

# Use of Corrosion Inhibitors in Global Shipping

## Of Electronic Equipment

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### ABSTRACT

During transit and storage, moisture or condensation may cause irreversible damage to highly sensitive electronic equipment. This can lead to great losses if the equipment is very expensive or its surface is critical.

There are several ways of protecting electronic equipment shipped to and from humid and tropical areas. Moisture-vapor barrier packaging, desiccants and corrosive gas scavenging bags have been used with various levels of success. Use of vapor phase corrosion inhibitors (VCIs) is one type of protection that is gaining wider acceptance. The cost savings ensuing the switch to VCI technology results in a substantial amount of money.

Corrosion testing, long-term exposure effects and performance in typical applications were investigated. The results are presented in this paper.

### INTRODUCTION

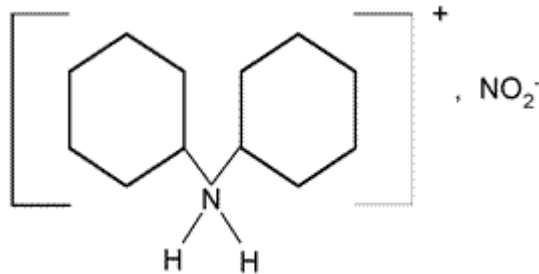
Shipping electronic equipment quite often proves to be a challenge due to the ever-increasing sensitivity of the printed circuit boards. Smaller dimensions and more compact assemblies place a strain on equipment reliability<sup>1</sup>. Exposure to corrosive agents during transportation may lead to premature failure in the field.

Several methods of protecting electronic equipment during transit and storage are available to the industry. They entail different levels of ease of application, cost, practicability and protection.

A method that has been utilized over the years is the use of MIL-B-131 Class 1 (Plastic, non-woven backing) barrier films<sup>2</sup>. The barrier film greatly reduces the amount of moisture entering the package, while the desiccant absorbs moisture found in the package. A vacuum is usually applied shortly after the installation of the desiccants in the package. While this method may provide good protection, it is labor intensive.

Another problem rests with customs procedures and storage in the country of debarkation. Quite often customs agents slit open the packages to inspect their content. Though a best effort is put forth in re-sealing the bags, the integrity of the package is no longer the same. The dry, low-pressure air has now been replaced with a humid environment that easily overwhelms the desiccant. This leaves the product susceptible to corrosion.

Use of vapor phase corrosion inhibitors in the electronic industry is one type of protection that is gaining wider acceptance<sup>3-8</sup>. VCIs are generally salts of moderately strong volatile bases and weak volatile acids. For example, one of the first VCIs developed was the salt formed by the reaction of Dicyclohexylamine with Nitrous acid:



Though it is still used in specific situations, DICHAN (Dicyclohexylammonium nitrite) has a very limited use in electronics. It offers limited protection to copper and is not recommended in applications where solder or lead is present. Volatile corrosion inhibitors combine corrosion-inhibiting properties with their ability to vaporize. Because of their volatility at ambient temperature, VCI compounds can readily reach inaccessible crevices in assemblies and form a molecular layer on the metallic surfaces<sup>9-20</sup>. Protective vapors disseminate within an enclosed space until equilibrium is reached. This equilibrium is determined by the partial vapor pressure of the VCI compound. Polyethylene films based on VCI technology eliminate the need for desiccants and substantially reduce the amount of labor necessary for packing electronic equipment. The flexibility, moisture protection, low cost and light weight of polyethylene are its most outstanding attributes. It has good transparency in thin sections such as films. Due to the nature of the resin carrier, customs agents can easily inspect the contents of a package. Temporary interruption of the VCI atmosphere during customs inspection is not detrimental to ensuring the protection of the equipment. Upon the re-sealing of the bag, the VCI source will promptly replenish the enclosure with volatile corrosion inhibitors so that preservation of the electronic may still be provided.

## EXPERIMENTAL

The VCIs used in this study were made of amine carboxylates and proprietary compounds. They were either incorporated in a low-density polyethylene film (VCI films) during extrusion or coated on a polyurethane foam (VCI foam). Another means of delivery consisted of a polyethylene cup containing a few grams of a blend of VCI compounds. A breathable membrane sealed on the edge of the cup ensured the slow release of VCI

vapors and prevented the spilling of the powder (VCI emitters).

### Test A

A predominant North American telecommunication company (Company A) manufactures cellular phone equipment that is shipped overseas. Company A used to protect the equipment during shipping with barrier bags and desiccants. Over the years, substantial cost overruns occurred due to broad corrosion problems. Eighty-six percent of the preservation packaging failed during an expedition to the Far East. The equipment had to either be returned to North America or repaired on site. Besides the fact that using barrier bags is labor intensive, the integrity of the package was compromised during customs inspections. Because of the opacity of the metallized films, agents would slit open the bags to carry out their work.

