

## **CORROSION INHIBITORS FOR METAL SERVICE CENTERS**

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Metal Service Center personnel who are aware of what causes corrosion and how to prevent it can save money by extending the life of their metal products for days, weeks or even months. The key is the need to stay alert for the potential of corrosion forming on their metal inventory and processed bars, wire, rod, sheets, blanks and coils.

### **THE PROBLEM**

Although some inventory can have mill applied "slushing oil" for protection, prolonged storage and harsh environmental conditions of high humidity, salt laden air and/or acidic conditions from pickling operations can break down the mill oil films on exposed surfaces. Corrosion can occur on both incoming stock as well outgoing metal. When processing metal, a Service Center may inadvertently weaken the film due to exposure to metalworking coolants, film migration caused by metal movement, or exposed fresh metal. Some Service Centers clean the metal to remove oxide, scale, oil and other foreign material to give the metal a paintable surface. If the time of storage after cleaning is lengthy, a corrosion inhibitor is often a requirement.

Once started, corrosion can spread along metal surfaces or burrow into the metal creating pits. In some cases, corrosion can weaken the metal's strength by attacking grain boundaries and cause stress corrosion cracking. Removing corrosion can be time consuming and very expensive. Customer rejection, downgrading or scrapping metal due to corrosion can cut directly into a Center's bottom line and severely reduce profit margins.

Although much of the commentary in this paper focuses on steel and its relative ease of rusting, the principles can also apply to non-ferrous metals (i.e., aluminum, copper, zinc) because they all have potential to oxidize and/or stain. As long as steel remains a major product for construction and manufacturing, inhibitors will be required to prevent corrosion (rust, oxidation and staining) from occurring.

### **BACKGROUND**

#### **Current Practices**

Most Metal Service Centers maintain inventory and occasionally use temporary corrosion inhibitors. Others that clean metal may intentionally apply a coating to protect the metal. Some even apply a forming lubricant that serves to both protect and allow their customers to form the steel without applying a lubricant at the press.

The term "temporary" is normally understood to be any time period from days to years depending on the customer's needs and processing requirements. When needed, customers can easily remove corrosion inhibitors with solvents or alkaline washes. Some customers may not want the steel's film to interfere with welding or even direct finishing such as painting without cleaning. Thus, there are two fundamental requirements that can be at odds with each other:

- 1.) Proper corrosion inhibitor film properties to prevent rust during steel processing, storage and shipment conditions.

- 2.) A film that does not interfere with customer processes.

There are other considerations that Service Centers take into account, such as:

- a.) Ease of application
- b.) Environmental effects
- c.) Compatibility with equipment and substrates
- d.) Cost

Some Service Centers employ vapor corrosion inhibitors (VCI) that are impregnated into paper for wrapping bundles or coils of processed steel products. While often effective for uncoated metal, VCI atmospheres must be carefully controlled and contained.

### **The Underlying Chemical Cause of Corrosion**

Corrosion on steel is often called rust; on other metals it is called staining and/or oxidation. No matter how it is described, corrosion is the metal's return to its natural oxide state by compounding with oxygen. A corrosion reaction is essentially an electrochemical process consisting of a small electrical circuit in locations that can be a pinpoint in size or large areas of dissimilar metallic components such as: a surface defect, scratch, contaminant or even a crystallographic variation of the metal's atomic structure. Moisture typically acts as a catalyst to activate the circuit. The rate of corrosion can be accelerated by the presence of salts, acids and other water soluble compounds such as sulfate and chlorides. Other factors such as external electrolysis, human fingerprints, bacteria, water movement and weather conditions can influence corrosion rates.

The most typical condition that Steel Service Centers face in their rust prevention program is seasonal high humidity conditions. This can also include steel "sweating" that occurs when high humidity air comes into contact with cold steel, especially after the steel has cooled to below the atmosphere's dew point. Heavy, wind blown rain can get at steel products through open doorways, leaky roofs and loose tarps. Another frequent condition for rust formation can occur after use of a saw or cut off process when a water soluble coolant is used. Although most coolants are formulated to prevent rust, a coolant's residue may remain for long periods of time and allow nesting rust to form. Some Service Centers use non-water containing synthetic misting coolants to avoid such problems.

When metallurgists and chemists realized that electrolysis was the fundamental underlying reaction that caused corrosion, they were able to counteract the reaction process with chemical techniques that either prevent the circuit from forming or interrupt the electrical flow. For example, the addition of certain alloying metals into steel to create stainless achieves the goal of circuit interruption.

