Technical Report Number 99-05

# FINAL REPORT
# VOLATILE CORROSION INHIBITOR (VCI)
# TEST STUDY

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# INTRODUCTION

## I. SUMMARY:

This study, funded by AMSTA-AR-WET, resulted in a determination of the most effective method of preservation for small arms components. The data presented in this report supports the conclusion that a VCI sealed within a barrier bag provides the best protection against corrosion for these parts. Further, the lower the water-vapor-transmission rate of the barrier material the greater the quality of the preservation. It was also found that although the addition of a preservative oil is not harmful, it does not improve the corrosion prevention of this method. Additional recommendations are as follows:

1. A VCI is the preferred material to provide corrosion protection for small arms weapons and its spare parts.
2. Do not use a preservative oil with a MIL- B-22020 Class 2 bag. The Class 1 bag shall be used.
3. It is not cost effective to use a preservative oil with a VCI product.
4. Use of approved commercial VCI products in accordance with a specification control drawing needs to be prepared to be utilized as a mechanism for specifying commercial products.
5. A class C, MIL-B-117 bag should be limited in its use due to the high WVTR of the MIL-B-121 material.
6. It is more cost effective and practical to use a VCI bag in lieu of a VCI wrap/product within a bag.
7. A barrier bag should be placed around an item in lieu of around a container. If not possible, a neutral/non-corrosive wrap should be used to aid in corrosion control.
8. A caveat statement shall be present on all Special Packaging Instructions utilizing VCI materials. "Compatibility test of MIL-I-8574 applies."

## II. BACKGROUND:

There are a number of preservation methods available for the prevention of corrosion during long-term storage of phosphate-coated parts for small arms weapon systems. The most widely utilized method is that of the combined use of applied preservative oils (formerly known as P-type preservatives defined in MIL-P-116) and a VCI barrier wrap. Over the years some reports of corrosion have surfaced. Test studies that have been conducted have provided no more than an array of inconclusive data. To compound this dilemma, the emergence of a variety of new VCI formulas, the stress on environmental issues, and the metamorphosis of the application of military specification and standards, has been cause for a call for testing of the compatibility/effectiveness of these chemical compounds. It is therefore the intent of this study to fully test a wide variety of methods of preservation, including existing army preservative methods and new commercial corrosion protection

products. An analysis of the results will serve as a basis for the formulation of a DOD-wide policy for the preservation and packaging of small arms.

The background information offered in this section of the report will provide the reader with a means of understanding the materials tested, and an overview of the series of tests conducted.

## II. PRESERVATION USING VOLATILE CORROSION INHIBITORS (VCI)

In the years prior to 1950, chemists had been experimenting with a variety of vapor-emitting chemicals. Under certain controlled conditions, these chemicals demonstrated properties of corrosion inhibition and the neutralization of the effects of moisture-laden air within a package. This knowledge gave birth to the challenge of formulating a method of harnessing the raw form of VCI compounds (fine white crystalline powders) into feasible, workable material for packaging applications.

Eventually, processes for impregnating or coating intimate wrapping materials were developed. As a coating, the VCI chemical is mixed with casein which acts as an adhesive to bond the crystals to the paper surface. In impregnated papers, the process consists of soaking the paper in a solvent containing a concentration of the inhibitor. The solvent evaporates and leaves the crystals impregnated in the fibers and the surface of the paper.

The anti-corrosive power of the VCI paper results from the sublimation of the crystals. The vapor moves from the paper, filling the entire volume of the pack. Once the vapor concentration reaches a certain level, equilibrium is established. The vapor sublimates in crystal form on the surface of the item at a rate similar to that of the initial sublimation. This sublimation forms an invisible protective film coating on all surfaces of the item, including cracks and crevices. This film resists the corrosive effects of water vapor. Corrosion is prevented as long as the chemical remains active. This time period is dependent upon the effectiveness of the pack in keeping the concentrated vapors inside.

The availability of VCI as a wrap made it practical for DOD applications. The reported advantageous features of the chemicals as listed below also enhanced the introduction VCI into the field of military use.

a. Packaging material, volatile corrosion inhibitor, treated-opaque (MIL-P-3420): This specification established the requirements for treated material (Kraft paper, barriers, or fiberboard laminates) which may be coated or impregnated with the corrosion inhibitor. These treated materials are furnished in two forms, three classes based on strength of the materials and six styles based on the composition of the material. Form "a" material has the carrier coated with the inhibitor. Style A is made from flat Kraft paper. Style B is made from crepe or embossed Kraft paper. Style C is a greaseproof, waterproof, moldable material made by laminating heavy or medium VCI treated Kraft paper to aluminum foil (QQ-A-2876).

