Cost Savings Corrosion Protection for Deep Storage

And Preservation of United States Air Force Vehicles and Equipment

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ABSTRACT

The United States Air Force initiated an Air Staff Level Test Program for the protection of military vehicles and air ground support equipment. As a result of corrosion, millions of dollars of valuable assets are lost every year and the need for war readiness is jeopardized. Many different preservation products have been evaluated over the years and consequently utilized. This last initiative was for the evaluation of Vapor Corrosion Inhibitor (VCI) products and systems in deep storage[1] and preservation for war readiness materials (WRM).

VCIs are chemical compounds having significant vapor pressures that allow vaporization of the molecules and subsequent adsorption of these on metallic surfaces[2]. The advantage of VCIs is that the vaporized molecules can reach inaccessible areas commonly found in electronic enclosures, between metal junctures and similar other systems including fluid reservoirs. VCIs have the ability to effectively prevent corrosion of dissimilar metals and provide a desirable effect in protecting metals from corrosive atmospheric elements.

The USAF criteria and requirements, test details itself and the results obtained will be described in this paper. Parameters for the test were identified and established for specific results at the completion of the initiative. Ease of application, environment, worker safety, war readiness and enhanced war fighting capabilities would be positive factors if they could be given within the established guidelines.

Key Words: VCI (Vapor Corrosion Inhibitors), WRM (War Readiness Materials), PACAF (Pacific Allied Forces), CENTAF (Central Allied Forces), USAF (United States Air Force), AGE (Air Ground support Equipment), VIC (Vehicle in Commission).

INTRODUCTION

In recent years, militaries worldwide have taken a more aggressive posture in the prevention of corrosion. Corrosion problems in the military go as far back in history to ancient times and were treated in various ways. Identification of prevention as a necessary part of maintenance, operations and storage occurred during World War II[3]. Many products and methods have been used over the years and now, millions of dollars are spent in research every year in the war against corrosion. The loss of valuable assets is a major concern, however, more importantly, war readiness and the prevention of catastrophic failure are primary in the overall scope of corrosion prevention.

The United States Air Force, like many other US military branches have taken a bold initiative to make an objective evaluation of different methods. This paper will detail the test objective, parameters, environment, the actual test, benefits and results. The evaluation of Vapor Corrosion Inhibitor (VCI) technology as a total system of protection was the main purpose of this test program. The USAF had adopted a chemical preservation storage program, which was subsequently delayed for this evaluation.

EXPERIMENTAL PROCEDURE

Test Objectives

This evaluation was initiated to validate and compare preservation systems for deep storage of vehicle and air ground support equipment (AGE) with a commonly used chemical preservation technology and a newer VCI system. VCI performance on different metals in industrial and marine atmospheres have been studied and analyzed experimentally to show corrosion rates as shown in Table 1[4]. VCI products have been used since the World War and newer VCI technologies have been further developed since that time. This test program evaluated a system of products as a solution.

The expected life for a deep storage/preservation system was defined for a 3-5 year time frame, with minimal or no upkeep. The reapplication of current chemical preservation being used as well as requirements for exercising, time and labor were considered. Due to the reduction of forces, reapplication of the products and exercising of vehicle and equipment assets is difficult and costly.

Zero deterioration of equipment was considered as one of the criteria in considering the VCI system. The desired result 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 break out is critical and necessary in a deep storage program.

Test Parameters

There were a number of key parameters set by the USAF for the program. Preparation for the actual test began with the identification of the vehicles and equipment to be allocated for preservation. USAF teams selected and issued orders for the preparation of the selected assets. The length of the test was predetermined for a term of one year.

