°F
H		
Halocarbon Oils	N	N
Heptane	C	--
Hydrazine	N	N
Hydrochloric Acid	R	180°F
Hydrochloric Acid, 36% (conc.)	R	180°F
Hydrofluoric Acid, 3%	R	--
Hydrofluoric Acid, 48%	C	C
Hydrofluosilicic Acid, 30%	R	180°F
Hydrogen Peroxide, 50%	R	--
Hydrogen Sulfide, Aqueous	R	180°F
Hypochlorous Acid	R	180°F
I J K		
Isopropanol	C	C
Ketones	N	N
Kraft Liquors	R	200°F
L		
Lactic Acid, 25%	R	200°F
Lactic Acid, 85% (Full strength)	R	C
Lead Acetate	R	200°F
Lead Chloride	R	200°F
Lead Nitrate	R	200°F
Lead Sulfate	R	200°F
Lemon Oil	N	N
Limonene	N	N
Linseed Oil	N	N
Lithium Chloride	R	200°F

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Lithium Sulfate	R	200°F
Lubricating Oil, ASTM 1,2,3	R	--
M		
Magnesium Carbonate	R	200°F
Magnesium Chloride	R	200°F
Magnesium Citrate	R	200°F
Magnesium Fluoride	R	200°F
Magnesium Hydroxide	R	200°F
Magnesium Salts, inorganic	R	200°F
Magnesium Nitrate	R	200°F
Magnesium Oxide	R	200°F
Magnesium Sulfate	R	200°F
Maleic Acid, 50%	R	180°F
Manganese Sulfate	R	200°F
Mercuric Chloride	R	200°F
Mercuric Cyanide	R	200°F
Mercuric Sulfate	R	200°F
Mercurous Nitrate	R	200°F
Mercury	R	180°F
Methane Sulfonic Acid	R	180°F
Methanol, up to 10%	R	180°F
Methanol, greater than 10%	C	C
Methanol, pure	N	N
Methyl Cellosolve	N	N
Methyl Chloride	N	N
Methyl Ethyl Ketone	N	N
Methyl Formate	N	N
Methyl Isobutyl Ketone	N	N
Methyl Methacrylate	N	N
Methylamine	N	N
Methylene Chloride	N	N
Mineral Oil	R	--
Monoethanolamine	N	N
Motor Oil	N	N
Muriatic Acid	R	180°F

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N		
Naphthalene	N	N
Nickel Acetate	R	200°F
Nickel Chloride	R	200°F
Nickel Nitrate	R	200°F
Nickel Sulfate	R	200°F
Nitric Acid, up to 25%	R	150°F
Nitric Acid, 25 - 35%	R	130°F
Nitric Acid, 70%	R	105°F
Nitrobenzene	N	N
O		
1-Octanol	C	N
Oils, edible	N	N
Oils, Sour Crude	N	N
Oleum	N	N
Olive Oil	N	N
Oxalic Acid, Sat'd	R	170°F
Oxygen	R	180°F
Ozonized Water	R	200°F
P Q R		
Palm Oil	N	N
Paraffin	R	180°F
Peanut Oil	N	N
Perchloric Acid, 10%	R	--
Phenylhydrazine	N	N
Phosphoric Acid	R	180°F
Phosphorus Trichloride	N	N
Picric Acid	N	N
Pine Oil	N	N
Plating Solutions	R	180°F
Polyethylene Glycol	N	N
Potash	R	200°F
Potassium Acetate	R	200°F
Potassium Bicarbonate	R	200°F
Potassium Bichromate	R	200°F

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Potassium Bisulfate	R	200°F
Potassium Borate	R	200°F
Potassium Bromate	R	200°F
Potassium Bromide	R	200°F
Potassium Carbonate	R	200°F
Potassium Chlorate	R	200°F
Potassium Chloride	R	200°F
Potassium Chromate	R	200°F
Potassium Cyanate	R	200°F
Potassium Cyanide	R	200°F
Potassium Dichromate	R	200°F
Potassium Ferricyanide	R	200°F
Potassium Ferrocyanide	R	200°F
Potassium Fluoride	R	200°F
Potassium Hydroxide	R	200°F
Potassium Hypochlorite	A	A
Potassium Iodide	R	200°F
Potassium Nitrate	R	200°F
Potassium Perborate	R	180°F
Potassium Perchlorate, sat'd	R	180°F
Potassium Permanganate, sat'd	R	180°F
Potassium Persulfate, sat'd	R	--
Potassium Phosphate	R	200°F
Potassium Sulfate	R	200°F
Potassium Sulfide	R	200°F
Potassium Sulfite	R	200°F
Potassium Tripolyphosphate	R	200°F
Propanol, up to 0.5%	R	180°F
Propanol, greater than 0.5%	C	C
Propionic Acid, up to 2%	R	180°F
Propionic Acid, greater than 2%	C	C
Propionic Acid, pure	N	N
Propylene Dichloride	N	N
Propylene Glycol, up to 25%	R	180°F

