# CORROSION OF AIRCRAFT METALS IN FIRE RETARDANTS

by

Samuel A. Bradford

NORTHERN FOREST RESEARCH CENTRE
INFORMATION REPORT NOR-X-66
JUNE 1973

CANADIAN FORESTRY SERVICE
DEPARTMENT OF THE ENVIRONMENT
5320 - 122 STREET
EDMONTON, ALBERTA T6H 3S5
CANADA

TABLE OF CONTENTS

| | Page |
|---|---|
| ABSTRACT | iii |
| INTRODUCTION | 1 |
| CORRATER TESTS | 3 |
| Apparatus and Materials | 3 |
| Procedure | 4 |
| Results | 5 |
| POTENTIOSTATIC MEASUREMENTS | 7 |
| Apparatus and Materials | 8 |
| Procedure | 8 |
| Results | 9 |
| WEIGHT LOSS MEASUREMENTS | 22 |
| Apparatus and Materials | 22 |
| Procedure | 22 |
| Results | 23 |
| INTERMITTENT IMMERSION TESTS | 25 |
| Apparatus and Materials | 25 |
| Procedure | 26 |
| Results | 27 |
| CONCLUSIONS | 29 |
| GENERAL COMMENTS | 30 |
| ADDITIONAL RESEARCH | 31 |
| Figure 1. Anodic polarization measurements of Alcladding (commercially pure aluminum) on 7075-T6 aluminum alloy immersed in Fire-Trol 100 | 12 |
| Figure 2. Anodic polarization measurements of Alcladding (commercially pure aluminum) on 7075-T6 aluminum alloy immersed in Fire-Trol 931 | 13 |

Page

Figure 3. Anodic polarization measurements of Alcladding (commercially pure aluminum) on 7075-T6 aluminum alloy immersed in Phos-Chek 202 XA................ 14

Figure 4. Anodic polarization measurements of aluminum alloy 7075-T6 immersed in Fire-Trol 100............ 15

Figure 5. Anodic polarization measurements of aluminum alloy 7075-T6 immersed in Fire-Trol 931............ 16

Figure 6. Potentiostatic measurements of aluminum alloy 7075-T6 immersed in Phos-Chek 202 XA............... 17

Figure 7. Potentiostatic measurements of magnesium alloy AZ63-T4 immersed in Fire-Trol 100.................. 18

Figure 8. Potentiostatic measurements of magnesium alloy AZ63-T4 immersed in Fire-Trol 931.................. 19

Figure 9. Potentiostatic measurements of magnesium alloy AZ63-T4 immersed in Phos-Chek 202 XA............... 20

Table 1. Summary of corrater test results .................. 6

Table 2. Initial corrosion rates .......................... 21

Table 3. 24-hour corrosion tests on magnesium alloy AZ63-T4. 24

Appendix A. Corrater test measurements of corrosion rate and pitting index................................ 33

CORROSION OF AIRCRAFT METALS
IN FIRE RETARDANTS

by

Samuel A. Bradford

## ABSTRACT

Long term fire retardant solutions are corrosive to many metals used in the fabrication of aircraft. This investigation concerns the nature and extent of corrosion caused by three commercial fire retardant chemicals on three aircraft metals, specifically aluminum, aluminum alloy 7075-T6, and magnesium alloy AZ63-T4. Each retardant was prepared according to field use specifications and two samples were then diluted to simulate the effect of wash-down water. Results indicate that the corrosiveness of the three commercial products varies with concentration and the type of metal acted upon.

# CORROSION OF AIRCRAFT METALS IN FIRE RETARDANTS

## INTRODUCTION

This research[1] was undertaken to investigate the corrosive nature of long-term fire retardants in full concentration as well as in diluted forms. The retardants being used in Canada to fight forest fires are Fire Trol 100, Fire Trol 931, and PhosChek 202XA.

The retardants are usually flown by airtankers from bases located at public airstrips. The liquids come into contact with metals of the airtanker and support equipment, but also residual retardant from spills on runways and loading sites could be picked up by other aircraft frequenting the airports and cause unsuspected damage. In the interest of safe air operation it has become essential to obtain accurate data on the corrosiveness of these retardants in contact with aircraft metals.

