Technical Bulletin

#116

Volatile Corrosion Inhibitors: Volatility vs. Temperature

ARMOR Protective Packaging® products utilize proprietary ARMOR Volatile/Vapor Corrosion Inhibitor (VCI) Nanotechnology. VCI are a class of corrosion inhibiting compounds which have sufficient vapor pressure to release molecules from a carrier into the air. The presence of humidity or moisture greatly aids in the release of ARMOR VCI. Once released, the molecules are disseminated throughout an enclosed air space to the metal surface by diffusion. ARMOR VCI molecules attach themselves to the metal surface to form an invisible thin film, only a few molecules thick. The VCI film passivates the surface and inhibits the electrochemical reaction that causes corrosion.

VCIs rely on their vapor pressure to volatize out of the carrier to fill an enclosed area. It is desirable for a VCI to provide the inhibitor rapidly and to have a lasting effect. Therefore, the compound should have a high enough vapor pressure to saturate all the accessible vapor space as quickly as possible but also have a low enough vapor pressure to sustain protection over a long duration. ARMOR Protective Packaging® uses mixed inhibitor technology that provides a range of vapor pressures. It should be noted that not all VCI formulations perform this way. ARMOR's VCI technology is a result of years of research and development and backed by field experience of over 30 years.

The amount of inhibitor molecules emitted by a VCI is a function of temperature and humidity. As temperature and humidity rise, so does the rate of corrosive attack on the metal. Likewise, the vapor pressure of ARMOR VCI increases as well, resulting in the release of additional VCI vapors to protect the metal surface. The opposite is also true; as temperature and humidity decrease, the vapor pressure of ARMOR VCI also decreases.

Temperature Effects

Temperature can have a significant effect on the corrosion of metals. Like many other chemical reactions, corrosion rates increase as temperature increases. For most packaging applications, processing, storage, and shipping occurs within the temperature range of 0°C to 75°C. Within this temperature range, the corrosion rate doubles for every 10°C to 15°C rise in temperature.

The VCI concentration increases in the packaging environment as temperature increases. The vapor pressure of any solid or liquid changes dramatically as temperature changes. The vapor pressure of any substance increases non-linearly with temperature according to the Clausius–Clapeyron relation. The vapor pressure changes by the square of the change in temperature. The following graph depicts three VCIs that ARMOR uses as part of the mixed inhibitor technology.

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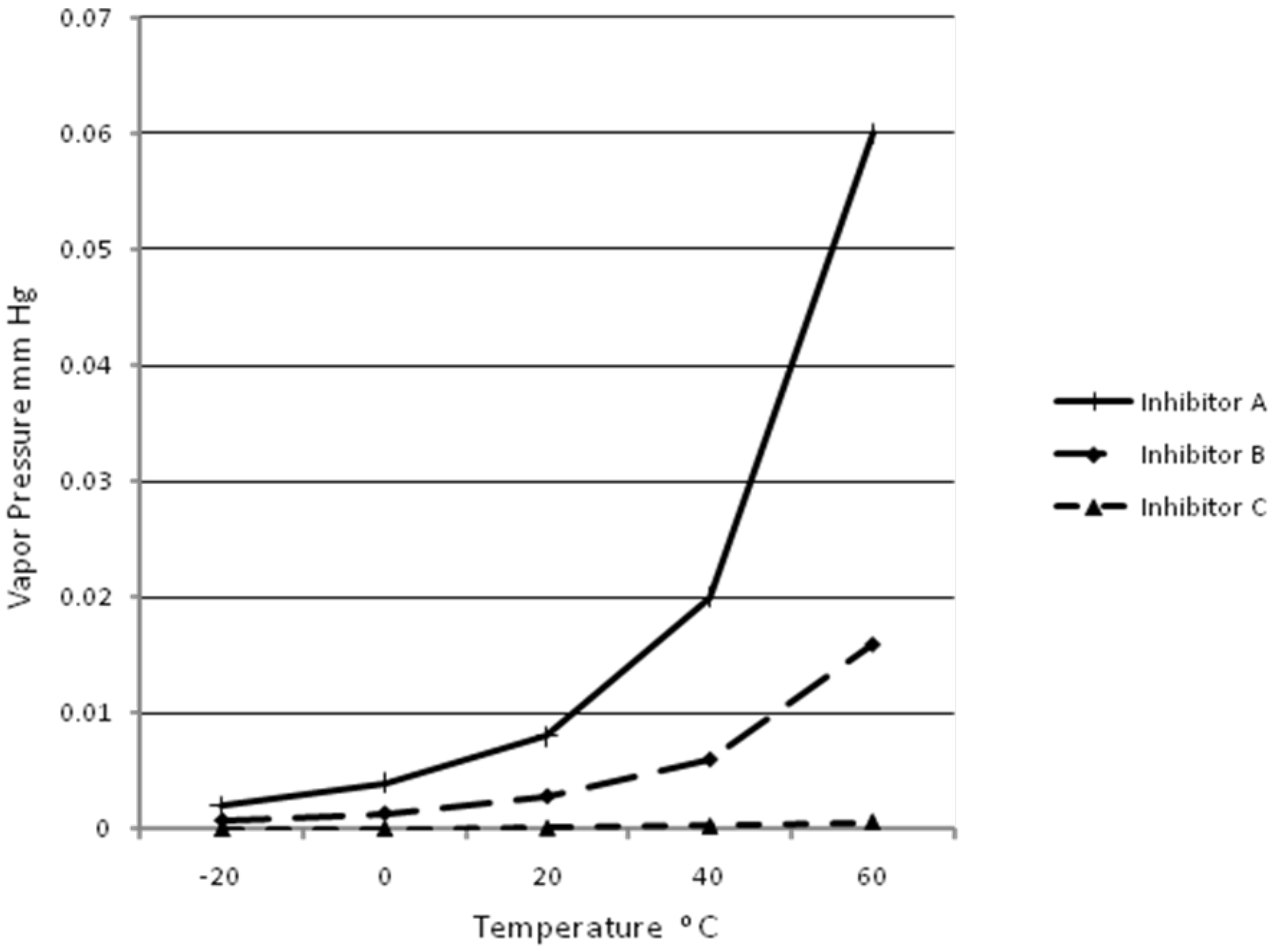

