

Metal Corrosion Preventives:

KEY CONCEPTS

- Metal corrosion preventives perform the important function of protecting metal parts by forming a protective layer on the surface of the component.
- Selection of the correct metal corrosion preventive is a complex process based on application, the needs of the end-user and subsequent processing steps.
- Future trends influencing the use of metal corrosion preventives are the increased use of non-ferrous metals, environmental issues, worldwide regulations and the reduced storage time for metal parts inventory.

Protect Metal and Specific Applications

Government regulations make it more important than ever to understand how these vitally important additives are selected and evaluated.

MANUFACTURING OF COMPLEX MACHINERY INCLUDING AIRCRAFT, AUTOMOBILES AND OTHER DURABLE GOODS SUCH AS WASHING MACHINES requires a series of process steps. As metals undergo steps that include forming and removal operations, they are vulnerable to corrosion in part because these operations can expose bare metal to moisture and oxygen.

Corrosion can be problematic in hindering manufacturing and significantly impacts the global economy. Between 1999 and 2001, CC Technologies conducted research in an agreement with the Federal Highway Administration. The study mentioned that corrosion problems cost the U.S. economy approximately \$279 billion per year, which represents 3.2% of the gross domestic product.¹

While corrosion problems are mostly associated with ferrous alloys, they also can be detected in such non-ferrous alloys as aluminum, brass, copper, magnesium and zinc. In fact, interactions between dissimilar metals can lead to galvanic corrosion.

A class of metalworking fluids formulated to deal with corrosion problems is known as metal corrosion preventives. This article provides an update on the types of corrosion preventives currently available, how they should be selected and evaluated for a specific application, what types are available for low-volatile organic carbon (VOC) applications and future trends.

To provide this information, TLT interviewed key industry experts involved in the development of additives for use in metal preventives and who formulate metal preventives.

The individuals contacted were:

1. E. Jon Schnellbacher, Additives International
2. Rick Butler, Chemtool, Inc.
3. Dr. Paul Bonner, Croda, Inc.
4. Dr. Mike Duncan, Daubert Chemical Co., Inc.
5. Bill Kingston, King Industries, Inc.
6. Ben Faber, The Lubrizol Corp.
7. Dr. Britt Minch, The Lubrizol Corp.
8. Dr. Heike Herrmann, Rhein Chemie Rheinau GmbH
9. Mike Pearce, W.S. Dodge Oil Co., Inc.

KEY FUNCTIONS

STLE-member Dr. Mike Duncan, vice president of technology for Daubert Chemical Co., Inc., in Chicago, says, “NACE International defines a corrosion inhibitor as a chemical substance or a combination of substances that, when present in the environment, prevents or reduces corrosion. The consequences of corrosion can vary and range from severe (weakening of the structure on a vehicle or a bridge) to cosmetic (deterioration of the appearance of a fender on an automobile).”

Duncan indicates that the primary function of a metal corrosion preven-

tive is to decrease the corrosion rate of a metal component by forming a protective film layer on the surface of the component. He says, “This protective film layer prevents the corrosive substance (chlorides, sulfates, nitrates, moisture, oxygen, hydrogen sulfide, etc.) from reaching and reacting with the surface of the component. Secondary functions of the corrosion preventive are usually dependent upon the specific application, use of the corrosion preventive and whether the corrosion preventive remains as a fluid in use or is applied, dried, cured or cooled for use as a temporary film or permanent coating.”

STLE-member Bill Kingston, technical marketing manager for rust preventives for King Industries, Inc., in Norwalk, Conn., thinks that corrosion preventives act by interfering with one or more parts of the electrochemical corrosion process. He says, “The common types of temporary corrosion preventives typically work by excluding electrolytes from the metal surface.”

Dr. Paul Bonner, lubricant applications team leader for Croda, Inc., in Sanity, UK, considers corrosion to be a problem where metal parts are being processed. He says, “In the worst case, corrosion can be thought of as nature stealing back the metal through gradual erosion, such as converting iron turnings into flakes of rust. Here the corro-

sion preventive is like a security guard that is designed to protect the metal part.”

To provide a better understanding of the function of a corrosion preventive, the nature of the electrochemical process must be discussed. Bonner says, “Corrosion is an electrochemical process with oxidation of the metal and reduction of water and oxygen. Figure 1 shows the movement of electrons and ions in the case of galvanic corrosion where there is a potential difference between the two dissimilar metals.”

Corrosion preventives function by forming a physical protective barrier on a cleaned piece of metal according to Bonner. He adds, “Corrosion preventives form a barrier that is absolutely effective by excluding the oxygen required for initiation and propagation of the electrochemical process.”

STLE-member Ben Faber, metalworking product manager for The Lubrizol Corp., in Wickliffe, Ohio, states that corrosion preventives are used mainly in a temporary manner for a finite period of time. He says, “A corrosion preventive is intended to be a temporary coating that can protect during the shipment and storage of parts, and can be easily removed if parts need further processing. Depending on how the corrosion preventive is formulated, it can provide months to years of corrosion protection.”

Faber highlights the importance of the corrosion preventive in the entire manufacturing process for a specific metal part. He says, “The corrosion preventive can also act as a pre-lube for light forming or machining processes and also play an important role in displacing any water or residual coolant on a metal part that could cause staining. This water displacement feature means that parts can be coated more quickly and with no washing steps, which improves the efficiency of the entire process.”

