SUCCESSFUL CORROSION PROTECTION UTILIZED

BY MILITARY WORLDWIDE

Anna M. Vignetti

Cortec Corporation

4119 White Bear Parkway

Saint Paul, Minnesota 55110

U.S.A

ABSTRACT

This paper will address the use of successful corrosion protection solutions for different problems identified by the US military as well as military worldwide. Various corrosion problems and solutions being utilized that deal with high tech electronics, vehicle undercarriages, fluid reservoirs, storage, and cleaning will be discussed.

Vapor corrosion inhibitor (VCI) products and solutions give an environmentally friendly, efficient, safe and easy to use alternative. Effective corrosion prevention is provided with the benefit of war readiness. Specific laboratory testing presented in this paper for ASTM and MIL specification standard test procedures support the successful use of VCIs in field applications. Many solutions for corrosion protection are now utilized with the incorporation of VCI systems and products in different delivery systems.

INTRODUCTION

Military organizations worldwide have different options to choose from for the prevention of corrosion in vehicles, aircraft, equipment, facilities, and naval vessels. Many existing and newer VCI products were tested, tried, and recommended for corrosion control. But even today, some militaries choose not to use any additional prevention measures due to the fact that war readiness may be jeopardized.

Billions of dollars in assets are lost every year by the military, as well as industry and just as industry is making significant changes in the way they do business, so is the military. Many factors are now being considered when evaluating corrosion prevention. It is not to losing the war with the enemy. In addition to war fighting capability, it is necessary to develop a corrosion control and prevention strategy to be able to fight the war better, faster, efficiently and economically. Corrosion in its different forms can contribute to losing the war.

VCI technology provides an effective and relatively inexpensive method of controlling corrosion in closed systems and other environments. In the case of precise scientific instruments, electrical and electronic equipment, VCIs offer a definite advantage over classical methods of protection. When added in small concentrations, VCIs effectively check, decrease or prevent atmospheric corrosion due to the reaction of the metal with the environment. VCIs can be defined as an individual or combination of chemical compounds that have significant vapor pressures that allow vaporization of the molecules and the subsequent adsorption onto metallic surfaces.[1,2] "Volatile corrosion inhibitors are secondary electrolyte layer inhibitors that possess appreciable saturated vapor pressure under atmospheric conditions, thus allowing vapor-phase transport of the inhibiting substance", according to Miksic and Miller.[3] Two review papers, written by Fodor[4] and Miksic[5], provide a very good overview on the classification/nomenclature, mechanism and nature of adsorbed VCI compounds.

Types of Prevention|

Today, the many different methods utilized range from the blockage of moisture and other atmospheric contaminants on metal with ordinary greases, to silica gel for the absorption of moisture, to expensive alternatives such as dehumidification. This paper will further discuss these products and methods.

Water Displacing Products. Typically, these products are petroleum based. They can be light oils or thixotropic greases. With the focus on safety and the environment, the interest in these products by the military and industry decreases everyday. They are widely used and are relatively inexpensive in a basic form. Costs increase with the addition of contact inhibitors and other properties that may be required such as extreme pressure additives. Aside from these incremental costs, the cost of labor to apply and remove these products as well as the solvent based cleaners needed, make this option laborious as well as costly and unsafe to the worker and ecology. Petroleum based products can be effective to a certain extent. In addition to water displacement, they can also create a barrier coating on metal surfaces.

A great deal of time and study has gone into the perfection of paints and coatings for the prevention of corrosion on metals which are meant to protect the surface, as well as decorate, displace water, fluids, and corrosive contaminants. This is an excellent means of permanent protection. Depending on the coating, applications may range from easy to extremely difficult and time consuming. So goes the range in costs. Here also, a great deal of attention is being given to improving corrosion protection properties as well as making the products safer and more efficient to use and also friendly to the environment.

Water Absorption. Silica gel products, commonly known as desiccants can provide an economical alternative for temporary protection. In a situation where protection of metal is strictly related to moisture and the protection time is short term, this method has its good points. They are now used worldwide by industry and the military for storage and shipping. Electronic failures are in most cases caused by moisture and corrosion. Desiccants prove to be valuable in shipping and storage and in some cases during electronic and electrical operations.

