

SELECTION GUIDE: ENVIRONMENTAL CORROSION PROTECTION



**Novation[®] Heat Exchanger with
Microchannel Coil Technology**



Turn to the Experts.™

**Carrier Corporation
Syracuse, New York**

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INTRODUCTION

The air conditioning industry faces a constant challenge to provide higher efficiency levels and greater equipment reliability. This challenge is even more difficult to meet when the goal is to simultaneously maintain equipment size and limit potential cost impact.

The Novation® heat exchanger with microchannel coil technology provides a solution that can meet all these requirements.

Compared to traditional coil technology, the microchannel heat exchanger (MCHX) coil offers the following benefits:

- Improved heat transfer and thermal performance
- Increased coil and overall unit efficiencies
- Substantial refrigerant charge reduction
- Compact size with reduced coil volume
- Enhanced structural robustness

When applied properly, the standard MCHX design will provide all the benefits listed above.

All condenser coils may be subjected to corrosion due to environmental factors. This selection guide will provide information on the causes of corrosion and identify corrosive environments in order to aid in the selection of the proper coil. Corrosion protection recommendations for the MCHX coil must be made based on the application environment.

CAUSES OF CORROSION

Environmental exposure of air conditioning components can often lead to an undesirable outcome if the correct materials are not applied. Condenser coils need to be protected from environments that may lead to localized and/or generalized corrosion. Premature corrosion of heat exchangers, specifically condenser coils, may lead to unexpected performance degradation, poor aesthetics, and possible equipment failure. In order to minimize these effects, material selection and protection schemes must be considered.

The environment in which HVAC/R equipment is applied varies throughout the globe and in some instances, even within a local area. Corrosive environments occur not only in coastal or marine climates and industrial areas, but also are present in urban or rural areas; localized microclimates; and combinations of these conditions. Factors including but not limited to the presence of flue gas, sewage vents or open sewage systems and diesel exhaust can all have a detrimental effect on HVAC/R coils.

These pollutants, in combination with other factors such as wind direction, humidity, water, fog, temperature, proximity to pollutant source, and dust or particle contamination, may result in the premature failure of equipment.

Corrosion can proceed in a general manner (general corrosion) or in a more localized manner (galvanic corrosion, pitting corrosion, formicary corrosion), depending on conditions and the material systems used.

Galvanic Corrosion

The necessary conditions for galvanic corrosion occur when dissimilar metals, in contact, are exposed to an electrolyte. The environment creates the electrolytes necessary for general and localized corrosion of materials. An understanding of the environment in which HVAC/R equipment is being applied is essential to the proper selection of materials and protection means.

General Corrosion

General corrosion is the degradation of metal caused by a reaction with the surrounding environment. Since general corrosion consumes metal and typically forms metal oxides, unsightly surface conditions usually result. As an example, copper is susceptible to attack from sulfur-containing gases. Unprotected metal will continue to react with the contaminant resulting in corrosion. Under severe, prolonged conditions, the metal continues to corrode until the integrity of the material and equipment is jeopardized. Unprotected aluminum tubes in polluted industrial environments can lead to tube leaks and failure of the refrigeration system. Sulfur and nitrogen based electrolytes in combination with chloride environments are often the cause of accelerated corrosion of these metals.

CORROSIVE ENVIRONMENTS

As previously discussed, potentially corrosive outdoor environments include areas adjacent to the seacoast, industrial sites, heavily populated urban areas, some rural locations, or combinations of any of these environments. These macro environments are often characterized as rural, urban, marine, industrial, or industrial marine. In addition, some air-handling applications, indoor environments such as swimming pool areas, water treatment facilities, and industrial process areas can also produce corrosive atmospheres.

Local environments called micro environments must also be considered. Close proximity to laundry facilities, diesel-burning devices/exhaust piping, sewer vents, traffic, etc. can lead to premature failure of improperly protected equipment, in a similar manner as the macro environmental conditions.