Faced with many problems, Company A decided to use a method that would eliminate corrosion and the concerns inherent to visual inspections by customs personnel. This new procedure would have to be compatible with the electronic components. Another important trait would be cost reduction for materials as well as labor. Finally, Company A was interested in a method that would be friendly to its employees and end-users. Personnel health and safety along with the impact on the environment were also critical aspects in choosing the method. After reviewing several ways of protecting the electronic equipment, Company A decided to further evaluate VCI technology.

Several real life tests were devised to properly assess the protective properties of VCI films, VCI foams, and VCI emitters. One of the most challenging shipping destinations was the Far East. As previously mentioned, corrosion would lead to a large number of costly rejects or reworks. Company A packaged six units in a barrier film aided by desiccants under vacuum (control units). Six other units were prepared using VCI technology (Figures 1-3). A VCI film with VCI foam and VCI emitters protected the equipment under normal atmospheric pressure. The control units as well as those packaged with the VCI products were placed on an ocean-going vessel from North America to Singapore. The journey took six weeks with the temperature varying from 7 to 54°C (45 to 130°F) and the relative humidity being as high as 97%.

### Test B

Another major North American telecommunication company, Company B, faced the same problems that Company A dealt with. Standard packaging methods involved MIL-B-131 vapor barrier bags. The packaging material was opaque, required the application of a vacuum and needed heat sealing. As aforementioned, this technique was expensive in terms of labor and materials. Shipping both domestically and Internationally, Company B encountered numerous equipment failures due to corrosion. Finally, disposal of the barrier bags in landfills did not portray the environmental consciousness of Company B. Following several studies on alternative methods, Company B decided to further evaluate VCI technology as it met the requirements it had established for the new procedure. The VCI bags made of polyethylene are translucent, do not need heat-sealing and are

recyclable. The packing procedure did not require vacuum use, making it very cost effective. Finally, the cost of the materials was less than that of the barrier bags.

To some extent, Company B approached the evaluation in a different manner than Company A. Accelerated corrosion testing in humid environments was a main point of their investigation. Copper, steel and brass coupons were introduced in either a barrier bag or a VCI film. Each bag was sealed with PVC tape. A set of coupons without packaging was used as control. The test samples were then placed in a humidity chamber (Method ASTM D 1748)<sup>21</sup>. The temperature inside the chamber was 49°C (120°F). A 100% condensing relative humidity was established in the chamber per the standard test method. The panels were evaluated for signs of corrosion at 7, 14 and 21 days.

### Test C

A large European telecommunication company (Company C) manufactures digital phone equipment that is shipped to several locations over the world. Company C found similar problems with using barrier bags that affected Company A and Company B. Company C used a combination of the approaches used by the two aforementioned companies. It carried out a yearlong evaluation of the VCI films both in the laboratory and in the field. The laboratory testing involved humidity chambers, while the field assessment duplicated real-life conditions.

## RESULTS

### Test A

The units shipped by Company A were evaluated for corrosion upon their arrival in the Far East. Four out of the six units packaged with the barrier film and desiccants were severely corroded and subsequently rejected by the end user. All six units packaged with the VCI film and VCI emitters were free of corrosion and were accepted by the customer. Another benefit was that the customs agents easily inspected the assemblies at the debarkation site.

The procedure using VCI technology was implemented in 1992 for all destinations. Since then there has been no corrosion reject. Company A was able to reduce the labor cost by 63%. At the same rate, the materials cost was cut by more than half (54%). Another benefit was the VCI film is 100% recyclable, eliminating the need for disposal in landfills.

### Test B

Results for the test designed by Company B showed that VCI bags offered excellent protection to all three metals in a high humidity environment contrary to the control set and the vapor barrier bags (Figures 4-6).

Based on the laboratory reports, Company B first implemented this new procedure on a small scale. Units were packaged and shipped to several locations (Figure 7). Since the

implementation in early 1999, there have been no corrosion claims. As was the case with Company A, substantial savings were obtained by eliminating rejects and reducing the labor and materials cost.

### Test C

Based on positive test results in both the laboratory and the field, Company C implemented the use of VCI technology for the protection of their equipment during transit and storage. Company C has been using this technique since 1994 (Figure 8). Since then, the cost reduction subsequent to the implementation has been reduced 50 to 60% for both labor and materials. Another obvious benefit was a sharp decrease in corrosion problems that translated into further savings.