As stated, the factors for successful utilization are restrictive. Desiccants can absorb the moisture out of the atmosphere creating an atmosphere less conducive to corrosion. The drawback is that the initial calculation for the amount placed in the container, package or area is specific. It is difficult to calculate moisture due to the unpredictable nature of the environment and the climate. This necessitates the addition of more desiccant and frequent inspections. Inspections can be costly as well as the replacement of the water-absorbing product. Another consideration that needs to be addressed with this option, in most cases, the requirement for an airtight seal or cover is difficult and expensive to accomplish.

Dehumidification. This method or process if utilized correctly has proven to be successful, but not without its limitations. It is more commonly used by the military and less often by industry. Ultimately, the metal being protected needs to be sealed so that the air flow is totally restricted, whether it is the interior of a vehicle such as a tank or a piece of equipment in some type of container. A dehumidifier is then connected and then used to extract moisture. Electricity is mandatory which may be a deterrent in case of remote locations where equipment is prepositioned for war readiness. Keeping a seal on the object has also proven to be a challenge. Cost of the dehumidification equipment along with the upkeep and maintenance required may put a strain on any budget.

Vapor barrier bags are often used with this method. Maintaining a seal is the first step and is critical to success. This multi-layer film is sturdy, and excellent for one time use. A drawback is high costs of materials and labor associated with creating airtight protection. In addition, vapor barrier bags are not recyclable. Again, a good way to protect electronics. In real world military environments, this would not be the best alternative during operations.

Vapor Corrosion Inhibitors. There are three classes of VCI compounds. They are ranked according to their electrochemical mechanisms. Now, an overused term, VCI corrosion prevention needs to be carefully considered and analyzed according to the protective mechanisms.[6]

> **Anodic** inhibitors prevent metal corrosion by anodic passivation. An anodic inhibitor will increase the corrosion potential and decrease the corrosion current density. A few common inhibitors in this class are sodium nitrite, dicyclohexylamine nitrite and sodium benzoate. They can be effective given the right circumstances or requirements but have limitations. In many cases anodic inhibitors will have a negative effect on worker safety and the environment.
>
> **Cathodic** inhibitors can exhibit two very different effects. They can either slow the cathodic reaction itself or they can selectively precipitate onto the cathodic sites, which increase circuit resistance. This circuit resistance restricts diffusion to the cathodes.
>
> **Mixed** inhibitors are compounds in which the electron density distribution causes the molecules to be attracted to both the anodic and cathodic sites.

They are adsorbed onto the metal surface, creating a monomolecular layer, which influences the electrochemical activity at both the cathode and anode.

A monomolecular film serves as a buffer, which maintains the pH level, at its optimum range for corrosion resistance. The adsorption process is not instantaneous. It requires a defined time for the formation of the inhibitor layer.

The necessary molecular binding energy and the surface area, which the molecules occupy, are important for successful adsorption. The mixed inhibitor molecules are water-soluble and possess a binding energy to metal surfaces that is higher than the binding energy of water dipoles. Strong exothermic reactions are created, which can displace surface moisture. These inhibitors are more desirable because of their universal effect on the corrosion process.[6]

BENEFITS AND ADVANTAGES TO VCI TECHNOLOGY

The widespread use of VCI type products and systems is proof that this new technology does have the benefits that the military and industry require to have successful corrosion prevention as well as providing key advantages. To recapitulate them:

1. Ease of application.
2. Efficiency in application and non-removal (removal only if necessary).
3. Economics provided:

   -Lower cost products

   -Reduction of labor in application and removal

   -Reduction of exercising and maintenance

   -Reapplication of products needed less frequently

   -Reduced loss of assets

4. Non-removal of products in most cases.
5. Enhanced combat readiness.
6. Extended life expectancy of equipment

EXPERIMENTAL

A. **Fingerprint removal properties**

Handling of metal components lends itself to corrosion due to the corrosive nature of the salts in the human skin. Since it is difficult to ensure that the hands are covered, study was given to test the ability to remove the fingerprint oils and provide corrosion protection. A military test and specification was developed as a result.

Procedure: Per MIL-C-15074, Corrosion preventive, finger print remover.