Contaminants in an environment typically result in the creation of electrolytes that facilitate the corrosion process. Electrolytes are substances that are electrically conductive when dissolved in water. Common electrolytes may contain chloride contaminants from sources such as seawater, road salts, cement dust, pool cleaners, laundry facilities, and household cleaning agents, which are typically sodium or calcium chloride-based compounds. Other relevant contaminants that contribute to the formation of electrolytes include sulfur and nitrogen bearing compounds from the combustion of coal and fuel oils. Chemical contamination from industrial processes, e.g., ammonia, can also contribute to the formation of an electrolyte.

In view of this it is necessary to identify each of these environments so that appropriate corrosion protection methods may be used.

Coastal / Marine

Many emerging HVAC/R markets have a majority of their populations located in coastal regions, leading to an increased number of applications in corrosive environments. Coastal or marine environments are characterized by the abundance of sodium chloride (salt) and sulfur compounds that are carried by sea spray, mist, fog, or prevailing winds. Sea spray, mist, and fog contain tiny droplets of salt water that can be transported many miles by ocean breezes and result in equipment contamination. The deposition of salt water spray onto metallic substances is the most corrosive aspect of the marine environment.



Several factors should be considered when choosing the best solution for a coastal or marine environment: land formation (e.g., islands, depending on size, often are influenced by coastal contaminations); distance from the coast and the direction of the prevailing winds (wind direction helps to determine the distance that contaminants can be carried); corrosion on other equipment or infrastructure in the area (an excellent indicator of the corrosiveness of the environment); common practices that have worked well in the area; and other pollution sources, such as industrial influences.

Industrial

Industrial environments are very diverse, with the potential to produce a variety of corrosive compounds. An industrial environment can exist on a macro or micro scale, each with the same detrimental effect. Sulfur and nitrogen containing contaminants are most often linked but not limited to industrial and high-density urban environments. Combustion of coal and fuel oils release sulfur oxides (SO_2 , SO_3) and nitrogen oxides (NO_x) into the atmosphere. Other contributors such as ammonia and its salts and hydrogen sulfide can have a detrimental effect on materials. Many of these gases accumulate in the atmosphere and return to the ground in the form of acid rain or low pH (acidic) dew.



Not only are industrial emissions potentially corrosive, but many industrial dust particles can be laden with harmful metal oxides, chlorides, sulfates, sulfuric acid, carbon and carbon compounds. These particles, in the presence of oxygen, water, or high humidity can be highly corrosive and may lead to many forms of corrosion including general corrosion and localized corrosion such as pitting and formicary corrosion.

Combination Marine/Industrial

Salt-laden seawater mist, combined with the harmful emissions of an industrial environment (either on a macro or micro level), poses a severe threat to the life of HVAC/R equipment. The combined effects of salt contamination and industrial emissions will accelerate corrosion of any improperly protected coil. This harsh



environment requires superior corrosion resistant properties for HVAC/R components to maintain acceptable product quality. For coils, complete encapsulation of the coil surfaces such as with e-coated MCHX coils is strongly recommended. When identifying this type of environment it is essential that local influences not be overlooked. Open sewage systems, vents, diesel exhaust, emissions from dense traffic, land fills, aircraft and ocean vessel exhaust, industrial manufacturing, chemical treatment facilities (cooling tower proximity), and fossil fuel burning power plants are potential contributors to consider.

Urban

Highly populated areas generally have high levels of automobile emissions and high rates of the byproducts of the combustion of building heating fuels. Both conditions elevate sulfur oxide (SO_x) and nitrogen oxide (NO_x) concentrations. Corrosion severity in this environment is a function of pollution levels, humidity,



average temperature, and equipment usage, which in turn depend on several factors including population density for the area, emission control, and local pollution standards. In areas with rapid growth, such as many areas in China and India, contamination levels can change drastically; thus, the future direction of a region should be considered when looking at the best corrosion protection system.

Note that any HVAC/R equipment installed near diesel exhaust, incinerator discharge stacks, fuel-burning boiler stacks, areas exposed to fossil fuel combustion emissions, or areas with high automobile emissions should be considered industrial applications.

