January 2005
www.nace.org

MP MATERIALS PERFORMANCE

CORROSION PREVENTION AND CONTROL WORLDWIDE

FOCUS ON

INFRASTRUCTURE CORROSION

Field Observations on Waterjetting Bridges

Corrosion Protection of Ductile Iron Pipe

Preservation of High-Performance Military Engines

Special Feature:

Results of the Seventh Annual NACE Corrosion Career Survey

NACE INTERNATIONAL
THE CORROSION SOCIETY

CT Chemical Treatment

Preservation of High-Performance Military Diesel Engines Using Volatile Corrosion Inhibitors

LUKA MIŠKOVIĆ AND TADIJA MADŽAR, *Ministry of Defense, Republic of Croatia*
ANNA M. VIGNETTI AND BRIAN L. WUERTZ, *Cortec Corp.*
IVAN ROGAN, *CorteCros, Ltd. Co.*

In the Armed Forces of the Republic of Croatia, long-term storage protection is required on most military equipment. The metal parts of this equipment are affected by corrosion and deterioration. To prevent deterioration, protective coatings, dehumidification, and volatile corrosion inhibitors have been used.

This article describes the preservation of high-performance diesel engines using three methods, including protective coatings, dehumiciificadon, and volatile corrosion inhibitors (VCIs). The preserved engines being investigated were kept in Republic of Croatia Ministry of Defense storage for 2 years under different climatic conditions in Croatia. Subsequent inspection of the exterior surfaces confirmed no traces of corrosion.

When influenced by a chemical, physical, or biological environment, the aging process of engineering materials increases. This phenomenon leads to diminished performance rime as well as technical outdaring.

Relative humidity (RH) is especially significant for metal corrosion. The critical humidity for steel is 60% and is considerably lower if sulfur dioxide (SO_2) is present. In practice, the RH should be kept between 30 and 50%. 'Ihe rapidity of corrosion also depends on gases found in the air, such as SO_2, hydrogen sulfide (H,S), ammoniac, hydrochloric acid (HC1), and others. In industrial zones, the most common contaminant is SO_2, while along the coastline, chlorides dominate.

Environmental temperature also influences corrosion time. For the storage of protected materials, the temperatures should be kept < 10°C. Technologies for materials protection include the methods of thermal protection, a change in environment, and the prevention of contact between the materials and the environment using protective coatings.

Preservation

Preservation is necessary ro prevent deterioration of a material or appliance during the period of time when not in use. Stored appliances must be protected because of the unfavorable influence of actual storage conditions (Figure 1).

The optimal preservation method is generally the one having the best investment/result ratio. In choosing the right preservation method, multiple factors must be considered, such as the time of storage, storage conditions, appliance construction, the time needed for preservation/depreservation, the number of staff needed, and the total cost. In addition, the most important area for the armed forces is the availability of quick depreservation of the preserved equipment for deployment.

Preservation methods can be divided into three major groups: the use of protective coatings, dehumidification (static and dynamic), and the use of

noncontact protective materials known as VCIs.

Dehumidification methods include dessication, most often silica gel (static method) or special equipment (dynamic method) to keep the RH in the optimal range, <45% (Figure 1). Without hermetic closure, the appliance is exposed to RH changes (Figure 2) and can be affected by these RH fluctuations. Hermetic treatment prevents the impact of RH (Figure 3). Consequently, VCIs and related technologies have developed rapidly and have been in use for the last 25 years.

Basic Characteristics of VCIs

VCIs are chemical compounds that evaporate from the fluid or solid on the metal surface, producing a very thin monomolecular protective film (Figure 4). This protective film inhibits metal through a reaction with water and air, providing protection to anodic and cathodic areas (Figure 5)

VCIs evaporate and condition an enclosure, migrating and protecting parts and surfaces not in direct contact with the inhibitor. VCI technology is simple, easily utilized, and provides low-cost protection. The material characteristics remain unchanged as the invisible protective ion layer of VCI causes no changes, even on sensitive electronic devices where conductivity, dielectric constant, and dimensional tolerance are crucial.