The retardants investigated were (1) Fire Trol 100, produced by Arizona Agrochemical Corporation. It is primarily a suspension of clay in an ammonium sulfate solution. (2) Fire Trol 931, also produced by Arizona Agrochemical Corp. It is mainly a diammonium polyphosphate solution. (3) Phos-Chek 202XA, made by Monsanto Chemical Company and

---

1 Research was conducted and this report was prepared by Dr. Samuel A. Bradford of the Department of Mining and Metallurgy, University of Alberta, under contract to the Canadian Forestry Service of the Department of the Environment.

is primarily a solution of diammonium orthophosphate. The retardants have small amounts of other ingredients, some of them designed to act as corrosion inhibitors.

The retardants were tested in full-strength concentration,[2] diluted 1:1 by volume, and diluted 1:5 by volume; that is, 1 part retardant to 5 parts water. Distilled water was used for the dilutions. Edmonton city water was used for all rinses.

The metals tested in the retardants were (1) aluminum 1100 Al, which is commercially pure aluminum with a maximum of 1.0% Si + Fe, 0.20% Cu, 0.05% Mn, 0.10% Zn, and 0.15% lesser impurities; (2) aluminum alloy 7075-T6, which contains a maximum of 0.50% Si, 0.7% Fe, 1.2-2.0% Cu, 0.30% Mn, 2.1-2.9% Mg, 0.18-0.40% Cr, 5.1-6.1% Zn, 0.20% Ti, and 0.15% lesser impurities. It is solution heat treated and artificially aged. (3) magnesium alloy AZ63-T4, containing 6.0% Al, 0.15% Mn minimum, and 3.0% Zn. It is solution heat treated.

Tests run on these aircraft metals consisted of (1) Corrater tests for corrosion rate, pitting tendency, and film stability; (2) anodic polarization measurements of corrosion rates under more oxidizing conditions; (3) weight loss measurements of average corrosion rates; and (4) intermittent immersion tests for intergranular attack, stress corrosion cracking susceptibility, and crevice corrosion.

---

2 Manufacturer's recommended mixing ratio; i.e., Fire Trol 100, 3.34 lbs retardant powder per Imp. gal. water; Fire-Trol 931, 1 Imp. gal. liquid concentrate per 4 Imp. gal. water; Phos-Chek 202XA, 1.37 lbs retardant powder per Imp. gal. water.

A. Corrater Tests.

Corrosion rates, pitting tendencies, and film stabilities were measured with a Corrater®, which is an instrument widely used in industry to moniter corrosion of metal and changes in corrosiveness of solutions. It consists essentially of a two-pronged probe made of the metal being tested, a source of d.c. voltage that is applied to the probe electrodes, and a micro-ammeter to measure the current flow between the probes. The meter is calibrated directly in mpy (mils per year) corrosion rate. The pitting index is found by reversing the applied potential. The pitting index is qualitative, but it has been found that deep, narrow pits result when the pitting index is larger than the instantaneous general corrosion rate.

1. Apparatus and Materials.

These tests were made with a Model 1171D portable Corrater® manufactured by Magna Corporation, Santa Fe Springs, Cal. The instrument uses the polarization resistance technique as described above to measure corrosion rates on two scales, 0-15 mpy or 0-150 mpy. The higher range can be increased by reducing the applied potential and multiplying the results by a proportional factor. The apparatus has a linearity of ± 2% and a repeatability of ± 2%.

Probes for these tests were made up in the University shops. The metal prongs and electrical wiring were mounted in a polyvinyl chloride body and sealed with epoxy cement. One probe each was machined from commercially pure aluminum 1100Al rod and from aluminum alloy 7075-T6 plate. Five probes were made from pins machined out of a magnesium alloy AZ63-T4 cast aircraft wheel. Severe attack of the magnesium alloy in the retardant solutions made it necessary to start with new probes for most of the test runs. The prongs were all 0.188 inch in diameter with a spacing of 0.175 inch between them.

