# USE MADISON'S COATINGS TO SOLVE CHEMICAL RESISTANCE PROBLEMS

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UPDATED MAY 2002

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## 1. INTRODUCTION

Protective coatings or linings are unique specialty products which represent the most commonly used method of corrosion control. They are used to give long term protection under a broad range of corrosive conditions, extending from atmospheric exposure to full immersion in strongly corrosive chemical solutions. There are various protective coatings/linings available in the market, and each of these coatings/linings has a characteristic combination of capabilities and limitations. A careful analysis of the problem, therefore, is required in order to choose the coating/lining which would be the most effective and economical.

Since 1973 Madison Chemical has developed a variety of high solids, high performance polyurethane coatings. Madison technology has been used to coat or line over 200,000 underground and aboveground steel tanks registered and installed in North America. Continual product and market development has also seen Madison technology used for applications involving oil & gas piping, water and wastewater tank internals and municipal piping. There have been ***zero failures*** associated with Madison's coatings on these applications. An educated customer, however, is always regarded as Madison's most important product. With this philosophy, I will try to explain why and how a Madison polyurethane coating can solve your chemical resistance problem.

## 2. THE FUNCTION OF A CHEMICAL RESISTANT COATING/LINING

Chemical resistance is the ability of a coating/lining to resist breakdown of a structure by action of chemicals to which it is exposed. The chemical resistant or protective coating/lining in itself provides little or no structural strength, yet it protects other materials so that the strength and integrity of the structure can be maintained. The function of the protective coating or lining is to separate two highly reactive materials; i.e., to prevent strongly corrosive industrial fumes, chemical liquid solutions, solids, or gases from contacting the reactive underlying substrate of the structure. The fact that coatings are usually a relatively thin film separating the two reactive materials indicates the vital importance of the coating. The concept is to attain a corrosion-free structure protected by the coating as a barrier.

In order to fulfill its function, according to this concept, a coating must be a completely continuous film. Any imperfection becomes a focal point for the attack of chemicals and the breakdown of the structure. Good adhesion to the substrate is also the key requirement for the chemical resistant coating/lining, particularly in long-term immersion service. It is thus expected that the chemical resistance of the coating/lining will basically depend on the following two factors:

*a*. the nature of the coating/lining;

*b*. the application of the coating/lining.

## 3. THE NATURE OF MADISON'S POLYURETHANE COATINGS

The nature of a coating/lining decides essentially how good the chemical resistance can be after the coating/lining has properly been applied over a structure. Organic coatings are complex mixtures of chemical substances that can be grouped into four broad categories: (1) *binders*, (2) *pigments*, (3) *volatile components* (VOCs), and (4) *additives*. The best chemical resistance of a coating can therefore be achieved by carefully formulating these selected substances.

*Binders* are the materials which form the continuous film that adheres to the "substrate" (the surface being coated), bind together the other substances in the coating to form a film, and present an adequately hard and protective surface. There are many coating binder resins available in the industry, such as epoxy, polyester, polyurethane, and so on. Madison produces superior coatings/linings and related products mainly based on polyurethane technology.

Polyurethanes are polymers that contain the urethane structure (NHCOO). Urethanes are usually formed by the reaction of an alcohol (i.e., a polyol which contains -OH hydroxyl group) with an isocyanate. By the proper selection of polyols and isocyanates with different hydroxyl and isocyanate values as well as different functionalities, polymerization by cross-linkage can be controlled. A highly cross-linked system generally results in good chemical and corrosion resistance. Compared to other organic binders, polyurethanes have the advantage that they meet the most stringent service conditions. Thus they can be made very hard or highly flexible. They have the best abrasion resistance among all organic coatings and are resistance to chemicals (including oils) and oxidation. Properly formulated, they show excellent adhesion to substrates, considerable gloss, and are serviceable over a temperature range from -50 to $130^0$C. Most Madison polyurethane coatings can achieve adhesion in excess of 2000 p.s.i. when applied to Near White Blasted steel without a primer. Among other properties of these coatings are instant setting and cold-curing ability.