### **Film Types**

Corrosion inhibitor coatings are formulated with specialized chemical compounds to reduce or eliminate the metallic substrate's susceptibility to corrosive reactions. These compounds are delivered in a carrier and form circuit breaking films on the metallic substrate. There are three

basic film types that allow corrosion inhibition to effectively function. These are barrier films, passivating films, and polar compounds.

- 1.) **Barrier Films** such as petroleum hydrocarbon oil, wax, asphalt or grease prevent the air (oxygen and water vapor) from getting to the metal surface. These films have limited protective qualities because air can work its way into the steel surface by penetrating these simple barrier films. Barrier films primarily depend on the film's thickness, coverage and physical porosity and less on chemical compounds themselves. Some are difficult to remove.
- 2.) **Passivating or Boundary Films** are chemical compounds (usually delivered in an aqueous carrier) that weakly react with a steel surface to form compounds that resist any incursion from atmospheric factors by neutralizing corroding substances. These compounds vary considerably and are selective for certain types of corrosive atmospheres. They are relatively easy to remove.
- 3.) **Polar Compounds** are chemical molecules in which one part weakly binds itself to the steel surface to form a continuous layer. The other end is hydrophilic (water rejecting) but soluble in a matrix of oil or solvent that serves as a carrying agent. These chemical additives are also fairly easy to remove.

## THE SOLUTION

### Product Types

There are various basic types of corrosion inhibitors used in Metal Service Centers. These include:

- a. Solvent based
- b. Solvent/oil mixes
- c. Oil based
- d. Water extendable oils
- e. Water extendable synthetics (no oil)
- f. Dry solid films

Because each type offers advantages and disadvantages, Service Centers can select any type that meets its needs, application equipment, customer requirements and costs. Although desirable, one product often does not fulfill every customer's requirements.

The advantages and disadvantages are summarized in the following table.

<b>TYPE</b>	<b>ADVANTAGES</b>	<b>DISADVANTAGES</b>
SOLVENT	Dry imperceptible film, easy to apply, no mixing, typically weldable and easily cleaned	Flash point, VOCs, may have objectionable odor, containers should be properly stored and

	after solvent evaporates	sealed to prevent evaporation
SOLVENT/OIL	Slight film, offers compromise between oil and solvent characteristics depending on the solvent/oil ratio	Flash point, VOCs, may have objectionable odor, containers should be properly stored and sealed to prevent evaporation; slight oily film could interfere with welding and other processes
OIL	Higher flash point, reduced VOCs, may have self healing qualities; heavier film may offer lubrication qualities and abrasion resistance	Oily film, can be messy to apply and wasteful causing slippery conditions; more difficult to clean, may interfere with welding and other processes; may cause smoke and produce health hazards to workers
WATER EXTENDABLE OIL	Cost effective, very light oily film after drying, usually very easy to clean; no flash point after mixing	Requires mixing and drying; local water quality can be very important; may develop biological issues; oily residue may be an issue; poor wetting and inadequate coverage properties may cause problems
WATER EXTENDABLE SYNTHETIC	No flash point or VOCs, cost effective, very light film after drying, usually very easy to clean; weldable film	Requires mixing and drying; local water quality can be important; film may remain water soluble; film must be established before drying; very high concentrations may cause tacky residues
DRY FILM	Tight solid film; uniform film coverage; improved adhesion; low coating weights; superior lubrication compared to fluid films; reduced housekeeping issues at customers	Application methods may require special equipment; longer dry times; may require use of heat for application and/or drying

**VOC** = Volatile Organic Compound

Any Service Center customer who wishes to paint directly over a corrosion preventive film surface should carefully test the paint first for compatibility before using.

Besides corrosion inhibitor effectiveness and film type, other important issues for Metal Service Centers to consider are:

- 1.) Ease of application

- 2.) Safety in use
- 3.) Environmental aspects
- 4.) Water and coolant displacing characteristics
- 5.) Storage conditions and length of exposure to indoor, outdoor or protected environments
- 6.) Odor acceptability
- 7.) Residues that are not gummy, tacky or staining
- 8.) Ease of removal
- 9.) Cost effectiveness

Each product's formulation (carrier and additives) must be suitable for the environment that may be encountered by the metallic substrate. One product may not fit all Service Center conditions. In addition to corrosion inhibitors (i.e., polar additives, passivators) discussed earlier, carriers (solvents, oils or water), polymers, resins, surfactants, antioxidants, surfactants, wetting agents, film formers, pour point depressants and other chemicals may be formulated into corrosion preventives to increase film thickness or impart special performance qualities. For example, special additives may be needed to neutralize acid environments or incorporate lubrication for products used for forming called "pre-lubes."

