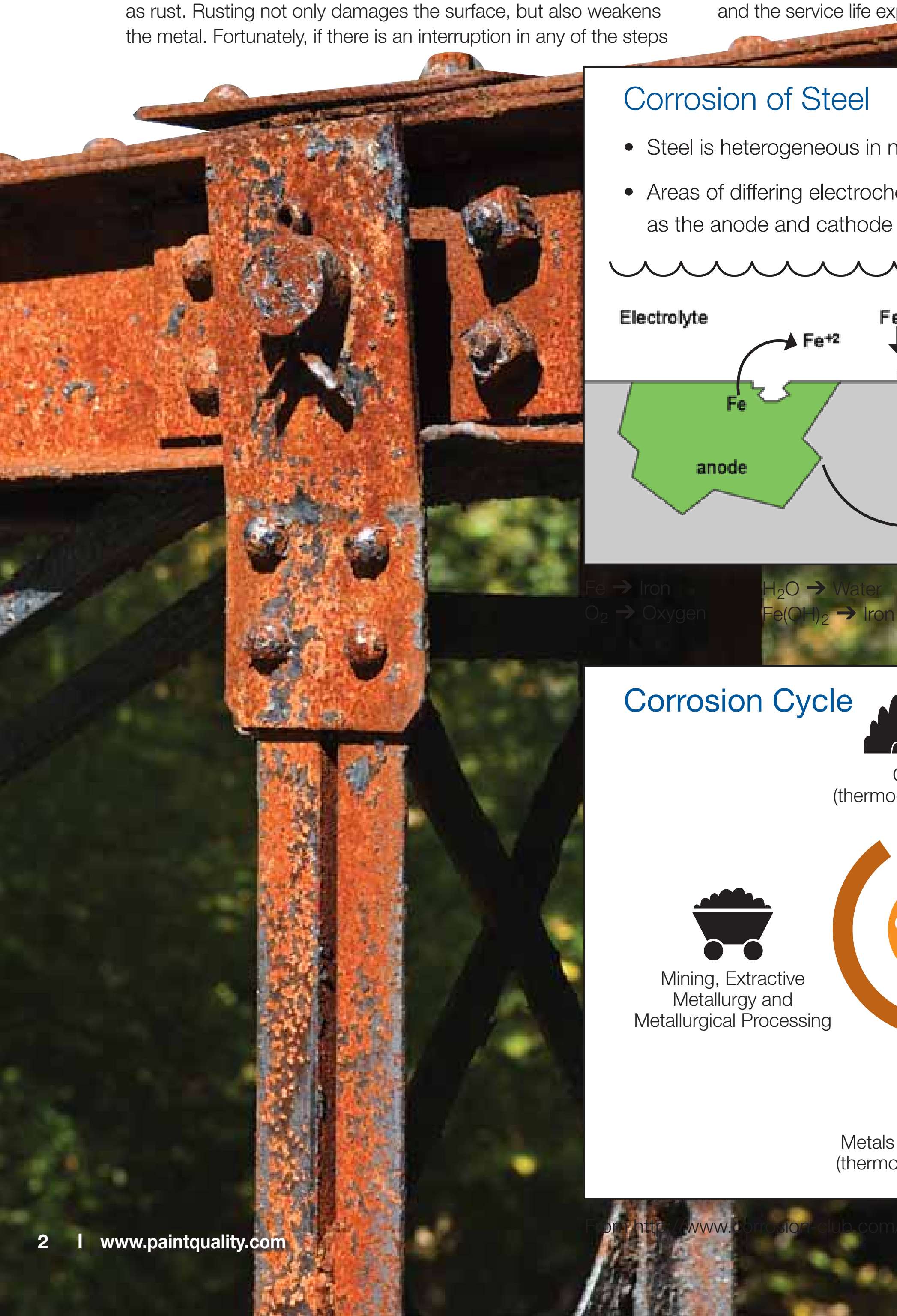
Considerations about PAINT For Metal Surfaces

