Protective Coating Guide for Fans

Introduction

The direct cost of corrosion in the U.S.A. is approximately 15 billion dollars annually. The application of special finishes for the prevention of corrosion, abrasion and erosion has been the subject of study in the air handling industry for quite some time. As might be expected, some materials or finishes are more resistant to corrosion than others, but no finish or coating is completely immune from corrosion in all respects. Therefore, protection from corrosion is of degree only, based upon a variety of choices of base materials and coatings made for any particular potential corrosion problem. The data set forth in this document is based on the experience of and recommendations by the manufacturer of such paints or coatings.

Fan Corrosion

The rate of corrosion for any application depends to a large extent on the concentrations of fumes, their temperature, and the amount of moisture associated with them. These parameters make it extremely difficult to define the corrosion resistance of any one coating by a single rating. This is shown in the Corrosion Resistant Guide (Table 4 on pages 6 and 7). Plant engineers with experience in specific applications may be in a better position to suggest the best coating for their requirements. Refer to them when possible for such advice.

The following are seven of the most common reasons to apply a protective coating to a fan.

1. Protection from corrosion by acids and alkalies.
2. Protection from weather elements (rain and UV).
3. Protection from abrasion and physical wear.
4. Protection against process contamination.
5. Provide easy cleanable surface or decontamination.
6. Good aesthetics.
7. Safety (fireproofing, low glare, visibility).

Some restrictions on fans to be coated are deserving of mention:

- Bearings cannot be placed in a corrosive airstream.
- The coating of variable intake vanes and outlet dampers is not recommended since it is almost impossible to properly protect some of their component parts such as linkages, bearings, etc.
- Shaft seals of a variety of types are available and should be used. Special types of seals may be required in some instances.
- Belt and shaft guards are usually made from light gauge material. Steel blasting would distort these parts. Therefore, steel blasting (and special coatings requiring steel blasting) is not recommended for these parts.
- Belt and shaft guards are usually painted OSHA yellow.
- Drains, especially in handling moist atmospheres, are a necessity.

With these points in mind, the corrosion resisting paint or finish can be applied either to the airstream of the fan or to the entire fan, both inside and out.

Bearings, motors, and drives are items that are usually not coated by the fan manufacturer. Shafts are normally coated with a very thin coating of an asphaltum based paint to prevent corrosion. A light asphaltum coating has been specified for fans but many field problems, such as rusting, were reported. To prevent this, a heavy coating of asphaltum must be specified.

Airstream and *all surfaces* are commonly specified as requiring corrosion protective coatings. *Airstream* surfaces include the entire impeller, the inside of the housing and all surfaces of the inlet cone and ring. *All surfaces* include all surfaces inside and outside except the motor, drives, shaft, and protective guards.

Some fans are used in the direct or indirect contact with food. In these cases, the paint coatings must meet the requirements of either the FDA or USDA. Due to the expense of meeting the requirements and the limited demand, there is a limited number of coatings available.

Government regulations have limited the amount of volatile organic compounds (VOCs) in coatings. This has increased the use of high-solids coatings, waterborne coatings and powder coatings to avoid these regulations. It also has limited the availability or in some cases has obsoleted some coatings. An example of a coating that used to be used on fans but is now very difficult to get is chlorinated rubber.

Surface Preparation

For all paints on steel surfaces, fans are phosphatized and washed followed by one prime coat and one or more finish coats, depending upon the application and its requirement. Phosphating is the formation of a layer of zinc, iron or manganese phosphate crystals on the surface of the part to be painted. It is used to increase corrosion resistance and improve paint adhesion. The phosphate coating is a transition layer. It is less dense than most metals but more dense than paint. It has an intermediate thermal expansion between paint and metal. The effect is that the phosphate layer can smooth out the thermal expansion differences that would otherwise exist between the metal and the paint.

Generally, the parts to be coated are treated with a phosphating solution, which is sprayed on. Upon curing, the paint solidifies and is locked into the phosphate pores. Adhesion is greatly enhanced. The quality of the phosphate on a surface is usually expressed in milligrams per square foot of surface rather than in units of thickness.

