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Evaluating Efficacy of Volatile Corrosion Inhibitors versus Traditional Methods for Preservation of Industrial Equipment and Operational Spare Parts

Eric Uutala
Cortec Corporation
4119 White Bear Parkway
St. Paul, MN 55110
euutala@cortecvci.com

Cliff Cracauer
Cortec Corporation
4119 White Bear Parkway
St. Paul, MN 55110

Boris Miksic, FNACE
Cortec Corporation
4119 White Bear Parkway
St. Paul, MN 55110

ABSTRACT

Corrosion protection of industrial equipment and spare parts during mothballing and deep storage is an ongoing issue worldwide. Many factors must be considered when determining best practice for asset preservation; length of time, type of equipment, accessibility, preventative maintenance schedule, and environmental and storage conditions have the greatest influence, while other conditions may also need to be considered. Traditional preservation methods such as nitrogen blanketing, desiccation, or heavy, wax based surface applied coatings can be costly to implement and maintain, and can become even more costly if they fail. Replacement of equipment can result in millions of dollars in losses - both in replacement cost and facility downtime. Incorporation of volatile corrosion inhibitor (VCI) systems is an effective method to replace traditional preservation programs. These systems are often more cost effective to implement, have little to no maintenance cost, and have less failures in long term preservation programs. These VCI systems will be explored in both laboratory and real world settings, compared to traditional systems, and costs of each will be compared.

Key Words: Mothballing, deep storage, preservation, equipment, inhibitor

INTRODUCTION

Extensive research has been done on the topic of mothballing and layup procedures using VCI[1]. Effective preservation of industrial equipment and operational spare parts requires many considerations. Among these considerations are:

Length of Protection

Short preservation times can mean high protection costs. Often, this leads to an approach where no VCI or other traditional methods of protection are used, because the upfront cost of preservation is perceived to be too high.

Conversely, long term protection leads to low cost of protection. In this case, while clients will see the value in preservation, they struggle to determine the best method. Decisions are not always made based on technical validity of method, but rather convenience of application and/or inspection. Examples would include the use of humidity indicator cards or coupons to determine the presence or absence of corrosion protection within a package.

Accessibility

Storage in remote areas (jungle, undeveloped locations) creates challenges in corrosion monitoring, and replenishing protection. Equipment design can create further challenges related to accessing some of the internal spaces and other critical areas that require protection.

Type of Equipment

Value of equipment can be critical. However, the more important factor is replacement lead time and/or amount of time to rework equipment that has corrosion. Unique or specially designed equipment often have long lead times if a replacement is required. This can lead to downtime at a plant which can be orders of magnitude more costly than the equipment itself. Therefore, the cost of protection and preservation is irrelevant compared to the value of protecting the asset and the work time it provides.

Steam turbines, for example, are subject to regular, short term down time for maintenance. In this time, corrosion can occur on ASTM [(1)] A470[2] steel blades and discs. Specifically, these surfaces are subject to stress corrosion cracking (SCC), crevice corrosion, and hydrogen embrittlement. VCI liquids have been tested as effective corrosion preventives in this application.[3]

Preventive Maintenance Schedule

Equipment and spare parts may have a regular preventive maintenance schedule, with weekly, monthly, or yearly inspections. Or, they have no scheduled inspection after the preservation process. This can have a significant impact on the preservation system used on a specific piece of equipment.

Environmental and Storage Conditions

Arguably, this is the most important factor to consider in any preservation job. Material selection will vary greatly depending on the conditions in which the equipment will be stored, ranging from tropical coastal conditions to climate controlled warehouses.

[(1)] ASTM International (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

Costs of VCI Methods versus Traditional Layup Methods

Total cost of preservation can be determined based on the specific method chosen. When using a method such as nitrogen blanket, the cost of the nitrogen generator must also be considered. With a heavy duty wax based coating, removal time must be considered. Table 1 outlines the basic costs involved with traditional layup methods, compared to similar VCI systems.