CORROSION PREVENTIVE TYPES

STLE-member E. Jon Schnellbacher, technical director for Additives International in Flint, Mich., places corro-

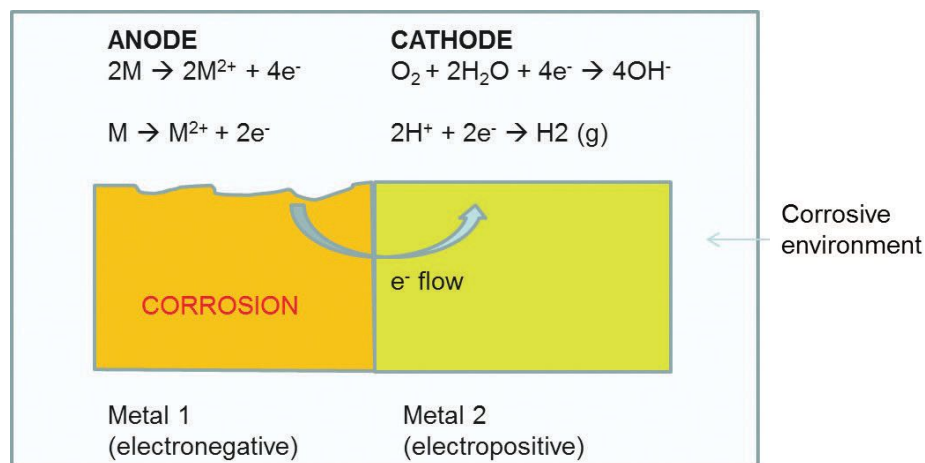


Figure 1 | The movement of electrons and ions between two dissimilar metals in a process known as galvanic corrosion is shown. (Figure courtesy of Croda Corp.)



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sion preventives into the following four primary categories: barriers, insulators, reactants and non-catalytic products. Some of these additives fit into more than one category. He says, “Barrier corrosion preventives protect the metal with a coating that forms a barrier to protect the metal from oxidation and corrosion. Typically the corrosion preventives—which have less attraction and thinner films—provide short-term protection (in-process corrosion preventives) while the thicker films and cured coatings provide longer-term protection (i.e., paints).”

Schnellbacher continues, “Insulating corrosion preventives provide protection by reducing the flow of electrons. This reduced electron flow slows the corrosion or oxidation process. Glass and plastic coatings are typical insulators. The reactant-type corrosion preventives react with oxidizers, moisture and oxygen in the environment. Once they are reacted, they are not free to cause corrosion. Reactants like amines are particularly effective in vapor-phase protection.”

Another type of reactant also acts as an insulating and barrier corrosion preventive. Schnellbacher explains, “By a process called indemnification, the corrosion preventive acts sacrificially by corroding the lower electronegative material, which enables the more important metal substrate to be protected. The oxidized sacrificial material then provides an insulating barrier to keep out moisture and oxygen.”

Non-catalytic materials slow corrosion by binding or using up one of the reactants so they are not available to corrode. “Typically you need metal, moisture, oxygen and heat to drive a reaction,” Schnellbacher notes. “If one of those is reduced or removed, the rate of reaction also slows.”

Dr. Heike Herrmann, manager application technology for Lubricant Additive Business of Rhein Chemie Rheinau GmbH in Mannheim, Germany, discusses the components used in preparing corrosion preventives. She says, “Corrosion preventives are based on different base fluids (e.g., mineral

oils, synthetic base oils, solvents or water). Usually these high-performance products contain combinations of functional additives, so called additive packages. Besides common corrosion protection additives, other components used include film-forming agents, demulsifiers or emulsifiers and solubilizers. In general, these packages are adapted to the base fluid used. Therefore, it is common that if a specific anti-corrosion additive package designed for oils shows good performance in oils, then the package is typically worse in solvents, while the opposite is true if the package is designed to work with solvents.”

Herrmann also discusses the advantages and disadvantages of using each base fluid. She says, “Oils lead to a thicker film and often increased corrosion protection. A disadvantage includes a sticky surface leading to greater difficulty in removal. Solvent systems lead to thin films due to lower viscosity and enhanced evaporation of volatile components. Benefits are a touch-dry and non-sticky surface. Negative effects for solvents are usually a high VOC and a very thin film,

which may have insufficient protection properties. Water-based systems exhibit low VOC but are generally poorer corrosion preventives than oil or solvent-based fluids.”

Faber further discusses the types of additives used in corrosion preventives. He says, “Most of the corrosion preventives used today utilize a mixture of oxidized waxes and petroleum sulfonates dissolved in an oil or in a hydrocarbon solvent. The advantage to this chemistry is that it is the traditional fluid used in production, and these types of fluids fit seamlessly within the manufacturing processes used today. They also have historically verified performance, and everyone in the supply chain is familiar with how to handle these films.”

For water-based products, the same chemistry (waxes and sulfonates) is used with surfactants that can emulsify these additives in water. Faber says, “As the water evaporates, the emulsion breaks and the additives form a film, much like they do in a solvent-based fluid. Some formulators also utilize volatile surfactants, so the final film will be more resistant to humidity during storage.”