## DISCUSSION

As demonstrated by the testing carried out by the telecommunication companies, VCI technology is very effective in providing protection to sensitive electronic equipment. Despite harsh environments and less than ideal conditions, the VCI films ensured that the equipment would be free of corrosion and functional upon arrival to the customer. The extended period over which the VCI products have been used in such applications put forth the innocuity of these chemical compounds. The companies reported no premature failure due to corrosion or other factors.

Another added benefit is that VCI films can readily be recycled. Contrary to laminated constructions such as barrier films, which are disposed of in landfills, VCI bags may be reprocessed into other products.

Finally, several studies have demonstrated the low impact of VCI compounds to people and the environment<sup>22,23</sup>.

## CONCLUSIONS

Following extensive accelerated and real-life testing, phone equipment manufacturers switched to using VCI technology. The cost savings ensuing the switch amounted to several million dollars.

The benefits of using VCI technology are numerous. The use of VCI films is economical, has a low health and environmental impact, is non-detrimental to the proper function of the protected equipment, allows easy visual inspection of the packaged goods, and, obviously, provides excellent protection to sensitive electronic equipment.

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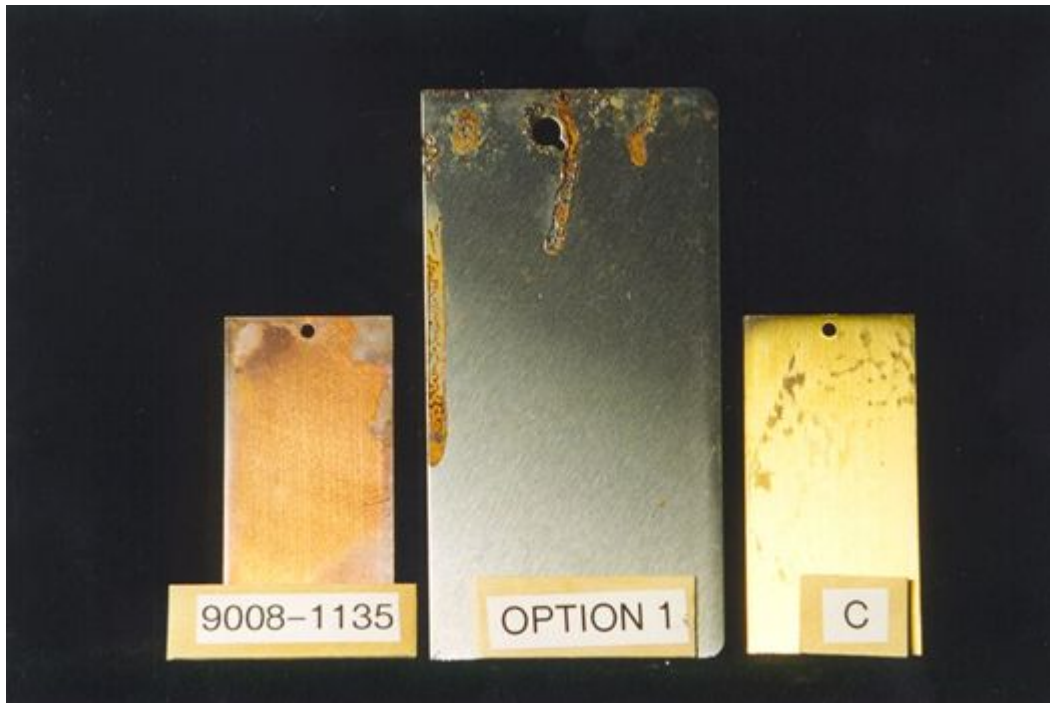
**Figure 1. Cellular Phone Equipment Protected by VCI Technology Company A**