*Pigments* have the primary purpose of providing color and opacity to the coating film,. However, they can also have important effects on application characteristics and on film properties including chemical resistance. A chemical resistant binder resin could be formulated with reactive pigments and thereby become much less chemical resistant. On the other hand, when formulated with highly inert pigments, a coating's chemical resistance can be improved. With the exception of zinc rich and aluminum rich primers, Madison uses only highly inert pigments in all our polyurethane coatings.

*Volatile components* are used to play a major role in the process of applying coatings - they are liquids that make the coating fluid enough for application. Although solvents do not remain in the coating, they can affect the coating in many different ways, i.e., by creating porosity, poor coating strength, and lack of adhesion. However, because of the great need to reduce VOC emissions, a major continuing drive in the coating industry is to reduce use of solvents. Most coatings made by Madison's leading edge technology are solvent-free and are 100% solids to meet your VOC requirements, while still providing good application properties.

*Additives* are materials that are included in small quantities to modify some property of the coating. Madison uses a variety of additives to help cross-link the polymerization reaction, improve adhesion, release entrapped air and make application easier. Directly or indirectly, all of those factors enhance the chemical resistance of the coatings.

## 4. THE CHEMICAL RESISTANCE OF MADISON'S POLYURETHANES COATINGS

There are a variety of methods and standards available for determining the chemical resistance of coatings. Because chemical resistance is the most important property of many coatings, one would think that the measurement of chemical/corrosion resistance would be a well developed science. Unfortunately, this is not the case. This is because that coatings, most of them being polymeric materials, interact with chemicals in very different ways. A common mechanism is absorption into the coating, which increases weight and volume (swelling). Another mechanism may be the leaching of a component in the coating. Seldom is a polymeric coating attacked only on its surface. Therefore, chemical testing of polymeric coatings has not been as codified as testing for metals, as the metals corrode primarily from their surfaces and their corrosion rates usually are fairly constant.

In evaluating chemical resistance, especially for immersion service, many coating manufacturers would apply a coating to one or both sides of the carbon steel panels, conduct immersion of one-half to two-thirds of the total panel surface area in specified chemicals, and then visually examine the appearance of the coating surfaces. Quite often, the chemical resistance data provided by your coating manufacturer does not contain the following information: how thick the tested coating is; how good the surface preparation is; what types of failures are included; and finally what criteria they used to determine "pass" or "failure". Thus, the words such as "excellent", "good", "fair", and "failure" have actually no meaning to you. One should therefore carefully identify and examine the test data from your coating's manufacturers'.

Madison uses a revised testing method of ASTM D543 (Standard Test Method for Resistance of Plastics to Chemical Regents) for evaluating the chemical resistance of all Madison polyurethane coatings. Instead of coated steel panels, "free films" of the coating are used by totally immersing the film in specified chemicals. The recommended coating thickness for each individual product is used as the actual testing thickness of these free films, which normally are within the range of 10 to 20 mils. These arrangements provide the most severe corrosive conditions to get fast and accurate indications of the coating's long term chemical resistance performance. After immersion of the chemical, the percentage increase or decrease in weight, length, width, and thickness is calculated. The criterion we use to determine a "pass" or "failure" is 3%. The general appearance of the specimen after immersion is also evaluated. The criteria for "pass" are: no blistering, no cracking, no significant color change, and no significant softening.

To conduct the modified ASTM D543 test, at least 3 coatings free films are weighed, size measured, and then immersed into a chemical solution for at least 7 days at ambient temperature. After the immersion time, they are dried and weighed again combined with evaluation of other properties (e.g. size change, general appearance, etc.). Coatings that have passed all the above mentioned criteria are *recommended* for continuous immersion at ambient temperature. Coatings that have passed the criteria for general appearance but have failed in the percentage of dimensional or weight change are *limited resistance* (they are not recommended for continuous immersion but are suitable for situations involving spillage, splashing, fumes and intermittent exposure at ambient temperature). Coatings that have failed one or more of the appearance criteria are *not recommended* for any service involving the chemicals.

We believe these self-imposed criteria are the toughest in the industry. Often a competitive product will seem to have good chemical resistance in a certain area but be unsuitable for any exposure other than casual contact. If the coating manufacturer neglects to provide exact details of the test methodology and the pass-fail criteria being used, insist that they do so.

