Preservation of U.S. Air Force Vehicles and Equipment

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The U.S. Air Force (USAF) initiated an Air Staff Level Test Program to protect military vehicles and air ground support equipment. Corrosion damages millions of dollars of valuable assets every year, jeopardizing war readiness. Many different preservation products have been evaluated and utilized over the years. A recent initiative evaluated vapor corrosion inhibitor (VpCI) products and systems in deep storage and preservation for war readiness materials. This article discusses USAF corrosion control requirements and its evaluation of VpCI systems.

In recent years, armed forces worldwide have become more aggressive in preventing corrosion. Corrosion problems in the military date back to ancient times, but recognizing prevention as a necessary part of maintenance, operations, and storage began as recently as World War II.[1] Many different preservation products and methods have been evaluated and utilized[2] over the years. Currently, millions of research dollars are spent each year in the war against corrosion. Losing valuable assets is a major concern; however, war readiness and the prevention of catastrophic failure are paramount in the overall scope of corrosion prevention.

The U.S. Air Force (USAF), like many other U.S. military branches, has taken bold steps to objectively evaluate different methods. The most recent initiative evaluated vapor corrosion inhibitor (VpCI) products and systems in deep storage[3] and preservation for war readiness materials. VpCIs are chemical compounds that have significant vapor pressures that allow molecules to vaporize and then adsorb on metallic surfaces.

This article details the objective, parameters, environment, benefits, and results of the USAF's VpCI test. Evaluating VpCI technology as a total system of protection was the focus of this test program. The USAF had adopted a chemical preservation storage program, but it was subsequently delayed for this evaluation.

Experimental Procedures

TEST OBJECTIVES

The evaluation was initiated to validate and compare deep storage preservation systems for vehicle and air-ground support equipment with a commonly used chemical preservation technology and a newer VpCI system. VpCI performance on different metals in industrial and marine atmospheres was studied and analyzed experimentally to show corrosion rates (Table 1).[4] VpCI products have been used for 5 decades, and newer VpCI technologies have since been developed. This test program evaluated a system/solution approach.

The test defined the expected life of a deep storage/preservation system at 3 to 5 years, with minimal or no upkeep. It considered the reapplication of current chemical preservation as well as requirements for exercising, time, and labor. The reduction of forces makes reapplying the products and exercising the vehicle and equipment assets difficult and costly.

The next objective was to attain zero equipment deterioration. The desired goal was to achieve a sustained 90% overall vehicle in commission (VIC) success rate in corrosion protection and mechanical functions. Minimal mechanical degradation was a critical factor in the test. Again, as a result of less manpower, the decrease of mechanical problems at breakout is critical and necessary in a deep storage program.

TABLE 1

VCI PERFORMANCE IN INDUSTRIAL AND MARINE ATMOSPHERES

Metal		Corrosion Rates (mils/y) No Inhibitor	VpCI Protected
Aluminum (1,000, 3,000, 5,000, 6,000 series)		0.3	<0.25
Mild steel		21.8	<0.13
HSLA (high-strength, low-alloy steel)		1.2	0.08
Naval brass		0.2(A)	0.03
Titanium		0.0(B)	0.0(B)
Stainless steels:	Type 410	0.01(C)	0.01(D)
	Type 304	<0.1(E)	0.01(F)
	Types 301, 316, 321	0.0(G)	0.0(G)
Copper		0.22(E)	0.01(F)

Notes:
(A)Dezincification, (B)Immune to attack; no pitting or weight loss observed, (C)Pitting, (D)Pitting reduced, (E)Staining, (F)No Staining, (G)Free from pitting and weight loss.

TEST PARAMETERS

The USAF set a number of key parameters for the program. Preparation for the actual test began with identifying the vehicles and equipment to be preserved. USAF teams selected and issued orders to prepare the selected assets. The test length was predetermined for a term of 1 year.

Preparation

The USAF team requested that the individual sites prepare the assets to "excellent" working and physical condition. The VpCI manufacturer then assessed and calculated product needs based on vehicle and equipment specifications. The company provided training procedures, materials, equipment, and personnel to assist and train military personnel in the application of the VpCI products. Contractor and military personnel were deployed to prepare the equipment and perform the actual preservation. Each asset was thoroughly inspected and repaired prior to the procedure.

Test Sites

Five locations were chosen to fairly evaluate different climatic zones and atmospheric conditions. Guam was chosen because of its extreme climates and severe corrosion conditions. The trade winds and high ultraviolet (UV) light exposure make this location suitable for the tropical environment. Two locations in Korea, one located centrally and the other near the coast, would give a good evaluation of the four seasons in two different environments. The climate varies from very hot and humid to extremely cold with a great deal of precipitation. Last, two locations in Oman round out the categories of climatic conditions. The first offers desert extremes with high UV. The second, with hot, humid conditions, is found on the Persian Gulf coast. During testing, the assets were located in climate-controlled and bare sheds as well as outside in all climates and atmospheres.

