Combatting Corrosion in the U.S. Navy

A 2006 LMI Government Consulting study identified that the navy's corrosion funding requirement was \$2.44 billion [1] an updated to \$3.15 billion in 2010 [2].

Corrosion may require repair and it often impacts maintenance availabilities. Perhaps even more problematic is weapon systems and electronics degradation its impact on readiness and safety. Successful corrosion management leads to a reduction in total ownership cost by managing maintenance availabilities which has a flow on effect of enabling greater deployment flexibility.

Appropriately applied coatings, including polysiloxane and chemical agent-resistant coatings (CARC), are designed to prevent the corrosive environment from attacking the metal substrate.

Coating systems fail from exposure to ultraviolet (UV) radiation, chemical and biological agents, freeze-thaw cycles and abrasion. The coating failure rate exacerbates the corrosion rate [3], starting a cycle that degrades over time (Figure 1).

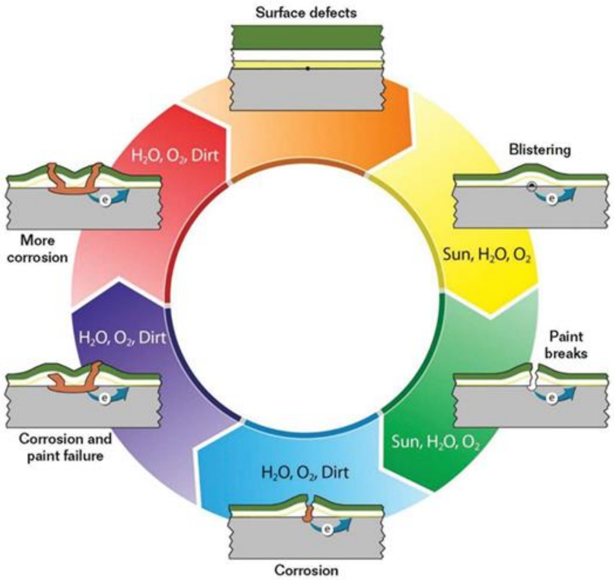

Figure 1. Paint failure and corrosion cycle.

Prolonged exposure to UV radiation causes organic coatings deterioration, a process known as photo-oxidation deterioration, which can be exacerbated by local geographic conditions. Furthermore, CARC "flat gloss" systems absorb more UV and infrared radiation than gloss finishes and are more prone to photo-oxidation deterioration.

Chemical and biological induced damage increased dramatically over the years in line with an increase in the concentration of carbon dioxide, sulfur dioxide, greenhouse gases, and other pollutants. These pollutants produce water-soluble salts, a precondition for acid rain which over time damages and breaks down all coatings and finishes.

Precipitation and humidity all accelerate the rate of corrosion. Daily condensation and dew will pond in all surface micro-cracks in a coating. As the water expands during a freeze-thaw cycle, it also expands the surface micro-crack allowing more water to pond. As the cycling continues, the micro-cracks grow both wider and deeper, until the crack penetrates the full coating thickness and the metal substrate is exposed to water and the corrosion cycle commences.

Abrasion causes coating damage when dust, dirt, mud, gravel, rocks, wind, snow, ice, and other solid materials impact the coating. The extent of the abrasion depends on a number of factors which includes impact energy, angle of impact and repetition.

The driving force for metallic corrosion is the change in Gibbs energy (ΔG), as the system seeks a lower energy state. Three of the most common corrosion mechanisms of painted metal are blistering, cathodic delamination, and anodic delamination [4].

Blistering is triggered when surface impurities are exposed to water. Cathodic delamination requires a micro-crack in the paint film and the presence of either oxygen or water to establish anodic and cathodic sites. Aluminum substrates are susceptible to anodic delamination; the aluminum oxide layer is consumed in an anodic reaction, which weakens the bond between the paint and the substrate.

In summary, there are many degradation mechanisms that initiate coating failure, only one is required to start the corrosion cycle, Figure 1.

Transhield Inc. (Transhield) has developed an advanced protective cover technology to extend the life of coating systems and provide the U.S. Navy with the following benefits including multiple lines of defense against corrosion.

Transhield's R&D team have focused on designing lightweight corrosion control covers, with a life span of two

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to four years. In addition, the designs have an excellent strength to weight ratio requiring only one person to deploy most covers, providing long term protection in even the most severe environments.