The method by which the phosphatizing process works is as follows: The acid first attacks the metal at the crystalline grain boundaries. The phosphate crystals begin to grow along the grain boundary lines. After the grain boundaries are attached, the acid begins to etch the grain surfaces, and phosphate crystals appear at these sites. The resulting mass of phosphate crystals spread over the surface and grow into one another. The process is controlled by regulating the temperature, chemical concentrations, and the rinsing pressure. The final surface appears smooth to the naked eye.

In some cases, steel, sand or glass bead blasting of the parts to be coated is necessary. For the paint to adhere, the profile generated by steel blasting is required. The surface profile for most fans coated with special paint is 1 to 2 mils peak to peak.

The two basic standards to describe surface preparation are the National Association of Corrosion Engineers Standards (N.A.C.E.) and the Steel Structures Painting Council (SSPC) "Surface Preparation Specifications." Table 1 identifies some of the SSPC specification.

Table 1. Surface Preparation Specifications

Solvent Cleaning (SSPC-SP1) is removal of oil, grease, dirt, soil and contaminants by cleaning with a solvent, vapor, alkali, emulsion or steam. (NACE-N/A)
Hand Tool Cleaning (SSPC-SP2) is removal of loose rust, loose mill scale and loose paint by hand chipping, scraping, sanding and wire brushing. (NACE-N/A)
Power Tool Cleaning (SSPC-SP3) Removal of loose rust, loose mill scale and loose paint by power tool chipping, descaling, sanding, wire brushing and grinding. (NACE-N/A)
White Metal Blast Cleaning (SSPC-SP5) is removal of all visible rust, mill scale and paint and foreign matter by blast cleaning. (NACE-1)
Commercial Blast Cleaning (SSPC-SP6) is blast cleaning until at least two-thirds of each square inch is free of all visible residues. (NACE-3)
Pickling (SSPC-SP8) is complete removal of rust and mill scale by acid pickling, duplex pickling or electrolytic pickling. (NACE-N/A)
Near White Blast Cleaning (SSPC-SP10) is blast cleaning until at least 95% of each square inch is free of all visible rust, mill scale, paint and foreign matter. (NACE-2)

Selection of Coatings

Paints can be grouped according to their physical type, such as waterborne, high-solids or powder metal paints. No one paint can meet the requirements of every application. The selection process must answer the following questions:

a. In what environment will it be used?
b. How long must it last?
c. How much cost can be tolerated?

Waterborne coatings are those in which water is the major solvent or dispersant. Numerous resins are used in waterborne systems. Modified epoxies, polyesters, acrylics, alkyds, vinyl acetate-acrylics and styrene-acrylics are available. Both thermoplastic and thermosetting formulations (discussed later) are used. Some resin systems cure when heated. Others require the addition of a crosslinking agent.

The major advantages of waterborne coatings are:

- reduced fire hazard
- reduced solvent emission
- lower toxicity
- use equipment similar to solvent spray

The primary limitations of waterborne coatings include:

- surfaces must be very clean
- stainless steel or plastic pipe and fittings are recommended (due to corrosion in application equipment)
- some formulations must be protected from freezing
- better control of booth temperatures and humidity may be required
- longer flash-off times may be needed

High solids coatings are usually solvent based and contain greater than normal amounts of pigment and binder-usually at least 40% on weight basis. Some coatings are 65% solids or higher. The major advantages of high solids coatings are:

- less paint must be shipped, stored, pumped and sprayed
- lower oven air volumes are required
- less paint must be sprayed to provide a given film build
- formulations may be less expensive to produce
- less energy is needed for solvent evaporation. Savings of 20-25% are common
- less solvent is emitted to the atmosphere. This means less difficulty in meeting regulatory requirements

The primary limitations of high solid coatings are:

- high viscosity. Paints must often be heated to 200°F to achieve sprayability
- difficulty in pumping and atomizing, especially when cold
- cleaning and phosphating quality is usually more important than for conventional paints because there is less solvent present to "clean as it coats"
- sticky overspray which is messy to clean up because it never dries

These negatives may actually be beneficial since it means that pretreatment must be better than usual. Thus, corrosion resistance may be improved.