Preparation. The USAF team requested that the individual sites prepare the assets to be in "excellent" working and physical condition. The VCI manufacturer then assessed and calculated product needs based on vehicle and equipment specifications. The company provided training procedures, materials, equipment necessary; and personnel to assist and train military personnel for the application of the VCI 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 in order to make a fair evaluation in different climatic zones and atmospheric conditions. Guam was chosen due to the extreme climates and severe corrosion conditions. The trade winds and high ultra violet light exposure make this location a suitable choice for the tropical environment. Two locations in Korea, one located centrally and the other on the coast, were selected to conduct to give a good evaluation of the four seasons in two different environments. The seasons vary from very hot and humid to extremely cold conditions with a great deal of precipitation. Lastly, two locations in Oman complete the various climatic conditions requiring testing. Desert extremes that encompass high UV are found in the first location and hot, humid conditions are found in the other on the Persian Gulf coast. The assets location during the time of the test were determined to include inside storage in climate controlled and bare sheds and also outside in all climates and atmospheres.

Identification of Assets. The identification and choice of assets was made to include the widest range of different vehicles and equipment possible to make a fair evaluation. Specifically, tactical, road building, personnel vehicles, and AGE. The AGE equipment included bomb lifts, compressors, trailers, generator sets among others. 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 were chosen to evaluate AGE; being Guam and Osan, Korea. At the time of preservation, it should be noted that condition and preparation of the assets 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 vehicles of medium size were chosen for the chemical preservation process.

Products. The products used encompassed a suite of products with the same and compatible technology to provide a system solution. Many of these products are already being used successfully by militaries worldwide. Applicable military specifications, (Table 2), National Stock Numbers (NSN), Qualified Product Listing (QPL), and NATO numbers are already in place for most of the products.

From the start, surface preparation was accomplished with cleaning/degreasing and rust removing products that were modified with VCI additives to further enhance corrosion prevention. VCI emitting products were used for electronic compartments and miscellaneous enclosures, which included large void spaces and the cabs of the vehicles. Temporary and permanent coatings were used as under carriage coatings as well as clear, permanent coatings for overall coverage of selected assets. Lubricating products were used for bare metal surfaces on moving parts such as forklift chains and hydraulic cylinders. Additives for fuel, coolants, oil and hydraulic lubricants complement the internal systems. Finally, the four types of covers utilized which especially fabricated to contain VCI additive technology. It should be noted that all of the VCI products used in this test program were selected to be environmentally friendly.

Application Procedure. A step by step process was used in the application. Throughout the application of the products, one to five personnel worked on an individual asset. More than one procedure could be performed at a time allowing for optimum use of time and personnel. Military procedure for repair and preparation of the assets prior to the preservation were part of normal maintenance directives.

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

Step 2. Remove rust with liquid or wipe type product both containing VCI additives.

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

Step 4. Apply permanent VCI water base; clear coating for assets chosen. Apply one coat at a 2 mil (50 micron) wet film thickness. For severe corrosion conditions where vehicles will not be stored inside or with a cover, wait 30 minutes to one hour and apply second coating at a 2 mil thickness.

Step 5. Apply VCI lubrication coating to all working and moving parts as well as bare metal such as hydraulic cylinders. Apply paraffin base VCI coating to rusted areas beneath vehicles or equipment. In accordance with (Table 2, No.2 & 4).

Step 6. Lower liquid levels of coolants, hydraulic oil, regular oils (Table 2, No.3) to required capacity for the additives. Fill fluid reservoirs with required VCI additive product. Calculations for requirements are made prior to application in order to facilitate their addition. Charts specifying capacities and measured fluids to be added were provided prior to application.

Step 7. Apply VCI modified lubricating grease to all areas normally greased including zirc fittings (Table 2, No.4).

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

Step 9. Apply chosen VCI protective covers. Four covers were chosen: VCI polyethylene shrink film, VCI reinforced films with and without soft interior linings and VCI high UV resistant, reinforced covers with a soft interior lining. Specifications of these products are given in (Table 2, No. 8 & 9). Refer to Figure 1, 60K Cargo Loader with VCI Military Shrink Wrap.

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

TEST RESULTS

Evaluations were done concurrently with other storage tests. Sister services use of VCI products and their successes are considered in the evaluation, as well as other allied military services and industry alike. Other storage tests completed as well as different methods identified over a period of time were bench marks for establishing parameters for the test, results required to make a storage process successful, as well as undesired aspects identified with these bench mark.