Results of actual long-term chemical immersion tests have been very consistent with those obtained with the modified ASTM D543 method. For examples, Corrocote HydroThane/ Corropipe II WasteLiner and Corrocote II/Corropipe II Ultraliner have shown almost zero percent of weight and size changes after over 1 year continuous immersion in a saturated sodium hydroxide solution, with no effects on their general appearance. After immersion exposure for 1 year, they are also very resistant to 35% hydrochloric acid, 20% sulfuric acid, gasoline, and saturated sodium chloride.

# CHEMICAL RESISTANCE CHART

| Salt Solution | H/W/F | CC II | TX15 | CC+/F+ | CC-S | PW | CLD | UL | FLX | Common Epoxy* |
|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum sulfate (0-sat.) | R | R | R | R | R | R | R | R | R | NA |
| Calcium chloride (0-sat.) | R | R | R | R | R | R | R | R | R | NA |
| Ferrous chloride (0-sat.) | R | R | R | R | R | R | R | R | R | R |
| Potassium chloride (0-sat.) | R | R | R | R | R | R | R | R | R | NA |
| Sodium chloride (0-sat.) | R | R | R | R | R | R | R | R | R | R |
| Sodium glucoheptonate (0-sat.) | R | R | R | R | R | R | R | R | R | NA |
| Sodium Dichomate (10%) | | R | | | | | | R | R | |
| Sodium Sulphate (10%) | R | R | | R | | LR | | LR | R | |
| Sodium Sulphate (25%) | R | R | | R | | LR | | NR | R | |
| Ferrous Chloride (Eaglebrook pH<1) | R | | R | | | | | R | | |
| **Solvent Solution** | **H/W/F** | **CC II** | **TX15** | **CC+/F+** | **CC-S** | **PW** | **CLD** | **UL** | **FLX** | **Common Epoxy*** |
| Acetone | NR | NR | NR | NR | | NR | | NR | NR | |
| Benzene | R | R | R | R | R | R | R | R | R | NA |
| Benzyl Alcohol | NR | NR | NR | NR | | NR | | NR | NR | |
| Cyclosol 63 | R | LR | NR | LR | | R | | R | NR | |
| Chloroethane | NR | NR | NR | LR | LR | R | LR | LR | LR | LR |
| Chloroform | R | R | R | R | R | R | R | R | R | R |
| Ethanol | NR | NR | R | LR | LR | LR | LR | NR | LR | R |
| Ethyl Acetate | | | | | | NR | | NR | NR | |
| Ethyl ether | R | R | R | R | R | R | R | R | R | LR |
| Gasoline | R | R | R | R | R | R | R | R | LR | R |
| Heavy aromatic naphtha | LR | NR | NR | R | R | R | R | R | NR | NA |
| Isopropyl alcohol | NR | LR | LR | LR | LR | R | R | R | R | NA |
| Kerosene | R | R | R | R | R | R | R | R | R | NA |
| Methanol (0-20%) | R | LR | LR | R | R | LR | R | R | LR | NA |
| Methanol (100%) | NR | NR | NR | LR | LR | LR | R | NR | LR | NA |
| Methyl amyl ketone | LR | NR | NR | LR | LR | LR | LR | R | LR | LR |
| Methyl ethyl ketone | NR | NR | NR | LR | LR | NR | LR | NR | LR | LR |
| Methyl isobutyl ketone | R | NR | NR | LR | LR | LR | LR | R | R | LR |
| Methylene chloride | R | NR | NR | R | LR | LR | R | R | LR | LR |
| Naphtha | R | R | R | R | R | R | R | R | R | R |
| Phenol | | | NR | | | | | NR | NR | |
| Toluene | NR | NR | NR | LR | LR | LR | R | R | NR | NA |
| Triethyl Pentane | R | LR | | | | R | | R | R | |
| Triethylene Glycol | | | | R | | LR | | R | | |
| Varsol | R | R | R | R | R | R | R | R | LR | LR |
| **Acid Solution** | **H/W/F** | **CC II** | **TX15** | **CC+/F+** | **CC-S** | **PW** | **CLD** | **UL** | **FLX** | **Common Epoxy*** |
| Acetic acid (25%) | LR | LR | LR | R | LR | LR | R | R | NR | NR |
| Boric acid | R | R | R | R | R | R | R | R | LR | NA |
| Fatty acids | R | R | R | R | R | R | R | R | R | NR |
| Fluosiliic Acid | R | | R | R | | R | | R | LR | |
| Hydrochloric acid (10%) | R | LR | LR | R | LR | LR | R | R | R | R |
| Lactic acid (0-30%) | R | R | R | R | R | R | R | R | R | NA |
| Nitric acid (10%) | R | R | R | R | LR | R | R | R | LR | NR |
| Nitric acid (20%) | LR | NR | LR | R | NR | LR | R | R | NR | NR |