Powder coating is the application of paint in the form of a finely ground powder. The powder adheres weakly by means of electrical attraction. After application, the coated part is heated to melt the powder then cooled so the melted powder forms a solid film.

Powder coating has the following advantages:

- little waste since overspray can be used
- no solvent cost or handling problems
- less fire hazard (higher ignition energy than solvent air mixtures)
- less toxicity
- no air or water pollution
- no liquid mixing or pumping is required
- no flash-off space is needed
- less tendency to trap airborne dirt
- fewer shrinkage stresses developed during cure

The major disadvantages of powder coatings are:

- powder films have more appearance problems. There is more orange peel than conventional coatings
- the powder must be kept dry and this demands constant attention to equipment and technique
- changing colors is difficult. Each color must be kept separate
- cleaning before application is very important
- requires a baking oven
- hard to apply in tight areas, i.e., corners, behind angles and hidden areas

Paints can also be classified as "thermoplastic" or "thermosetting."

Thermoplastic

Thermoplastic is a coating which will dissolve in its own solvent system. It is usually a single package material which dries only by solvent evaporation.

Thermoplastic coatings are typified by vinyls and phenoxies. They cure by solvent evaporation and there is no crosslinking of the resin. The coating will redissolve readily in the original solvent system. The term thermoplastic means that if the coating is exposed to heat (thermo) then it will become more plastic, i.e., soft and pliable.

Thermosetting

Thermosetting is a coating which will not dissolve in its own solvent system. It is normally a two component coating which cures by solvent evaporation followed by a chemical reaction. This chemical reaction of crosslinking enables a low molecular weight material to become a large molecule or network of large molecules.

The following table is the generic classification of coatings differentiated by their chemical composition:

Table 2. Various Generic Coating Types

Thermoplastic
Alkyds
Vinyls
Acrylics
Typical water base house paints

Thermosetting
Bake Phenolic
Epoxy-Phenolic
Water Base Epoxy
Inorganic Zincs
Polyurethanes
Polyesters

Here is a quick breakdown of some generic types by the thermoplastic or thermosetting definition. Some alkyds and acrylics are baked and become thermosetting coatings.

Chemical Composition of Generic Coatings (Thermoplastic)

Acrylics — Acrylic acid, made from acrylonitrile, is converted to various acrylates. These and methyl methacrylate are the raw materials that are polymerized into acrylic resins.

Vinyls — Resins are typically made by linking together (polymerization) of vinyl chloride, a very toxic gas, vinyl acetate and vinyl alcohol. These resins are formed by a reaction between acetylene and an acid.

Alkyds — Commonly referred to as oil based paints. Chemically, alkyds are modified polyesters. The modification is the natural oil, used along with the alcohol, to react with a dibasic acid to form the polymer. The curing mechanism is a reaction between oxygen in the air and the oil of the polymer. This is a complex reaction and not completely understood.

Chemical Composition of Generic Coatings (Thermosetting)

Epoxy — Epoxies require a catalyst to bring about the crosslinking that gives the coating its many desirable properties. The most commonly used catalysts are the reactive amines and polyamide resins.

Polyesters — Coatings based not on epoxy resins but on modified alkyd chemistry, formed by the polycondensation of dicarboxilic acids and dihyroxy alcohols.

Phenolics — Phenolic resins are made by the reaction of phenol and formaldehyde. The reaction is driven by heat.

Inorganic Zincs — Zinc dust is added to inorganic binders. The Zinc metal acts as the cathode and corrodes in preference to the steel substrate.

Epoxy Phenolics — Coatings are modified phenolic coatings created by blending phenolic resins with epoxy resins.

Polyurethane — Coatings are derived from prepolymers containing isocyanate groups and hydroxyl-containing materials such as polyols and drying oils.

Epoxy Polyamides — These coatings have a slower crosslinking which leads to a more flexible finish.

Practical Properties & Application Requirements of Various Coatings

The following description of generic coatings provides a guide to specifying and selecting corrosion resistant coatings for fan equipment. For chemical resistance to specific chemicals, refer to Table 3.