Style G is a grease-proof, waterproof material made of a heavy or medium VCI-treated Kraft paper constructed to conform to MIL-B-121, Grade A, Type I or II.

b. VCI-treated, heat sealable, flexible, transparent film (MIL-B-22019): This specification covers a transparent, flexible, heat-sealable film, coated or impregnated with VCI. It is intended for use in packs where transparency is desired to facilitate inspection of the item without disturbing the pack. MIL-B-22020 is the specification for bags that are fabricated from MIL-B-22019 material. The bags are available by NSN in eleven different sizes, or may be procured in dimensions as specified by the contract or purchase order. These bags are intended primarily for use in the packaging of items that are adaptable to protection by VCI-treated materials for domestic and overseas shipment, and shipboard use.

In addition to these specified materials, volatile corrosion inhibitors have become available for commercial applications in several advanced formulas. VCI tablets, inserted into a barrier bag with the item to be preserved, is one example of such an application. Other products which are currently on the market are VCI sponges, VCI spray formulas, VCI emitting systems, VCI coating solutions, and VCI plus desiccant combo pouches. VCI in these forms makes it ideal for extremely quick and simple packaging procedures. This significantly reduces the risks of exposure to the open air. However, these materials may not have the high volatility component for immediate protection. The new VCI materials are designed for multi-metal assemblies and not necessarily bare steel. Thus, the component that protects the bare steel is eliminated because it generally is too aggressive for metals like copper, cadmium and zinc.

As used in complete military packaging applications, the VCI materials are used in conjunction with a variety of combinations of other packaging materials. The basic methodology implemented has been the application of MIL-PRF-3150 or VV-L-800 preservative, utilization of the VCI as a barrier, with an outer package of a MIL-B-117 bag and an ASTM D5118 fiberboard box.

## III. PACKAGING, HANDLING AND STORAGE OF VCI MATERIALS:

The degree of sensitivity of VCI materials, attributed largely to the fact that the preservative qualities are catalyzed and subsequently diminished by exposure to the open air, required that a specification be written to govern the procedures for the use of those materials. MIL-I-8574, entitled "Utilization of Volatile Corrosion Inhibitors", provides details on the handling, properties, limitations, test requirements, and storage life/conditions of the MIL-P-3420, MIL-B-22020, and MIL-B-22019 materials. The specification states that VCI's must be stored in air-tight, dry, cool environments and should not be exposed to direct sunlight. MIL-I-8574 also states that VCI's should not be used in direct contact with plastics, non-ferrous metals, optical surfaces, and/or housing assemblies for electronics components. The specification also provides direction in methodology, as it states that the VCI wraps

should completely enclose the item and be sealed in air-tight barriers. Information regarding the quantities of VCI required for various preservation applications, quality assurance provisions, compatibility testing, and outer packaging is also included.

In addition to the precautionary statements stated in MIL-I-8574, the following drawbacks to using a preservative oil alone, or with a VCI, have been noted:

a. Preservative oils do not always provide a continuous coating.
b. The preservative oil must be removed by the user before applying the operating lubricant.
c. If preservative oil is not removed prior to use, the preservative attracts dust and dirt.

## IV. OVERVIEW OF TEST SERIES:

Originally, the test study was set-up to run one series of a high-humidity test on the group of samples delineated in TABLE I. The test procedure was derived from those of previous test studies on VCI materials. The test was a 154-day long uniform exposure test (104 +/- 5° F and 85 +/- 5% RH) for the simultaneous evaluation of the 84 sets of test samples. The samples were pulled from the chamber at 34, 64, 84, 124 and 154 day intervals. This test method, however, did not result in a significant number of failures. To obtain meaningful results in a reasonable period of time, the testing was continued in a salt-fog spray environment to accelerate corrosion. This phase was conducted in accordance with ASTM B117 (Standard Practice for Operating Salt Spray (Fog) Apparatus), exposing the samples to a 5% salt-fog spray solution with examination at 7-day intervals. Each subsequent phase of this test consisted only of the samples which passed the prior phase or were deemed to require further testing. The samples used for both phases are identified in the following table. Either a test grade steel plate or a phosphated machine gun component are identified in the table.

Samples 1 and 2 in the Phase II (Salt Fog) were previously subjected to 34 days of the Phase I environment. Samples 3 and 4 in Phase II, 64 days of Phase I; samples 5 and 6, 84 days and samples 7-8, 124 days, respectively.

The laminations/coatings of the barrier materials are not continuous and may be reason for some failures such as sample 3 at 7 days in Phase II. However, sample 3-7 passed at 84 days. Other reasons could be an improper seal or a pinhole in the barrier that had gone undetected. There also might have been an error in preparing or marking samples 9 and 12. Experience has indicated that the results should have been reversed.

This series of tests, spanning over two years, produced a significant amount of data which permitted a fair analysis to be made. The analysis ultimately provided the means to develop policies regarding the preservation and packaging of small arms, therefore accomplishing the original objectives of the study.

**CONCLUSIONS:**

a. A fiberboard box will react (causing corrosion) with an item that is preserved with an oil or VCI, if the item is not wrapped or bagged.

b. A VCI or a preservative oil greatly increases the corrosion protection than just a sealed bag or wrap.

c. A method utilizing a bag made from MIL-B-131 provides better protection than most other methods.

d. The corrosion protection of a MIL-B-22020 bag decreased when in combination with a preservative oil.

e. Preservative oil in combination with MIL-P-3420 did not improve the corrosion resistance over just MIL-P-3420.

