Vapor Corrosion Inhibitor Field Applications in Electronics

BORIS MIKSIC, FNACE, AND ANNA M. VIGNETTI

This article identifies and documents examples of the successful use of vapor-phase corrosion inhibitors (VpCIs) in the field to protect electronics and electrical systems. Ongoing studies and analysis conducted worldwide have deemed VpCIs an effective form of protection. The myriad field and industrial applications of VpCIs prove advantageous for the military, electronics companies, utilities, and many others.

In the last decade, the electronics and electrical industries have increasingly used vapor-phase corrosion inhibitors (VpCIs) for circuit protection. As electronics continue to shrink in size and grow in capacity, the importance of corrosion control increases because even microscopic levels of corrosion can be devastating. Despite today's unprecedented level of knowledge regarding the causes of corrosion in electrical circuits, many electronics manufacturers and assemblers have yet to embrace new technologies. Some apply their favorite conformal coatings and leave the end user or system integrator to deal with the consequences. The results of this singular approach are often catastrophic to electronic equipment. Without additional corrosion-inhibitive procedures, electronics, which are exposed to ambient atmospheric conditions, can fail prematurely. Consequently, it is crucial that both industry and the end user understand that successful strategies and tactics can provide a superior protection solution. Applying VpCIs can quickly, efficiently, and economically minimize corrosion's impact on electrical and electronic systems.

The Mechanism of VpCI Activity

VpCIs can be classified in the following three groups and are ranked according to their electrochemical mechanisms: anodic, cathodic, and mixed (both anodic and cathodic).

ANODIC

Anodic inhibitors prevent metal corrosion by anodic passivation. They play a vital role in the anodic process. An anodic inhibitor increases the corrosion potential and decreases the corrosion current density.

CATHODIC

Cathodic inhibitors can exhibit two very different effects. They can either slow the cathodic reaction itself or selectively precipitate onto the cathodic sites, actually increasing circuit resistance. This circuit resistance restricts the diffusion of reducible species to the cathodes.

MIXED

Mixed inhibitors are compounds in which the electron density distribution causes the molecules to be attracted to both anodic and cathodic sites. They are adsorbed onto the metal surface, creating a monomolecular layer that influences the electrochemical activity at both the cathode and the anode. These inhibitors are more desirable because of their universal effect on the corrosion process.

VpCIs are mixed-inhibitor systems based on aminecarboxylate chemistry. They inhibit the cathodic process by incorporating one or more oxidizing anions in an organic (amine) molecule of VpCI. The nitrogen of the amine group can enter into a coordinate bond with metals, thus enhancing the adsorption process. The adsorption of cations increases the overpotential of metal ionization and slows the corrosion process. The inhibitor's monomolecular film serves as a buffer that maintains the pH level at its optimum range for corrosion resistance.

The inhibitor's adsorption process is not instantaneous. It requires a defined time period to form the adsorbed inhibitor layer on the target metal surface. Two issues must be identified to ensure successful adsorption:

- The surface area, which the molecules occupy, and the necessary molecular binding energy.
- VpCI molecules are water-soluble and possess more binding energy to metal surfaces than that of water dipoles. Also, they create strong exothermic reactions that can displace surface water—this establishes an anchor point that prevents the corrosive species from reaching the metallic surface (Table 1).

TABLE 1

BINDING ENERGIES OF VpCI TO THE METAL SURFACE

Molecule	Binding Energy to Surface (Kcal/mol [kJ/mol])
Water	~43 (180)
VpCI - A	~150 (628)
VpCI - B	~800 (3,347)

VpCI Test Example

CIRCUIT BOARDS PACKAGED IN VpCI-COATED CORRUGATED BOX

A cellular phone manufacturer experienced corrosion problems when its products were shipped around the world. The products ranged from individual cell phones to large networks. Because it is used in many countries, the equipment is often subjected to extreme temperatures and other corrosive atmospheres.