Vapor pressure vs temperature for three Volatile Corrosion Inhibitors

ARMOR Protective Packaging® mixed inhibitor technology provides a range of vapor pressures. High vapor pressure VCI (Inhibitor A) volatizes more rapidly to provide protection as quickly as possible. The lower vapor pressure VCIs (Inhibitor B and Inhibitor C) have low enough vapor pressures to sustain protection over a long duration.

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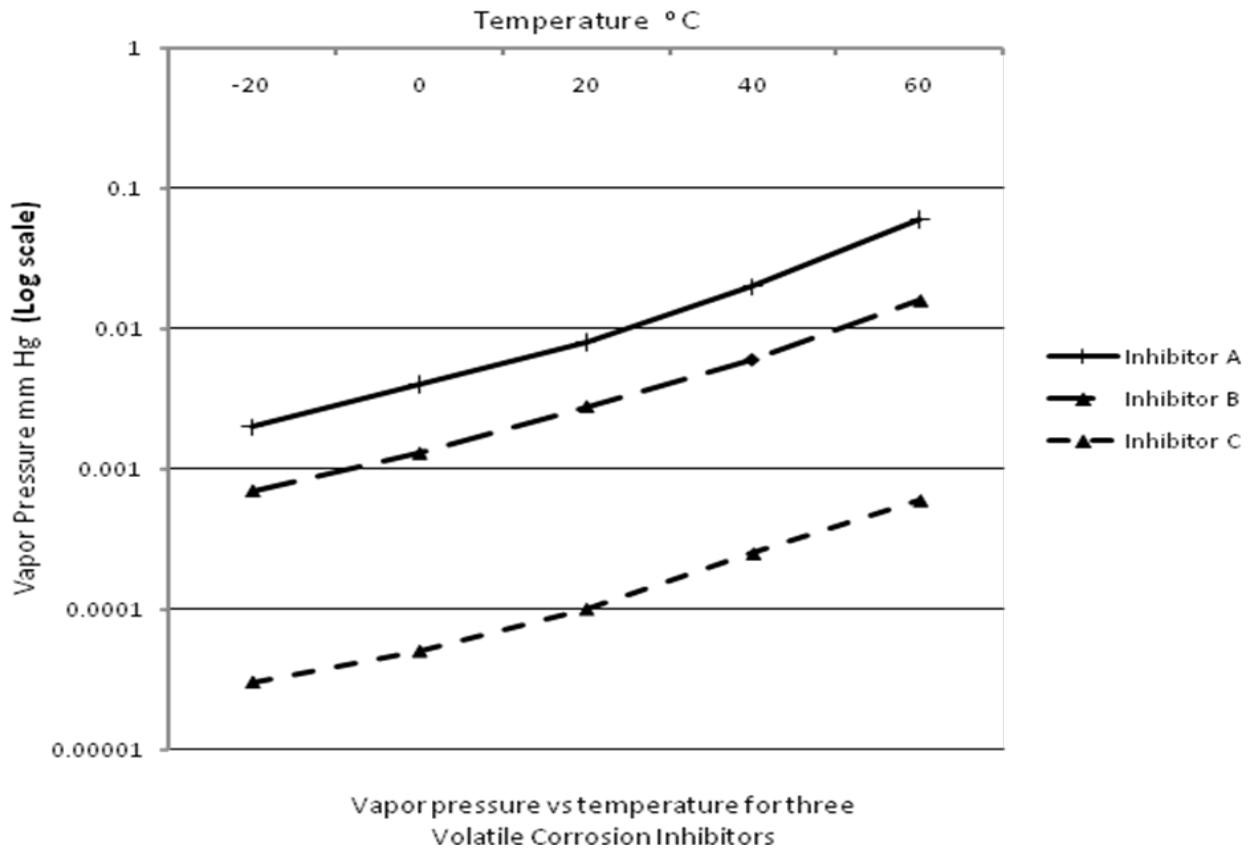
Because the vapor pressure changes dramatically with changes in temperature, the relative vapor pressures can best be viewed on a logarithmic scale. The following graph depicts the temperature/vapor pressure relationship for the three inhibitors utilizing a Log scale for vapor pressure.



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Humidity Effects

Because moisture provides the electrolyte, which is required for corrosion reactions, humidity is a major factor for the corrosion rate of metals. In general, the corrosion rate increases as humidity increases. The critical level of relative humidity in order for significant corrosion to occur is 60%. As moisture levels increase, VCIs become more active. The presence of moisture increases the concentration of VCI in the air space and on metallic surfaces.

Higher humidity levels increase the concentration of VCIs in the enclosed environment. The VCI carrier contains corrosion inhibiting ionic compounds. When moisture is present in and on the carrier, the ionic compounds partially dissolve to form ions. The vapor pressure of the VCI ion solution is higher than that of the ionic compounds resulting in more VCI being released when moisture is present.

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