

Evaluation Of Relative Humidity Dependence For Volatile Corrosion Inhibitor Desorption

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ABSTRACT

Major Volatile Corrosion Inhibitor (VCI) packaging manufacturers tout the ability of VCIs to desorb once the protected metal part is unwrapped. This design feature is key to providing the clean metal part to be assembled, put in use, or further machined without the need for the part to be cleaned. Most VCIs rely on high vapor pressures and low binding affinities to desorb from the metal surface effectively. This paper describes a latent protective film that remains on the part after unwrapping. Furthermore, we evaluated how the relative humidity (RH) of the environment affects the VCI's ability to desorb from the metal surface.

Key words: Chemical Inhibitors; Coatings; Science of Corrosion; Testing

INTRODUCTION

The use of volatile corrosion inhibitor packaging continues to be a mainstay in protecting metal parts in shipping and storage. Initial protective packaging applications of VCIs involved coated paper¹⁻⁴ which was used to wrap or interleave metal parts for transportation and/or storage. This type of wrapping evolved into film packaging where the inhibitors were extruded into film.⁵ In either form, paper or film, the packaging allows for the protection of metal fabricated parts without complications of rust preventative (RP) oils, which would typically have to be washed off. As VCI chemistries vaporize from the film or paper and diffuse throughout the package, they are attracted to the polar nature of the metal part, forming a protective molecular layer on metal surfaces.^{6,7} This occurs even when the part is not in direct contact with the paper or film.

In contrast to VCI adsorption during packaging, what happens when metal part is unpacked from the VCI material? How long does VCI desorption take? Is there going to be an effect on downstream processes if there is still VCI remaining? These are some of the questions that end users will ask of VCI packaging manufactures. There seems to be no real general understanding of the inhibitor film longevity. Furthermore, there does not appear to be any reports in the literature on VCI desorption. As more and more suppliers try to enter the marketplace, it is imperative that these valuable technologies be used and understood appropriately.

Background

The mechanism of protection is based on two principles: 1) the VCI compound migrates from the packaging material to the metal surface and 2) the VCI creates a modified surface on the metal to prevent corrosion. This last principle is highly discussed and there are many publications that argue the true means of protection.⁸⁻¹⁰ These arguments revolve around whether it is an active film that affects the electrochemical pathway of the corrosion cell, or a passive layer that can prevent corrosive materials from reaching the metal surface, or both. None-the-less, the first step of VCI migration to the metal surface does occur and can be measured. There are few techniques published for monitoring VCI absorption to a metal surface.¹¹⁻¹⁶ The simplest technique for measuring VCI migration is observing the surface tension change over time. Under certain circumstances, as the VCI film is deposited onto the surface of the metal, the surface tension will change and become more hydrophobic, or water repelling. This phenomenon is easily observed by measuring the contact angle of water droplet on the surface of the metal.

Wetting is the ability of a liquid to maintain contact with a solid surface. This results from intermolecular forces of liquid and solid surface when brought together. The direct contact of water with a metal surface in the presence of oxygen is the perfect recipe for corrosion. By creating a passive, surface film one can impart protection of the part by blocking water from contacting the metal surface. This is an understood mechanism for when mineral-based, rust preventatives are used. In actuality, there is a much more complicated mechanism, but for all intense and purposes we will focus on the effectiveness of hydrophobic films as a proxy for a rust prevention.