**Background Test Data**

## TEST MATERIALS

A. The six VCI materials were tested for conformance IAW Fed-Std-101, Method 4031. The MIL-P-3420, Mil-B-22019, CORTEC CP Tablets, 110, 126 and 146 all met the minimum requirements of the FED-STD.

B. The preservative oils VV-L-800, MIL-PRF-3150 and Mil-C-16173 Gr 3 were tested for conformance: MIL-PRF-3150 and VV-L-800 per para 3.6 of Fed-Std-791 Method 5329 and Mil-C-16173 Gr 3, per para 4.6.11 3 of ASTM D 1748. All three oils met minimum requirements.

C. The water-vapor transmission rates were determined for the three different Mil-B-117 bags, per ASTM D3833 and expressed in grams of $H_20$ vapor/100 sq. in/24 hrs. The rates are MIL-B-121 (MIL-B-117 class C) 0.5773, L-P-378 (MIL-B-117 class B) 0.2760 and MIL-B-131 (MIL-B-117 class E) 0.02

D. MATERIAL SOURCES

| MATERIAL | TYPE/STYLE | SOURCE |
|---|---|---|
| MIL-P-3420 | Style C | Ludlow, Homer LA. |
| MII-B-22019 | Type II | IVEX , Troy, OH |
| MII-B-117 | Class B,C, and E | Rock Island Arsenal |
| VV-L-800 | GSA | Mfg Octagon Process, Inc. |
| MIL-PRF-3150 | GSA | Royal Lubricants |
| MIL-C-16173 Gr3 | GSA | Ashland Oil |

## INITIAL SAMPLE LISTING

1. Two types of samples were used: test grade steel plates and in-process phosphated machine gun component parts.

2. Samples were graded for corrosion using the grading table of ASTMD 610. It was somewhat harder to grade the phosphated parts because of the numerous edges and blackened non-uniform surfaces. Grading in some cases is just indicated as a failure.

**TABLE OF SAMPLES:**

| | | |
|---|---|---|
| 28. MIL-B-22020 + MIL-PRF-3150 | 10 | F |
| 29. MIL-B-22020 + MIL-C-16173 | 10 | F |
| 30. ASTM D5118 + MIL-B-121 | 8 | F |
| 31. ASTM D5118 + MIL-B-121 + VV-L-800 | 8 | F |
| 32. ASTM D5118 + MIL-B-121 + MIL-PRF-3150 | 8 | F |
| 33. ASTM D5118 + MIL-B-121 + MIL-C-16173 | 8 | F |
| 34. ASTM D5118 + MIL-P-3420 | 8 | F |
| 35. ASTM D5118 + MIL-P-3420 + VV-L-800 | 8 | F |
| 36. ASTM D5118 + MIL-B-121 + MIL-PRF-3150 | 8 | F |
| 37. ASTM D5118 + MIL-B-121 + MIL-C-16173 | 8 | F |
| 38. VCI 126 | 8 | C |
| 39. VCI 126 + VV-L-800 | 8 | C |
| 40. VCI 126 + MIL-PRF-3150 | 8 | C |
| 41. VCI 126 + MIL-C-16173 | 8 | C |
| 42. MIL-B-117, CL-B + TABLET | 8 | C |
| 43. MIL-B-117, CL-C + TABLET | 8 | C |
| 44. MIL-B-117, CL-E + TABLET | 8 | C |
| 45. MIL-B-117, CL-B + 329 | 8 | F |
| 46. MIL-B-117, CL-C + 329 | 8 | F |
| 47. MIL-B-117, CL-E + 329 | 8 | F |
| 48. MIL-B-117, CL-B + 146 | 8 | C |
| 49. MIL-B-117, CL-C + 146 | 8 | C |
| 50. MIL-B-117, CL-E + 146 | 8 | C |
| 51. ASTM D5118 + VCI 110 | 8 | C |
| 52. ASTM D5118 + VCI 146 | 8 | C |
| 53. ASTM D5118 + TABLET | 8 | C |
| 54. MIL-B-117, CL-B + VCI 146 + VV-L-800 | 8 | C |
| 55. MIL-B-117, CL-C + VCI 146 + VV-L-800 | 8 | C |
| 56. MIL-B-117, CL-E+ VCI 146 + VV-L-800 | 8 | C |