Existing packaging allows moisture to penetrate, creating a strong possibility of corrosion. The manufacturer wanted to protect the electronics that were being shipped in corrugated cardboard boxes without adding shipping labor or part numbers. As a result, the following tests were performed:

BACKGROUND

The manufacturer was already using two corrugated boxes with an electrostatic dissipative (ESD) protective coating designed for circuit boards.

PROPOSED REMEDY

Apply a VpCI coating over the ESD coating and test circuit boards to provide multimetal corrosion protection.

METHODS

- F-12 cyclic corrosion test (modified).
- Razor blade test (Table 2).
- Surface resistivity test.

MATERIALS

- F-12 test kit.
- Razor blade test.
- VpCI liquid coating.

PROCEDURE

Two circuit boards were tested for surface resistivity before applying the VpCI coating solution. Box #1 surface resistivity was 10^6 to 10^7 Ω^2. Box #2 surface resistivity was 10^6 to 10^7 Ω^2.

VpCI liquid coating with a viscosity of 20 to 21 (Zahn cup #2) was prepared. To adjust the viscosity, S-50 thickener was used. One of the boxes was coated with VpCI liquid coating at a coating weight of 15 g/m^2. The other box was not treated.

After applying the VpCI solution, the boxes were placed in an oven set at 40°C for 2 h to dry. After drying, surface resistivity was checked again. VpCI box surface resistivity was 10^6 to 10^7 Ω^2. Non-VpCI box surface resistivity was 10^6 to 10^7 Ω^2.

The razor blade and F-12 tests were performed according to the standard procedures for each, using eight cycles for the F-12 test.

RESULTS

Significant staining (oxidation) of the solder mask was observed on the unprotected circuit board (Figure 1). The VpCI-protected circuit board looked exactly as it did before testing—no oxidation or staining was observed (Figure 2).

Surface resistivity of the two boxes was tested after the F-12 test. The results are as follows:

- VpCI liquid-coated corrugated board provides very good corrosion protection to circuit boards.
- A VpCI coating can be applied over the ESD coating and does not alter the ESD properties.

TABLE 2

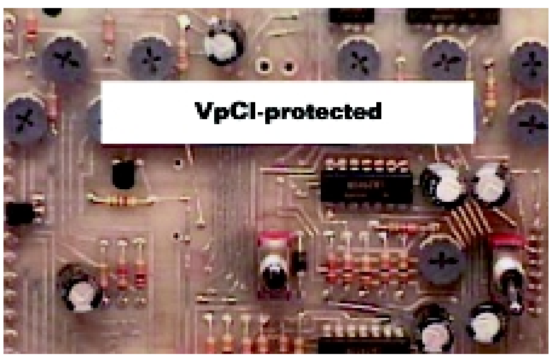
RAZOR BLADE TEST

	CS			Aluminum			Copper		
Material 1	Panel #1	Panel #2	Panel #3	Panel #1	Panel #2	Panel #3	Panel #1	Panel #2	Panel #3
Board #1	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Control	Fail	—	—	Fail (slight)	—	—	Fail	—	—

FIGURE 1

The solder mask oxidized on an unprotected circuit board after a field test.

FIGURE 2



A VpCI-protected circuit board looked exactly as it did before undergoing a corrosion field test.

- A VpCI liquid coating applied at a coating weight of 15 g/m^2 (wet) or above is recommended.
- VpCI-coated corrugated board provides corrosion protection for carbon steel, aluminum, and copper.

IN-FIELD APPLICATION

This manufacturer will use corrugated cardboard shipping boxes coated with a VpCI liquid at the minimum coating weight of 15 g/m (wet). Higher rates may provide additional protection in extreme conditions.

Field Applications

VpCI CORROSION PROTECTION SYSTEM FOR STORAGE

Customer

Hong Kong Nuclear Power Group (China)

VpCI Products Used

- Tablets.
- Powder packets.
- Stretch film.
- Emitting devices.
- Foams.
- Paper.
- Electronic spray.
- Water-based coatings.
- Lubricating coatings.