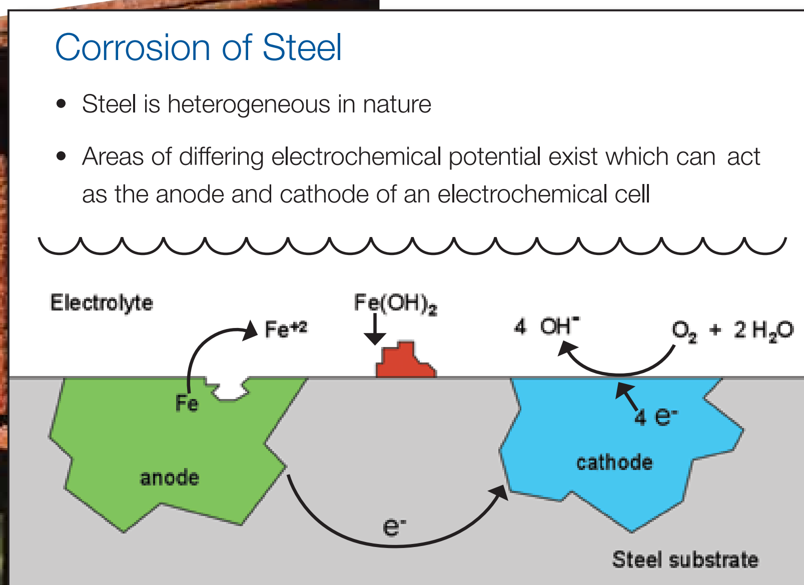
Due to the vulnerability of unprotected metal surfaces to the corrosive effects of moisture and the atmosphere, DIY'ers and architects must take different considerations into account when specifying paints for these substrates, compared to substrates such as wood and masonry. This module focuses on those considerations, ranging from the choice of primers and paints to the importance of the topcoat. We will focus here on two of the key technologies that span industrial maintenance applications from light to heavy duty environments — Epoxies and Acrylics.

Paint Quality Institute℠

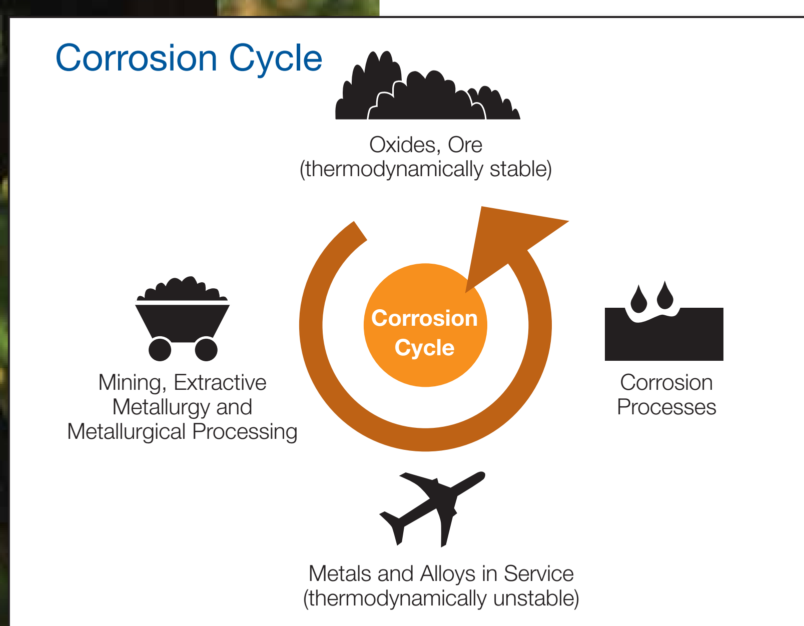
Oxidation: Enemy of Metal

Maintenance coatings are designed primarily to protect metal surfaces from corrosion. Corrosion of metal not only damages structures and can lead to safety concerns, it is also a very costly problem. It has been estimated by various studies that the annual cost of corrosion to our economy is a few percent of the total gross domestic product. Corrosion of a metal occurs when it undergoes oxidation, generally in the presence of water and oxygen, to form metal oxides. Oxidation refers to the loss of electrons by a substance during a chemical reaction that results in the formation of a new compound. The rusting of ferrous metals is a common example. In this electro-chemical process, iron is oxidized by loss of electrons to form ferrous ions ($Fe+^2$), which then combine with hydroxyl ions and water to form iron oxides, also commonly known as rust. Rusting not only damages the surface, but also weakens the metal. Fortunately, if there is an interruption in any of the steps of the electrochemical reaction, the entire process stops. A way to accomplish this is to cover the metal surface with a protective coating that will block moisture, oxygen and electrolytes (i.e., salts) from reaching the metal substrate. A number of different coating technologies can be used to attain this objective, including waterborne acrylic coatings, alkyds, epoxies, and polyurethanes. Another way to interrupt the electrochemical reaction is to have another metal in contact with the surface that is more prone to corrosion – this metal will sacrificially start to corrode instead of the substrate. An example of this is when a steel surface is galvanized with zinc, or when a zinc-rich coating is applied as a primer – the zinc corrodes and therefore protects the iron. We will focus on selecting the optimum coating system based on substrate type, environment and the service life expectation for metal surfaces.