Testing of VCI performance in industrial and marine atmospheres was carried out in a field exposure test, Table 1. The different metals evaluated are, for the most part, the predominant metals in the vehicles and equipment used for the USAF preservation evaluation. The length of the test was one year and the purpose of the evaluation was to measure the corrosion rates in mils/year. The test site was Cure Beach, North Carolina. The procedure was as follows:

1. The preparation of the metal coupons were made according to ASTM G1-90, Standard practice for preparing, cleaning, and evaluating corrosion test specimens.
2. The metal coupons were placed into wooden enclosures.
3. Emitting devices (NSN 6850-01-338-1393) were placed inside the enclosures.
4. Enclosures were opened and the metal coupons removed after test duration.
5. Corrosion rate measurements were made according to ASTM G1-90.

Results show that the unprotected coupons measured greater corrosion rates. Correlation of this field test can be made with the USAF evaluation. In a visual evaluation, vehicles and equipment protected with the VCI system did not show any signs of corrosion.

Monitoring

A thorough inspection and extensive photographic records of the assets were made prior to storage by military and contractor personnel. A limited number of preserved assets were evaluated at 6 months for the PACAF region and at 9 months for the CENTAF locations. Results of corrosion protection at this point were impressive. Although high condensation and excessive amounts of water were experienced in the preservation in the Pacific Rim locations, better than a 90% rate of corrosion protection was achieved. After removal from storage, the vehicles were placed into areas that would provide heavy use for a period of 90 days. The goal of zero defects was accomplished and mechanical failures were not reported as a result of the VCI protection system used.

In September of 2000 (after 12 months of preservation), the PACAF assets were de-preserved. Photographs and extensive evaluations were made to record the condition of the assets. Indications and physical results show that the corrosion protection and mechanical soundness exceeded the 90% VIC. Removal of the covers took at the most 3-4 minutes. The start up of the vehicles took the major portion of the recorded time in the depreservation procedure. Removal of any of the VCI products other than the covers was unnecessary and will continue to provide protection to the assets. Immediate war readiness was accomplished.

Chemical preservation products

Ten vehicles were designated for the traditional chemical preservation. The evaluation shows that the application and removal time involved make this a costly alternative. The application of the exterior and interior products was very specific and detailed. The assets were stored inside and were not exposed to outside climatic conditions. Application time per vehicle was up to 4-5 days. The necessity to practically pull the vehicles apart made it very time consuming and labor intensive. Break out times ranged from 5.5 to 6 hours per vehicle. The use of flammable solvents made this a hazardous removal and cumbersome work practice.

VCI Product application

The application of the VCI system has been analyzed by vehicle, cost of the VCI products, and the labor/man hours required. A brief analysis is presented in Table 3. Additional time and labor were not required for the application process. Break out times averaged at 18 minutes per vehicle. This included the removal of any cover used and the actual start up of the vehicle. No matter what the size of the asset, only a few minutes were needed for the removal of the cover. Removal of any other VCI product was not necessary. The assets were ready for immediate utilization or war readiness. All vehicles and equipment were placed in high usage areas to evaluate the effects if any of the products to the operation of the asset.

Benefits identified with VCI systems

The benefits derived and identified in the evaluation of VCI systems in deep storage and preservation were quickly noted throughout the application process and upon the completion of the test. Ease of application and the ability for military personnel to be proficient in the application of the VCI products was the first benefit identified to be advantageous. The efficiency of the application and removal created further economic advantages. Although the cost of the products was competitive to current products being used, this was not the most critical factor in the evaluation.

During the term of the test, exercising of the equipment was not needed. Of the few repairs identified after breakout, none were as a result of the VCI preservation system. This in itself is critical due to the decreased need for man-hour labor for exercising, repair, parts and maintenance. Normal costs attributed to labor and parts is substantially less and further analysis will be given to determine overall savings.