1. The synthetic fingerprint solution was prepared according to the following formulation. (See Table 1)

2. A pad of gauze was placed in a flat dish and 1.5 ml of fingerprint solution was placed on the pad.

3. The rubber cork was sanded with sandpaper and rinsed with de-ionized water.

4. 5 steel panels were washed with methanol and air-dried.

5. Using the rubber cork, the fingerprint solution was placed on the panels and immediately placed in an oven set at 121°C for 5 minutes.

6. One panel was placed in boiling methanol for 2 minutes. Another panel was immersed in 1,1,1-trichloroethane for 1 minute. Three panels were immersed in a VCI product for 2 minutes.

7. All panels were placed in a desiccator with water for 24 hours.

8. After 24 hours, the dessicator was opened and the condition of the panels was visually evaluated.

Results are presented on Table 2.

B. **VCI oil base Coating**

There are various ways of evaluating the performance of coatings. Test methods simulate the environment under which military equipment may be used or stored. Testing under highly humid conditions (ASTM D 1748), salt spray (ASTM B117) and cyclic (ASTM G 85) was carried out using carbon steel panels (SAE 1010).

A VCI Oil Base Coating was tested according to the following standard test methods:

ASTM D-1748

ASTM B-117

ASTM G-85

C. **VCI temporary soft coating**

Similar to the oil base coating, a VCI soft coating was run through a battery of testing. The tests carried out for this coating varied from physical to anticorrosion properties. A VCI temporary outdoor coating with self-healing properties was tested according to the following standard method:

MIL-C-16713E Grade 1,Class1

RESULTS

The results for the above mentioned experiments are reported in the following tables:

Table 2 — MIL-C-15074 specification test results.

Table 3 — ASTM D-1748, B-117, G-85

Table 4 — MIL-C-16173E Grade 1, Class 1

DISCUSSION

The many applications now exemplifying the use of VCI technology extend throughout the world. Dozens of products and systems have been tested, approved and documented, which may be used as references. Following are field applications varying from simple corrosion protection to more sophisticated systems solutions.

NASA currently uses VCIs in two different areas and is now in the process of evaluating the corrosion protection of other critical applications. The first application, although simple in nature, is potentially catastrophic if not addressed. The O-rings in the space shuttles are very susceptible to corrosion due to salt-water atmospheric contamination. With the simple application of the VCI coating, approved under MIL-C-16173E, Table 4, NASA's requirement is met in order to eliminate or reduce the corrosion. The product offers the additional properties of vapor emission of VCI molecules to nearby areas as well as a self-healing property.

In the protection of electronics, extensive testing was done at NASA addressing VCI interference with Hyperbolic Ignition and Lox Mechanical Impact Testing. The VCI emitting products and spray were tested and approved for use[7]. By placing the product in enclosed electronic cabinets or boxes, the VCI is allowed to form a molecular barrier on the multi-metal surfaces of the electronic components. The potential adverse effects of molecular layers were of great concern to NASA and to the US Navy. Based on extensive testing, it has been proven that VCI products are safe for even the most sensitive equipment, i.e.: optical coatings and instruments.[9] Telecommunication and radar equipment is effectively and economically protected with VCI products that are located in highly corrosive atmospheres. The additional property of static dissipation according to

MIL-PRF-81705 may also be required.

The US Navy is a user of the VCI emitting products for the electronics areas and the USAF also uses the devices in void spaces. Currently, the emitting devices are used on Naval Aircraft, Navy ships and Naval Air Stations.[2, 8] US Navy usage extends to other corrosive sites on naval vessels. The ships are exposed to a salt laden environment continuously. Prevention with VCIs extends to coatings that are used in areas that may already be rusted and where appearance is not a factor. Permanent water base products are also now being tested and used on ships where aesthetics and the need for a dry and hard coating are more important. These coatings are especially good due to their environmentally friendly nature and water clean up of spray equipment. VCI additives are also used in coatings and oils. For surface preparation, water base cleaner/degreasers and rust removers are used and that offers worker safety and low environmental impact.