Fe → Iron
O_2 → Oxygen
H_2O → Water
$Fe(OH)_2$ → Iron (II) Hydroxide



From http://www.corrosionclub.com/thermocycle.htm

Paint for Metal Surfaces

Whether you are painting a metal door, stairwell, incidental nail heads on a wall, or a storage tank or a bridge, special care must be given to the coating selection. Indeed, the condition of the metal substrate, the type of metal and the expected service life, are all critical factors that drive the selection of the coating system. The coating of metal surfaces in industrial and commercial facilities is commonly referred to as maintenance painting. Maintenance painting is usually divided into categories that describe the environment in which the metal structure exists – these range from light to heavy duty.

Industrial maintenance painting on the "heavy duty" side refers to structures that are in severe service environments. Metal structures such as storage tanks and bridges are coated to protect the surfaces from hostile atmospheres that can corrode the surface and degrade conventional architectural paints not designed specifically for this type of application. An example of a "heavy duty" application would be in a marine environment where the structure is exposed to saltwater spray, such as an offshore oil rig.

Light duty maintenance painting usually involves painting metal surfaces with corrosion-resistant coatings in milder environments. Architects are generally more involved with this type of application than they are with heavy duty industrial painting.

The main components of a maintenance coating are the same as those in a conventional architectural coating: namely, pigment, binder, liquid and additives. (See Module #1: "The Ingredients of Paint and Their Impact on Paint Properties," PQI Form # CM10N052.) However, their formulations differ because of differing objectives. Architectural coatings are formulated primarily with decorative purposes in mind, while maintenance coatings are formulated for functional purposes, including corrosion inhibition and adhesion to metal.

▶ Condition of Surface Prior to Painting

▶ Painting Environment

▶ Service Life

Know Your Application

Before specifying a coating for any metal surface, make a thorough assessment of the application. When selecting a coating for a project, three of the most important considerations are:

The Substrate	The Environment	Surface Preparation
• What is the surface that needs to be coated? • A wide variety of metals can be painted. Most common: - Ferrous metals - Galvanized metals - Aluminum • Make sure the coating you specify will inhibit corrosion and adhere to the substrate.	• Under what conditions will the coating have to be applied and perform? • Interior or exterior? • Aggressive environment (e.g., salt spray near coast) or non-aggressive? • It makes a difference when specifying coating, film thickness, surface preparation, etc.	• Proper surface preparation is vital to the success of any paint job. • It's especially important when specifying coatings for metal because of substrate vulnerability to corrosion and the likely presence of rust. • Guidelines on preparing metal for painting are available from organizations such as NACE and SSPC: The Society for Protective Coating.

Know Your Environment

In addition to substrate considerations, special care should be given to the environment in which the coating must perform. In addition to the generic descriptions of environment as heavy, medium or light duty, there have been attempts to better describe the possible environments where metal structures are found, such as the classifications given by ISO, captured in the table below:

ISO Corrosion Standards (from ISO 12944-2)

Corrosion Category		C1	C2	C3	C4	C5-I	C5-M
Atmospheric Classification		Very low	Low	Medium	High	Very High (industrial)	Very High (marine)
Typical Environments	**Interior**	Heated buildings with clean atmoshere, e.g offices, shops, schools, hotels	Unheated buildings where condensation may occur	Production rooms with high humidity and some air pollution, e.g. food processing plants, laundries, breweries, dairies	Chemical plants, swimming pools, coastal ship and boatyards	Buildings or areas with almost permanent condensation and with high pollution	Buildings or areas with almost permanent condensation and with high pollution
	Exterior	—	Atmosphere with low level of pollution. Mostly rural areas	Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity	Industrial areas and coastal areas with moderate alkalinity	Industrial areas with high humidity and aggressive atmosphere	Coastal and offshore areas with high salinity