The reduction of breakout time in comparison to other preservation programs was considered to be also a very significant factor. The enhancement of immediate war readiness makes the VCI deep storage and preservation system the best alternative if deep storage is considered for any vehicle or piece of equipment. Briefing after briefing regarding this system creates a great deal of interest. A final executive report will be made and presented to the Air Staff at the Pentagon.

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The environmentally friendly products/systems are advantageous to worker safety as well. The USAF as other military branches has taken the initiative to replace hazardous products as well as cumbersome work practices.

CONCLUSIONS

The benefits of this innovative VCI technology have been quoted as being revolutionary in the storage of vehicles and equipment storage. The technology has been proven commercially and industrially in all industries. The savings have been determined to outweigh the costs and any risks involved in the testing.

Comparing both processes, the VCI products were shown to be the overall system that can provide all of the above benefits with superior corrosion protection even in extreme atmospheric conditions. The consideration of reduced manpower stands out and has been quoted as "revolutionary" in the way assets can be protected.

The entire VCI storage process/system approach was very quick and the procedures for placing vehicles into storage are very simple. Basically, after one day of training, the USAF team was well versed and confident. Moreover, the VCI products were very users friendly and easy to apply. Preparation was not labor intensive.

USAF expectations after exercising the vehicles in the 90 days that followed the final depreservation, are that the VCI process and materials would be a great asset to incorporate into the USAF War Readiness Materials (WRM) vehicle storage program. The amount of time to prepare and break out the vehicles and equipment combined with corrosion protection given should greatly contribute to war fighting capabilities.

REFERENCES

1. B. A. Miksic, "Temporary Protection, Lay-up and Mothballing", 1988 Handbook, Manual.

2. K. L. Vasanth and C.M. Dacres, "Vapor Phase Inhibitors for Navy Applications", CORROSION 97, paper no.179 (Houston, Texas, NACE International, 1997).
3. K. L. Vasanth, "Corrosion Inhibition in Naval Vessels", CORROSION 96, paper no.233, (Denver, CO, NACE International, 1996).
4. B. A. Miksic, "Volatile Corrosion Inhibitors Find a New Home", Sept. 1977, Material Engineering Forum, Pages 14-18.

TABLE 1

VCI PERFORMANCE IN INDUSTRIAL AND MARINE ATMOSPHERES

ASTM G1-90

Metal Coupons	**Corrosion rate in Mils/Year**	
	Unprotected	**Protected with VCI**
Aluminum 1000, 3000, 5000,6000 series	2.15	<0.25
Mild Steel	21.8	<0.13
HSLA (high-strength, low alloy Steel)	1.2	0.08
Naval Brass	0.2[1]	0.03
Titanium	0.0[2]	0.0[3]
Stainless Steels: 410	0.01[3]	0.01[4]
304	<0.1[5]	0.01[6]
301, 316, 321	0.0[7]	0.0[7]
Copper	0.22[5]	0.01[6]

Notes:

1. Dezincification 2. Immune to attack; no pitting or weight loss observed 3. Pitting 4. Pitting reduced 5. Staining 6. No Staining 7. Free from pitting and weight loss

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	Static dissipative material
8	MIL-22019C MIL-22020D	Barrier materials, Transparent, Flexible, Sealable, VCI treated Bags, Transparent, Flexible, Heat seal, VCI treated
9	MIL-B-40028B	Bags, Barrier with Vapor Corrosion Inhibitor treated liner

TABLE 3

Vehicle	Application in Man Hours Per vehicle	VCI Product Cost Per vehicle
Average of 120 vehicles	4.14 hours	$338 USD
HMMVW	2.69 hours	$160 USD
40K Air Cargo Loader	7.5 hours	$795 USD

Notes: 1. Many other types of vehicles were included; these were chosen to illustrate the differences in cost. 2. Application included the entire process from initial cleaning, coating and on to the last step.

Figure 1. 60K Air cargo loader covered with VCI High UV, Flame Retardant Shrink film.