Identifying Assets

Assets—personnel vehicles as well as equipment for tactical, road building, and air-ground functions—comprised the widest possible range of vehicles and equipment for a fair evaluation. The air-ground equipment (AGE) included bomb lifts, compressors, trailers, and generator sets. Different storage scenarios were made for the same asset if more than one was used in the test.

Each of the five locations was chosen to preserve a total of 180 vehicles. Two locations—Guam and Osan, Korea—were chosen to evaluate AGE. At the time of preservation, asset preparation varied from fair to excellent. Lessons learned from one location to the next helped in the preparation but did not affect the outcome of the final results. A total of 119 vehicles and 60 pieces of AGE were used in the final preservation. Ten medium-sized vehicles were chosen for the chemical preservation process.

Products

The products used compatible technology to provide a system solution. Many of these products are already being used successfully by armed

TABLE 2

LIST OF MILITARY SPECIFICATIONS

No.	Inhibitors	Description
1	MIL-PFR-87937C	Cleaning compound, aerospace equipment
2	MIL-C-16173E	Corrosion preventive compound, solvent cutback, cold application
3	MIL-P-46002B	Lubricating oil, contact and volatile corrosion inhibited
4	MIL-C-83933A	Corrosion preventive compound, cold application
5	MIL-C-81309E	Corrosion preventive compound, water displacing, ultra thin film
6	MIL-I-22110C	Inhibitors, corrosion, volatile, crystalline powder
7	MIL-PRF-81705D	Barrier materials, flexible, electrostatic protective, heat-sealable
8	MIL-PRF-22019D	Barrier materials, transparent, flexible, sealable, VpCI-treated bags, transparent, flexible, heat seal, VpCI-treated
9	MIL-B-40028B	Bags, barrier with VpCI-treated liner

forces worldwide. Military specification numbers (Table 2), National Stock Numbers (NSN), Qualified Product Listings (QPL), and NATO numbers are already in place for most of the products.

From the start, surface preparation entailed cleaning/degreasing and removing rust from products that had been modified with VpCI additives to enhance corrosion prevention. VpCI-emitting products were used for electronic compartments and miscellaneous enclosures such as large void spaces and vehicle cabs. Temporary and permanent coatings were used to coat undercarriages. Clear, permanent coatings provided overall coverage for selected assets. Bare metal surfaces on moving parts such as forklift chains and hydraulic cylinders were lubricated. Fuel coolant, oil, and hydraulic additives complemented the internal systems. Finally, four types of covers were used that were custom-fabricated to contain VpCI additive technology.

Application Procedure

The application followed a step-by-step process. Throughout application, up to five individuals worked on a single asset. Multiple procedures were performed simultaneously, allowing for optimum use of time and personnel. Normal maintenance directives included military procedures for repairing and preparing assets prior to preservation (Figure 1).

Step 1: Prepare the vehicle or equipment according to the state or condition desired at breakout time. Complete a thorough inspection, noting discrepancies, condition, and record of vehicle condition. Take pictures showing the condition and discrepancies.

Step 2: Remove rust with a liquid or wipe-type product containing VpCI additives.

Step 3: Wash down with a VpCI cleaning product (Table 2, No. 1). Remove heavy oil or grease with a VpCI wipe. Do not rinse. Allow it to partially air dry and wipe with a dry cloth.

Step 4: Apply a permanent VpCI water base, clear-coating for selected assets. Apply one coat at a 2-mil (50-µm) wet film thickness. For severe corrosion conditions, where vehicles will not be stored inside or with a cover, wait 30 min to 1 h and apply a second coat at a 2-mil thickness.

FIGURE 1

60K cargo loader with VpCI military shrink wrap.

Step 5: Apply a VpCI lubrication coating to all working and moving parts as well as bare metal such as hydraulic cylinders. Apply a paraffin-based VpCI coating to rusted areas beneath vehicles or equipment (Table 2, Nos. 2 and 4).

Step 6: Lower the liquid level of coolants, hydraulic oil, and regular oils (Table 2, No. 3) to the required capacity for the additives. Fill fluid reservoirs with the required VpCI additive product. Required product calculations are made prior to application. Charts specifying capacities and measured fluids to be added were also provided.

Step 7: Apply a VpCI-modified lubricating grease to all areas normally greased (Table 2, No. 4), including zirconium fittings.