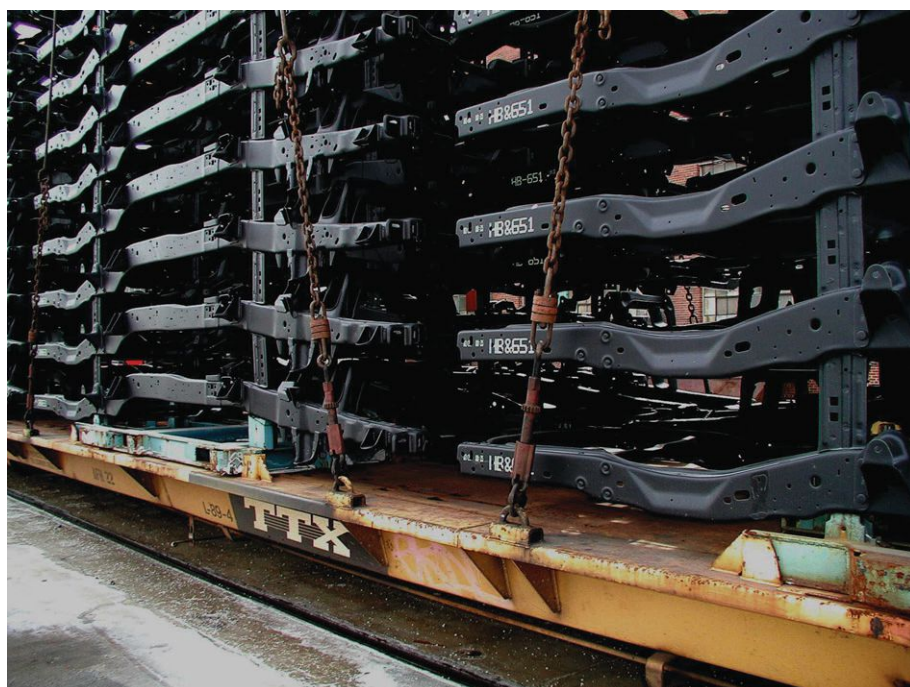


Figure 2 | One of the functions of corrosion preventives is to protect metal parts as they are shipped from one facility to another. (Figure courtesy of Daubert Chemical Co., Inc.)

A new type of corrosion preventive under development as a replacement for wax-based films is polymer films, according to Faber. He says, “The key advantages to polymer films are that they can be more durable and allow for easy handling of parts. These products also can be prepared to better handle outdoor conditions and can be more resistant to UV light. Polymer films are vastly different from historical corrosion preventives, though, because they do not displace water like an oil-based corrosion preventive, and polymer films generally require a cleaner metal surface prior to application. Polymer films also require thicker dry films and in most cases must be applied at a minimum of 50 microns, while thin-film corrosion preventives can be as thin as two microns, and heavy-duty petroleum products are still effective at less than 50 microns. Overall, any switch to new chemistries will require education and process changes by end-users to account for the inherent differences.”

According to Kingston, water-based corrosion preventives fall into three types. He says, “Within the water-based category are synthetic fluids (clear solutions), semisynthetic (typically emulsions with very small particle size giving a clear appearance) and emulsions. While providing favorable low-VOC properties, water-based corrosion preventives also reduce the danger of fire. Performance differs depending upon the finished fluid type with clear solution-type formulations somewhat limited to short-term indoor storage since they must rely only on direct chemical corrosion inhibition. Emulsion types can greatly increase performance because barrier-type ingredients such as oils and waxes can be used.”

Kingston points out that extended drying time required before packaging and handling compared with most non-water solvents is the biggest obstacle to wider use of water as a carrier.

Duncan factors in removal as an important way to classify corrosion preventives. He says, “An end-user needs to look at the part being protected and whether the barrier film is to remain



Figure 3 | Specific requirements for corrosion preventives are required with some end-use or factory-filled fluids. (Figure courtesy of Daubert Chemical Co., Inc.)

on the part or be removed before putting the part into service (see Figure 2 on page 38). Film types to consider are vanishing or non-discernible, oily, thixotropic, waxy, resinous, hard or soft and permeable or non-permeable. Some specific requirements that may be needed are lubricity, acid neutralizing, compatibility with end-use or factory-fill fluids (see Figure 3), adhesives and sealants, plastics, gaskets and hoses, metal removal fluids and cleaners.”

A summary of Duncan’s insights on the advantages and disadvantages of each type of corrosion preventive is shown in Table 1 on page 40. Included are the approximate operating time frames for each type.

Two other types reviewed by Duncan are vapor-phase corrosion preventives and pre-lubes. He says, “Vapor-phase corrosion preventives are used in short-term storage of empty fuel tanks, engines, transmissions, gear and hydraulic pumps. They are easy to apply, produce self-healing films, and are compatible with the fuel or lubricant used in the system and can be multi-metal compatible. Disadvantages include long and expensive qualifica-

tion test protocols, may contain solvents that can evaporate out of open containers or systems, may have a low flash point and a high VOC and may contain high levels of volatile hydrocarbons, short-chain carboxylic acids and amines that can present health, safety and environmental issues and oil misting.”

SELECTION OF A CORROSION PREVENTIVE

Faber recommends that selecting a corrosion preventive involves determining the metal that needs to be protected, how the film should be applied and the type of film applied.

“Most corrosion preventives are developed and tested with steel in mind,” he says, “so when using a metal other than steel, it is important to check whether the fluid is compatible with the metal. This concern also comes up with coated steels such as galvanized or phosphate steels. Application of the corrosion preventive is typically done through dipping metal parts into a dip tank or spraying. For dip-tank application, the end-user needs to consider the effects of evaporation when using

Table 1 | Advantages and disadvantages for each type of corrosion preventive are shown. (Table courtesy of Daubert Chemical Co., Inc.)