| Acid Solution (cntd) | H/W/F | CC II | TX15 | CC+/F+ | CC-S | PW | CLD | UL | FLX | Common Epoxy* |
|---|---|---|---|---|---|---|---|---|---|---|
| Oleic | R | R | R | R | R | R | R | R | R | NA |
| Oxalic | R | R | R | R | R | R | R | R | R | NA |
| Phosphoric (0-10%) | R | R | R | R | R | R | R | R | R | R |
| Phosphoric (25%) | LR | LR | LR | R | LR | LR | R | R | R | NA |
| Phosphoric acid (50%) | | | | | | | | R | | |
| Sulphuric acid (25%) | R | LR | R | R | R | R | R | R | R | NA |
| Sulphuric acid (50%) | LR | NR | LR | LR | LR | LR | LR | LR | NR | LR |
| **Alkalis Solution** | **H/W/F** | **CC II** | **TX15** | **CC+/F+** | **CC-S** | **PW** | **CLD** | **UL** | **FLX** | **Common Epoxy*** |
| Ammonium Hydroxide (30%) | R | R | | | | R | | LR | LR | |
| Calcium Hydroxide (10%) | R | R | | | | R | | | | |
| Calcium Hydroxide (25%) | R | R | | | | R | | | | |
| Chromium Trioxide (10%) | R | LR | | | | R | | R | NR | |
| Chromium Trioxide (25%) | LR | NR | | | | R | | R | NR | |
| Hydrogen Peroxide (3%) | R | R | R | | | | | LR | R | |
| Hydrogen Peroxide (30%) | NR | LR | NR | | | | | NR | LR | |
| Potassium hydroxide (0-sat.) | R | R | R | R | R | R | R | R | R | NA |
| Potassium acetate (0-50%) | R | R | R | R | R | R | R | R | R | NA |
| Sodium hydroxide (0-sat.) | R | R | R | R | R | R | R | R | R | R |
| Sodium hypochlorite (0-sat.) | R | R | R | R | R | R | R | R | R | NA |
| **Other Solutions** | **H/W/F** | **CC II** | **TX15** | **CC+/F+** | **CC-S** | **PW** | **CLD** | **UL** | **FLX** | **Common Epoxy*** |
| Anti-freeze | R | R | R | R | R | R | R | R | R | NA |
| Bentonite (50% water, 50% bentonite, 180F) | | | | | LR | NR | | NR | | |
| Brake Fluid | NR | NR | NR | NR | NR | LR | LR | LR | LR | NA |
| Corn Syrup | | | | R | | R | | R | | |
| Diesel Fuel | R | R | R | R | R | R | R | R | LR | NA |
| Distilled Water | R | R | NR | R | | R | | R | NR | |
| Furnace Oil | | R | R | R | | R | | R | R | |
| Molasses | | | | R | | R | | R | | |
| Sea/Tap water | R | R | R | R | R | R | R | R | R | R |
| Jet Fuel JP-8 | R | R | R | R | R | R | R | R | R | NA |