Know Your Surface Preparation

The initial condition of the metal to be painted, and the method of preparing the surface are also extremely important considerations for any industrial painting job. A thorough assessment of the structure, including the existing protective coating system, needs to be made. This includes any failures such as cracking or peeling, the adhesion of the remaining coating, and any corrosion that may have occurred. Depending on the state of the existing paint system and the degree of damage to the substrate, a surface preparation will be specified. Surface prep could range from a simple power washing of the surface to remove dirt in the case of a fully intact existing coating, to complete removal of the original coating and corrosion products by abrasive blasting, and several intermediate possibilities. Specifications for the various methods and the degree of cleanliness that can be obtained are provided by organizations such as NACE and SSPC. Paint manufacturers will generally provide the minimum surface preparation that is needed for a particular paint to insure good adhesion and final performance. A table showing some of the common surface preparation methods are shown below:

Examples of Structural Steel Blasting Standards

Degree of Cleaning	SSPC	NACE
Solvent	SP-1	
Hand tool	SP-2	
Power tool	SP-3	
White metal blast	SP-5	No. 1
Near White blast	SP-10	No. 2
Commercial blast	SP-6	No. 3
Brush off	SP-7	No. 4

Corrosion-Inhibitive Metal Primers

Primers used in general-purpose maintenance finish systems for metal surfaces perform two vital functions: they provide the bond between the topcoat(s) and the underlying substrate, and they protect the metal from corrosion. The key to fulfilling these roles is a binder that both provides good adhesion and forms a tight continuous film, thereby preventing moisture, oxygen and electrolytes from reaching the substrate. For decades, the coatings industry relied almost entirely on solvent-borne resins to satisfy the binder needs of metal primers. Over the past 25 years, increasingly stringent volatile organic compound (VOC) regulations have diminished the use of low solids, solvent-based coatings of all chemistries. In response, paint chemists have now developed high solids resins such as 100% solids epoxies for use in solvent-less primers, as well as water-based resins based on epoxies and acrylics. Advanced water-based dispersions of epoxy resins and also hydrophobically modified acrylic binders make it possible for the formulation of high quality waterborne primers that can match or exceed solvent-borne primers in performance with considerably lower levels of volatile organic compounds (VOCs). In addition to these specially designed binders, water-based primers for use on metal contain a number of other ingredients intended specifically to inhibit corrosion. In harsh environments such as in chemical, paper, or water treatment plants and in coastal areas with high concentrations of airborne chloride ion, metals are particularly prone to attack and degradation. In these environments, a three-layer coating system is frequently used to maximize the time between maintenance painting. Each layer has a specific function and is optimized for that function. The primer is designed to adhere tightly to the metal. The mid-coat or tie coat is applied thickly and is designed to function as an impenetrable barrier to moisture and oxygen. The topcoat is designed to protect the underlying layers from UV light, marring, and scratching and where applicable to decorate the object or structure.

In heavy duty environments, the primer is often based on an epoxy resin that is crosslinked with a polyamide hardener to form a highly crosslinked barrier coating. In many cases, the primer will contain a high level of an electroactive metal (typically zinc) which serves to sacrificially protect the underlying metal – these primers are known as zinc-rich primers. In light and medium duty environments, the primer can be based on waterborne epoxy or acrylic resins. These primers can rely on the barrier properties of the coating to prevent water and electrolytes from reaching the metal surface, but are also formulated with inhibitive (or reactive) pigments which improve corrosion resistance by releasing ions that interact with and pacify the metal surface against corrosion (see inset).

Ingredients that Inhibit Corrosion

Reactive Pigments

- Usually in the form of borates, phosphates, molybdates or chromates
- Interrupt the oxidation process
- Do so by pacifying active metal surface or by acting as a sacrificial agent

Flash Rust Additive

- Flash rusting: problem that occurs on bare ferrous metal when water-based coating dries slowly
- This additive protects metal while water evaporates

Light Maintenance Topcoats

Primers and Topcoats Emphasize Different Attributes

While adhesion and corrosion protection are principal requirements for primers, features such as exterior durability, lack of dirt pickup, chemical resistance, and gloss carry a higher priority in topcoats.