If we were to consider a generic piece of equipment with dimensions of 20'x20'x10', the associated costs for preservation would be as follows:

Table 1
Cost Comparison of Preservation Methods on 20ftx20ftx10ft (6.1mx6.1mx3.05m) Piece of Equipment (External)

Product	Material Cost	Equipment Cost	Total Cost
Wax Based Coating	$120[4]	$150-950[5,6]	$270-1070
VCI Liquid A	$5	$150-950	$155-955
MIL-PRF-131[7] Barrier Film	$0.18/sq. ft.[8]	$5000-6500[9,10,11]	$5180-6680
VCI Shrink Film (250μ)	$0.08/sq. ft.	$650[12]	$730
Nitrogen Blanket	N/A	$5000-20000+	$5000-20000+
Desiccant	$0.31/cubic foot	None	$1240

The same costs would apply to protecting the internals of a piece of equipment, such as a pressure vessel. However, a secondary VCI liquid can be used, specifically for void space protection.

Table 2
Cost Comparison of Preservation Methods on 20ftx20ftx10ft (6.1mx6.1mx3.05m) Vessel (Internal)

Product	Material Cost	Equipment Cost	Total Cost
Wax Based Coating	$120	$150-950	$270-1070
VCI Liquid B (Internal)	$540	$150-950	$690-1090
Nitrogen Blanket	N/A	$5000-20000+	$5000-20000+
Desiccant	$0.31/cubic foot	None	$1240

Material costs were calculated based on product cost combined with recommended application/dosage rate. Utilizing a VCI system of liquid and shrink film (250 micron), this piece of equipment can be preserved for $1000, which includes cost of material and all equipment needed.

When considering the cost of a system, setup and removal cost must also be considered. VCI products can be flushed or sprayed with water, in the case of VCI liquids, or simply removed, in the case of VCI shrink film. Traditional methods may require harmful solvents and/or time consuming procedures for removal and disposal. Nitrogen blanketing often requires hours of monitored leak testing prior to final purge.

EXPERIMENTAL PROCEDURE

The efficacy of VCI technology for corrosion protection of industrial equipment and spare parts during layup has been confirmed via multiple laboratory test methods, as well as real life applications.

Laboratory Testing – VIA Method

NACE [(2)] TM 0208-2008[13] was designed to determine the vapor inhibiting ability of VCI products. In this test, carbon steel plugs are polished with sand paper, cleaned with methanol, and then placed within a jar apparatus. VCI packaging is hung from the underside of the jar, ensuring that the VCI does not contact the steel plugs (Figure 2). The jar is sealed and allowed to sit in ambient laboratory conditions for 20 hours. At this point, a glycerin and water solution is introduced, and humidity is created. The jars are allowed to sit for 2 hours, and are then placed in an oven set at 40±3C for 2 hours. The jars are then opened, and the steel plugs are visually inspected (Figure 3, 4).

The NACE TM was modified as follows: first, steel plugs were cleaned with an ambient temperature methanol dip, as opposed to a 60 second boiling methanol immersion. Further, the plugs were hand dried with a lint free wipe, as opposed to a heat gun or hair drier, per the NACE TM.

This type of test is especially relevant for VCI materials that will be used in mothballing and layup applications, since many of them will never be in direct contact with the metal surfaces they are meant to protect. If the products are unable to pass this test, they will likely fail in preservation applications as well. VCI shrink films are regularly run to a modified version of NACE TM0208-2008 to ensure their efficacy.

Laboratory Testing – VCI Packaging versus Barrier Film for 15 Year Storage

In preparation for a 15 year build ahead storage program, automotive transmission components were wrapped in one of the following: a single layer VCI film, a multi-layer VCI film, or a standard foil barrier film. After being wrapped, components were exposed to modified ASTM [(2)] D-1748[14] conditions. Test conditions were 49C (120F) and constant condensing humidity, per ASTM D-1748. However, the test was much larger than that of the standard, in order to allow the number and size of components to be tested. As such, the wrapped components were not in constant rotation, per the standard. Parts were removed, unwrapped, visually inspected, and photographed on a 4 week schedule, for a total of 20 weeks.