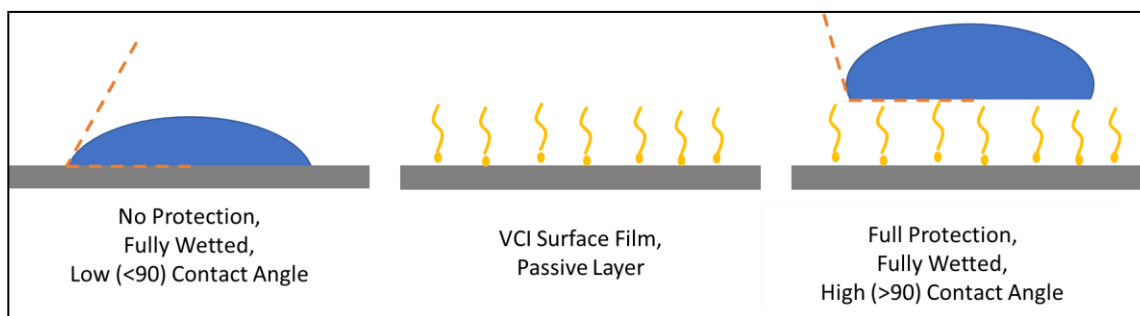


Chart 1. Diagram of VCI Surface Film and Contact Angle

Under film forming conditions, water can “bead up” on the surface. As the surface becomes more hydrophobic, the shape of the droplets will be more pronounced. Using contact angle of purified water on a metal surface one can identify the general hydrophobic nature of the protective film. The use of contact angles to measure VCI adsorption over time has been long studied. There are varying reports on the length of time for an effective surface film to setup on the surface. Some reports suggest in as little as 1 hour¹¹ and others for as long as two days¹³. Regardless, all reports that utilize contact angle measurements rely on principle of the hydrophobic tail of the VCI contributes to the overall surface tension change and pronounced water droplet (larger contact angle).

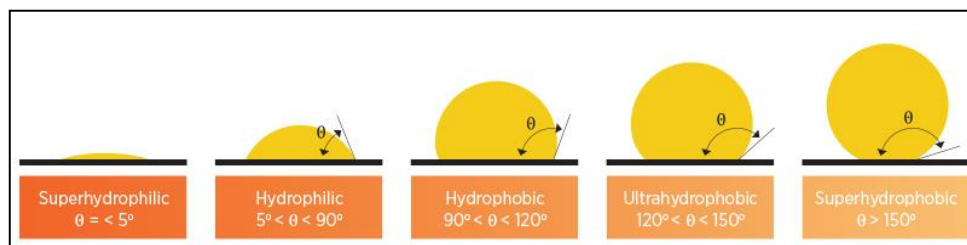
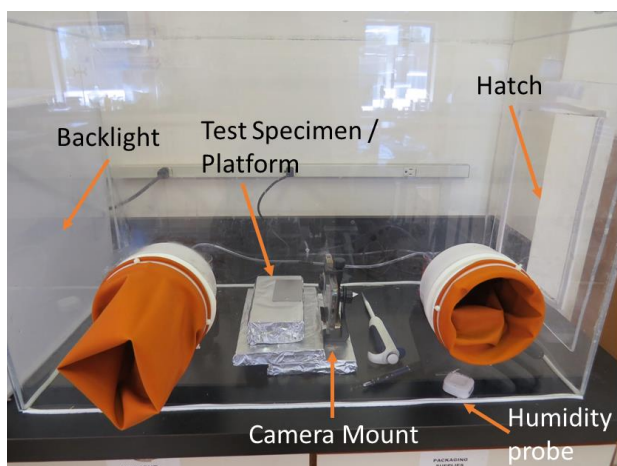


Chart 2. Contact Angle Versus Surface Tension

EXPERIMENTAL APPARATUS/PROCEDURE

Apparatus: An instrument called a contact angle goniometer or tensiometer measures the static contact angle, advancing and receding contact angles, and sometimes surface tension. Static contact angle offers a quick, easy, and quantitative measurement of surface tension (wettability). The measurement is based on Young’s equation which assumes that interfacial forces are thermodynamically stable. Although, these are powerful instruments with high level of accuracy, for our experimentation they are not cost effective, too large in profile or conducive to studying changes in RH.

We opted to build a climate-controlled test chamber from clear, acrylic sheets. The chamber is insulated so that we could vary the internal RH and run the water drop testing in a controlled manner. The test chamber was built with a removable hatch to allow for specimens to be easily inserted/removed. Ports and rubber gloves were attached to allow for operation of tools within while also maintaining internal conditions. The internal humidity was increased by use of small air pump and distilled water bubblers. The bubblers were operated until consistent humidity was achieved and then switched off. To decrease humidity, we utilized desiccant packs which are easily obtained from online marketplaces. The RH was monitored by two, digital-humidity probes and the average was reported.



Apparatus Setup