Three turntables revolving at 1 rpm were constructed in the University shops to provide the stirring required in the test specifications. Consequently, three test runs could be made simultaneously.

2. Procedure.

The test method used was that given in Section 4.3.4 of the U.S. Department of Agriculture, Forest Service Interim Specification 5100-00301. The only deviation was that during the initial conditioning period instead of using static solutions, the retardants were stirred at 1 rpm to prevent settling.

Briefly, the test consisted of:

a. an eight-hour conditioning period;

b. monitoring of the uniform corrosion and pitting tendency for eight hours followed by a gentle rinse and monitoring for an additional eight hours;

c. a hard rinse followed by monitoring for three hours to study film stability.

3. Results.

The complete set of test measurements are given in Appendix A, pages 34 to 60. A qualitative summary of the results is given in Table 1. It shows:

(1) Fire Trol 100 is not corrosive to aluminum or the aluminum alloy 7075-T6, although it has a tendency to pit pure aluminum. The retardant would cause extremely severe attack on bare magnesium alloy AZ63-T4 and would be difficult to hose off.

(2) Fire Trol 931 would not cause general corrosion or pitting problems on aluminum or aluminum alloy 7075-T6. The full-strength retardant will severely corrode magnesium alloy and is difficult to wash off. The problem diminishes as the retardant is diluted.

(3) PhosChek 202XA in full strength causes moderate general corrosion of aluminum and 7075-T6 and is difficult to wash off. When the retardant is diluted it causes no special problem. The retardant tents to pit magnesium alloy AZ63-T4 but general corrosion is low.

TABLE 1

SUMMARY OF CORRATER TEST RESULTS

| Metal | Retardant | Dilution | General Corrosion | Pitting | Film Stability |
|---|---|---|---|---|---|
| Mg Alloy AZ63-T4 | Firetrol 100 | full strength | catastrophic | no | high |
| | | 1 : 1 | catastrophic | no | high |
| | | 1 : 5 | catastrophic | no | high |
| " | Firetrol 931 | full strength | catastrophic | no | high |
| | | 1 : 1 | high | yes | moderate |
| | | 1 : 5 | moderate | no | high |
| " | PhosChek 202XA | full strength | low | yes | low |
| | | 1 : 1 | low | possibly | high |
| | | 1 : 5 | low | yes | high |
| Aluminum | Firetrol 100 | full strength | low | yes | moderate |
| | | 1 : 1 | low | yes | moderate |
| | | 1 : 5 | low | no | low |
| " | Firetrol 931 | full strength | low | no | high |
| | | 1 : 1 | low | no | moderate |
| | | 1 : 5 | low | no | low |
| " | PhosChek 202XA | full strength | moderate | possibly | high |
| | | 1 : 1 | low | no | high |
| | | 1 : 5 | low | no | moderate |
| Al Alloy 7075-T6 | Firetrol 100 | full strength | low | no | low |
| | | 1 : 1 | low | possibly | moderate |
| | | 1 : 5 | low | no | moderate |
| " | Firetrol 931 | full strength | low | no | high |
| | | 1 : 1 | low | no | high |
| | | 1 : 5 | low | yes | moderate |
| " | PhosChek 202XA | full strength | moderate | no | high |
| | | 1 : 1 | low | no | high |
| | | 1 : 5 | low | no | moderate |

B. Potentiostatic Measurements.

Anodic polarization of the metals was measured in an electrolytic cell with a potentiostat to determine their behavior in the retardants when under more oxidizing conditions. Such conditions might occur, for example, if the retardant is highly aerated, if the retardant is not thoroughly mixed, or if the metal is in electrical contact with a more noble metal in the retardant.

Aluminum alloys are commonly clad with a thin skin of pure aluminum (Alcladding) that acts as a sacrificial coating. A scratch through the cladding exposes both pure aluminum and the higher-strength alloy base to the retardant. The potential on the pure aluminum cladding is thus increased and its corrosion rate often is greater than if the aluminum alloy were not present.