VCIs used in the protection of weaponry, which includes cannons, anti-tank rockets, tanks, missiles, ammunition, charge bags, cartridge cases; military organizations are found to be a solid, reliable alternative for corrosion prevention. Testing has been completed to ensure the compatibility of the ammunition with the VCI.[10] Products and systems for protection include: VCI film and paper for packaging for storage and shipping, lubricating oils, VCI protective coatings and emitting devices.

CONCLUSION

In conclusion, the utilization of different VCIs products and preservation solutions has been developed over the years. Militaries and their contractors are increasingly testing, identifying, and approving VCI products as a successful means of protection. Corrosion prevention, being the ultimate goal, is not enough in this day and age. The safety of military personnel, environment, elimination of hazardous waste disposal, labor costs, and war readiness make VCI technology extremely attractive and interesting to the military. The efficiency and ease of application along with the benefit of non- removal, in most cases, makes VCI technology the most desirable alternative available today.

REFERENCES

1. Riggs, Olen L. Jr. (Nathan, C. C. Ed), "Corrosion Inhibitors", CORROSION 73, (NACE International, 1973).
2. Vasanth, K. L., "Vapor Phase Corrosion Inhibitors for Navy Applications", CORROSION 97, paper no.179, (New Orleans, Louisiana, NACE International, Louisiana, 1997).
3. Miksic, B. A., R. H. Miller, "European Symposium on Corrosion Inhibitors", 5th Proceedings, 107th Manifestation of the European Federation on Corrosion, pp. 217-236, September 1980.
4. Fodor, G. E., "Inhibition of Vapor-Phase Corrosion — A Review", Report No. BFLRF-209, Southwest Research Institute, San Antonio, Texas, September 1985.
5. Miksic, B. A., "Use of Vapor Phase Inhibitors for Corrosion Protection of Metal Products", 11-16-1, NACE Symposium Proc., 1983.

6. Vignetti, A. M., "Vapor Corrosion Inhibitors: Successful Field Applications in Electronics", CORROSION 2000, paper no.707, (Orlando, FL, NACE International, 2000).
7. NASA Internal Report no. 96-2T0178, September 1996.
8. Vansanth, K. L., "Corrosion Inhibition in Naval Vessels", CORROSION 96, paper no.233, 1996, (NACE International, 1996).
9. Creo Electronics Corporation, Burnaby, British Columbia, Independent Test Report for VCI Sensitivity on Optical Coatings and Instruments, November, 1989.
10. P. Piacun, "Conservation of Weaponry", Cortec Corp. European Business Meeting, Rome,Italy, 1996.

TABLE 1

Fingerprint Removal Test Solution

Ingredient	**Quantity**
Sodium chloride	7 grams
Urea	1 gram
Lactic acid	4 grams
DI water	Till 1 liter

TABLE 2

MIL-C-15074, Corrosion Prevention, Fingerprint Removal Test

Material	**Results**	**Fingerprint Removal**
Methanol	No corrosion	100%
1,1,1-Trichloroethane	Severely corroded	0%
VCI-327	No corrosion	100%

TABLE 3

VCI-Oil base coating Test Results

ASTM DFT Carbon Steel(1010)

Humidity D-1748 2 mils (50 microns) 2000 hr.

Salt Spray B-117 2 mils (50 microns) 170 hr.

Prohesion G-85 2 mils (50 microns) 500 hr.

TABLE 4

MIL-16173D, Grade 1, Class 1 Results, VCI temporary, soft coating

Test	Test Method (Section)	Result
Material	3.2	Pass
Toxicity	4.8	Pass
Film Characteristics	4.6.11.7	Pass
Solvent Distillation Endpoint	4.6.1	Pass
Discernibility	3.6	Pass
Stability	4.6.6	Pass
Recovery from Low Temperature	4.6.6.1	Pass
Uniformity	4.6.6.1.2 & 4.6.11.4	Pass
Storage Stability	3.73	Pass
Flash Point	4.6.2	Pass
Removability	4.6.10.1	Pass
Salt Spray	4.6.11.4	Pass
Weathering, Accelerated	4.6.11.5	Pass
Flow Resistance	4.6.15	Pass
Sprayability	4.6.7	Pass
Corrosion	4.6.8.1 & 4.6.8.2	Pass

Low Temperature Adhesion	4.6.12	Pass
Drying	4.6.13	Pass