Rural

A rural environment typically is unpolluted by exhaust and sulfur containing gases. Rural environments are usually sufficiently inland so that contamination and high humidity from coastal waters are not present. Coil protection in these environments is typically not required beyond the standard MCHX coil offerings.

However, rural environments may contain high levels of ammonia and nitrogen contamination from animal excrement, fertilizers, and high concentrations of diesel exhaust. In this case, these environments should be considered industrial applications and would require corrosion protection of the MCHX coil.

Localized Environment - Corrosivity of the Surroundings

All of the above environments are subject to microclimates which can significantly increase the corrosivity of the environment. Care should be taken to ensure that the localized environment surrounding the HVAC/R equipment does not contain contaminants that will be detrimental to the equipment. An example would be equipment placed near a diesel vehicle loading area or a diesel generator. Although the general area in which the building is located may meet the scope of a coastal or marine environment, the localized elements that surround the equipment may actually classify the application as industrial or industrial marine, and protection of the coil should be planned accordingly.

Localized environments can result from a variety of contaminants, including but not limited to those originating with:

- Traffic
- Airports
- Power plants
- Power generators
- Factories and chemical plants
- Breweries and food processing plants
- Wastewater treatment plants
- Dumps and incineration plants
- Cruise ships and shipping traffic
- Swampy areas (rotting vegetation)
- Farms and nurseries
- Fisheries

The contaminants in the preceding list must be considered in combination with other contributing factors, including but not limited to:

- Distance from contaminant source. The most detrimental effect in a micro environment occurs within 50 ft (15 meters); in a macro environment, within 1 mile (1.6 km)
- Prevailing wind direction
- Acid rain (note that sources may be hundreds of miles away)
- Condensation
- Temperature
- Humidity

The following are examples of contaminants that can create a micro environment within 50 ft (15 meters). (See Fig. 1.):

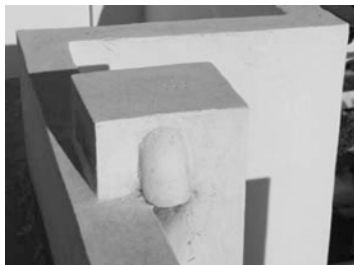
- Heavy/frequent fertilizer or insecticide usage
- Chemical/cleaner storage areas
- Bus or truck loading areas or heavy traffic
- Power generators
- Fan-powered exhaust vents
- Cooling towers due to drift of chemical treatments



Laundry Vent



Diesel Tank/ Loading Area



Plumbing Vent Stack



Diesel Bus Loading Area



Cooling Tower



Exhaust Vent

Fig. 1. Sources of Contaminants in Micro Environments

NOVATION® HEAT EXCHANGER WITH MICROCHANNEL COIL TECHNOLOGY

The MCHX coil design utilizes several aluminum alloys, in combination with a metallic coating, for construction of the heat exchangers. The alloys are carefully chosen to extend the life of the coil. Furthermore, the coil has been designed so that any galvanic couple within the coil has been carefully chosen to provide the maximum life possible for the coil.

A microchannel coil is composed of three key components: The flat microchannel tube, the fins located between alternating layers of microchannel tubes, and two refrigerant manifolds. The manifolds, microchannel tubes, and fins are joined together into a single coil using a nitrogen-charged brazing furnace. Overall product quality and integrity are maximized since only one uniform braze in the furnace is required.

The refrigerant carrying tube is essentially flat, with its interior sectioned into a series of multiple, parallel flow microchannels that contain the refrigerant (Fig 2). In between the flat tube microchannels are fins that have been optimized to increase heat transfer. The flat tube microchannels are layered in parallel with the tubes connected between two refrigerant distribution manifolds. The coil is divided into two passes. One pass is used to de-superheat and condense the discharge gas. The second and final pass is used to finish condensing and provide liquid subcooling (Fig. 3).