Transhield's advanced corrosion reduction covers are designed to protect coatings and specifically CARC systems. These covers contain a soft, inert, hydrophobic fiber to protect painted surfaces and glass from rubbing that occurs between the cover and the surface resulting from wind and precipitation effects.

The first line of defense is to provide protection from UV radiation, chemical and biological agents, precipitation and debris. Designed to be effective even when temperatures range from -30 to 140°F[1], Transhield advanced protective covers have excellent long term UV protection, most providing up to 99% protection.

Transhield leverages the fact that a waterproof membrane that is also water vapor permeable protects steel against corrosion better than a less permeable membrane or a total barrier [5] to provide the **second line of defense**. Transhield anti-corrosion covers have water vapor transmission rates which achieve the necessary humidity reduction beneath the cover.

Harnessing Vapor Corrosion Inhibitors (VCIs), embedded inside the cover itself, enables Transhield to deliver a **third line of defense**.

VCIs released from the cover are attracted to the metallic substrate and form a protective molecular barrier. Results from extensive corrosion inhibitor research reveal that VCIs perform best when they are in a volatile form. Airborne VCI molecules also provide a self-healing capacity as they are attracted to the bare metal if for any reason the VCI barrier is broken. This capability requires a precise VCI formulation at an optimum vapor pressure, achieved by Transhield's patented technology.

There are many laboratory standards and natural weathering tests to quantify the performance of vapor corrosion inhibitors and it is crucial to test the advanced corrosion control covers, including the VCI in the field to confirm the cover's performance where it really matters [6].

Typical test results show that coupons far inside the cover experienced 0% corrosion, inside and immediately adjacent to the cover 15% corrosion, which compared favorably with the control which experienced 77% corrosion, Figure 2. Photographs of the coupons after the test are shown in Figure 3.

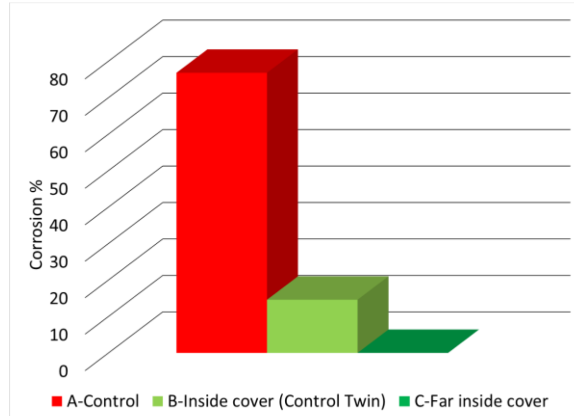

Figure 2. Corrosion after six months of natural weathering.

Figure 3. Coupons after six months of natural weathering.

The synergy of a superior VCI package, an efficient VCI delivery system, the ability to remove humidity away from the surface, and blocking out UV rays is the key to protecting Navy assets from corrosion. Furthermore, employing an anti-corrosion cover sooner in the life cycle of equipment optimizes its effectiveness and overall value.

Independent Approval: In 2013, NAVSEA approved the next generation advanced protective cover with VCI technology developed by Transhield. Made from ArmorDillo®, these second-generation covers provided a lighter, more form-fitting cover.

Bottom Line: Three fundamental components are required to protect assets:

1. Covers must be made from VCI enhanced fabric.
2. Cover design matters; covers must be form-fitting.
3. Covers need to be installed correctly and secured property to protect equipment.

References

[1] Herzberg, E.F., et al., The Annual Cost of Corrosion for Army Ground Vehicles and Navy Ships, Report SKT SOTI, April 2006.
[2] Herzberg, E.F., et al., Estimate for the Annual Cost of Corrosion for Navy Ships: FY2088-10 Update, Report DAC2ITI, September 2012.
[3] Broesder, E., Forever Young, *World Pipelines,* January 2012.
[4] Lezzi, R.A., Corrosion Mechanisms of Painted Metal, PSCT Symposium, September 20, 2012, Philadelphia, PA, PSCT, 2012
[5] Visioli, D.L., Chen, J.C., Shi Hua Zhang, Effect of Polymer Film Permeability on Retarding or Preventing Corrosion, 2010 Place Conference, Peachtree Corners, GA: TAPPI, 2010
[6] Ozol, S., Todt, G.L., Vold, J., Preserving CARC with Corrosion-Control Covers, Materials Performance, Vol. 53, No., 2, 2014, p. 41.

[1] -34 to 60°C

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