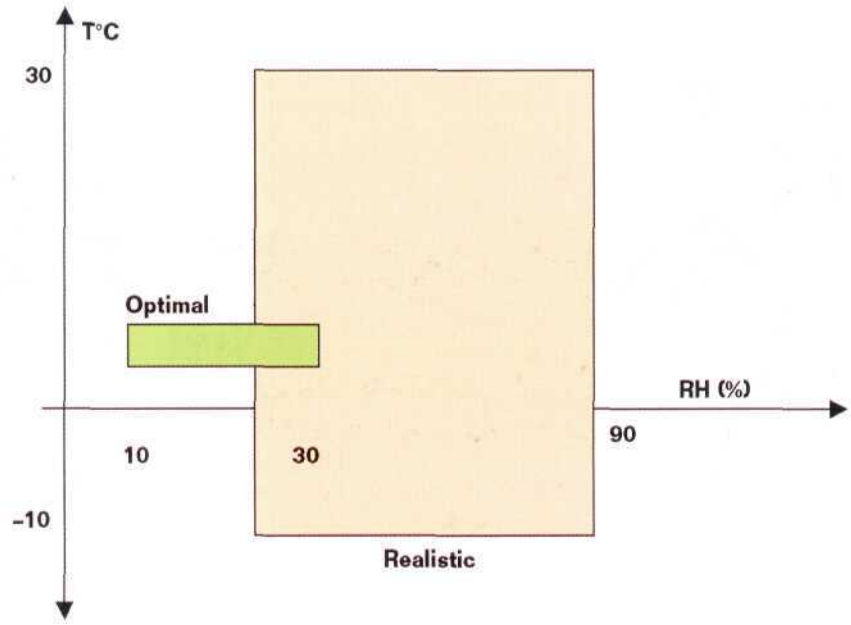
Procedures

When the engine is delivered (Figure 6), it is tested to ensure that it meets all the technical requirements set by the manufacturer. If not, it is returned for a work-over.

PREPARATION FOR PRESERVATION

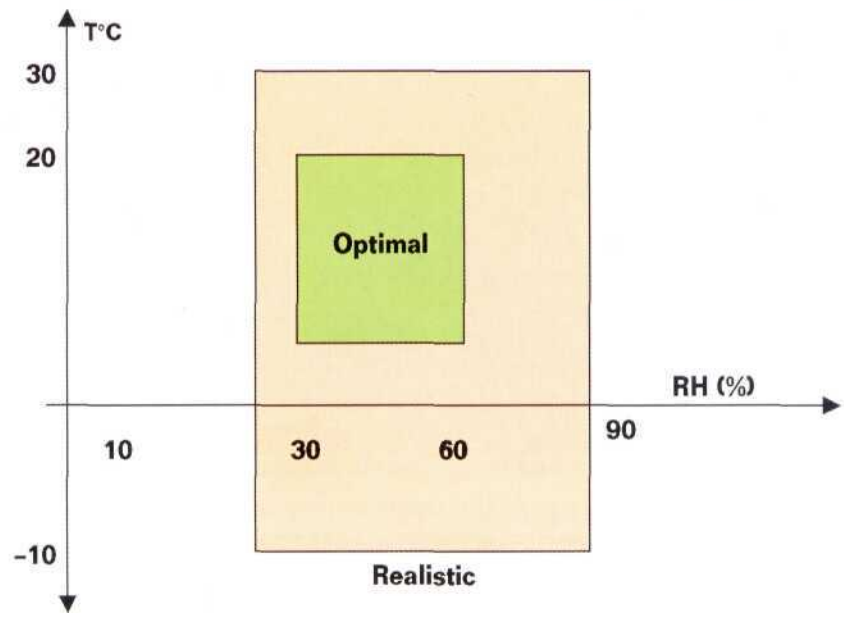
If a VCI concentrate is being used, mixing can be performed by releasing the appropriate amount of working oil, liquids, and fuel from the engine, and then by adding the same quantities of the VCI concentrate. Protective VCI tape is cut according to the length of the engine suction collector, air filter area, and other components. Masking, anticorrosive, and high-temperature coatings should be prepared according to the manufacturer's instructions. Preservation materials should be stored in the original sealed packages. Preparation of the engine should also include technical inspections and the removal of dirt and corrosion products.