Corrosion preventive	Operating time frame	Advantages	Disadvantages
100% solids wax-based	> 48 months	<ul style="list-style-type: none"> • Zero VOC • Stable and long shelf life • Thick films • Produces dried coatings quickly • Self-healing films 	<ul style="list-style-type: none"> • Must be kept hot when applying • Dip applied only • High capital expense in application equipment
Mineral oil-based	< 24 months	<ul style="list-style-type: none"> • Zero or low VOC • Very stable and long shelf life • Easily diluted with additional mineral oil • Can be sprayed, dipped or painted • Thick films • Provide dried coatings quickly without heating • Easily removed by wiping • Self-healing films 	<ul style="list-style-type: none"> • Does not form hard coating unless formulated with reactive polymers • Oil misting may be a health and safety issue if applied by spray
Solvent-based	< 48 months	<ul style="list-style-type: none"> • Very water resistant • Stable if kept in closed containers • Easily diluted with additional solvent • Can be sprayed, dipped or painted • Very thick films • Provides dried coatings quickly without heating • Easily removed with solvent 	<ul style="list-style-type: none"> • Contains solvent that can evaporate out of the material • Low flash point • High VOC • May contain high levels of volatile hydrocarbons that present health, safety and environmental issues • Oil misting may also be a problem • May be difficult to remove if reactive polymers are used
Water emulsified long-term	< 24 months	<ul style="list-style-type: none"> • Provide a thicker permanent barrier film • Leaves a thin hard transparent film after curing • Remains fluid before application • Possible to formulate low-VOC coatings 	<ul style="list-style-type: none"> • More difficult to formulate • Polymer additives used may have short shelf lives • May be very difficult to remove • Heat may be needed to force the water to evaporate • Susceptible to microbial attack • Vulnerable to hard water • May contain volatile amines and coalescing agents, which can present health, safety and environmental issues • Oil misting may also be a problem
Water emulsified short-term	< 12 months	<ul style="list-style-type: none"> • Contain significant water • Provides a thicker barrier film • Leaves a thin oily transparent film • Remains fluid before application • Dried coating ranges from easily removed to difficult to remove with warm water • Can formulate low-VOC coatings 	<ul style="list-style-type: none"> • More difficult to formulate • Requires water to evaporate, which may require heating • Polymer additives used may have short shelf lives • May be very difficult to remove • Susceptible to microbial attack • Vulnerable to hard water • May contain volatile amines, which can present health, safety and environmental issues • Oil misting may also be a problem
Water soluble short-term	< 3 months	<ul style="list-style-type: none"> • Contain significant water • Relatively simple to formulate • Remains fluid before application • Leaves a very thin, dry transparent film • Easily removed • Can formulate with low-VOC coatings 	<ul style="list-style-type: none"> • Minimal barrier film • Susceptible to microbial attack • Requires water to evaporate, which may require heating • Vulnerable to hard water • May contain volatile amines, which can present health, safety and environmental issues

solvent- or water-based corrosion preventives. If the product is applied by spraying, it may be necessary to adjust the viscosity to optimize the spray pattern and limit overspray and run-off.”

Once applied, Faber expressed concern that most corrosion preventive

films are delicate and can be damaged if handled. He says, “Oil-based films tend to be forgiving with handling, but for many applications an oil-soaked package is not acceptable. For other applications, oil can provide useful lubrication in a subsequent machining process.”

The most important characteristic that Faber believes needs to be addressed is matching the performance of the corrosion preventive to the environment that it must perform in. He explains, “The best corrosion preventives may allow a part to be stored for



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years, but if protection is only needed for two months, then this is a case of over-engineering. A prime example of matching performance with environment is for pickling lines. The corrosion preventive used here must be able to handle the acid fumes they will encounter, and the typically formulated product will have very poor performance. If you take that same acid environment corrosion preventive and put it in a salt location, it will show poor performance.”

Duncan includes other factors that need to be taken into account in selecting a corrosion preventive. He says, “Among the issues that need to be taken into account are how the metal substrate is prepared or cleaned before the corrosion preventive is applied. Is it clean-bare metal or are rust or oxidation products, remnants of the metal-working fluid and water present on the surface? The type, availability and cost of the application equipment must be considered along with how the film is removed and compatibility of the corrosion preventive with secondary or additional processing steps.”

Kingston believes that selecting the proper corrosion preventive is a complex process. “The best selections result from open cooperation between the end-user, the corrosion fluid formulator and the additive supplier,” he notes. “This process is driven by the needs of the end-user. It is almost impossible to completely satisfy all requirements so that tradeoffs are required.”

Schnellbacher emphasizes it is important to consider how the metal parts will be processed later in manufacturing when selecting ingredients for a corrosion preventive so they do not interfere with a later processing step. He says, “An example of this is the use of azoles as an ingredient. They are excellent for yellow metal protection because they provide an electrochemically bonded barrier connection for the metal surface. However, this also may interfere with electroplating later down the process line.”

Schnellbacher also cites three other characteristics to consider in selection

VOC reduction is certainly the megatrend affecting the industry, but another important trend is the gradual elimination of the corrosion preventive.

including appearance of the end-use material (wet or dry to the touch), available drying time and how it is packaged.”

All of the respondents indicate that selection of the proper fluid is based on actual environmental conditions encountered by the protected part and what other properties will be required from the corrosion preventive. Herrmann says, “Questions to be answered to find the right corrosion preventive include the storage and transport conditions—is the metal part stored indoors or outdoors and is off-shore transport involved? Two other factors are the length of the storage time and what additional properties (such as demulsibility/emulsibility, water separation, VOCs) are needed in the corrosion preventive.”

Bonner considers the issues with disposal and worker exposure. “In selecting the proper corrosion preventive, the regulations regarding fluid disposal in the specific location of the application must be reviewed along with determining how readily workers will be exposed to the fluid,” he says.