| SAMPLE NUMBER/METHOD | QUANTITY | SPECIMEN |
|---|---|---|
| 1. MIL-B-117, CL-B | 8 | F |
| 2. MIL-B-117, CL-C | 8 | F |
| 3. MIL-B-117, CL-E | 8 | F |
| 4. ASTM D5118 | 8 | F |
| 5. MIL-B-117, CL-B + VV-L-800 | 10 | F |
| 6. MIL-B-117, CL-C + VV-L-800 | 10 | I |
| 7. MIL-B-117, CL-E + VV-L-800 | 10 | F |
| 8. MIL-B-117, CL-B + MIL-PRF-3150 | 10 | F |
| 9. MIL-B-117, CL-C+ MIL-PRF-3150 | 10 | F |
| 10. MIL-B-117, CL-E + MIL-PRF-3150 | 10 | F |
| 11. MIL-B-117, CL-B + MIL-C-16173 | 10 | F |
| 12. MIL-B-117, CL-C + MIL-C-16173 | 10 | F |
| 13. MIL-B-117, CL-E + MIL-C-16173 | 10 | F |
| 14. MIL-B-117, CL-B + MIL-P-3420 | 10 | F |
| 15. MIL-B-117, CL-C + MIL-P-3420 | 10 | F |
| 16. MIL-B-117, CL-E + MIL-P-3420 | 10 | F |
| 17. MIL-B-22020 | 10 | F |
| 18. MIL-B-117, CL-B + MIL-P-3420 + VV-L-800 | 10 | F |
| 19. MIL-B-117, CL-C + MIL-P-3420 + VV-L-800 | 10 | F |
| 20. MIL-B-117, CL-E + MIL-P-3420 + VV-L-800 | 10 | F |
| 21. MIL-B-117, CL-B + MIL-P-3420 + MIL-PRF-3150 | 10 | F |
| 22. MIL-B-117, CL-C + MIL-P-3420 + MIL-PRF-3150 | 10 | F |
| 23. MIL-B-117, CL-E + MIL-P-3420 + MIL-PRF-3150 | 10 | F |
| 24. MIL-B-117, CL-B + MIL-P-3420 + MIL-C-16173 | 10 | F |
| 25. MIL-B-117, CL-C + MIL-P-3420 + MIL-C-16173 | 10 | F |
| 26. MIL-B-117, CL-E + MIL-P-3420 + MIL-C-16173 | 10 | F |
| 27. MIL-B-22020 + VV-L-800 | 10 | F |

| | | |
|---|---|---|
| 78. MIL-B-117, CL-B + TABLET + MIL-C-16173 | 10 | F |
| 79. MIL-B-117, CL-C + TABLET + MIL-C-16173 | 10 | F |
| 80. MIL-B-117, CL-E + TABLET + MIL-C-16173 | 8 | F |
| 81. MIL-B-117, CL-B + OIL 327 | 8 | F |
| 82. MIL-B-117, CL-C + OIL 327 | 8 | F |
| 83. MIL-B-117, CL-E + OIL 327 | 8 | F |

KEY:

F IS REPRESENTATIVE OF A TEST PLATE.

C IS REPRESENTATIVE OF A COMPONENT.

| | | |
|---|---|---|
| 57. MIL-B-117, CL-B + VCI 146 + MIL-PRF-3150 | 8 | C |
| 58. MIL-B-117, CL-C + VCI 146 + MIL-PRF-3150 | 8 | C |
| 59. MIL-B-117, CL-E + VCI 146 + MIL-PRF-3150 | 8 | C |
| 60. MIL-B-117, CL-B + VCI 146 + MIL-C-16173 | 8 | C |
| 61. MIL-B-117, CL-C + VCI 146 + MIL-C-16173 | 8 | C |
| 62. MIL-B-117, CL-E + VCI 146 + MIL-C-16173 | 8 | C |
| 63. MIL-B-117, CL-B + VCI 110 + VV-L-800 | 8 | F |
| 64. MIL-B-117, CL-C + VCI 110 + VV-L-800 | 8 | F |
| 65. MIL-B-117, CL-E + VCI 110 + VV-L-800 | 8 | F |
| 66. MIL-B-117, CL-B + VCI 110 + MIL-PRF-3150 | 8 | F |
| 67. MIL-B-117, CL-C + VCI 110 + MIL-PRF-3150 | 8 | F |
| 68. MIL-B-117, CL-E + VCI 110 + MIL-PRF-3150 | 8 | F |
| 69. MIL-B-117, CL-B + VCI 110 + MIL-C-16173 | 8 | F |
| 70. MIL-B-117, CL-C + VCI 110 + MIL-C-16173 | 8 | F |
| 71. MIL-B-117, CL-E + VCI 110 + MIL-C-16173 | 8 | F |
| 72. MIL-B-117, CL-B + TABLET + VV-L-800 | 10 | F |
| 73. MIL-B-117, CL-C + TABLET + VV-L-800 | 10 | F |
| 74. MIL-B-117, CL-E + TABLET + VV-L-800 | 10 | F |
| 75. MIL-B-117, CL-B + TABLET + MIL-PRF-3150 | 10 | F |
| 76. MIL-B-117, CL-C + TABLET + MIL-PRF-3150 | 10 | F |
| 77. MIL-B-117, CL-E + TABLET + MIL-PRF-3150 | 10 | F |