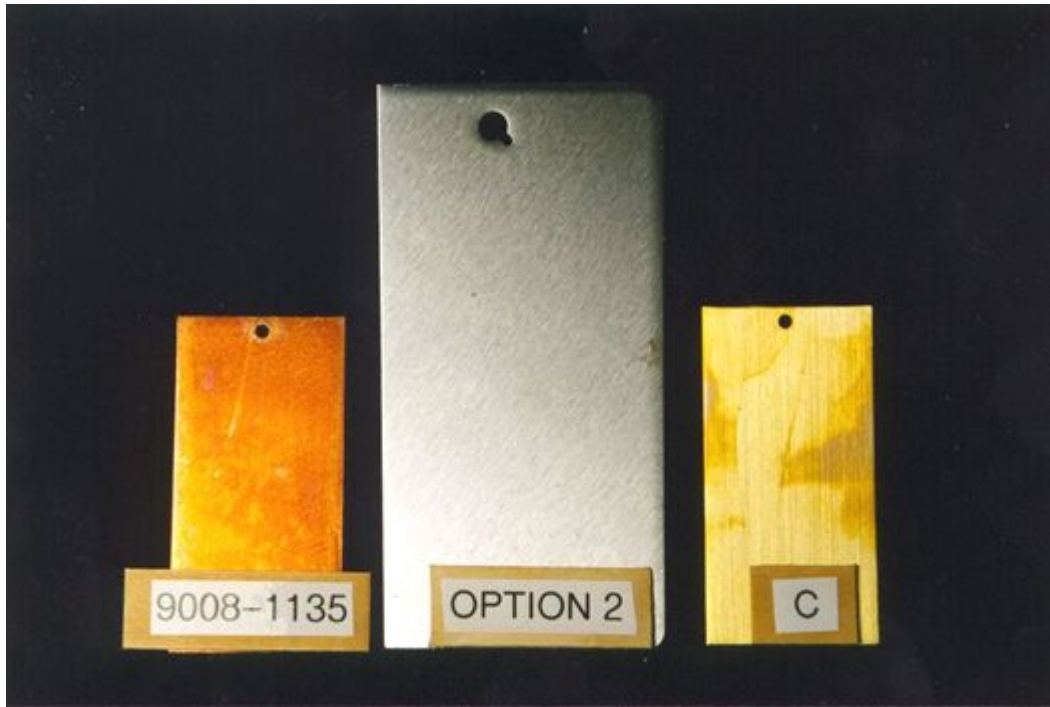
**Figure 2. Package Made of VCI Film and VCI Emitters Company A**



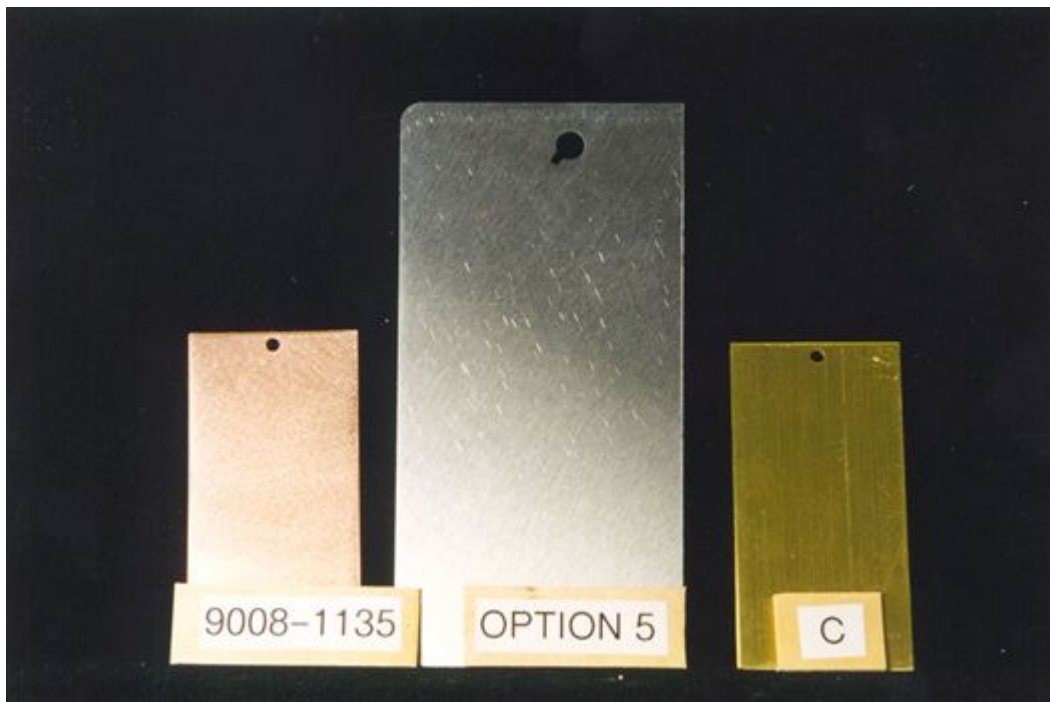
**Figure 3. Final Assembly using VCI Technology Company A**



**Figure 4. Control After 21 Days in a Humid Environment  
(Copper/Steel/Brass)**



**Figure 5. Barrier Bag After 21 Days in a Humid Environment  
(Copper/Steel/Brass)**



**Figure 6. VCI Film After 21 Days in a Humid Environment  
(Copper/Steel/Brass)**



**Figure 7. Phone Equipment Protected by VCI Technology Company B**



**Figure 8. Digital Phone Equipment Packaged in VCI Bags Company C**