Schnellbacher suggests considering the entire processing of the part to minimize incompatibilities of chemistries. “An example of an incompatibility might be considering nitrated metals, which could be exposed to amines in a later manufacturing step,” he says.

Duncan outlines a number of performance requirements that need to be considered in selecting a corrosion preventive. He says, “Among the issues to determine are how the component will be exposed to the environment (wrapped in a bag, open to the atmosphere, vibration or exposed to the elements such as rain, UV-sunlight, road salt, etc.) and will there be unusual op-

erating conditions (hydrochloric acid fumes, incidental food applications, biodegradable requirement, high-rotational speeds, radiation, etc.).”

PROTECTING ALUMINUM ALLOYS

Preventing staining of aluminum alloys represents a different challenge than is seen with ferrous alloys. Kingston draws a distinction between the two metals. “Most corrosion inhibitors were developed for use on steel or other ferrous metals,” he says. “Protecting steel seems more straightforward because we are more familiar with the effect of different environments on steel corrosion. High humidity, acids and salt increase the rate of steel corrosion in a familiar way.”

Kingston continues, “Aluminum has some characteristics that are different from steel including the presence of a very thin aluminum oxide protective layer between pH values of 4.5 and 9.0 providing corrosion protection. Above and below this pH range, aluminum is inherently more active than steel and tends to corrode faster if unprotected. Water-based corrosion preventives furnish better performance than their oil-based counterparts on aluminum, which is in direct contrast to steel. Determining the right type of and treat rate for additives on aluminum usually is done empirically.”

Duncan states that different types of aluminum alloys require different corrosion preventives. He says, “While a thin aluminum oxide layer can provide some resistance to corrosion, it is important to know what other metal alloys are in use with aluminum to determine how to formulate the corrosion preventive. Aluminum alloys containing significant amounts of copper are most vulnerable to pitting corrosion.

Those aluminum alloys containing magnesium are known for their inherent corrosion resistance at ambient temperatures but not at elevated temperatures. One aluminum alloy (7039) is very corrosion resistant because it contains magnesium and zinc.”

Duncan feels that most petroleum-based corrosion preventives will protect aluminum. He says, “The big concern is using high pH additives such as caustic soda (sodium hydroxide) solution, and strong amines will stain aluminum even though they are not corrosive to steel alloys. Many of the non-ferrous metals utilize additives that are either fully neutralized salts (no large excess of acid or base) or are neutral chemistries.”

Hermann agrees but also expresses concern with using corrosion preventives that are too acidic. She says, “The amphoteric character of the aluminum oxide protective layer means that the corrosion preventives should be more or less neutral to avoid both acidic and basic attack of the aluminum surface.”

Schnellbacher feels that formulators can select certain alkaline pH ranges for water-based corrosion preventives that can be used on most aluminum and steel alloys. He says, “Most common metals do not like acidic conditions. Aluminum and yellow metals like neutral to slightly alkaline conditions. Ferrous metals like neutral to high alkaline pH ranges. However, there are always exceptions to these generalized rules.”

Bonner points out that one class of additives that are effective are silicates. He says, “Silicates are known to help preserve the aluminum oxide layer by forming their own polymeric anionic surface.”

Dr. Britt Minch, research manager for The Lubrizol Corp., draws a distinction between steel and aluminum protection based on surface energy. He says, “The difference in the surface energy of the two metal substrates will become very obvious when applying a water-based coating; aluminum substrates will not wet as easily as steel substrates. Wetting agents can be employed to provide better wetting.

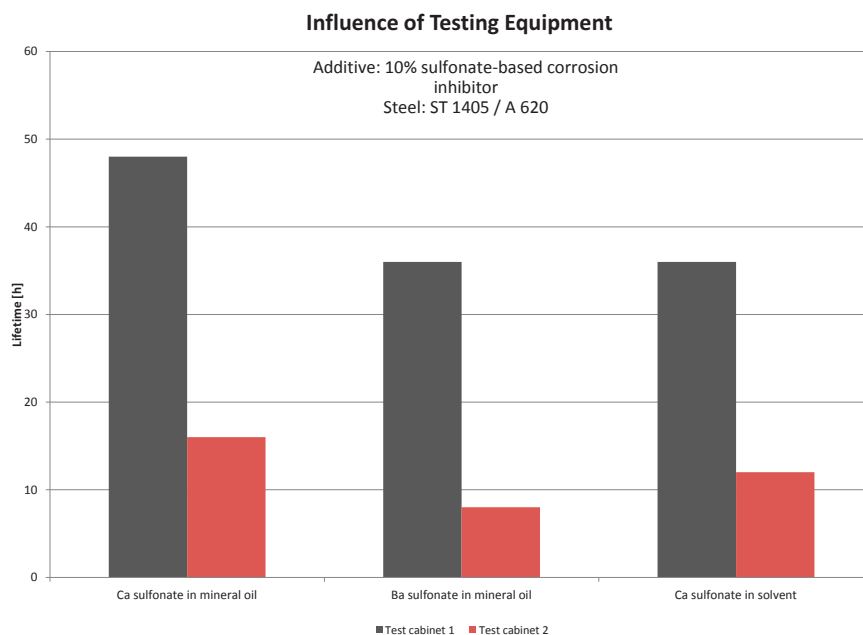


Figure 4 | The results of the salt spray test can be affected by the choice of the test chamber. (Figure courtesy of Rhein Chemie Rheinau GmbH.)