## RESULTS OF THE UNIFORM EXPOSURE TO HIGH HUMIDITY TEST

| SAMPLE METHOD | 34 DAYS | | 64 DAYS | | 84 DAYS | | 124 DAYS | | 154 DAY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1. MIL-B-117, CL-B | F-6 | F-5 | F-8 | F-5 | F-5 | F-5 | F-7 | F-6 | | |
| 2. MIL-B-117, CL-C | F-5 | F-4 | F-6 | F-5 | F-5 | F-5 | F-5 | F-4 | | |
| 3. MIL-B-117, CL-E | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 4. ASTM D5118 | F-1 | F-2 | F-1 | F-1 | F-9 | F-2 | F-4 | F-1 | | |
| 5. MIL-B-117, CL-B + VV-L-800 | F-1 | F-2 | F-8 | F-9 | F-2 | F-4 | F-2 | F-1 | F-2 | F-1 |
| 6. MIL-B-117, CL-C + VV-L-800 | F-1 | F-2 | F-1 | F-1 | F-1 | F-2 | F-1 | F-1 | F-1 | F-1 |
| 7. MIL-B-117, CL-E + VV-L-800 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 8. MIL-B-117, CL-B + MIL-PRF-3150 | F-8 | F-9 | F-6 | F-6 | F-7 | F-7 | F-8 | F-9 | F-9 | F-6 |
| 9. MIL-B-117, CL-C+ MIL-PRF-3150 | F-3 | F-5 | F-4 | F-3 | F-2 | F-1 | F-4 | F-6 | F-3 | F-5 |
| 10. MIL-B-117, CL-E + MIL-PRF-3150 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 11. MIL-B-117, CL-B + MIL-C-16173 | P | P | P | P | P | P | P | P | P | P |
| 12. MIL-B-117, CL-C + MIL-C-16173 | F-5 | F-4 | F-2 | F-5 | F-6 | F-4 | F-3 | F-2 | F-1 | F-2 |
| 13. MIL-B-117, CL-E + MIL-C-16173 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 14. MIL-B-117, CL-B + MIL-P-3420 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 15. MIL-B-117, CL-C + MIL-P-3420 | F-6 | F-9 | F-9 | P | F-8 | F-9 | F-8 | F-6 | F-8 | F-3 |
| 16. MIL-B-117, CL-E + MIL-P-3420 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 17. MIL-B-22020 | NO | NO | NO | NO | NO | NO | NO | NO | NO | P |
| 18. MIL-B-117, CL-B + MIL-P-3420 + VV-L-800 | NO | NO | NO | NO | NO | NO | NO | NO | NO | P |
| 19. MIL-B-117, CL-C + MIL-P-3420 + VV-L-800 | P | P | P | P | P | F-8 | F-9 | F-7 | F-7 | F-6 |
| 20. MIL-B-117, CL-E + MIL-P-3420 + VV-L-800 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |

# TEST REPORT FOR PHASE I
# UNIFORM EXPOSURE TO HIGH HUMIDITY

February 1997

**BACKGROUND/TEST METHODOLOGY:** In October 1996, LOGSA PSCC, located at Tobyhanna Army Depot, began to run a 154 day long uniform exposure test (104 +/- 5° F and 85 +/- 5% RH) for the simultaneous evaluation of 84 sets of test samples.

**RESULTS:** A table of the results is provided. The left side of the chart denotes the method of packaging utilized. The pass/fail designation in each box across the chart denotes the result which correspond with the pull cycle (34, 64, 84, 124, and 154 days) appearing at the top of the chart. all "failed' samples are followed by numeric value ranging from 1 through 9. These values correspond to the rating criteria found in ASTM D610, Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments. The rating are provided for informational purposes only, as evidence of corrosion in any percentage could be construed to be a failure of the packaging method. "NOT OPENED" samples are considered to be "PASSED". Many of the NO samples were transparent or MIL-B-131 barriers so that evaluation could be completed without opening. For samples which were in barriers which could not be seen through the 134/154 day samples were opened and examined. If those samples were found to be passed, all the preceding samples were labeled "Not Opened" and assumed to be passed. These unopened samples were utilized in the second phase of the test.

**ANALYSIS:** An evaluation of the failures in regards to the packaging procedures/materials utilized justifies the following conclusions:

a. A preserved item (either with an oil and /or VCI) without a wrap and/or barrier bag, will react with a fiberboard container.

b. MIL-B-121 barrier material is less effective in any combination than the other barrier materials.

c. Bag or wrap alone does not prevent corrosion. A VCI and/or preservative is required.

The remainder of the sample combinations were considered to have passed. In order to drawing further conclusions, a more severe test procedure is to be introduced. The samples are to be subjected to modified salt fog spray test.