FIGURE 1



Storing conditions for stand-by appliances.

FIGURE 2

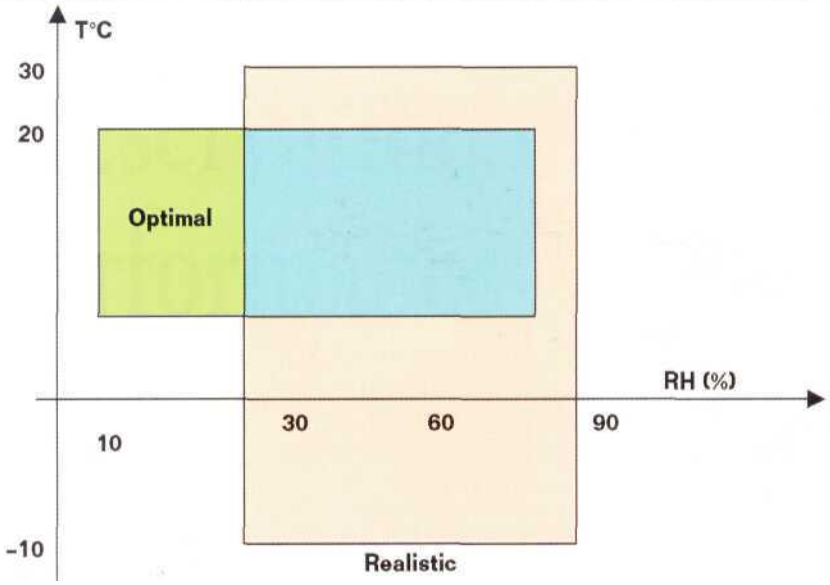


Improvement of storage conditions without hermetic closure.

PRESERVATION

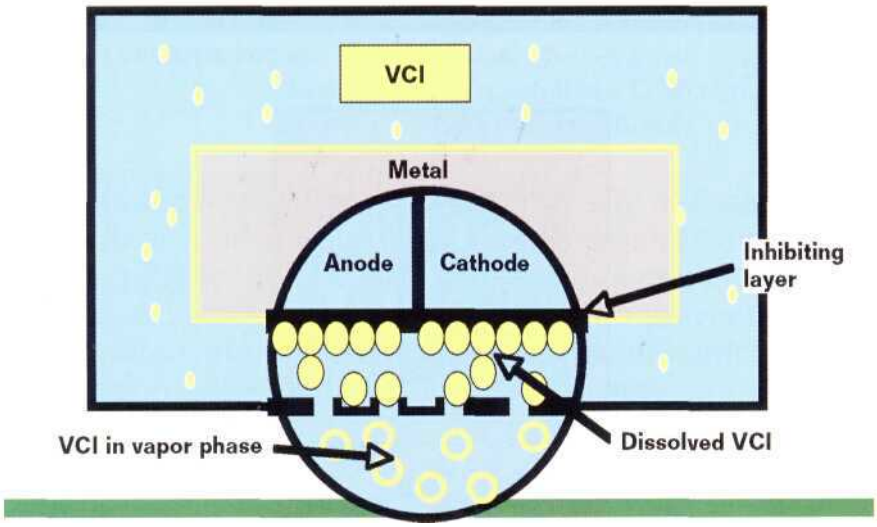
'Ihe engine preservation is performed with protection, protective coatings, and VCIs. "Ihe engines contain many different

FIGURE 3



Improved storing conditions with hermetic treatment of the appliance.

FIGURE 4



Ionic action of VCI creating a molecular, inhibiting layer.

areas that require protection, including the cooling system, engine lubrication system, air compressor, fuel supply system, compression area, and the engine exterior.

Cooling System

For first-time preservation, calcification is removed from the cooling system using an acidic solution to dissolve existing deposits. Once this is done, the system is filled with cooling fluid. The outer surfaces of the cooler are washed with water and dried with compressed air. VCI is added into the cooling water; 1.5 to 2% is added into the final solution, and then the water and additive are stirred together and added to the cooling system.