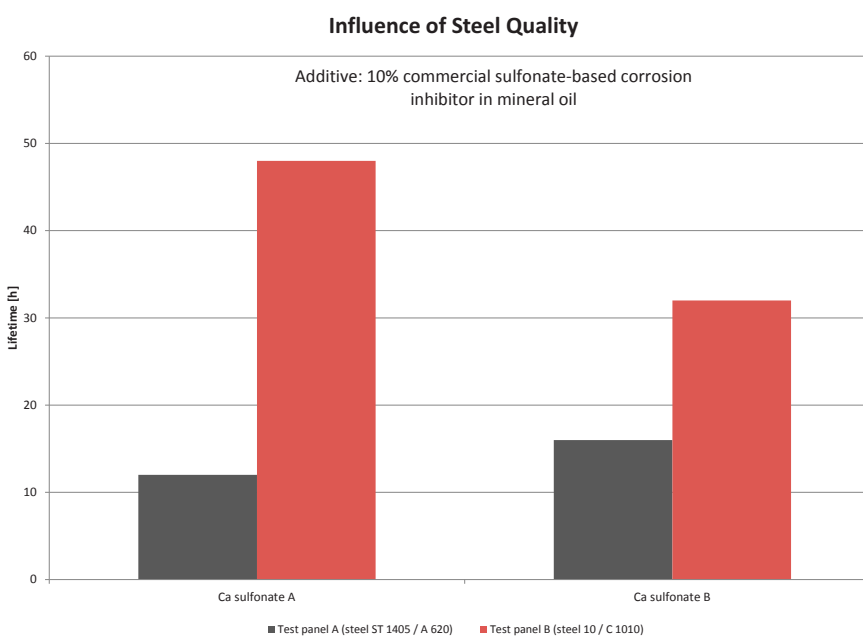


Figure 5 | The results of the salt spray test can be affected by the choice of the steel alloy. (Figure courtesy of Rhein Chemie Rheinau GmbH.)

Fewer wetting issues are observed with solvent- or oil-based corrosion preventives.”

Minch believes that most corrosion preventive coatings will work on both steel and aluminum alloys, but it is tough to generalize due to the wide range of aluminum alloys.

SCREENING TESTS

Herrmann says, “There are different types of tests to simulate storage and transport conditions. The most common tests used are the salt spray test (ASTM B117), humidity test (ASTM D2247) and the alternating atmosphere test (DIN EN ISO 6270-2) that

are all performed in a corrosion cabinet. Furthermore, there are field tests and special standard tests established by OEMs. It is important to perform the test not only with the standardized metal but also with the material used in the final application and in the same test cabinet.”

Herrmann illustrates how changing the test chamber and steel alloy under evaluation also can change the results in salt spray tests shown in Figures 4 and 5 on page 43.

Schnellbacher believes that test selection is extremely important in predicting the best choice of corrosion preventive. He says, “There are various types of corrosion. It makes sense to use accelerated tests that are as close as possible to the actual operating conditions and metal parts seen in real life. For example, it does not make sense to use a procedure to test a wax coating above the melting temperature of the wax if the part will never see these con-

Salt Fog (ASTM B 117) – 50 Hours Exposure

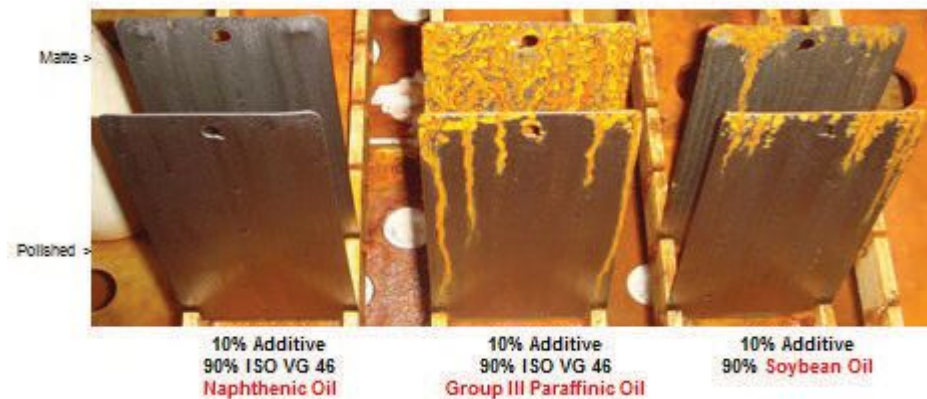


Figure 6 | Base stock selection is important to ensure that the corrosion preventive performs well in the salt spray test. (Figure courtesy of King Industries, Inc.)

ditions. The wax would melt off leaving the parts exposed, but what does that predict?”

Schnellbacher continues, “Use tests that are appropriate to the conditions. For example, aircraft parts tend to see hydrogen embrittlement, and therefore

it is important to run tests to evaluate this type of corrosion.”

The break-point or the lowest concentration where corrosion is likely to occur will need to be determined for a specific corrosion preventive according to Schnellbacher. He adds, “It is also

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Table 2 | Other corrosion preventive tests are listed by test designation and description. (Table courtesy of Daubert Chemical Co., Inc.)

Test designation	Description
AMS 2700	Passivation of corrosion-resistant steels
SAE J2334	Laboratory cyclic corrosion testing
ASTM D130	Copper corrosion
ASTM D665	Rust-preventing characteristics in the presence of water
NACE TM0169	Immersion corrosion tests
ASTM G44	Immersion testing
ASTM G50	Atmospheric corrosion
ASTM G61	Cyclic potentiodynamic polarization resistance
ASTM G71	Galvanic couple test
ASTM G142	Hydrogen embrittlement

Table 3 | MIL-SPECS and other end-user specific test requirements are provided. (Table courtesy of Daubert Chemical Co., Inc.)