| SAMPLE METHOD | 34 DAYS | | 64 DAYS | | 84 DAYS | | 124 DAYS | | 154 DAY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 37. ASTM D5118 + MIL-B-121 + MIL-C-16173 | P | P | P | P | P | P | P | P | P | P |
| 38. VCI 126 | P | P | P | P | P | P | P | P | P | P |
| 39. VCI 126 + VV-L-800 | P | P | P | P | P | P | P | P | P | P |
| 40. VCI 126 + MIL-PRF-3150 | P | P | P | P | P | P | P | P | P | P |
| 41. VCI 126 + MIL-C-16173 | P | P | P | P | P | P | P | P | P | P |
| 42. MIL-B-117, CL-B + TABLET | P | P | P | P | P | P | P | P | P | P |
| 43. MIL-B-117, CL-C + TABLET | P | P | P | P | P | P | P | P | P | P |
| 44. MIL-B-117, CL-E + TABLET | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 45. MIL-B-117, CL-B + 329 | P | P | P | P | P | P | P | P | P | P |
| 46. MIL-B-117, CL-C + 329 | P | P | P | P | P | P | P | P | P | P |
| 47. MIL-B-117, CL-E + 329 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 48. MIL-B-117, CL-B + 146 | P | P | P | P | P | P | P | P | P | P |
| 49. MIL-B-117, CL-C + 146 | P | P | P | P | P | P | P | P | P | P |
| 50. MIL-B-117, CL-C + 146 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 51. ASTM D5118 + VCI 110 | F-9 | F-8 | F-7 | F-6 | F-6 | F-4 | F-5 | F-8 | | |
| 52. ASTM D5118 + VCI 146 | F-9 | F-5 | F-6 | F-5 | F-4 | F-6 | F-3 | F-2 | | |
| 53. ASTM D5118 + TABLET | P | P | F-9 | F-8 | F-8 | F-8 | F-7 | F-8 | | |
| 54. MIL-B-117, CL-B + VCI 146 + VV-L-800 | P | P | P | P | P | P | P | P | P | P |
| 55. MIL-B-117, CL-C + VCI 146 + VV-L-800 | P | P | P | P | P | P | F-9 | F-8 | F-7 | F-8 |
| 56. MIL-B-117, CL-E+ VCI 146 + VV-L-800 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 71. MIL-B-117, CL-E + VCI 110 + MIL-C-16173 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 72. MIL-B-117, CL-B + TABLET + VV-L-800 | P | P | P | P | P | P | P | P | P | P |
| 73. MIL-B-117, CL-C + TABLET + VV-L-800 | P | P | P | P | P | P | P | F-8 | F-7 | F-8 |
| 74. MIL-B-117, CL-E + TABLET + VV-L-800 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 75. MIL-B-117, CL-B + TABLET + MIL-PRF-3150 | P | P | P | P | P | P | P | P | P | P |
| 76. MIL-B-117, CL-C + TABLET + MIL-PRF-3150 | P | P | P | P | P | P | P | P | P | P |
| 77. MIL-B-117, CL-E + TABLET + MIL-PRF-3150 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 78. MIL-B-117, CL-B + TABLET + MIL-C-16173 | P | P | P | P | P | P | P | P | P | P |
| 79. MIL-B-117, CL-C + TABLET + MIL-C-16173 | P | P | P | P | P | P | P | P | P | P |
| 80. MIL-B-117, CL-E + TABLET + MIL-C-16173 | NO | NO | NO | NO | NO | NO | NO | NO | NO | P |
| 81. MIL-B-117, CL-B + OIL 327 | P | P | P | P | P | P | P | P | P | P |
| 82. MIL-B-117, CL-C + OIL 327 | P | P | P | P | P | P | P | P | P | P |
| 83. MIL-B-117, CL-E + OIL 327 | NO | NO | NO | NO | NO | NO | NO | NO | NO | P |

| SAMPLE METHOD | 34 DAYS | | 64 DAYS | | 84 DAYS | | 124 DAYS | | 154 | DAY |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 57. MIL-B-117, CL-B + VCI 146 + MIL-PRF-3150 | P | P | P | P | P | P | P | P | P | P |
| 58. MIL-B-117, CL-C + VCI 146 + MIL-PRF-3150 | P | P | P | P | P | P | F-9 | F-7 | F-6 | F-6 |
| 59. MIL-B-117, CL-E + VCI 146 + MIL-PRF-3150 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 60. MIL-B-117, CL-B + VCI 146 + MIL-C-16173 | P | P | P | P | P | P | P | P | P | F |
| 61. MIL-B-117, CL-C + VCI 146 + MIL-C-16173 | P | P | P | P | P | F-8 | F-9 | F-8 | F-7 | F-4 |
| 62. MIL-B-117, CL-E + VCI 146 + MIL-C-16173 | NO | NO | NO | NO | NO | NOP | NO | NO | P | P |
| 63. MIL-B-117, CL-B + VCI 110 + VV-L-800 | P | P | P | P | P | P | P | P | P | P |
| 64. MIL-B-117, CL-C + VCI 110 + VV-L-800 | P | P | P | P | P | P | P | F-8 | F-9 | F-7 |
| 65. MIL-B-117, CL-E + VCI 110 + VV-L-800 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 66. MIL-B-117, CL-B + VCI 110 + MIL-PRF-3150 | P | P | P | P | P | P | P | P | P | P |
| 67. MIL-B-117, CL-C + VCI 110 + MIL-PRF-3150 | P | P | P | P | P | P | F-9 | F-9 | F-8 | F-5 |
| 68. MIL-B-117, CL-E + VCI 110 + MIL-PRF-3150 | NO | NO | NO | NO | NO | NO | NO | NO | P | P |
| 69. MIL-B-117, CL-B + VCI 110 + MIL-C-16173 | P | P | P | P | P | P | P | P | P | P |
| 70. MIL-B-117, CL-C + VCI 110 + MIL-C-16173 | P | P | P | P | P | P | P | F-7 | F-8 | F-6 |