As with water-based primers, the use of water-based acrylic topcoats on metal has also grown tremendously. Three of the main reasons are:

1. The compelling advantages of waterborne acrylic maintenance coatings from the standpoints of health, safety and protection of the environment. High quality water-based coatings have considerably lower levels of VOCs than solvent-based products. Plus, there is no need to deal with toxic and flammable solvents.
2. The ever-improving performance of water-based acrylic maintenance coatings. For example, high quality acrylic systems can last as much as two to four times longer than commonly used alkyd systems. Water-based maintenance coatings are also very stable. Unlike alkyds, latex coatings do not cross-link over time, which means they do not tend to yellow, crack or become brittle. Cracks in a metal coating are a nemesis, because they allow water to penetrate the film. This difference translates into longer repaint cycles and reduced maintenance costs.
3. The coating's favorable application characteristics, including quick drying time. Painters can often apply a second coat within hours after application of a first coat. In comparison, solvent systems commonly used for metal may require a full day's cure before another coat can be applied.

When it comes to application, maintenance paints should always be applied to metal surfaces in thick coats for optimum durability and corrosion resistance. That's because the thicker the coat, the less chance of moisture penetrating the paint through pinholes in the film. Similarly, two coats of a topcoat are generally recommended rather than a single coat for two reasons: increased overall thickness of the coating, and elimination of the possibility of pinholes extending through the coating. Brushes may be used for smaller applications, while rollers or airless sprayers are better for covering large areas.

Acrylics: Film Formation is A Key to Corrosion Resistance

Acrylics are thermoplastic latex resins which rely mainly on their barrier properties to provide corrosion resistance. Maximum protection against corrosion requires a uniform, highly continuous hydrophobic film. There must be no microscopic channels that allow access for moisture and oxygen to the metal substrate. One of the components necessary to produce such a film in a waterborne coating is an appropriate rheology modifier (RM) or thickening agent. Figures 1 and 2 compare the "non-associative" cellulosic type thickener to the "associative" urethane rheology modifiers. The former creates random domains and results in flocculated films. Urethane thickeners on the other hand, generate a uniform, highly continuous film that is far more resistant to the passage of moisture. A second approach to enhance film formation is to "control" the dispersion and spacing of the pigments. Coatings are engineered materials consisting primarily of pigment particles in a binder matrix. In most coatings, pigment particles are not homogeneously dispersed in the binder matrix leading to microscopic film defects such as clusters of pigment particles, voids, and cracks, which allow oxygen and moisture to penetrate the film, reach the metal surface and accelerate its oxidation. Avanse™ type acrylic resins specifically interact with pigment particles leading to the formation of much more uniformly dispersed pigment particles throughout the breadth and thickness of a paint film, which can be seen in the two micrographs below. These films having fewer film defects and greater homogeneity resulting in significantly improved corrosion resistance as demonstrated by films that were exposed to a salt spray for 35 days, shown below.


Figure 1

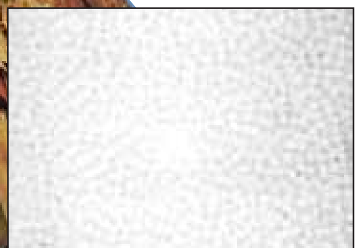
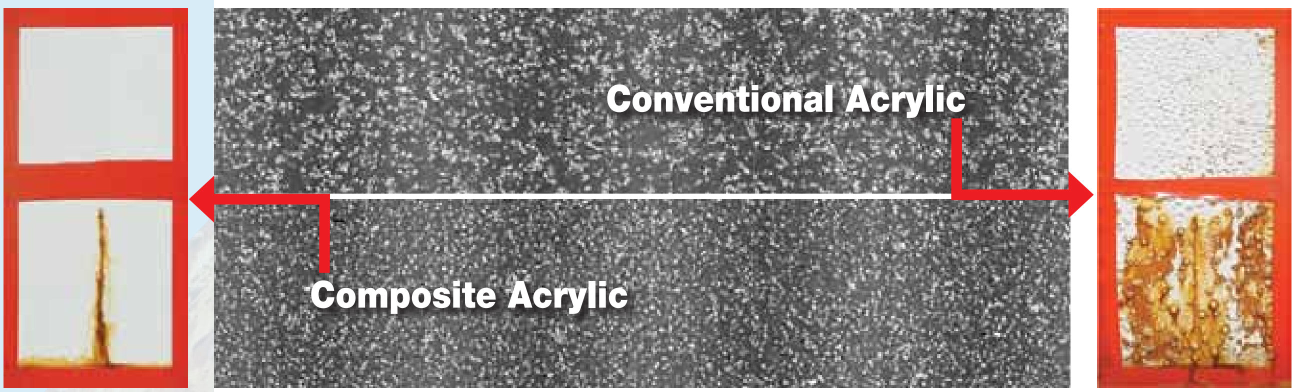