Real World Analysis

VCI preservation systems have been used in military and industrial applications worldwide for over 60 years. More recently, these projects have focused on vehicle and heavy equipment preservation, which addresses multiple systems, starting with grease points along the axle, moving to all relevant fluid reservoirs (oil, fuel, coolant, etc), and finishing with a VCI shrink wrap around the entire piece. The goal is to leave a vehicle or piece of equipment that is completely preserved, but ultimately ready for use at a moment's notice.

[2] ASTM International (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

Figure 1: Fully preserved military equipment, after preservation with an integrated VCI system.

RESULTS AND DISCUSSION

VIA Test

VCI films (both shrink and standard) are regularly run through VIA testing, to ensure that they can provide effective corrosion protection while not in contact with the metal surface. Figure 2 below shows test setup. Figure 3 represents typical VIA results for an effective VCI film.

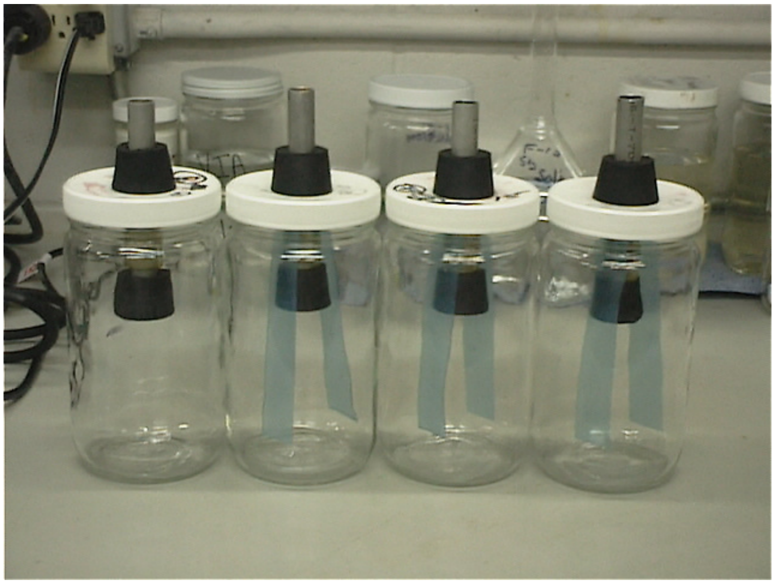

Figure 2: VIA Test Setup, with VCI film.

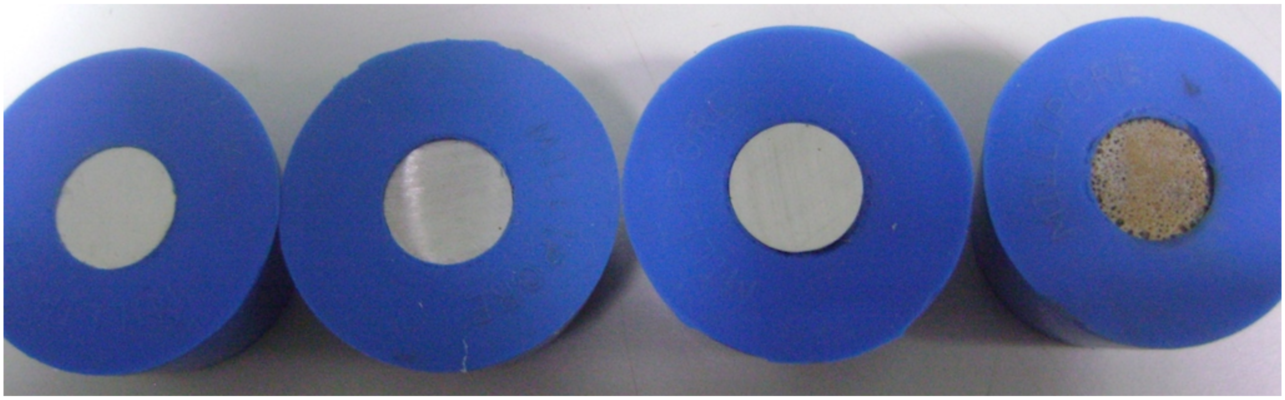

Figure 3: VIA Test results with VCI shrink film. Control plug is on the far right.