# TEST REPORT FOR PHASE II
# SALT FOG SPRAY TESTING

September 1998

**BACKGROUND/TEST METHODOLOGY:** This test study includes all those samples from Phase I which had not failed. Fifty-two sets of two samples each were exposed to a 5% salt spray solution in accordance with ASTM B117 (Standard Practice for Operating Salt Spray (Fog) Apparatus). A pull-schedule of 7-day intervals was followed for a period up to 140 days.

**RESULTS:** A table of the results is provided.

**ANALYSIS:** An evaluation of the failures in regards to the packaging procedures/materials utilized justifies the following conclusions:

a. Bag or wrap alone does not prevent corrosion. A VCI and/or preservative is required.
b. MIL-B-131 barrier material provides the best protection against corrosion.
c. VCI barrier materials increase the corrosion protection to a certain degree.
d. Some CORTEC products gave favorable results.

# SALT FOG TEST RESULTS

| SAMPLES | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days/Grade | | Days/Grade | | | | | | | | | | | |
| 29. MIL-B-22020 + P3 | 14 | 4 | 14 | 10 | | | | | | | | | | |
| 31. PPP-B-636 + MIL-B-121 + P9 | 7 | 4 | 7 | 4 | | | | | | | | | | |
| 32. PPP-B-636 + MIL-B-121 + P7 | 7 | 10 | 7 | 10 | 14 | 7 | 14 | 8 | | | | | | |
| 33. PPP-B-636 + MIL-B-121 + P3 | 7 | 10 | 7 | 10 | 14 | 9 | 14 | 10 | 98 | 1 | 98 | 8 | | |
| 34. PPP-B-636 + MIL-B-3420 | 7 | 10 | 7 | 10 | 14 | 10 | 14 | 10 | 98 | 8 | 98 | 9 | | |
| 35. PPP-B-636 + MIL-B-3420 + P9 | 7 | 10 | 7 | 10 | 21 | 10 | 21 | 9 | 98 | 3 | 98 | 8 | | |
| 36. PPP-B-636 + MIL-B-3420 + P7 | 7 | 10 | 7 | 10 | 21 | 10 | 84 | 7 | | | | | | |
| 37. PPP-B-636 + MIL-B-3420 + P3 | 7 | 10 | 7 | 10 | 21 | 10 | 84 | 10 | 98 | 7 | 98 | 6 | | |
| 38. VCI 126 | 35 | 7 | 35 | 7 | 42 | 8 | 42 | 8 | 35 | FAIL | 35 | FAIL | | |
| 39. VCI 126 + P9 | 105 | 10 | 105 | 10 | 105 | 6 | 105 | 5 | 98 | 8 | 98 | 6 | | |
| 40. VCI 126 + P7 | 35 | 7 | 35 | 10 | 42 | 8 | 42 | 8 | 35 | FAIL | X bag open | | | |
| 41. VCI 126 + P3 | 84 | 8 | 84 | 8 | 84 | 7 | 84 | 10 | 84 | 8 | 84 | 8 | | |
| 42. MIL-B-117 CLB + TABLET | | | | | | | | | 35 | 8 | 35 | 8 | | |
| 43. MIL-B-117 CLC + TABLET | | | | | | | | | 35 | 10 | 35 | 10 | | |
| 45. MIL-B-117 CL B + 329 | 21 | 7 | 21 | 6 | | | | | | | | | | |
| 46. MIL-B-117 CL C + 329 | 49 | 8 | 49 | 8 | | | | | | | | | | |
| 47. MIL-B-117 CL E + 329 | 105 | 8 | 105 | 8 | 140 | 8 | 140 | 8 | | | | | | |
| 48. MIL-B-117 CL B + VCI 146 | | | | | | | | | 35 | 10 | 35 | 10 | | |
| 49. MIL-B-117 CL C + VCI 146 | | | | | | | | | 35 | 10 | 35 | 10 | | |
| 63. MIL-B-117 CL B + VCI 110 + P9 | 14 | 9 | 14 | 9 | | | | | | | | | | |
| 72. MIL-B-117 CL B + TABLET + P9 | 35 | 9 | 35 | 5 | | | | | | | | | | |
| 73. MIL-B-117 CL C + TABLET + P9 | 49 | 8 | 49 | 7 | | | | | | | | | | |
| 74. MIL-B-117 CL E + TABLET + P9 | 105 | 4 | | 3 | | | | | | | | | | |
| 75. MIL-B-117 CL B + TABLET + P7 | 14 | 6 | 14 | 10 | 21 | 3 | 21 | 3 | | | | | | |
| 76. MIL-B-117 CL C + TABLET + P7 | 14 | 10 | 14 | 10 | 21 | 8 | 21 | 10 | | | | | | |
| 77. MIL-B-117 CL E + TABLET + P7 | 105 | 8 | 105 | 8 | | | | | | | | | | |
| 78. MIL-B-117 CL B + TABLET + P3 | 21 | 8 | 21 | 8 | | | | | | | | | | |
| 79. MIL-B-117 CL C + TABLET + P3 | 49 | 9 | 49 | 9 | | | | | | | | | | |
| 80. MIL-B-117 CL E + TABLET + P3 | 105 | 10 | 105 | 10 | 140 | 10 | 140 | 10 | | | | | | |
| 81. MIL-B-117 CL B + OIL 327 | 14 | 9 | 14 | 8 | | | | | | | | | | |
| 82. MIL-B-117 CL C + OIL 327 | 14 | 10 | 14 | 10 | 21 | 4 | 21 | 5 | | | | | | |
| 83. MIL-B-117 CL E + OIL 327 | 105 | 6 | 105 | 6 | | | | | | | | | | |