In many solutions, aluminum and its alloys will passivate; that is, they will oxidize until a protective film of hydrated oxide completely covers the surface, shielding the metal from the corrodant solution. Therefore, as the oxidizing power of the solution increases the corrosion rate increases for a time, then suddenly decreases when the film forms. It is important to know if the protective mechanism of passivation would work in these retardants.

1. Apparatus and Materials.

The measurements were made with a Model 70TS1 Wenking laboratory potentiostat, manufactured by Gerhard Bank Elektronik, Goettingen, West Germany. This instrument has a differential potential error of less than 1 mv and an accuracy of current readings of 1% of full-scale values, which would be better than 3% for any current reading.

The potential of the sample was measured with respect to a saturated calomel reference electrode (S.C.E.), Model K401 manufactured by Radiometer-Copenhagen.

The electrolytic cell was made up with two cathodes spaced one inch on either side of the anode. Cathodes and anode were made of the same metal. Metals tested were (1) Alclad 7075-T6 aluminum sheet, (2) aluminum alloy 7075-T6 sheet with the cladding removed mechanically by polishing on 600 grit paper, and (3) magnesium alloy AZ63-T4 bars machined from a cast aircraft wheel. The magnesium anodes were painted on all edges with Glyptol®, leaving a small, measured, unpainted area on each side. In very corrosive solutions the paint was covered with electrical tape to prevent peeling.

2. Procedure.

Potentiostatic measurements were made in the electrolytic cell by first setting a desired potential, which is essentially a measure of the oxidizing power in the electrolyte. After the cell stabilized, the current from the anode (the test sample) was read on a milliammeter. The current density is proportional to the corrosion rate. The test runs were made by starting with the sample in the retardant and with no applied potential. The natural potential of the sample depended on the metal and the solution, but was usually between -0.7 and -1.5 volts. A positive potential was applied to the metal in 2 mv steps and the resulting current density was recorded.

Current densities were calculated by dividing the anode current by the total anode area. They were plotted on a logarithmic scale because theoretically the log current density should increase linearly with increasing potential in less viscous solutions where the concentration of the solution around the anode is not changed by the anode reaction. In the retardants tested here, the theory doesn't hold. The logarithmic scale also allows low current densities to be graphed accurately.

3. Results.

The anodic polarization curves measured potentiostatically are shown in Figures 1 to 9 on pages 12 to 20. The caption under each figure explains its essential features. What is plotted in the graphs is the oxidizing power of the solution on the vertical scale, and a measure of corrosion rate on the logarithmic horizontal scale. Note that for the magnesium alloy in Fire Trol 100 and Fire Trol 931 the corrosion rate was so high that the current densities are given in milliamperes per square centimeter, while in all the other graphs the current densities are in microamperes per square centimeter.

Table 2 on page 21 is a tabulation of corrosion rates in mils per year calculated from the current densities with no applied potential.

It must be remembered that these measurements of current densities are instantaneous initial values obtained on a clean metal surface. They are not a simulation of service conditions, such as the Corrater tests are intended to be.

In summary, the graphs show:

(1) The corrosion rate of Alcladding in PhosChek 202XA was fairly high. The corrosion of the magnesium alloy in both Fire Trol 100 and Fire Trol 931 was extremely high, and dilution made it worse. All the other combinations were reasonably good.

(2) PhosChek provides some passivation for Alcladding, which in time will reduce the corrosion rate to an acceptable level. Fire Trol 100 will reduce corrosion slightly by passivation. Fire Trol 931 will not passivate these metals further

under more oxidizing conditions.

(3) Dilution of Fire Trol 100 and Fire Trol 931 will not cause trouble with aluminum or the aluminum alloy. Dilution of PhosChek 202XA will not cause serious trouble, except possibly with 1:5 dilution on the magnesium alloy, if this curve is correct.