***Code:*** R=Recommended (<3%); NR = Not Recommended(>5%); LR = Limited Resistance(>3%,<5%); NA = Not Available; H/W/F = Corrocote Hydrothane/ Corropipe II WasteLiner/FibreThane; CC II = Corrocote II Classic; TX15 = Corropipe TX-15; CC+/F+ = Corrocote Plus/Corropipe Omni/ FibreThane Plus; CC-S = Corrocote/Corropipe S; PW = Corrocote/Corropipe PW; CLD = Corroclad 2000; UL = Corrocote/Corropipe UltraLiner; FLX = Flexcel II/Corropipe II High Abrasion* = Chemical resistance data for common epoxy amine cured coatings are taken from 1993 NACE Course 50: Protective Coatings and Linings

# 5. APPLYING MADISON’S POLYURETHANE COATINGS

Selecting a proper coating for your application is the first step toward solving your chemical resistance problem. In order to fulfill this function, one should obtain the following information: (1) type of service (continuous immersion or spillage, splashing, intermittent exposure); (2) concentration of each ingredient in the chemical solution for your application; (3) pH value; (4) long-term service temperature and intermittent exposure temperature; (5) type of substrate you want to coat; (5) your surface preparation ability (e.g., the ability to sand-blast); (6), the type of coating application methods you want to use (brush, airless spray or plural component spray); and (7) the type of handling characteristics you want (e.g., cold temperature cure, one coat capability etc.)

As indicated in the above chemical resistance table, many of Madison polyurethane coatings are recommended for continuous immersion service involving aggressive chemicals. Some are also suitable for splashing, spillage and incidental contact with extremely aggressive chemicals. For your particular application, at least one or two coatings may be suited. Examples are:

Corrocote “S” and Corropipe “S” are 72% solids coatings which can be applied by brush, roller or single component spray equipment. A trained applicator may be able to build 10 or more dry mils in a single coat. It is well suited for situations such as sewage treatment, oil water separators, and chemical plant maintenance.

Corrocote II PW and Corropipe II PW are NSF approved, two-component, instant setting, solvent free, 100% solids coatings. Not only are these two coatings very suitable for protecting potable water tanks/pipes from internal corrosion and abrasion, but also, offer excellent resistance to various chemicals.

Flexcel II coating is like a very tough layer of rubber fused to the surface of the structure. Flexcel II has remarkable impact and abrasion resistance (less than 5 mg loss per 1000 cycles, ASTM D-4060 Taber CS-17), and it also has a good resistance to certain strong chemicals and solvents compared to non-elastomeric coatings.

Corrocote II Ultraliner and Corropipe II Ultraliner are two-component rigid coatings, which have the best all-around chemical resistance among all of the Madison’s polyurethane coatings.

Corrocote HydroThane/Corropipe II WasteLiner are Madison’s economical two component coatings with good chemical and corrosion resistance, particularly in aqueous environments such as waste water service.

The proper application of polyurethane coatings play an important role in the chemical resistance of the system: Firstly, the structure to which the coating is to be applied must be designed in such a way that it can easily accept the coating and provide a proper base for it. There are many types of difficult-to-coat areas commonly involved in today’s construction and structures. Sharp edges, corners, crevices, rough welds, etc., are normally the problem areas which should be eliminated. Secondly, contaminated substrates should be avoided because they usually prevent the coating from developing its full properties of adhesion and resistance. Thirdly, application of coatings must be done in the best possible manner with excellent surface preparation. Sand or metallic grit blast is normally a necessity for the surface preparation of a steel substrate before applying a coating on it. Near White Blast (NACE, NO.2 blast or SSPC-SP10 blast) with a minimum 2.5 mils (63 microns) profile is normally required for submersion service. In some cases involving immersion in very aggressive chemicals, a minimum 3.0 mils (75 microns) profile is necessary.

Finally, coatings should be properly applied onto the substrate so that a continuous and uniform film can be achieved. Particular attention should be paid to all these difficult-to-coat areas to ensure that they are properly protected.

Each of these factors involves considerable knowledge and experience on the part of the applicator. Careful selection of the applicator is critical.

## 6. SUMMARY

For chemical and related processors, unique concerns require a broad range of multi-purpose coatings to handle a wide range of acids, alkalines, salts and solvents. Madison's leading edge on polyurethane technology offers a full line of high performance, corrosion resistance coatings to solve your chemical resistance problems.