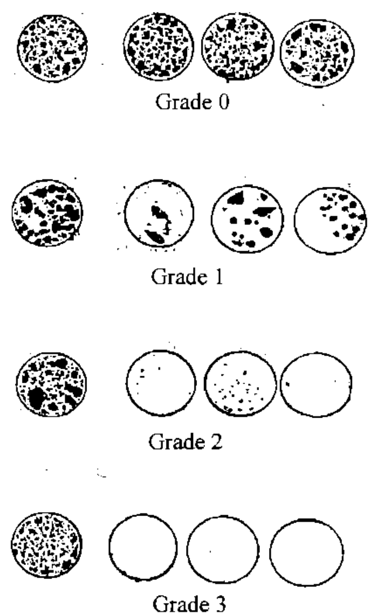

Figure 4: VIA Test Grades.

Laboratory Testing – VCI Packaging versus Barrier Film for 15 Year Storage

After 20 weeks of modified ASTM [(3)] D-1748 testing, the most effective corrosion protection system was with a multi-layer VCI packaging system[15]. This system was implemented for the 15 year warehouse storage program, and no corrosion claims were made during that time.

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(3) ASTM International (ASTM), 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

Figure 5: Automotive transmission component, after 16 weeks in modified ASTM [4] D-1748 testing, wrapped in VCI film.

Real World Analysis

VCI preservation systems have been successfully used around the world in military and heavy industrial applications, on vehicles, various pieces of equipment, and critical operational spare parts. Storage conditions have ranged from indoors (temperature controlled warehouses) to outdoor, tropical conditions. Applications have been successful in all of these areas. Figure 6-13 show examples of VCI preservation systems being used on a variety of equipment.

[4] ASTM International (ASTM), 100 Barr Harbor Drive., West Conshohocken, PA 19428-2959

Figure 6: VCI aerosol used to protect Combat Vehicle Reconnaissance (CVR) [(5)] wheels. VCI additives were also used in the fuel, coolant, engine, gearbox, drive, and brake systems.

[5] United Kingdom Ministry of Defence, Whitehall, London, SW1A 2HB, United Kingdom

Figure 7: CVR wrapped in VCI shrink film, in place for final preservation.

Figure 8: United States Air Force [(6)] Cargo Loader, preserved with VCI shrink film.

Figure 9: Three United States Air Force Cargo Loaders, preserved with VCI shrink film.

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(6) United States Air Force, 1690 Air Force Pentagon, Washington, DC, 20330-1670

Figure 10: Gas turbine shells, prior to preservation.

Figure 11: Gas turbine shells, after preservation with VCI shrink film.

Figure 12: Rotor being cleaned prior to preservation.

Figure 13: VCI shrink film being applied to rotor.

CONCLUSIONS

For more than 60 years, volatile corrosion inhibitors have been effectively implemented into preservation applications worldwide. VCI films are an integral part of these systems, and they will provide protection both in contact and vapor phase, as shown in NACE [(7)] TM0208-2008. Multi-layer VCI packaging systems have been successfully implemented in preservation of operational parts for programs lasting over 10 years, with no corrosion claims.

In the case of larger pieces of equipment, more diverse VCI systems have been effectively implemented for preservation. These types of systems have been used for the United States Armed Forces [(8)] and the United Kingdom Ministry of Defense [(9)] [16] along with many manufacturers of heavy industrial equipment.

Additionally, VCI systems provide a preservation method that is cost neutral at worst, and in many cases provide a cost benefit compared to traditional chemical methods. This does not take into account the labor savings, performance capability, or disposal costs, which can be difficult to quantify when speaking in generalities. When compared to nitrogen or dehumidification systems, VCI preservation programs provide a clear cost and performance benefit. Additionally, they can be implemented in virtually any environment, as they do not require access to power or other utilities needed to provide continuous protection and monitoring over an extended period of time.

VCI provides an effective layup and mothballing system that traditional methods cannot meet from a cost or performance standpoint. Equipment costs are minimal for application, as are costs associated with maintenance, cleanup, and disposal of waste materials.

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