ACRYLICS

Advantages: Excellent gloss retention, weathering resistance, moderate flexibility, high temperature resistance.

Disadvantages: Poor chemical resistance, poor solvent resistance.

VINYLS

Advantages: Fast dry in warm weather, excellent water and acid resistance, good adhesion, flexible.

Disadvantages: Usually low film builds, can lift other coatings, poor solvent resistance.

ALKYDS

Advantages: Inexpensive, good adhesion, flexible, good gloss, may be applied over most other alkyds.

Disadvantages: Poor chemical resistance, slow drying, low film build.

EPOXY POLYAMIDES

Advantages: Moisture tolerant during cure, long pot life, excellent adhesion.

Disadvantages: Less solvent resistant, more expensive, less chemically resistant.

POLYESTER

Advantages: High solids, excellent mineral acid resistance; strong and hard films.

Disadvantages: Poor solvent resistance, marginal adhesion.

(continued on page 4)

INORGANIC ZINCS

Advantages: Protect steel with single coat, not subject to ultraviolet degradation.

Disadvantages: Dry spray in hot windy weather, porous film to topcoat, limited pH range.

EPOXY PHENOLICS

Advantages: Heavy build, excellent acid and solvent resistance.

Disadvantages: Requires shotblasting.

POLYURETHANE

Advantages: Excellent weathering, enamel-like finish, flexible, damage resistant.

Disadvantages: Low film build, expensive, moisture intolerant, chemical cure, temperature sensitive.

Testing Paints

The major reasons for testing paints are to:

- Evaluate products
- Control quality
- Ensure process control

Paint viscosity is a very important property to control since it affects the quality of the applied paint. Viscosity is the resistance of a liquid to flow. Paint viscosity must be such that the proper atomization and flow-out can be achieved.

There are many instruments to measure viscosity. A common method is to use a Zahn cup. Paint viscosity is determined by measuring the time required for a given quantity of paint to flow through a hole in the bottom of a metal cup.

Film thickness of dry paint is important. Thin films will not provide corrosion resistance. Thick films are likely to crack. There is a direct correlation between wet film and dry film. Dry film is usually controlled by measuring the wet film with a gauge with various "V" notches. There are many commercial gauges to measure dry film thickness.

Tape adhesion is a test to measure the adhesion of a paint film to its substrate. It is often measured by pulling the paint away from a scribed "X" or grid with a strip of tape. The tape is pulled back upon itself as nearly in the plane of the painted surface as possible. A numerical rating system is used to evaluate the tape adhesion test results. If a scribed grid has been used, the failure of adhesion may be expressed as the percentage of squares which have experienced some loss of paint.

Salt spray testing is the use of a salt spray system in an attempt to accelerate the corrosion process and cause early paint failure. Panels are usually exposed up to 14 days to a mist of 5 percent (weight-to-volume) sodium chloride solution at 92° to 97°F. The mist is produced by blowing hot, saturated air through a 5 percent salt solution. The panels are evaluated for two types of rusting:

1. Face Rusting — The percentage of the surface which has rust visible through the paint.
2. Scratch-Creepback Rusting — the distance in 32^{nds} of an inch which has rusted away from a line scratched through the film to the metal.

Sometimes acetic acid is added to the salt spray solution to accelerate the corrosion. A common problem has been that customers have asked if the paint is salt spray tested to an ASTM standard. The problem with this is that the ASTM standard does not have acceptance/rejectance limits. As an example, the specification should read that the paint should be "salt spray tested to ASTM B117 for 200 hours and have no scribe blisters. Maximum creep from the scribe should be 1.0 mm creep."

Color matching is both important and difficult; important because of the customer reaction to mismatched colors and difficult because of human variability in color perception. Two panels which appear to be the same color to one person may seem dissimilar to someone else. A color may also change when viewed from different lighting, fluorescent versus outdoor light, for instance. Color chips are used as a general practice in the fan industry to offer matched colors.