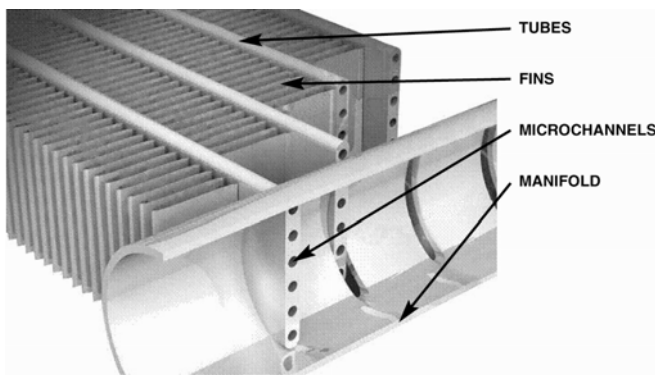


Fig. 2. Microchannel/Fin Center

The microchannel tubes in the heat exchanger have excellent heat transfer characteristics on the refrigerant side. On the air side, heat transfer is improved due to the enhanced surface area contact and the metallurgical bond between tube and fin. Fin design is optimized to enhance the fin heat transfer performance (Fig. 4). The fin-to-tube bond reduces thermal resistance between tube and fin, resulting in better heat conduction.

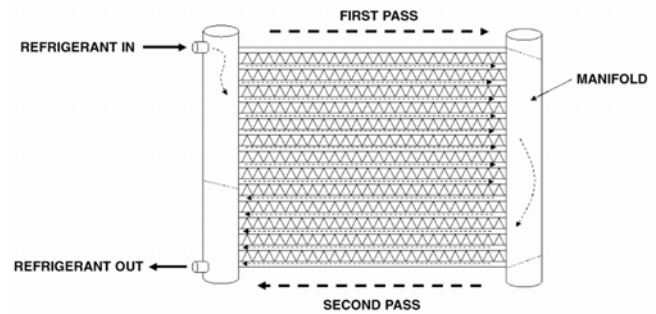


Fig. 3. Microchannel Coil Construction

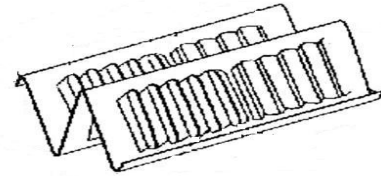


Fig. 4. Fin Layout

The MCHX coil construction provides for increased levels of structural rigidity. In addition to structural resilience, the physical properties associated with using an all aluminum construction compared to copper tubes provide a significant weight advantage. This advantage can translate into an overall equipment weight reduction that can significantly reduce installed cost if the equipment is installed on the roof of a building (e.g., chiller, rooftop, etc.).

The standard MCHX coil design uses a zinc enriched tube surface that performs in a manner similar to the zinc layer in galvanized steel. The tube is designed to undergo a gradual surface corrosion process that does not initially affect heat transfer performance. The zinc-enriched tube surface prevents corrosion pits from spreading deeply into the tube. The zinc layer will not be consumed during the effective service life of the MCHX coil when the coil is applied properly.

In corrosive environments, with an unprotected coil, rapid direct pitting attack of the tube and/or tube-to-manifold joint can occur and may lead to a catastrophic refrigerant leak and system failure. These conditions can be found in aggressive marine, industrial, urban, or highly alkaline environments. The latter condition can occur, for example, at new construction sites if the unprotected MCHX coil is exposed to excessive quantities of concrete dust and moisture.

It is therefore critical that the application environment is properly identified, and if needed, the appropriate corrosion protection is used.

CORROSION PROTECTION

The choices available for Carrier's commercial products offer protection for most common aggressive environments. The electrocoating (e-coating) process that Carrier employs is a proprietary process that assures the highest level of product quality.

Condenser Coils

MCHX Coil

In contrast to standard round tube/plate fin (RTPF) aluminum fin/copper tube condenser coils, MCHX coils are constructed utilizing all-aluminum alloys with brazed fin construction.

Microchannel heat exchangers generally provide higher thermal performance per unit volume compared to RTPF designs. Combined with other advantages such as lighter weight, lower refrigerant volume, greater structural rigidity and ease of cleaning, the MCHX coil is a logical replacement for the standard RTPF aluminum fin/copper tube condenser coil for many applications. As with RTPF coils, unprotected MCHX coils should never be applied in corrosive environments.