MIL-SPEC	End-user	Title
Army Regulation 750-59		Corrosion Prevention and Control for Army Material
MIL-C-11796C		Corrosion Preventive Compound, Petrolatum, Hot Application
MIL-C-23050		Compound, Rust Retarding, Spray on Type, Ballast Tank Preservative
MIL_C-62218		Corrosion Preventive Compounds, Cold Application (for New and Fielded Motor Vehicles and Trailers)
	Boeing	BAC 5008 - Application of Lubricants
	Sundstrand Aerospace	MS02.43-01 - Preservative Oil for Magnesium
	General Motors	GM 9540P - Cyclic Accelerated Corrosion Analysis of Nonchromate Conversion Coatings on Aluminum Alloys
	Caterpillar	EMD approval #130-01-26

common to run some corrosion tests on the substrate as the parts are drying (to test flash rust or immediate attack on the metal) and it is important to test in the presence of likely contaminants.”

Kingston maintains that none of the commonly used screening tests are without problems. He says, “Some tests suffer from reproducibility problems while others lack real-world correla-

tion. The best a formulator can do is to pick accelerated tests that most closely match the expected environment in which the metal must be protected.”

Figure 6 on page 44 shows panels from salt spray testing that show the choice of the base stock is very important in ensuring that the corrosion preventives perform well in the salt spray test.

Duncan agrees that simulating the

final application in screening testing is very important. He says, “It is also important to recognize that when shipping parts across country or overseas, parts can experience wide-temperature fluctuations and corrosive environments. These climactic changes may result in parts sweating from moisture condensation and unexpected corrosion as they move to warmer and more humid climates.”

There are many other tests to screen corrosion preventives. Among some of the other tests that are important are those listed in Table 2.

Duncan points out that a number of MIL-SPECS and end-user specific requirements are used to qualify corrosion preventives. Among some of the most important are those listed in Table 3.

Faber points out that the most heavily used screening test is the salt spray test. He says, “The salt spray test is relatively quick and is capable of showing clear discrimination.”

An example of data obtained from the salt spray test is shown in Figures 7-9. A high-performance corrosion preventive was coated on half of a steel panel while the other half was left unprotected. As shown, corrosion was seen on the uncoated panel after 30 minutes while the coated panel did not start to show corrosion until a test duration of 96 hours.

A second test that Faber indicates is important to use in screening a corrosion preventive is demulsibility. He says, “Using a demulsibility test can help determine whether a fluid is a good fit for a process where rinse water or coolant are routinely carried over into the corrosion preventive. This test can be a standard test like ASTM D1401, or there are many in-house variations used and accepted by the industry.”

Whatever screening tests are done, Bonner says, “Extended field trials under real application conditions are vital.”

LOW-VOC PRODUCTS

The regulation to limit VOCs in all products used in the South Coast Air Quality Management District (Rule



Figure 7 | Salt spray testing where the metal panel is coated with a high-performance corrosion preventive on one side and unprotected on the other side is shown at the beginning of the test.



Figure 8 | Results on the salt spray test after 30 minutes show corrosion on the unprotected side.



Figure 9 | Results on the salt spray test after 96 hours show that corrosion has just started on the side coated with the high-performance corrosion preventive.

(Courtesy of The Lubrizol Corp.)

1144) in the Southern California region of the U.S. has led to more interest in finding low-VOC corrosion preventives.² But, there are challenges to developing such products with comparable effectiveness.

Corrosion preventives with high-VOC contents have many attractive features, as explained by Bonner. He says, “Application where high-VOC corrosion preventives are used require quick drying and thin film formation (approximately one micron). This benefit works well because metal parts produced in one process are required to be stored for a short period of time until further processing is required where the thin film can be easily removed.”

Duncan says, “High-VOC corrosion preventives that are solvent-based are historically used where an immediate coating is required. Applications include vanishing oils (forming fluids) and cavity wax (inside door panels of an automobile). These products utilize

water displacing (separating) products and quick dry (dry film) corrosion preventives.”

Kingston says, “Corrosion-preventive formulations with high-VOC content are usually required for either fast drying or penetration ability. In addition, they are usually much better at corrosion prevention than the same additive level in oil alone.”

In switching to low-VOC corrosion preventives, performance is compromised in a number of aspects. Kingston says, “Low-VOC formulations tend to severely restrict the ability of the formulation to penetrate metal surfaces that have tight tolerances. This prevents lubricity and corrosion protection from getting to all of the areas of closely fitting parts or machinery where it is required.”

Faber notes that two low-VOC options available to the formulator are water-based and oil-based. In both cases, performance as compared to high-solvent containing corrosion pre-

ventives is compromised. He says, “In switching to a water-based product, the most important thing to understand is the longer drying time requirement. The worst thing a manufacturer can do is package a part coated with a water-based product that has not dried. The water trapped in the packaging will create a high-humidity environment that will greatly accelerate the corrosion process.”

For oil-based corrosion preventives, the compromises involve the nature of the coating and the corrosion protection. Faber says, “The coating for an oil-based product will always be wet and oily and not dry. Corrosion protection will be reduced because the final film is diluted with approximately 90% oil and this does not allow key additives (such as waxes and sulfonates) to form a robust film as they can in solvent and water products because they are still in solution.”