# SALT FOG TEST RESULTS

| SAMPLES | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days/Grade | | Days/Grade | | | | | | | | | | | | | |
| 3. MIL-B-117 CL E | 7 | 8 | 7 | 8 | 14 | 10 | 14 | 10 | 21 | 10 | 21 | 10 | 84 | 10 | 84 | 8 |
| 7. MIL-B-117 CL E + P9 | 105 | 3 | 105 | 3 | | | | | | | | | | | | |
| 8. MIL-B-117 CL B + P7 | 7 | 4 | 7 | 4 | | | | | | | | | | | | |
| 9. MIL-B-117 CL C + P7 | 7 | 10 | 7 | 10 | 14 | 10 | 14 | 5 | 21 | 7 | 21 | 8 | | | | |
| 10. MIL-B-117 CL E + P7 | 105 | 4 | 105 | 4 | | | | | | | | | | | | |
| 11. MIL-B-117 CL B + P3 | 7 | 4 | 7 | 5 | | | | | | | | | | | | |
| 12. MIL-B-117 CL C + P3 | 7 | 4 | 7 | 5 | | | | | | | | | | | | |
| 13. MIL-B-117 CL E + P-3 | 105 | 10 | 105 | 10 | 140 | 8 | 140 | 7 | | | | | | | | |
| 14. MIL-B-117 CL B + MIL-P-3420 | 21 | 10 | 21 | 10 | 28 | 10 | 84 | 10 | 98 | 5 | 98 | 9 | | | | |
| 15. MIL-B-117 CL C + MIL-P-3420 | 21 | 10 | 21 | 10 | 28 | 10 | 84 | 9 | 98 | 4 | 98 | 10 | | | | |
| 16. MIL-B-117 CL E + MIL-P-3420 | 140 | 10 | 140 | 10 | 140 | 10 | 140 | 10 | | | | | | | | |
| 17. MIL-B-22020 | 21 | 5 | 21 | 10 | 28 | 7 | 28 | 10 | 28 | 8 | 28 | 8 | | | | |
| 18. MIL-B-117 CL B + MIL-P-3420+P9 | 14 | 10 | 14 | 10 | 28 | 10 | 84 | 9 | 98 | 8 | 98 | 9 | | | | |
| 19. MIL-B-117 CL C + MIL-P 3420+P9 | 14 | 10 | 14 | 10 | 84 | 9 | 28 | 10 | 98 | 9 | 98 | 9 | | | | |
| 20. MIL-B-117 CL E + MIL-P-3420+P9 | 133 | 10 | 133 | 10 | 140 | 10 | 140 | 10 | | | | | | | | |
| 21. MIL-B-117 CL B + MIL-P-3420+P7 | 14 | 10 | 14 | 10 | 21 | 10 | 84 | 10 | 98 | 8 | 98 | 10 | | | | |
| 22. MIL-B-117 CL C + MIL-P 3420+P7 | 14 | 10 | 14 | 10 | 21 | 10 | 84 | 10 | 98 | 10 | 98 | 10 | | | | |
| 23. MIL-B-117 CL E + MIL-P-3420+P7 | 119 | 10 | 119 | 10 | 140 | 10 | 140 | 10 | 98 | 10 | 98 | 10 | | | | |
| 24. MIL-B-117 CL B + MIL-P-3420+P3 | 14 | 10 | 14 | 10 | 133 | 8 | 133 | 9 | | | | | | | | |
| 25. MIL-B-117 CL C + MIL-P 3420+P3 | 49 | 10 | 49 | 7 | | | | | | | | | | | | |
| 26. MIL-B-117 CL E + MIL-P-3420+P3 | 126 | 10 | 126 | 10 | 140 | 10 | 140 | 10 | | | | | | | | |
| 27. MIL-B-22020 + P9 | 14 | 1 | 14 | 3 | | | | | | | | | | | | |
| 28. MIL-B-22020 + P7 | 14 | 4 | 14 | 10 | | | | | | | | | | | | |