E-Coated Aluminum Fin/Aluminum Tube Coils

E-coated coils provide superior protection against many corrosive atmospheres with the exception of formic acid and nitric acid environments.

E-coated aluminum fin/aluminum tube coils have an extremely durable and flexible epoxy coating uniformly applied over all coil surfaces for complete isolation from the contaminated environment. A consistent coating is achieved through a precisely controlled electrocoating process that bonds a thin impermeable epoxy coating to the specially prepared coil surfaces.

Electrocoating is a multi-step process that ensures ultra clean coils are properly coated, cured, and protected from environmental attack (Fig. 5). This process includes complete immersion cleaning to remove contamination and ensure all surfaces are ultra clean. The water bath rinses residual dust and contamination away in preparation for the e-coating process. The fundamental principle of electrocoating is that the materials with opposite electrical charges attract each other. An electrocoating system applies a DC charge to the coil immersed in a bath of oppositely charged epoxy molecules. The molecules are drawn to the metal, forming an even, continuous film over the entire surface. At a certain point, the coating film insulates the metal, stopping the attraction, and preventing further coating deposition (self-limiting nature of the coating process).

The final rinse bath removes and recovers residual coating material to ensure a smooth coating and minimizes process waste. A precisely controlled oven bake cures the coating uniformly to ensure consistent adhesion on all coil surfaces. Finally, a UV protective topcoat is applied to shield the finish from ultraviolet degradation and to ensure coating durability and long life.

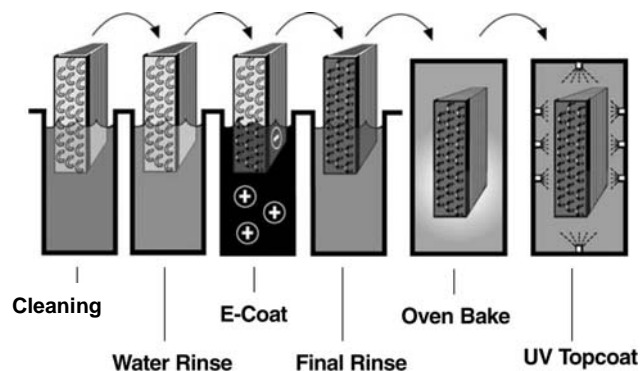


Fig. 5. E-Coat Process

This coating process creates a smooth, consistent, and flexible coating that penetrates deep into all coil cavities and covers the entire coil assembly including the fin edges. The process in conjunction with the coating material results in a less brittle, more resilient, and more durable coating without bridging between adjacent fins. E-coated coils provide superior protection in the most severe environments.

Field-Applied Coatings

Field-applied sprayed-on coatings will not provide sufficient protection in corrosive environments and should not be used on Novation® heat exchangers. The use of field-applied coatings on Novation heat exchangers may negatively affect the Carrier warranty. Possible reasons for inadequate protection include:

- Coil cleanliness is crucial for proper adhesion. Adequate field cleaning techniques are often overlooked.
- Field application cannot ensure continuous coating of coil surfaces on multiple row coils. It is difficult to ensure uniform coating quality throughout the depth of the fin pack.
- Interior coil surfaces remain untreated when sprayed-on from unit exterior (often spray applicators cannot reach deep into the coil assemblies, leaving inconsistent coating).

- Inconsistent coating thickness can minimize or negate coating protection. Recommended coating thickness cannot be ensured with field application on multiple row coils. Film thickness measurements are often overlooked.
- The coil must be void of corrosion prior to field application of the coating. Encapsulation of existing corrosion makes the coating ineffective by leading to continued deterioration and delamination.

E-Coated Material and Chemical Resistance

Chemical resistance of the e-coating material is described in the appendix, “E-Coating Chemical Resistance Guide.” Application of an e-coated coil should only be considered when the contaminant is listed in the Appendix guide. If the e-coating is NOT resistant to the contaminant listed or if the contaminant is not listed in the appendix, application in this environment is not recommended.