Corrosion Resistant Guide — The use of the information in Table 4 is straightforward. For example, if the airstream has formic acid at between 15 to 85% concentration, then air dried phenolic would be acceptable. The other coatings that require steelblasting would also be acceptable but at a higher cost. The higher cost would be due to the cost of steelblasting and going to a better grade of epoxy paint. Sometimes there is no acceptable coating for the environment or substance being handled and the fan itself must be constructed of a corrosion resistant material. For instance, if the airstream contains over a 15% concentration of chromic acid, no coating would be acceptable. In this case, the fan would have to be constructed of 316 stainless steel.

Field Problems

Field problems are defects which occur after the fan has been painted and cured. Typically, they appear after the fan has been placed in service by the customer. Some service defects occur or are made worse as a result of processes used in painting. Some defects listed as service defects are normal wear-out processes for the paint.

Fading is the gradual loss of color intensity. It is observed with most paints as they age. It usually results from a reaction of the paint with moisture or sunlight. These reactions are impossible to avoid if outdoor exposure is involved. Sometimes ultraviolet (UV) stabilizers can be added to the paint to retard degradation but generally UV-resistant pigments must be used to slow down the process. Some pigments have such a low UV-resistance that they cannot be used in outdoor paints.

Face and Scratch Rusting. Face rusting is the appearance of rust on an undamaged paint surface. Scratch rust occurs in locations where the paint has been damaged by impact or scratching. To prevent rusting, constant attention to process parameters is essential. Rinsing is particularly critical to ensuring rust resistance. During shipping and the installation process it is important to consider the nature of the coating and handle the fan accordingly to prevent scratching and impact damage.

Corrosion (Rusting). Corrosion is a defect in which the paint has failed to protect the underlying surface from the corrosive action of the environment. Moisture from the air reacts with the base material, generally with the formation of the oxides, which then swells up beneath the paint and lifts it from the coated surface. Corrosion usually occurs if the exposure conditions are more severe than the paint can withstand. Assuming the paint has been properly applied, the only solution is to use a more corrosion resistant coating. Corrosion is more likely to occur if the paint is applied too thinly or if it is overbaked or underbaked. Poorly cleaned or rinsed surfaces will result in low adhesion and make it easier for moisture to displace the paint film from the surface being protected.

Peeling (Lifting, Flaking, Poor Adhesion). Peeling results when a paint film loses contact with the surface. Sometimes the paint curls off the surface or can be peeled by hand. Other times it falls off in small pieces with or without rubbing. The major cause of this problem is simply poor adhesion between the paint film and the surface. This may be a result of a surface contaminated by oil or grease-like material. The solution is to look at the cleaning process or for contaminants which have coated the surface before painting. Common difficulties with the cleaning systems include temperatures, pressures, and times that are too low, inadequate rinsing, and concentrations which are too high or low.

Clean surfaces may become contaminated in a variety of ways. Touching the surface with oily hands or gloves can contaminate it. Allowing the fan to wait a long time between cleaning and painting can allow contamination from the air to accumulate and cause problems.

Blisters (Swelling). Blisters are tiny areas beneath the paint film where moisture has collected as a result of passage through the paint film from the top. Usually such areas represent locations on the surface where salt crystals occur as a result of poor rinsing after phosphating or other cleaning operations. Salt crystals dissolve in the water and then pass through the paint film and form droplets of salt solution. This solution can produce enough pressure beneath the paint film to cause it to lift away from the surface. Blisters are usually a result of poor cleaning and rinsing processes. The solution is to be sure that the cleaner concentrations and temperatures are correct, pump pressures are up to standard, filters are clean, and spray nozzles are unobstructed. This way the parts receive adequate cleaning solution and rinse water during all stages of the preparation process.

Chalking. Chalking is a breakdown of the paint film. Chemically, it results from the degradation of the paint binder, usually as a result of exposure to moisture and ultraviolet radiation. Chalked paint can be rubbed off the surface with finger pressure. Chalking is an inherent property of a paint film. It is not particularly influenced by application variables.

Normal Paint Wear Out. The normal deterioration of a paint film is a step-wise process which involves binder degradation, pigment failure and finally, large scale cracking and peeling. The binder degrades by reaction with water, sulfur dioxide, and other chemicals. The binder breakdown products work loose from the surface by thermal expansion and contraction. Pigment failure follows binder degradation. Once exposed as a result of binder loss, the pigment begins to fail by reaction with moisture and gases in the air. Large scale cracking and peeling follow pigment failure because moisture is now easily able to penetrate the paint film through cracks and openings under the paint.