Step 8: Apply VpCI electronic spray (Table 2, No. 5) to all electronic/electrical connections, control panels, wiring, items under the hood and dash, battery boxes, etc. Apply VpCI-emitting devices (Table 2, No. 6) to storage and battery boxes, electronic/electrical enclosures, and under the dashboards. Place VpCI foam pads in large void spaces and in cabs (Table 2, No. 7).

Step 9: Apply VpCI protective covers. Four covers were selected: VpCI polyethylene shrink film, VpCI reinforced films with and without a soft interior lining, and a VpCI high-UV reinforced cover with a soft interior lining. Table 2 (Nos. 8 and 9) gives the specifications for these products.

Steps 5 through 8 may be performed simultaneously for efficiency. The process was timed from start to finish.

Test Results

This evaluation concurs with other storage tests. It considers VpCI usage by other branches of the military as well as industry.

MONITORING

Prior to storage, military and contract personnel thoroughly inspected and extensively photographed records of the assets. A limited number of assets were evaluated at 6 months for the Pacific Air Forces (PACAF) region and at 9 months for the USAF, U.S. Central Command (CENTAF) locations. Results of corrosion protection at this point were impressive. Although there was high condensation and excessive amounts of water, they achieved more than 90% corrosion protection.

Following storage, the vehicles were placed in areas that would provide heavy use for a 90-day period. The goal of zero defects was accomplished, and mechanical failures were not reported as a result of the VpCI protection system.

In September 2000, after 12 months of preservation, the PACAF assets were depreserved. Photographs

TABLE 3

Vehicle	Application in Man-Hours/Unit	VpCI Product Cost (U.S. Dollars)/Unit
Average of 120 vehicles	4.14 h	$338
HMMVW	2.69 h	$160
40K air cargo loader	7.5 h	$795

Notes: Many other vehicle types were included to illustrate the differences in cost.
Application included the entire process from initial cleaning and coating to the final step.

and extensive evaluations recorded the assets' condition. They show that corrosion protection and mechanical soundness exceeded the 90% VIC rate. Removing the covers took no longer than 4 min, but starting the vehicles took the bulk of the recorded time in the depreservation procedure. It was no longer than replacing or jump-starting a dead battery. Removing VpCI products other than the covers was unnecessary; remaining products will continue to protect the assets. Immediate war readiness was accomplished.

APPLYING CHEMICAL PRESERVATION

Ten vehicles were designated for traditional chemical preservation. Lengthy application and removal times make this a costly alternative. Applying the exterior and interior products was a very detailed process. The assets were stored indoors. Application time per vehicle was up to 5 days—practically pulling the vehicles apart made this very time-consuming and labor-intensive. Breakout times ranged from 5.5 to 6 h per vehicle. Using flammable solvents made removal hazardous and cumbersome.

The USAF and other military branches have taken the initiative to replace hazardous products and cumbersome work practices.

VpCI PRODUCT APPLICATION

This test analyzed VpCI system application in terms of vehicle type, product cost, and required labor/man-hours. Table 3 presents a brief analysis. Additional time and labor were not required for the application process. The average breakout time was 18 min per vehicle—this included the removal of any cover used and the actual vehicle start-up. Regardless of asset size, only a few minutes were needed for cover removal. It was not necessary to remove other VpCI product. The assets were ready for immediate utilization or war readiness. All vehicles and equipment were placed in high-usage areas to evaluate the product's effects, if any, on asset operation.

VpCI SYSTEM BENEFITS

The benefits of VpCI systems in deep storage and preservation were quickly noted throughout the application process and upon completion of the test. One major advantage is the ease with which military personnel can become proficient in applying VpCI products. Another is the efficiency of application and removal—an economic benefit. Although product cost was competitive to that of existing products, it was not the most critical factor in the evaluation.

It was not necessary to operate the equipment during the test. Of the few malfunctions identified after breakout, none were caused by the VpCI preservation system. This in itself is critical because it decreased the costs of parts and labor. Further analysis will determine the overall savings.

The reduction in breakout time compared to that of other preservation programs was also significant. Interest in this system continues to grow, and a final executive report will be presented to the Air Staff at the Pentagon.

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Conclusion

This VpCI technology is revolutionary in terms of vehicle and equipment storage. It has proven itself commercially and industrially, and the savings outweigh the costs and any possible risks involved in testing.

A cost analysis comparing traditional and VpCI processes determined the VpCI products provide superior corrosion protection even in extreme atmospheric conditions. The reduction of manpower stands out because it revolutionizes asset protection. The entire VpCI storage process/system approach is simple and efficient. After only 1 day of training, the USAF team was well-versed in the technique.

After operating the vehicles in the 90 days following final depreservation, the USAF concluded the VpCI process and materials would be a great asset to the USAF War Readiness Materials vehicle storage program. The time required to prepare and breakout the vehicles and equipment and the system's level of corrosion protection would enhance war-fighting capabilities.

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