Some common industrial processes and their related contaminants that are resisted by the e-coated coils are shown in Table A.

Table A
Industrial Contaminants

Type of Industry/Application	Source of Contaminant	Contaminant
Pulp, Paper and Lumber Plants	Process Emissions	Nitrogen Oxides Sulfur Oxides
	Pulp Bleaching	Dichloromethane Chloroform Methyl Ethyl Ketone Carbon Disulphide Chlormethane Trichloroethane
	Sulphite Mill Operations	Sulfur Oxides
	Kraft Pulping and Recovery Processes	Volatile Organic Compounds
	Chip Digester and Liquid Evaporator	Terpenes Alcohols Phenols Methanol Acetone Methyl Ethyl Ketone
	Products of Combustion	Nitrogen Oxides Sulfur Oxides Carbon Monoxide Particulate Matter Fly Ash
Incineration Facilities Fuel Burning Power Generation Diesel/Gasoline Engine Operation	Products of Combustion	Sulfur Oxides Nitrogen Oxides Sulfur Trioxide Sulfuric Acid Ammonium Sulfate Ammonium Bisulfate Carbon Dioxide Sulphate Nitrate Hydrochloric Acid Hydrogen Fluoride Particulate Matter Ozone Volatile Organic Compounds
Cleaning Agent Processing	Process Emissions	Chlorine Chlorides
Water Treatment Facilities	Water Disinfection	Chlorine Ammonia Fluoride Chlorine Dioxide Hydrochloric Acid Bromine Chlorides

Table A
Industrial Contaminants (cont)

Type of Industry/Application	Source of Contaminant	Contaminant
Salt Mining/Processing Swimming Pool Agents	Process By-Products	Bromine Chlorine Sulfate Sodium Bisulfate Phosphate Chlorides
Chemical Industries	Process Emissions	Nitrogen Oxides Sulfur Oxides Methane Ammonia Volatile Organic Compounds Particulate Matter Chlorine Ammonia Ammonia Salts
Fertilizer Manufacturers	Process By-Products	Hydrogen Fluoride Sulfites Sulfuric Acid Hydrofluoric Acid Phosphoric Acid Fluorosilicic Acid Ammonia Ammonia Salts
Waste Water Treatment Facilities	Waste Digestion	Methane Sulfur Dioxide Nitrogen Oxides Volatile Organic Compounds Chlorine Chlorine Dioxide Ammonia Ammonia Salts
	Sludge Processing	Hydrogen Sulfide
Agriculture	Animal Waste and Fertilizers	Sulfur Nitrous Oxide Nitrogen Oxides Methane Hydrogen Sulfide Ammonia Ammonia Salts

SELECTION SUMMARY

Novation® Heat Exchanger Technology

Microchannel Coil (Aluminum Fin/Aluminum Tube)

The Carrier Electronic Catalog (E-Cat) can be used to determine whether or not corrosion protection is recommended for particular applications in coastal/marine environments. Following the input of the requested data, the E-Cat program output will advise the appropriate coil to be used. Other factors described previously in this book must also be considered to determine if corrosion protection is required.

JOB SITE COMMISSIONING AND PROPER EQUIPMENT STORAGE

An important factor that is often overlooked is the proper storage of HVAC/R equipment, including equipment with coated or uncoated coils, prior to start-up at new installations. It is not unusual for equipment to arrive on site several months prior to the actual installation and start-up, resulting in a potential for premature corrosion to occur if the equipment is not stored in a proper manner. Equipment should be stored so that it is not exposed to excessive construction debris and concrete dust, industrial contaminants, coastal contaminants, or high levels of humidity and moisture (i.e., do not store the equipment in shrink wrap as this can create a humidity chamber around the equipment unless the wrap is properly vented). If equipment is furnished with a weather-resistant coil cover, the cover should not be removed until the unit is ready for start-up.

Improper storage can lead to premature corrosion prior to start-up and can reduce the overall life of the equipment.

Extra care should be taken to ensure that equipment located on the ground level remains free from debris prior to start-up.