Figure 2



Epoxies on Metal

Epoxies are two-pack or two-component (Part A and Part B) systems which result in a highly cross-linked and very tough finish. It is this interconnected polymer network that gives epoxies properties necessary for applications in more corrosive environments. Because they form highly crosslinked networks, epoxies are a great choice for situations where the coating will come into contact with solvents and other chemicals. Their abrasion resistance also gives them the ability to be used in floor coatings, such as in a warehouse where the coating sees abrasion by foot and vehicle traffic. Epoxies are also known for their excellent adhesion to metal substrates, a main reason why they are often utilized as primers. Although they can be used in topcoats, due to their chemical structure most epoxies do not have tremendous durability to ultraviolet light, and so epoxy topcoats find more use in interior applications.

Product Selection Guide

Corrosion Category	C1	C2	C3	C4	C5-I	C5-M
Atmospheric Classification	Very low	Low	Medium	High	Very High (industrial)	Very High (marine)
Water based Acrylic						
Water based Epoxy						
Solvent based Epoxy						

Primer Considerations: Depending on the condition of the substrate and as we move to more corrosive environments a more robust sacrificial zinc rich primer is recommended.

Direct-to-Metal Water-based Coatings

Direct-To-Metal (DTM) coatings are all-purpose maintenance coatings that are designed for direct application to metals without the use of a primer. They function as both primer and topcoat in just one coating. Thus, DTMs have to provide good adhesion to the metal substrate, corrosion resistance, and aesthetic properties including gloss and durability (gloss and color retention). DTM coatings can be used for a variety of interior and exterior applications, are available in flat through gloss formulations, and are now offered in high performance waterborne acrylic latex and epoxy products. To insure proper protection of the substrate, two coats are usually recommended. When specifying a DTM coating, look for one that will perform in the intended service environment, typically a light to medium duty environment where a high-performing primer is not required. DTM acrylic coatings are VOC compliant and offer good flexibility and durable long-term protection. They also feature the same fast-drying properties as other waterborne coatings do. Wateborne epoxy DTMs are not as durable as acrylics towards ultraviolet light, and are best suited for interior uses. Compared to a primer-topcoat system, DTMs usually offer cost savings, both in terms of materials (only one coating needs to be purchased rather than two) and labor (only two coats need to be applied rather than three... one primer and two topcoat). In terms of performance, however, a primer-topcoat system generally provides a better appearance and better protection of the metal substrate than a DTM, especially in more aggressive environments. DTMs work well as a primer and as a topcoat, but not as well as an individual primer and topcoat. Thus, when choosing between a direct-to-metal coating and a primer-topcoat system, the decision often narrows down to one of cost savings versus performance.

Conclusion

System Considerations: Specifying paint for metal surfaces is not difficult as long as you know the substrate, the environment and the coating system. In the past, architects may have been reluctant to specify a latex system because they were not totally confident that a water-based coating could be applied to metal and provide good corrosion resistance. As a result of advancements in binders and rheology modifiers, that concern should no longer exist. Today's waterborne maintenance coatings for metal provide corrosion resistance comparable to, or better than, that imparted by solventborne coatings. In addition, they also provide all the benefits of conventional acrylic latex coatings, including durability, rapid drying, low toxicity and ease of handling and cleanup. Equally important, significant advancement has been realized on the waterbased epoxy side allowing for increase protection with a system that complies with more stringent VOC rules. We conclude with a representation of an optimum system based on environmental conditions – the combinations chosen are not meant to be exhaustive but illustrative of requirements for excellent performance.

Corrosion Category	C1	C2	C3	C4	C5-I	C5-M

C1:
Primer: Water-based
Midcoat: Water-based
Topcoat: Water-based

C3:
Primer: Epoxy Zinc Rich
Midcoat: Epoxy -Water-based
Topcoat: Acrylic -Water-based

C5-I:
Primer: Inorganic Zn Rich
Midcoat: Amine Epoxy
Topcoat: Amine Epoxy in Interior
Acrylic Epoxy in Exterior

Information provided by The Paint Quality Institute
www.paintquality.com

Form No. CM10N076