Engine Lubrication System

Protection of the entire lubrication system is achieved with SAE 50 engine preservation oil while the engine is running. After the engine has been washed, the protective oil is thoroughly mixed with the VCI additive at a 3:1 ratio and poured into the engine. The engine is then run under a light load for a maximum of 5 min, so that all the surfaces of the engine interior part can be evenly lubricated with protective oil. Ihe engine is then shut down, and the cylinder compression space- is blown out.

Air Compressor Box

Compressor box protection is achieved in the same manner. These operations are performed when there is preservation oil in the engine or gearbox. If the compressor has a separate box, the existing oil is released, the box is washed with rinsing oil, and then it is filled with SAE 50 oil for preservation.

Fuel Supply System

Any corrosion products are removed from the metal surfaces as are any other deposits or water. After the protection procedure is finished, all openings are taped with VCI anti-corrosive tape (fiber polyethylene).

Fuel Tank

The removable tanks are then removed, emptied, and inspected. Any corrosion products are subsequently removed, and the tanks are dried and coated with protective VCI oil.

If the tank cannot be removed, the remaining fuel is released and the waste pipe is separated, the deposit container or fuel meter is opened, and deposits are removed mechanically from the system. The remaining fuel is washed away and openings are closed. Ihe tank is filled with protective oil, which is then immediately released. The tank is then filled with 180 L of fuel to which a VCI additive has been added and thoroughly stirred into the fuel (1.5 to 2% by volume).

Compression Space

The compression space, cylinder walls above the piston rings, valve space, valve head, parts of the valve spin, and other sensitive and hard-to-reach surfaces are

treated with SAE 50 engine preservation oil mixed with VCIs. The mixture is introduced using manual or pressure injection with appropriate tools and nozzles. Protective oil is injected with the piston in the bottom dead-center position.

The engine axle is then turned over five or six times, so the oil can be properly and uniformly applied to the walls.

Exterior Protection of the Engine

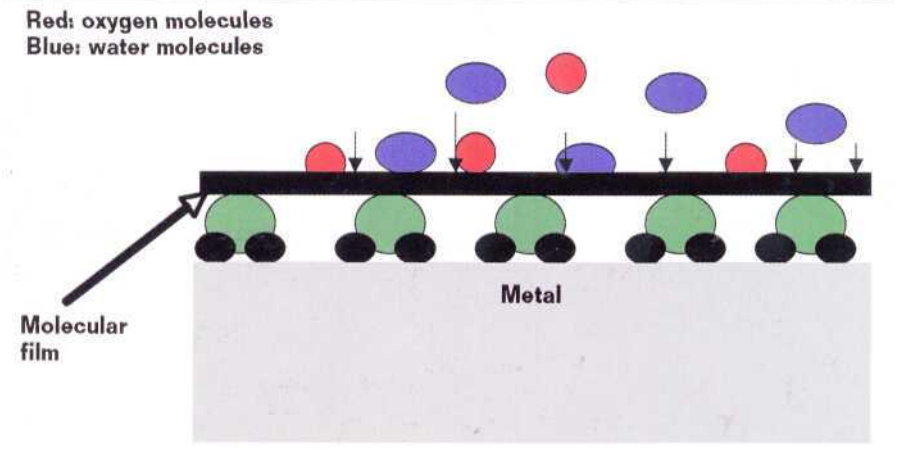
Once the interior surfaces and systems of the engine have been protected, the exterior surfaces of the engine are treated, and the engine is packaged for preservation. For this step VCI protective bands are placed in the exhaust and suction collectors and the openings are sealed with VCI protective foil and tape (Figure 7). All engine openings are covered with lids and fastened with self-adhesive tape. The water pump is left open until all the cooling liquid has been drained from the engine. Rust and damaged coatings are removed from the exterior of the engine, and recoated with the appropriate coating. VCI protective spray is applied to all electronic components and connectors on the engine. A VCI protective paste is then dissolved into an oil-based product and applied at 50 to 75 µm over all parts of the engine.