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Propylene Glycol, greater than 25%	C	C
Propylene Oxide	N	N
Pyridine	N	N
S		
Sea Water	R	200°F
Silicic Acid	R	--
Silicone Oil	R	--
Silver Chloride	R	200°F
Silver Cyanide	R	200°F
Silver Nitrate	R	200°F
Silver Sulfate	R	200°F
Soaps	R	200°F
Sodium Acetate	R	200°F
Sodium Aluminate	R	200°F
Sodium Arsenate	R	200°F
Sodium Benzoate	R	200°F
Sodium Bicarbonate	R	200°F
Sodium Bichromate	R	200°F
Sodium Bisulfate	R	200°F
Sodium Bisulfite	R	200°F
Sodium Borate	R	200°F
Sodium Bromide	R	200°F
Sodium Carbonate	R	200°F
Sodium Chlorate	R	200°F
Sodium Chloride	R	200°F
Sodium Chlorite	R	200°F
Sodium Chromate	R	200°F
Sodium Cyanide	R	200°F
Sodium Dichromate	R	200°F
Sodium Ferricyanide	R	200°F
Sodium Ferrocyanide	R	200°F
Sodium Fluoride	R	200°F
Sodium Formate	R	200°F
Sodium Hydroxide	A	A

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Sodium Hypobromite	R	200°F
Sodium Hypochlorite	R	200°F
Sodium Iodide	R	200°F
Sodium Metaphosphate	R	200°F
Sodium Nitrate	R	200°F
Sodium Nitrite	R	200°F
Sodium Perborate	R	180°F
Sodium Perchlorate	R	180°F
Sodium Phosphate	R	200°F
Sodium Silicate	R	200°F
Sodium Sulfate	R	200°F
Sodium Sulfide	R	200°F
Sodium Sulfite	R	200°F
Sodium Thiosulfate	R	200°F
Sodium Tripolyphosphate	R	200°F
Soybean Oil	N	N
Stannic Chloride	R	200°F
Stannous Chloride	R	200°F
Stannous Sulfate	R	200°F
Starch	R	200°F
Stearic Acid	R	--
Strontium Chloride	R	200°F
Styrene	N	N
Sugar	R	200°F
Sulfamic Acid	R	180°F
Sulfur	R	--
Sulfuric Acid, Fuming	N	N
Sulfuric Acid, 98%	R	125°F
Sulfuric Acid, 85%	R	170°F
Sulfuric Acid, 80%	R	180°F
Sulfuric Acid, 50%	R	180°F
T		
Tall Oil	C	C
Tannic Acid, 30%	R	--
Tartaric Acid	R	--

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Terpenes	N	N
Tetrahydrofuran	N	N
Tetrasodiumpyrophosphate	R	200°F
Texanol	N	N
Thionyl Chloride	N	N
Toluene	N	N
Tributyl Phosphate	N	N
Trichloroethylene	N	N
Trisodium Phosphate	R	200°F
Turpentine	N	N
U V		
Urea	R	180°F
Urine	R	200°F
Vegetable Oils	N	N
Vinegar	R	200°F
Vinyl Acetate	N	N
W		
Water, Deionized	R	200°F
Water, Demineralized	R	200°F
Water, Distilled	R	200°F
Water, Salt	R	200°F
Water, Swimming Pool	R	200°F
WD-40	C	C
White Liquor	R	200°F
X Y Z		
Xylene	N	N
Zinc Acetate	R	200°F
Zinc Carbonate	R	200°F
Zinc Chloride	R	200°F
Zinc Nitrate	R	200°F
Zinc Sulfate	R	200°F

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