Cost

After selecting the proper coating for a fan the final consideration is its cost. The cost of coatings varies greatly from thermoplastic to thermosetting coatings and with the surface preparation that is required. The following chart is a guideline of the relative cost (compared to enamel) of the coatings that have been mentioned in this document.

Table 3. Relative Coating Costs

Surface Preparation	Coating	Relative Cost
No Blasting	Enamel	1.0
	Asphaltum	2.5
	Vinyl	2.5
	Zinc (some require blasting)	3.5
	Epoxy	3.5
	Synthetic Resin	3.5
	Air Dried Phenolic	6.5
Blasting	Baked Phenolic	18.5
	Epoxy	19.0
	Phenolic Epoxy	19.0
	Heavy Vinyl	21.0
	Hi-Bake Epoxy	26.0

Table 4. Corrosion-Resistant Guide to Generic Coatings

CORROSIVE	NO STEEL BLASTING						STEEL BLASTING				
	ASPHALT-UM	VINYL	ZINC	EPOXY	AIR DRIED PHENOLIC	SYNTHETIC RESIN	HEAVY VINYL	EPOXY	BAKED PHENOLIC	PHENOLIC EPOXY	HI-BAKED EPOXY
NUMBER OF COATS	**2**	**2**	**2**	**1**	**4**	**3**	**5**	**2**	**2**	**2**	**2**
ACIDS											
ASCETIC	F	F	U	G	G	E	G	G	E	E	E
BORIC	E	G	E	G	G	E	E	E	E	E	E
CARBOLIC	F	U	U	G	G	U	U	G	E	E	E
CARBONIC	F	G	E	E	G	E	E	E	E	E	E
CHROMIC	F	G	U	F	U	G	G	U	F	U	G
CITRIC	G	G	U	G	G	G	E	G	E	E	E
FLUOROBIC	X	G	U	X	G	X	E	X	X	X	X
FORMIC	F	G	X	G	E	G	E	E	E	E	E
HYDROBROMIC	X	X	U	X	U	G	E	X	U	X	U
HYDROCHLORIC	G	G	U	G	G	E	E	G	E	G	E
HYDROFLOURIC	F	F	X	G	U	U	F	G	U	E	E
HYDROCHLOROUS	F	X	X	F	X	E	F	F	F	G	G
LACTIC	F	G	U	G	E	E	G	E	E	E	E
NITRIC	F	G	U	G	G	E	G	F	F	X	X
PERCHLORIC	U	F	U	F	F	U	E	U	G	U	G
PHOSPHORIC	F	G	U	G	G	E	E	G	E	E	E
PICRIC	F	X	X	U	X	E	F	X	X	X	X
SULFURIC ACID	F	F	U	G	G	G	U	U	E	G	G
SULFUROUS ACID	X	G	U	G	G	G	U	G	E	E	E
HYDROCARBONS											
BENZENE	U	F	E	G	G	U	E	E	E	E	E
BUTANE	X	X	X	X	G	E	G	X	E	X	X
GASOLINE	U	G	E	G	G	E	G	E	E	E	E
XYLOL / TOLUOL	G	U	G	G	U	U	U	E	E	E	G
GASES AND FUMES											
STEAM VAPOR (SATURATED)	G	G	X	G	U	E	X	E	E	E	E
AMMONIA GAS (DRY)	G	F	X	X	U	E	E	G	U	G	X
AMMONIA (WET)	X	X	X	F	U	X	X	X	U	X	X
CHLORINE (DRY)	G	G	X	G	G	E	E	G	E	E	E
HYDROGEN SULFIDE	G	G	U	G	G	G	E	E	E	E	E
SULFUR DIOXIDE	X	X	U	X	G	G	U	U	E	U	U

KEY: E — Satisfactory from 15%-85% (depending upon coating) of concentration of fumes and for continuous operation. Also suitable for splash or condensation.
G — Good for up to 5%-15% concentration of fumes. Not recommended for applications involving splash or condensation.
F — Fair. Recommended for low (maximum 5%) concentration application. Should not be specified unless detail application is available.
U — Unstatisfactory and is not recommended.
X — Sufficient data not available. User comments would be appreciated.