Herrmann adds, “Besides being liquid in nature, films produced by oil-

based corrosion preventives are also sticky in nature.”

Schnellbacher feels that low-VOC corrosion preventives can be good alternatives if there is sufficient coating of the material and sufficient drying/curing time. He says, “Corrosion preventives that are water-based, oils, plastics, conversion-coatings, nanotechnology and thixotropic coatings all can be used as alternatives to organic solvent-based materials.”

FORMULATOR PERSPECTIVE

STLE-members Rick Butler, technical manager for fluids for Chemtool, Inc., in Rockton, Ill., and Mike Pearce,

within a minute or two after production with no ill effects.”

In moving to low-VOC corrosion preventives, Butler and Pearce see the need for improved performance. Butler says, “Oil and grease-based corrosion preventives can be very low in VOC and still protect metal parts adequately. But improved corrosion inhibition is needed in most applications. Emulsions are fine for indoor or covered applications. They are not and never will be completely suitable or desirable for outdoor protection.”

Butler continues, “Low- and no-VOC semipermanent hard shell coatings are getting serious consideration

regulation, which becomes effective in less than three months, they indicated there will be little change in raw material selection until they receive supplier safety data sheets.³ Both indicate they will only use GHS compliant raw materials.

TRENDS

Kingston predicts that the four trends listed below will be significant in shaping the future of corrosion preventives:

1. Increasing use of non-ferrous metals
2. Drive for more cost-effective protection
3. Increasing use of environmentally low impact corrosion preventives
4. Increasingly restrictive worldwide regulatory environment.

He says, “Greater use of non-ferrous metals such as galvanized steel and aluminum are taking place particularly in transportation because the higher fuel economy standards require weight reduction. Better cost effectiveness will be needed through the use of less costly additives at lower treat rates, thinner protective films and more efficient application technologies. Environmental trends will lead to the greater use of water-based formulations, vegetable-based oils and biodegradable additives. Restrictions in the regulatory environment may deprive formulators of smaller-volume specialty additives that may start to disappear from the market and lead to a loss in machinery performance and life. This is a factor that has not been adequately considered by regulatory authorities.”

Duncan believes that a number of options available to the corrosion preventive formulators are falling out of favor due to environmental trends. He says, “Among the chemistries falling out of favor are aromatics (solvents and oils), arsenic, barium, boric acid, cadmium, chromium, cobalt, hydrocarbon solvents and nitrites.”

Faber cites that VOC reduction is certainly the megatrend affecting the industry. But another important trend

Corrosion preventives have been a relatively mature technology to date, but changes in regulations will lead to the development of newer products in the future.

sales for W.S. Dodge Oil Co., Inc., in Maywood, Calif., were contacted to get their views on the current types of corrosion preventives and what performance features need to be upgraded.

Butler says, “With few exceptions, we can meet any performance requirement with current market materials. Pearce says, “On the oil side, so long as VOC is not an issue, the technology is very mature and does its job well. On the water-based side, there are some good packages available.”

Pearce indicates that most of the corrosion preventives used in his region (Los Angeles) is for tube mills. He says, “Prior to the implementation of Rule 1144, solvent-based corrosion preventives worked well because the solvent displaced the leftover mill coolant and adhered to the surface of the tube. The blend of sulfonate inhibitor and barrier film (oxidate and petrolatum) gave six to 12 months of indoor protection but still was easily cleaned by conventional means. No extra drying time or heat was required; tubing was routinely bundled

as corrosion preventives. These coatings can be either clear or pigmented and can double as a lubricant and/or displace paint or powder coating.”

Pearce says, “For straight oil corrosion preventives, water displacement and barrier film formation need to be upgraded while water-based types require faster drying time and quick barrier film formation.”

From the perspective of using corrosion preventives that meet the requirement for Rule 1144, Pearce sees the need for a significant upgrade. He says, “I rate the solvent-based products in the B+ to A range while the oil-based fluids are only in the C range. Oil-based corrosion preventives do not form durable films and thus run off parts over time. Water displacement is nowhere near as good as solvent-based fluids and indoor storage effectiveness is only about six to nine months. Outdoor storage can only be done with hot melt products.”

When both respondents were asked about the impact of the upcoming GHS

is the gradual elimination of the corrosion preventive. He says, “End-users in some applications are now requiring that the coolant or metal cleaner act as the corrosion preventive in place of a traditional oil-based product. This switch started during the recession of 2009 when manufacturers realized they carried inventory for too long. In many cases today, inventory is not stored nearly as long as it used to be. Better packaging and more controlled storage conditions also are lowering the level of protection needed. The requirements are now at a level where corrosion inhibitor-packed coolants and cleaners can last long enough for more applications. The net result for end-users is that they save money because they have limited the number of fluids they use and shortened their production cycles.”

Herrmann indicates that one other trend is the move toward light-colored corrosion preventives. “More customers are requiring light-colored products

and some in specific regions are even looking for invisible and touch-dry films,” she says.

Bonner cites the need for less toxic corrosion preventives particularly in metal working industries. He adds, “The performance requirements for future corrosion preventives are high-acid fume resistance, super demulsibility and the ability to withstand high voltage (50,000 volts) and exhibit high flash points for use in electro-spray applications.”

Schnellbacher says, “Future trends in corrosion preventives will include waste minimization, lower-energy processes, recyclable and multi-use products.”

Corrosion preventives have been a relatively mature technology to date. But changes in regulations, such as the move to reduce VOCs and the need for end-users to continue to improve productivity and reduce costs, will lead to the development of newer products in the future. **TLT**



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