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PROTECTION OF EQUIPMENT FOR STORAGE AND TRANSPORT WITH VAPOR PHASE CORROSION INHIBITORS

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ABSTRACT

Application of Vapor phase Corrosion Inhibitors (VCI) for protection of various industrial and military equipment from corrosion during storage and overseas transport provides numerous advantages. When VCI inhibitors are being applied during the process of corrosion protection they will enable strong protection of the equipment during storage and transport without additional time and money needed prior to putting equipment in operation. During transport the equipment travels through various climate zones experiencing changes in temperature and humidity that are favorable to corrosion. Changes in humidity and temperature levels during transport even at very short distances can create moisture that condenses into water. Properly chosen combination of Vapor phase corrosion inhibitors enables the equipment and its components (especially electrical components) to resist the corrosion caused by moisture and aggressive saline environment. The requirements that need to be fulfilled during the application of inhibitors vary depending on the conditions of the application as well as required time limits of corrosion protection process. Vapor phase Corrosion Inhibitors (VCI's) are thermo-stable and they do not damage ferrous or non-ferrous metals. Inhibitors will not affect electrical, physical or chemical properties of lubricants if used in lubrication systems.

The paper includes laboratory testing data and application methods of shrink film, impregnated foams and coatings containing vapor corrosion inhibitor (VCI) that are being applied in conservation process of industrial and military equipment. The experimental part of this paper will include validation of effectiveness of this system using standard test methods according to ASTM, MIL-SPEC, NACE and DIN standards.

Key words: corrosion, vapour corrosion inhibitor

INTRODUCTION

Vapor corrosion inhibitors are organic compounds that have a low pressure saturated steam under atmospheric conditions and inhibit corrosion by adsorption to the metal surface. They alter the kinetics of electrochemical reactions. Most effective inhibitors are the ones whose vapor pressure is in the range 10-5 - 10-7 mm Hg [1-3]. Inhibitors diffuse trough the gas phase and are adsorbed to the metal surface in thickness of several nano layers and to protect it from corrosion, Figure 1.

Vapor corrosion inhibitors on the metal surface form hydrophobic protective coating. The main task of vapor corrosion inhibitors is to prevent the process of corrosion of metal parts during the entire life cycle of production, packaging, storage, transport and during application [4-11]. Vapor corrosion inhibitors (VpCI®) are thermostable, do not damage non-ferrous metals or affect electrical conductive properties and physical and chemical properties of the lubricant if applied in lubrication systems.

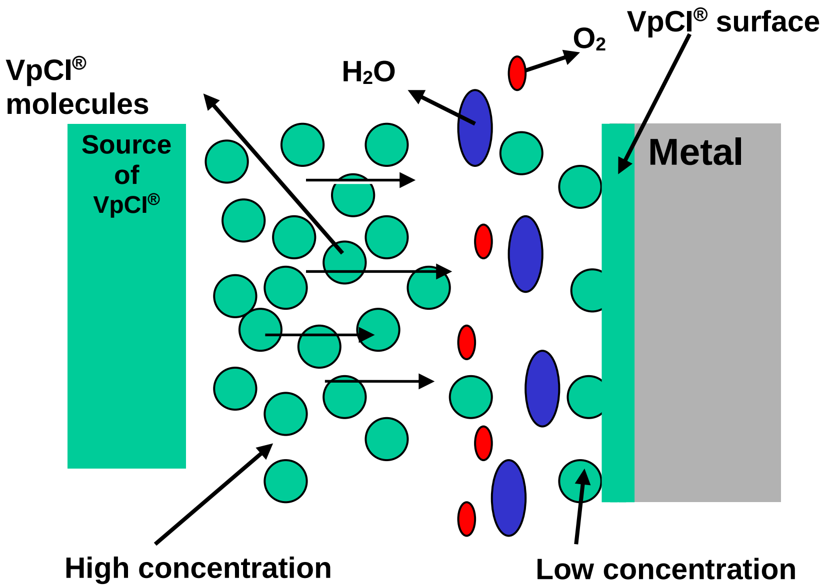


Figure 1. Diffusion of VpCI® molecules

For storage in indoor space up to one year or shorter transports: oil, paint or a good wax paper can be used. However, for storage of 3-5 years or overseas transportation requires stronger and safer corrosion protection. These are primarily: coatings, polyurethane foams or different materials for wrapping / polymer-based coating materilas.