### **Product Use Classifications**

Corrosion inhibitor products used in Metal Service Centers are often divided into the following classifications:

<b>CLASSIFICATION</b>	<b>DESCRIPTION</b>
Light Dry Films	Solvent based products that minimize film residues
Slushing Oils	Light viscosity oils also called mill oils
Reoils	Mill oils designed specifically for non-ferrous metals
Edge Sealers	Products applied over coil or sheet edges to protect edges that have been cut and are unprotected; also to prevent corrosive atmospheres from penetrating inside laps
Pre-Lubes	Lubricants meant to provide both corrosion protection and sufficient forming lubrication in presses; may be liquid, thixotropic or solid film in nature
Acid Resistant Coatings	Products specially designed to protect ferrous surfaces from acid fumes such as pickling baths
Outdoor Coatings	Products specially designed to protect metal from outdoor atmospheres including overseas shipments

## **Application**

Although the products can be applied in a variety of ways, the most common method used by Metal Service Centers is spray. Workers often use hand held sprayers and selectively apply the corrosion inhibitor product to exposed areas and those that need touch up. Some centers have spray or roller coating lines to provide complete coverage to coils, sheets or round shapes. Some process the steel by immersion methods in coating tanks. Whatever the system used, the objectives are to deliver the product to a relatively clean or compatible surface, achieve a continuous film with uniform coating weights, and if needed, allow the solvent or water carrier to dry. The film should withstand mild abrasion and surface rubbing during recoil or bundling. Coating weights can vary from 75-100 mg/ft<sup>2</sup> for slushing oils, 200-300 mg/ft<sup>2</sup> for prelubes and up to 500 mg/ft<sup>2</sup> for edge sealers. General light film corrosion inhibitors will have coating weights approximately 125-250 mg/ft<sup>2</sup> and provide a thin film that is usually less than 0.4 mils thick. Coating weights along with any excessive over application or waste are important in determining costs.

Another important application factor to keep in mind is timeliness. Allowing corrosion and rust to appear and damage metallic substrates may be tantamount to letting horses out of the barn door before closing. Or to use another cliché, an ounce of prevention is worth a pound of cure. Educating workers about corrosion and its prevention can be of great value to save a Service Center money.

## **Length of Protection**

The anticipated time of protection will depend on many factors:

- 1.) Accelerated test information from the supplier
- 2.) Each product's additive efficiency and film characteristics
- 3.) Field experience
- 4.) Humidity and temperature variations
- 5.) Metallurgical properties of the substrate
- 6.) Storage environment, time and transit conditions

Corrosion inhibitor manufacturers frequently use additive systems and quantities of additives that can perform with synergistic effects to be most cost effective. A manufacturer's claims about a product or its data must be carefully examined and if feasible, analyzed under controlled laboratory conditions to rate the relative effectiveness of any corrosion inhibitor product.

In-house Service Center testing is sometimes performed to allow mill personnel a hands-on experience of each product's application, characteristics and field results. However, laboratory standardized tests are a much better indicator of corrosion prevention results because of the exacting conditions and controlled observations often performed with detailed measurements.

## **Accelerated Laboratory Tests**

Standardized corrosion tests are specified by ASTM (American Society of Testing Materials) and NACE (National Association of Corrosion Engineers). Other test issuing organizations are DIN (Deutsches Institut für Normung), DOD (Department of Defense ref: MIL Specs), JIS (Japanese Standard Testing) and various manufacturers. For example, several steel and aluminum manufacturers have their own industry recognized tests and both domestic and foreign automotive, truck and off-road heavy equipment manufacturers have published their own test standards.

The most common tests normally applicable to Metal Service Centers are: humidity cabinet, stack stain and salt spray.

#### *Humidity Cabinet*

Typically performed under either ASTM D 1735 or D 1748 standards, coated standard metallic (ferrous and non-ferrous) panels are subjected to both elevated temperature (usually @ 50°C) and 100% relative humidity continuously circulated in a closed cabinet under misting or condensing conditions. Time and the amount of corrosion are recorded and a pass/fail rating given.

#### *Stack Stain*

Coated standard metallic panels are stacked on each other and subjected to a storage time of several days. The panels are then separated and observed for rust, stain and oxidation. This test is most frequently used for water extendable products. Stack stain tests are typically conducted at both ambient and elevated temperatures. Corrosion inhibitors can be tested under an as-received condition or diluted with water from the customer's facility.

#### *Salt Spray*

Coated metallic panels are subjected to a humidified salt atmosphere in a specially constructed cabinet. For example, ASTM B 117 calls for a 5% NaCl (sodium chloride salt) atmosphere @35°C. Time and the amount of corrosion are recorded and a pass/fail rating given. This is a very harsh test and normally not used unless the metal is subjected to salt laden air due to geographical storage and/or transit conditions.