Storage

The preserved engines were stored in enclosed warehouses, packaged as noted below, and placed so that the preservation chart, preserved engine status, possibility of depreservation, and possibility of moving the engine from the storage place could be seen.

The engine was wrapped in VCI film with VCI foil attached to the bottom of the engine to provide additional corrosion protection. Next the engine was placed in a wooden trunk and fastened to the base of the trunk. The preservation chart was placed in a water-resistant plastic bag and nailed to the upper-right side of the engine trunk. The protected engines were stored in Croatian Army warehouses throughout Croatia in regions characterized by continental, mountain, and Mediterranean climates. The engines were periodically inspected, and after 2 years several engines were unpacked and thoroughlyexamined.

FIGURE 5



Molecular VCI film on metal surface.

FIGURE 6

Engine ready for testing and preservation.

Results

After 2 years, the engines were put through depreservation using the following steps:

- Remove hermetic materials from the suction branch, air filter, and exhaust branch.
- Remove VCI protective tape from the suction branch and air filter.
- Check the level of oil and other fluids.
- Depreserve exterior surfaces, if necessary.

EXTERIOR SURFACES OF THE ENGINE

VCI-treated engines showed no corrosion on any exterior surface, whereas untreated engines had large amounts of

FIGURE 7

Preserved engine.

corrosion at different points on the exterior surfaces (totaling >20% of the engine's surfaces).

ELECTRONIC CONNECTIONS

The electrical connections of VCI-treated engines were corrosion-free and showed no deterioration. All electrical connections of untreated engines were heavily corroded and showed signs of pitting.

Conclusions

- A preservation method for army equipment using VCIs has been adopted by the Armed Forces of the Republic of Croatia.
- Several methodological procedures for protecting almost all groups of arms and army equipment have been adopted and prescribed from 1995 to the present.
- VCI preservation of high-power engines has been a major technological step in the long-term protection of stored engines.
- Engines that had been VCI-preserved since 2000 and fitted into armed vehicles before the preservation expiration date showed no traces of corrosion. During installation and start-up, the engines operated properly and provided smooth operation under all conditions, confirming the validity of the protection provided by the VCI procedure.

Bibliography

Esih, I. and Z. Dugi. *Tehnologija zatstite od korozije,* Zagreb, Croatia: Skolska knjiga, 1989.

Miksic, B.A. "Temporary Protection, Lay-up and Moth-hailing." Handbook, Manual. St. Paul MM: Cortec Corp., 1988.

Miksic, B.A. "Volatile Corrosion Inhibitors Find a New Nome." Material Engineering Forum (1997): p. 14-18.

Nathan, C.C., *Corrosion Inhibitors.* Houston, TX: NACE, 1973.

Schweitzer, P.A. *Corrosion Engineering Handbook.* 1996.

Vignetti, A.M. *Military Applications Using Vapor Corrosion Inhibitors.* St. Paul, MN: Cortec Corp.

Vignetti, A.M. "Successful Corrosion Protection Utilized by Military Worldwide," CORROSION/2001, paper no. 561. Houston, TX: NACE, 2001.

LUKA MIŠKOVIĆ is a General in the Armed Forces of the Republic of Croatia, Stanciceva 4, Zagreb, 10000, Croatia.

TADIJA MADŽAR is a General in the Armed Forces of the Republic of Croatia.

ANNA M. VIGNETTI is Vice President of Cortec Corp., 4119 White Bear Pkwy., St. Paul, MN 55110. She has been affiliated with the chemical industry in a sales and management capacity for the past 21 years. For nearly 15 years she has focused on the field of corrosion control. She has a bachelors degree in business administration and management. She is a 10-year member of NACE.

BRIAN L. WUERTZ is Technical Sales Supervisor at Cortec Corp. He has worked in many areas of corrosion control using methods that include x-ray diffraction, scanning electron microscopy, transmission electron microscopy, and others.

IVAN ROGAN is Manager of CorteCros, Ltd., Nova Ves 57, Zagreb, 10 000, Croatia. He has a bachelors degree in geology and petroleum engineering. He has been affiliated with the petroleum industry since 1951 and has written several articles on the exploration of crude oil. He is a 2-year member of NACE. *MP*