Temporary corrosion protection on these materials is achieved by adding a corrosion inhibitor in the coating and foams of different shapes as well as the polymer film during extrusion. In this case, those materials act as corrosion inhibitor carriers and a source of corrosion inhibitor.

Inhibitor carriers or source of corrosion inhibitors are commercially available in a variety of conditions such as: liquid, powder, paper, coating (wet or dry film), impregnated foam and polyethylene film. On figure 2. and 3. you can see a few examples of application of VpCI® inhibitors.

Figure 2**.** Application in transportation of equipment.

Figure 3. Application for military.

EXPERIMENTAL PROCEDURE

In this study, the efficiency of vapor corrosion inhibitor impregnated in PE foil, impregnated foam and coating is examined.

Testing of the coating with corrosion inhibitor VpCI®-368D

The coating used for the protection of aluminum, carbon steel and copper is polycyclic aromat in mineral oil comprising of hydro treated heavy distillate, aliphatic amine, corrosion inhibitor based on sulfate and vapor corrosion inhibitor based on amino carboxylate. Quanitity of vapor corrosion inhibitor in the coating is about 5%. The coating with vapor inhibitor was applied to the cleaned metal plates in layer thickness of 50-75 microns.

In accordance with DIN EN ISO 6270-2, a survey of samples were placed in a humidity chamber to determine the corrosion protection of samples of carbon steel, aluminum and copper. Samples were placed in a humidity chamber of heated saturated mixture of air and water vapor, with temperature of 42 ° C and 100% relative humidity lasting until corrosion occurred. Due to the small differences in temperature of samples and steam, condensation occurred on the surface of the samples. The samples after exposure to humidity chamber were evaluated in accordance with NACE Standard TM0208-2008.

Salt spray testing was conducted in accordance with ASTM B117, ISO 9227: 2006 with the aim of determining the resistance of the samples for signs of corrosion. Samples were subjected to a controlled environment within the salt chamber Ascott S450. Testing was carried out in 5% NaCl solution, and the temperature in the chamber was 35 ° C.

According to ISO standard 12944, for C3-medium corrosivity conditions, sample testing in salt chamber was prescribed in duration of 10 days (240 hours). Figure 4. shows the control samples of copper, aluminum and steel, and after exposure to humid chamber after 336 hours and exposure to salt chamber after 144 hours.

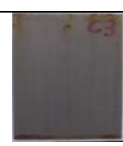
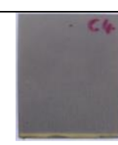
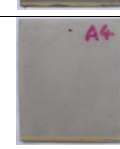
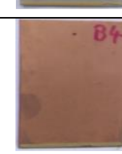
Tested sample	SALT CHAMBER ASTM B117		HUMIDITY CHAMBER D1735	
	Control plate	Salt chamber 144 hours	Control plate	Humidity chamber 336 hours
Steel				
Aluminum				
Copper				

Figure 4. Testing of the coating with corrosion inhibitor VpCI®-368D (dry film)

Testing of the coating with corrosion inhibitor VpCI®-369D

This coating is polycyclic aromatic hydrocarbon in mineral oil, consisting of hydrotreated heavy distillate, aliphatic amine, corrosion inhibitor based on sulfate and vapor corrosion inhibitor based on aminocarboxylate. The coating with vapor corrosion inhibitor was applied on clean rust-free plaits made from carbon steel, aluminum and copper in a thickness of 50-75 microns. Concentration of vapor corrosion inhibitor in this coating is about 5%.

The effectiveness of protection on test samples was carried out by exposure in humidity and salt chamber. Testing results are shown in Figure 5.

