

## Corrosion Inhibitors for Prolonged Protection of Military Equipment and Vehicles

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*Military assets require the implementation of corrosion control and monitoring techniques, in particular during long periods of storage. Plastic sheets and/or textile canvas, impregnated with vapor phase inhibitors, are used to cover weapons and vehicles. An electronic corrosion control monitoring system for covered vehicles and weapons is described.*

**The combat fields of modern wars**, including the struggle against global terrorism, are localized in diverse, harsh regions: tropical, desert, arctic, marine, and urban, with varied weather conditions that adversely affect the corrosion resistance of the equipment, weapons, and vehicles involved.

Corrosion and degradation of military hardware occur by an interaction between the surface of a material and its environment, damaging the equipment, weapons, vehicles, and machinery.<sup>1-2</sup> Localized corrosion can occur on parts of this equipment that are prone to corrosion. Many corrosion types are known: intergranular, in microcrystalline grain boundaries; galvanic, between different metals electrically interconnected; crevice, at interfaces between parts; pitting, forming perforations; dealloying, by leaching of a less noble metal from an alloy; fatigue, with cracks

generated by mechanical stress; fretting, caused by two metallic surfaces rubbing against each other; erosion-corrosion, by the combined action of mechanical wear; and electrochemical corrosion.<sup>1</sup> To prevent and mitigate these forms of corrosion, military assets require the implementation of corrosion control methods and techniques, including corrosion inhibitors, particularly the new “green” corrosion inhibitors, according to the characteristics of the corrosive environment.<sup>3</sup>

A significant development for corrosion control in the military services is the establishment of a central institution to serve the U.S. armed forces. The U.S. Department of Defense (DoD) Office of Corrosion Policy and Oversight (CPO) maintains a Web site, [CorrDefense.org](http://CorrDefense.org), that features content on corrosion and corrosion control of military facilities, equipment, and weapons. In addition, an alliance was created between the U.S. DoD CPO and defense departments in the United Kingdom, Canada, France, Germany, New Zealand, and Australia that ensures the expansion of corrosion control efforts worldwide.

### Corrosion Inhibitors

The use of corrosion inhibitors is rapidly expanding worldwide for numerous technological and industrial applications: in cooling water systems;<sup>4</sup> protected storage of military and electronic equipment;<sup>5</sup> acid pickling and cleaning;<sup>6</sup> the oil and gas

industry;<sup>7</sup> as additives to coatings, paints, and elastomers; for corrosion avoidance in oil pipelines;<sup>8-9</sup> and in desalination plants.<sup>10</sup> The importance and relevance of the inhibitor technology are evident from the many patents gathered in published reviews.<sup>11-12</sup>

Corrosion inhibitors slow the rate of corrosion reactions when added in relatively small amounts to a treated system. They are classified into three groups:

- Anodic inhibitors—which retard the anodic corrosion reactions by forming passive films
- Cathodic inhibitors—which repress the corrosion reaction such as reduction of dissolved oxygen
- Adsorption inhibitors—such as amines, oils, and waxes, which are adsorbed on the steel surface to form a thin, protective film that prevents metal dissolution

## Volatile Corrosion Inhibitors

Volatile corrosion inhibitors (VCIs) are used to protect ferrous tools and delicate machinery parts against corrosion, where it is impractical to apply surface treatments. These parts are kept in closed paper envelopes, in cardboard boxes, or wrapped with cotton canvas, well impregnated with a VCI. Sometimes, the parts are also sprayed with a VCI, depending on their size and shape. Figures 1 through 3 show several pieces of critical military hardware protected against corrosion with VCIs.

VCIs are evaluated by NACE International TM0208,<sup>13</sup> including some types of VCI materials (e.g., paper), using low carbon steels (CS) as representative of the broad class of ferrous metals. This standard was prepared by NACE Task Group 215, “Volatile Corrosion Inhibitors.”

## Military Asset Protection

The specific conditions of protecting military equipment in high humidity climates and the diversity of materials used in the construction of military equipment call for special quality VCI products to protect them from corrosion. The slightest occur-

rence of corrosion on arms and other equipment can cause changes in their technical performance, affect their reliability in practice, and result in loss of lives in times of war. VCIs do not significantly affect human health or combat readiness.

In practice, most of the military equipment and arms are continually kept in reserve, so it is of paramount importance to protect them from corrosion while maintaining their original technical properties. Trends in protecting such equipment have been based on reliability, easy application, quick mobilization, and economic benefits.

VCIs have been developed to meet the above requirements. Materials used are organic chemicals containing a proprietary amine compound. This compound is non-toxic, biodegradable, and environmentally friendly. Through years of experience with several armed forces around the world, cutting-edge technologies have been developed to preserve all types of military equipment.