Traditionally Metal Service Centers rely on humidity cabinet results. There are no exact time factors relating this test to actual storage and/or shipping times for steel products. There is a very general rule of thumb for cold rolled steel under indoor protected storage. For each day that a test panel passes (no corrosion), the anticipated time of protection is anywhere from 10 to 30 storage days under moderate temperature and humidity conditions (no salt or acid environment involved).

Corrosion inhibitor suppliers may use additional tests to evaluate their products compared to competitors. These tests include:

- 1.) Acid fume
- 2.) Wetting
- 3.) Sealing capability

- 4.) Water rejection
- 5.) Water displacement
- 6.) Cast iron chip test (CICT)
- 7.) Product storage stability
- 8.) Post processing compatibilities (cleaning, adhesive, welding, E-Coat, etc.)

A Metal Service Center customer may specify that a coating meet certain requirements. In that case, the Service Center would have to comply. If the customer has an approved list of products, it is important to determine if the inhibitor used by the Center must be an approved one or only certified to be equivalent in performance.

### **ENVIRONMENTAL ISSUES**

There are significant environmental issues with respect to the use of corrosion inhibitors. They include:

- a.) Presence of barium compounds
- b.) Volatile organic compounds (VOCs)
- c.) Waste treatment of carriers (ex. oil) and compounds

**Barium compounds** have been widely used in oil and solvent based corrosion preventives for many years. In general, they offer good corrosion protection and excellent water displacing characteristics. Many of these compounds work on a chemisorption method where one end of the molecule attaches itself to the steel and the other has water rejection characteristics. Because barium is an objectionable heavy metal in some waste treatment processes and discharge limits are severely monitored, it may be restricted in certain locations and by specific customers.

**VOCs** are generally petroleum distillates or solvents which are often used as carriers for corrosion preventives and cleaning agents. Many industrial locations require manufacturing firms to report their estimated VOC quantities emitted into the atmosphere. Usually the quantities used by Metal Service Centers are fairly low. However, all firms should be aware of their local emission regulations and restrictions. Also products that emit VOCs must be handled with care to avoid worker exposure and fire or flash point dangers. Ideally, organic solvent products should have flash points above 140°F to minimize these concerns. Solvents whose flash point is greater than 160°F begin to exhibit much slower evaporation rates and resemble oil. While there is no exact acceptance of where solvent and oil begin to be completely distinguishable, most solvent/oil blends that have a flash point above 200°F are considered to leave an oily film.

Petroleum oils and other corrosion inhibitor compounds entering the waste stream or water system can be both a pollution problem and an expensive disposal problem. Besides leakage, corrosion preventives that are oil based tend to be over used and flow down outside surfaces of steel coils and bundles creating housekeeping and safety problems. Oil soaked floors and walkways can be continual slippery hazards. Oil usage can also lead to the creation of mists released into the atmosphere and create the need for monitoring and expensive collection

equipment. When reviewing use costs for oil based corrosion inhibitors, metal processors often overlook cleaner and disposal costs.

### **COSTS**

The costs of using corrosion inhibitors must be considered based on the following factors:

- 1.) Coverage per thousand square feet
- 2.) Customer acceptance achieved with a minimal number of products
- 3.) Difficulty or ease of application
- 4.) Estimated waste or disposal issues (including containers)
- 5.) Necessity to avoid rejects or scrap
- 6.) New equipment costs amortized over a period of time
- 7.) Price per gallon delivered (including any container costs)
- 8.) Inhibitors that are diluted with water require in use calculations and mixing costs

Corrosion inhibitors that are required to displace water should have good water separation characteristics so that recirculation systems with reservoirs which contain the corrosion inhibitor will allow a complete water separation process to occur. This collection and reuse of the corrosion inhibitor will help keep costs down. Estimated coverage quantities can be provided by suppliers and corrosion inhibitor manufacturers. Usually these figures are based on ideal conditions. Actual storage conditions may dictate the use of specific minimum coating weights.

### **CONCLUSION**

There is always a potential corrosion problem in Metal Service Centers. Each Service Center needs to be aware and knowledgeable of how corrosion can occur and the means to prevent it. While many corrosion inhibitor choices are available, customer requirements, application means and environmental issues are critical in making the best selection to save metal from being rejected, downgraded or scrapped. Finally, there are always costs to consider including application and time.

When it comes to corrosion inhibitor cost, the rules to remember are: (1) select a reputable supplier with experience, proven performance and ISO registration; and (2) never choose a corrosion inhibitor based strictly on price. Only a quality and knowledgeable supplier can help Metal Service Centers achieve high productivity results for their metal products, customers and the bottom line.