Tested sample	SALT CHAMBER ASTM B117		HUMIDITY CHAMBER D1735	
	Control plate	Salt chamber 144 hours	Control plate	Humidity chamber 336 hours
Steel				
Aluminum				
Copper				

Figure 5. Testing of coating with corrosion inhibitor VpCI-369 Aerosol (wet film)

Testing of polyurethane foam with corrosion inhibitor VpCI®-137

The effectiveness of the protection of vapor corrosion inhibitor impregnated into polyurethane foam were carried out on samples of aluminum, copper and carbon steel by exposure to salty and humid chambers. Figure 6. gives an overview of the samples after the testing was conducted.

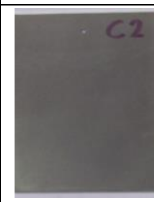
Tested sample	SALT CHAMBER ASTM B117		HUMIDITY CHAMBER D1735	
	Control plate	Salt chamber 144 hours	Control plate	Humid chamber 366 hours
Steel				
Aluminum				
Copper				

Figure 6. Testing the effectiveness of inhibitors impregnated in the foam

Testing of polymer with corrosion inhibitor MilCorr VpCI Shrink Film

The effectiveness of the protection of vapor corrosion inhibitors MilCorr VpCI® shrink film were carried out on samples of aluminum, copper and carbon steel and also by exposure to salt and humid chambers. Figure 7. provides an overview of the samples after testing.

Salt chamber after 10 days			
Humidity chamber after 10 days			
	Aluminum	Copper	Carbon steel

Figure 7. Testing of the polymer in salt and humidity chamber

RESULTS

1. Laboratory tests results after testing of the coating with vapor corrosion inhibitor VpCI®-368D DFT 50-70 microns in salt and humidity chamber show successful protection on steel and aluminum, while the protection of copper in salt chamber after 80 hours leads to corrosion (see figure 4.).

2. Results of laboratory testing of the coating with vapor corrosion inhibitor - VpCI®-369D DFT 60 microns show the successful protection of steel, aluminum and copper in humid chamber in lasting of 336 hours. In the salt chamber samples of aluminum and copper remained unchanged for 144 hours, while on carbon steel the corrosion occurred after 24 hours (see figure 5.).

3. Results of laboratory tests of the effectiveness of protection of vapor corrosion inhibitors impregnated foam VpCI-137 show successful protection on steel, aluminum and copper in a humid chamber for a period of 336 hours. On the sample of copper in aggressive atmosphere such as salt chamber corrosion has been abserved after 98 hours. In salt chamber carbon steel sample has been corrosion free for 72 hours. On aluminum corrosion was not noted for 144 hours (see figure 6.).

4. Results of laboratory testing of the effectiveness of the protection of vapor corrosion inhibitors impregnated in the polymer film called MilCorr VpCI® Shrink Film show successful protection on steel, aluminum and copper in salt and humid chamber for a period of 240 hours (see figure 7.).

CONCLUSIONS

By examining the effectiveness of the protection of vapor corrosion inhibitors in salt and humidity chambers the following has been proven:

- Vapor Corrosion Inhibitor VpCI®-368 D in form of coating shows effective protection on steel and aluminum, while the protection of copper salt chamber has been evaluated as less affective.
- Vapor Corrosion Inhibitor VpCI®-369 D in spray shows successful protection on steel, aluminum and copper in a humid chamber for a period of 336 hours, while the protection of carbon steel in aggressive atmosphere such as salt chamber was evaluated as less efficient. A sample of carbon steel has was noted to last 24 hours until corrosion occurred
- Vapor Corrosion Inhibitor VpCI®-137 impregnated in the sponge demonstrates the successful protection on steel, aluminum and copper in a humid chamber for a period of 336 hours, while the protection of copper in aggressive atmosphere such as salt chamber was evaluated as less efficient. A sample of carbon steel was present for 120 hours in salt chamber without corrosion.
- VpCI® inhibitor in MilCorr polyethylene film with vapor corrosion inhibitor showed effective protection to steel, aluminum and copper for a period of 240 hours

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