PROBLEM

The customer needed to protect more than $200 million dollars worth of stored spare parts, electronics, and facilities from corrosion. It chose a variety of VpCI products for total corrosion control.

Backup Diesel-Powered Generator

A VpCI coating was sprayed onto the sensitive parts. VpCI emitters and electronic spray were used to protect the control enclosures. VpCI film was used to cover the entire machine.

Small Spare Parts

Bearings were wrapped in VpCI paper while the screws and small parts were treated with a VpCI temporary water-based coating.

Motors and Transformers

Small motors and transformers were wrapped with VpCI stretch film. Large ones were protected with a VpCI temporary coating, then covered with VpCI film. A VpCI lubricating coating was sprayed onto parts requiring lubrication.

VpCI EMITTER

Customer

Electronics manufacturer (Germany)

Product

VpCI emitter

Application

The product was used for fire alarm systems for hotels, airports, factories, shipping centers, museums, and hospitals. Switch boxes and cabinets were equipped with a VpCI emitter before delivery. VpCI vapors protected electronics equipment from corrosion during shipping as well as in later operation, even in unfavorable conditions.

EMITTERS, FILM, ANTISTATIC FILM, FOAM

Customer

Components manufacturer (Illinois)

VpCI Products Used

- Emitting devices.
- Foam.
- Film.
- Antistatic Film.

Indoor protection was needed for up to 2 years

Protected Parts

Cellular phone electronic enclosures, PC boards, ancillary equipment, and installation material needed protection for up to 2 years.

VpCI Application

Packaging electronic enclosures was used to protect the parts from triboelectric charge generation, corrosion, and other related problems (e.g., pitting, oxidation, staining, and galvanic corrosion during shipments).

Account History

The customer was using vapor barrier packing material with desiccants in addition to antistatic bags for protection during shipment. The customer wanted a more cost-effective, less time-consuming export packaging method. VpCI emitters were placed in the electronic enclosures and VpCI antistatic bags were placed over the enclosures. VpCI foam pads and film protected all other miscellaneous electronic equipment.

VpCI PROTECTION SYSTEM

Customer

Chemical manufacturer (Texas)

VpCI Products Used

- Emitting devices.
- Electronic spray.
- Oil additive.
- Powder.
- Coating.

Application

- Mothballing a portion of the plant.
- Electronics: Emitters and electronic spray.
- Interior Cavities: Powder.
- Additive to Oils: Oil additive.
- Exterior: Coating.

Reasons VpCIs Selected

For many years, a wide variety of VpCIs have been used at various locations to preserve new and used equipment. The above products have proven successful and are commonly used for such an application. This portion of the plant could be mothballed for a period of 6 months to 2 years.

Conclusion

Numerous VpCI products can help eliminate the corrosion concerns of electronics manufacturers. VpCIs can improve the life expectancy and high-level performance of electronics. Understandably, no single VpCI application is universally valid. However, VpCI treatment offers positive results when parameters can be defined. Also, combining several VpCI delivery media will, in some cases, probably serve as a better overall method of corrosion inhibition. Therefore, lab bench tests can aid in validating methods and procedures that will support positive field test result applications.

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BORIS MIKSIC, FNACE, is President of Cortec Corp., 4119 White Bear Pkwy., St. Paul, MN 55110. He has developed more than 300 products and systems that use VpCIs and volatile corrosion inhibitors. He has an M.E. from the University of Zagreb, is a NACE fellow, and has been a NACE member for 26 years.

ANNA M. VIGNETTI is Vice President of Sales and Marketing at Cortec Corp., 4110 White Bear Parkway, St. Paul, MN 55110. She has been involved in the chemical industry as an administrator, salesperson, and manager since 1984. She is active in associations in the chemical, coatings, corrosion, and inks industries, making significant contributions to technical and sales development. She has a B.A in marketing and business administration, was President of the Chemical Association of Pittsburgh in 1992, and was Chair of the Symposium of Environmental Issues in the Chemical Industry. She is a 2-year member of NACE. *MP*