Table 4 (continued). Corrosion-Resistant Guide to Generic Coatings

CORROSIVE	NO STEEL BLASTING						STEEL BLASTING				
	ASPHALT-UM	VINYL	ZINC	EPOXY	AIR DRIED PHENOLIC	SYNTHETIC RESIN	HEAVY VINYL	EPOXY	BAKED PHENOLIC	PHENOLIC EPOXY	HI-BAKED EPOXY
NUMBER OF COATS	**2**	**2**	**2**	**1**	**4**	**3**	**5**	**2**	**2**	**2**	**2**
ACID SALTS, NEUTRAL SALTS, ALKALINE SALTS, ALKALIES, ETC.											
ALUMINUM CHLORIDE	G	G	X	G	G	E	E	E	E	E	E
ALUMINUM NITRATE	F	F	X	X	F	E	X	X	G	F	X
ALUMINUM SULPHATE	G	G	E	G	G	E	E	E	E	E	E
AMMONIUM HYDROXIDE	E	G	G	G	U	E	E	F	E	U	E
AMMONIUM NITRATE	E	E	E	E	G	X	E	E	G	G	E
AMMONIUM SULFATE	G	G	G	G	F	E	E	G	E	G	E
BRINE	X	X	X	G	G	E	X	G	E	E	E
BROMINE	U	U	U	X	U	X	X	U	U	U	U
CALCIUM CHLORIDE	E	E	G	F	G	E	E	E	E	G	E
CALCIUM CARBONATE	E	E	X	E	G	E	E	E	E	E	E
CALCIUM HYDROXIDE	E	E	G	E	E	E	E	E	E	E	E
CALCIUM DISULPHIDE	F	G	E	G	G	U	U	E	E	E	E
COPPER SUPHATE	G	G	E	G	E	E	E	E	E	E	E
FERRIC CHLORIDE	G	G	E	G	E	E	E	E	E	E	E
HYDROGEN PEROXIDE	F	F	X	G	U	G	U	U	U	U	G
POTASSIUM CYANIDE	X	X	X	X	G	X	E	X	E	X	X
POTASSIUM HYDROXIDE	E	E	U	G	F	E	E	U	U	U	G
POTASSIUM DICHROMATE	G	F	E	F	G	X	E	G	E	E	E
SODIUM BICARBONATE	E	E	X	G	E	E	E	E	E	G	E
SODIUM CHLORIDE	E	E	E	E	E	E	E	E	E	E	E
SODIUM DICHROMATE	E	X	E	X	U	X	X	X	F	X	X
SODIUM HYDROXIDE	F	G	G	G	U	G	E	G	U	U	G
SODIUM HYPOCHLORITE	F	F	U	F	U	G	U	U	U	U	G
ZINC CHLORIDE	X	X	X	X	G	E	G	X	G	X	X
ZINC SULFATE	G	X	U	G	G	E	U	E	E	E	E
MISCELLANEOUS											
ABRASION	U	U	G	U	G	G	G	G	G	G	G
MOISTURE	E	E	E	E	E	E	E	E	E	E	E
SALT SPRAY	E	E	E	E	G	E	E	E	E	E	E
ACETONE	U	U	E	G	G	U	U	G	E	E	E
ALCOHOL	F	F	E	G	G	E	E	E	E	E	E
METHYL ETHYL KETONE	F	U	E	G	G	U	U	U	E	G	G
MINERAL OILS	E	E	X	E	F	U	G	G	E	G	X
POLYVINYL ACETATE	X	X	X	E	U	X	X	X	G	X	X
TRI CHLORETHYLENE	X	U	U	G	G	U	U	U	E	U	U

KEY: E — Satisfactory from 15%-85% (depending upon coating) of concentration of fumes and for continuous operation. Also suitable for splash or condensation.
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