COIL MAINTENANCE AND CLEANING RECOMMENDATIONS

Routine cleaning of coil surfaces is essential to maintain proper operation of the unit. Elimination of contamination and removal of harmful residues will greatly increase the life of the coil, optimize equipment performance, and extend the life of the unit. Maintenance requirements and correct cleaning procedures for MCHX coils may be found in the Service instructions provided with each unit and should be followed carefully.

APPENDIX

E-Coating Chemical Resistance Guide

The coating material used for e-coat is resistant to fumes from the chemicals listed below. However, Carrier does not recommend direct coil immersion service for any of these chemicals. The chemical resistance guidelines were determined by a 24-hour spot test exposure of the chemical listed. Resistance was determined for these chemicals at the concentrations identified.

NOTE: All data, statements, and recommendations are based on research conducted by the e-coat manufacturer and are believed to be accurate. It is the responsibility of the user to evaluate the accuracy, completeness or usefulness of any content in this paper. Neither Carrier nor its affiliates make any representations or warranties regarding the content contained in this paper. Neither Carrier nor its affiliates will be liable to any user or anyone else for any inaccuracy, error or omission, regardless of cause, or for any damages resulting from any use, reliance or reference to the content in this paper.

E-coat is resistant to the following fumes:

Acetates (ALL)	Fluorosilicic Acid	Phenol 85%
Acetic Acid 99%	Formaldehyde 27%	Phosgene
Acetone	Fructose	Phosphate
Alcohols	Gasoline	Phosphoric Acid
Amines (ALL)	Glucose	Phenolphthalein
Amino Acids	Glycol	Phosphoric Acid
Ammonia	Glycol Lither	Potassium Chloride
Ammonia Salts	Hydrazine	Potassium Hydroxide
Ammonium Bisulfate	Hydrochloric Acid 37%	Propionic Acid
Ammonium Sulfate	Hydrofluoric Acid 30%	Propyl Alcohol
Ammonium Hydroxide	Hydrogen Fluoride	Propylene Glycol
Benzene	Hydrogen Peroxide 5%	Salicylic Acid
Borax	Hydrogen Sulfide	Salt Water
Boric Acid	Hydroxylamine	Sodium Bisulfate
Bromine	Iodine	Sodium Bisulfite
Butric Acid	Isobutyl Alcohol	Sodium Chloride
Butyl Alcohol	Isopropyl Alcohol	Sodium Hypochlorite 5%
Butyl Cellosolve	Kerosene	Sodium Hydroxide 10%
Calcium Chloride	Lactic Acid	Sodium Hydroxide 25%
Calcium Ilypochloric	Lactose	Sodium Sulfate
Carbon Dioxide	Lauryl Alcohol	Sorbitol
Carbon Disulphide	Magnesium Chloride	Stearic Acid
Carbon Monoxide	Magnesium Sulfate	Sucrose
Chlorides	Maleic Acid	Sulfates (ALL)
Chlorine	Menthanol	Sulfides (ALL)
Chlorine Dioxide	Menthol	Sulfites (ALL)
Chlorine Gas	Methane	Sulfur Dioxide
Chloroform	Methyl Ethyl Ketone	Sulfur Oxides
Chromic Acid 25%	Methyl Isobutyl Ketone	Sulfur Trioxide
Citric Acid	Methylene Chloride	Sulfuric Acid 25-85%
Cresol	Mustard Gas	Starch
Dichloromethane	Naphthol	Terpenes
Diesel Fuel	Nitrate	Toluene
Diethanolamine	Nitric Acid 25%	Trichloroethane
Ethyl Acetate	Nitrogen Oxides	Triethanolamine
Ethyl Alcohol	Nitrous Oxide	Urea
Ethyl Ether	Olale Acid	Vinegar
Fatty Acid	Oxalic Acid	Volatile Organic Compounds
Fluoride	Ozone	Xylene
Fluorine Gas	Perchloric Acid	

E-coat is NOT resistant to the following fumes:

Formic Acid
Nitric Acid



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