Military assets consist of fixed and mobile structures, including two principal groups: weapons systems for attack and defense operations and vehicular assets for transportation of military personnel, their supplies, and materials.<sup>14</sup>

## Ground Vehicles

Military services operate many types of armored vehicles, wheeled and non-wheeled. Exposed to harsh environments, they are assembled from numerous metallic components, but mainly CS and some low-alloy steels. Therefore, they are subjected to general corrosion, particularly in humid environments. Due to the limited corrosion resistance of these steels, they are often protected against corrosion by the application of chemical conversion coatings.

The most commonly used vehicle is the high mobility multipurpose wheeled vehicle, also known as the Humvee, particularly in the deserts of the Middle East. The complex interaction of chemical and climatic factors, such as hot afternoons and cold nights, with dew condensation, intense



**FIGURE 1** Heavy cannons on wheels covered with rough canvas fabric impregnated with a VCI.



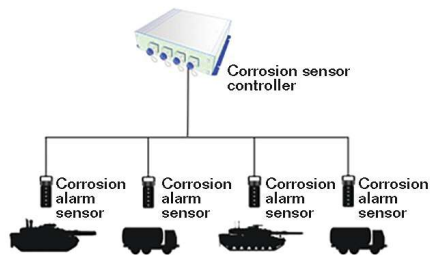
**FIGURE 2** Wrapped military hardware on a wood pallet ready for moving.



**FIGURE 3** Weapon parts wrapped with transparent plastic sheets containing a VCI.

solar radiation, and salt-laden atmosphere as well as saline, brackish, and briny water, create a harsh corrosive environment. The military vehicles are damaged by corrosion, erosion, abrasion, and wear that impair vehicle mobility and long service life, requiring costly, ongoing maintenance. Plastics, elastomers, and composites are generally unsuitable alternatives because they deteriorate by physicochemical mechanisms.

Polyethylene, vinyl, and canvas tarps, wetted with a VCI, are used as covers for long-term storage of vehicles. These covers also provide protection from ultraviolet radiation, humidity, rain, snow, dust, and mold. The covers are easy to install, are resistant to the climate factors, and are durable.



**FIGURE 4** Corrosion control monitoring system.

## Corrosion Control Monitoring

Corrosion control monitoring systems help to maintain a high level of operational readiness for preserved military equipment and vehicles by drastically reducing corrosion problems during storage. Early detection and resolution of corrosion problems not only help reduce maintenance costs but also provide the logical methodology to maintain operational readiness while minimizing the need for repair or replacement during mobilization. The system enables real-time monitoring of preserved military equipment. It consists of sensor controllers and corrosion sensors and is designed to be easily scalable according to the number of equipment packs or vehicles to be monitored (Figure 4).

Corrosion control monitoring software enables fleet management personnel to easily identify corrosion problems on a specific piece of equipment or vehicle. It alerts personnel upon detection of corrosion at a specific location, and the alert returns to its normal level only after the problem is rectified. This system reduces the regular need for on-site inspection and enhances productivity, helping to improve staffing allocation within the fleet management team.

## Conclusion

Proper use of VCIs in combination with a system of automated corrosion sensors can be an effective means of preserving equipment and vehicles during long-term storage. Critical advantages include savings in maintenance costs and prevention of corrosion damage that can reduce efficiency.

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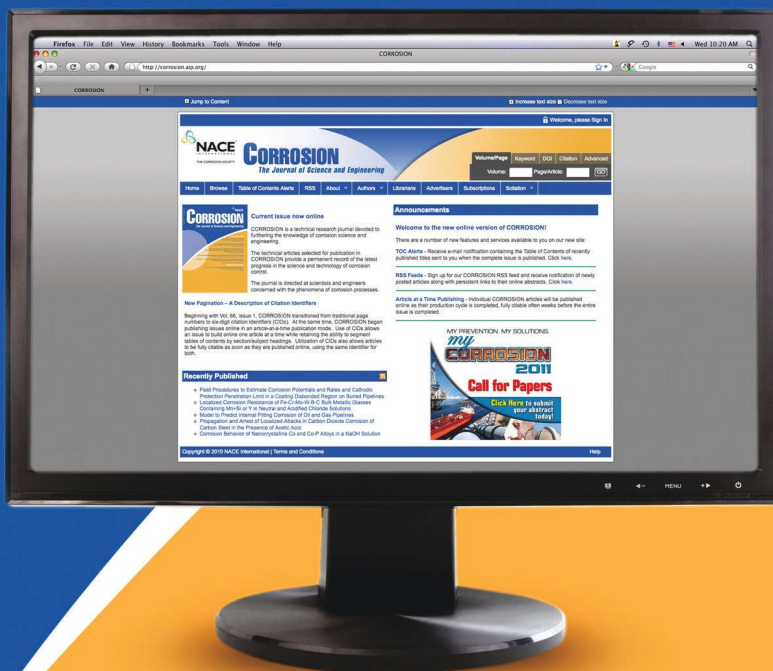
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