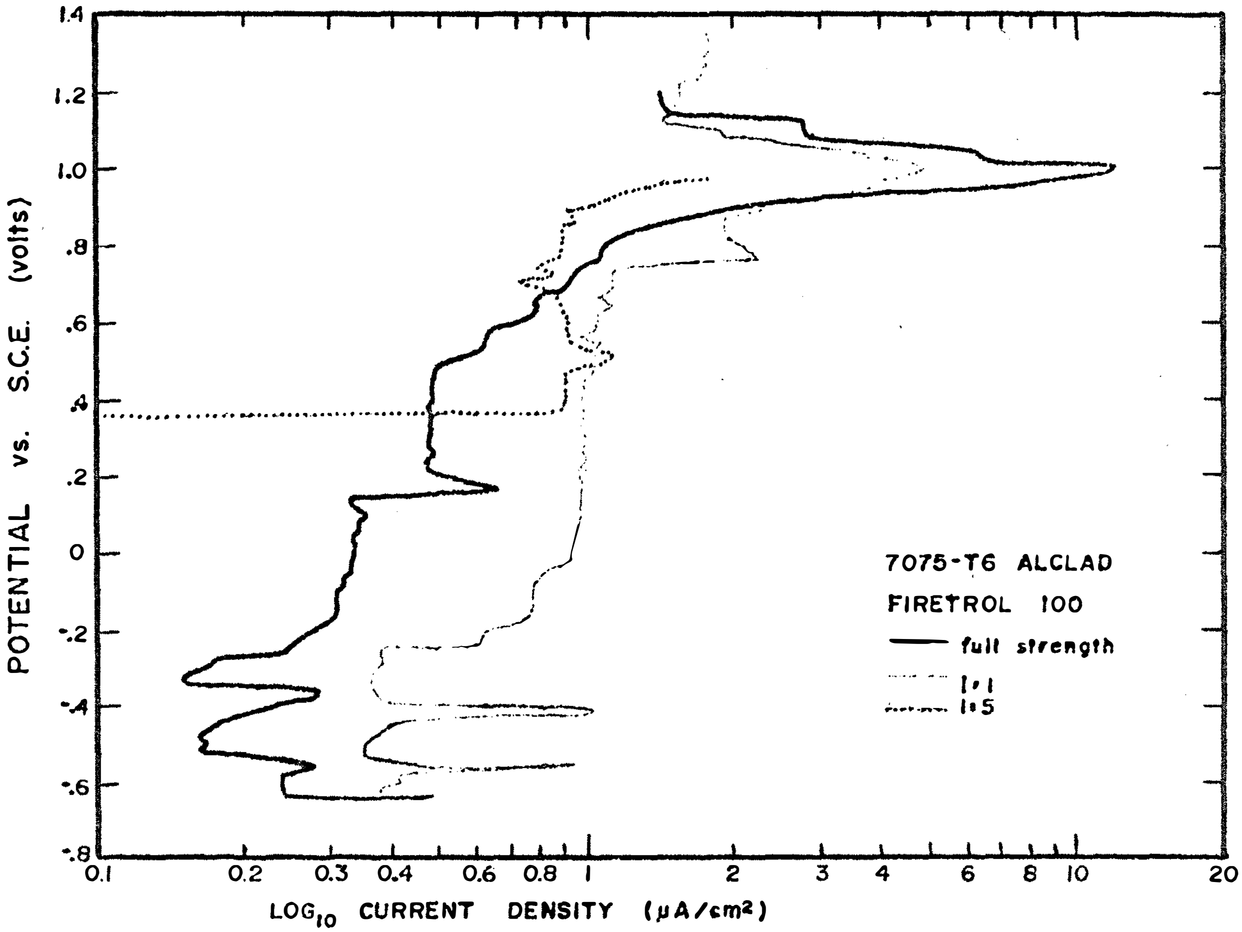


Figure 1. Anodic polarization measurements of Alcladding (commercially pure aluminum) on 7075-T6 aluminum alloy immersed in Firetrol 100. The metal passivates slightly in this liquid. Corrosion in the 1:1 dilution is about the same as in the full-strength concentration. Corrosion in the 1:5 dilution is negligible. Corrosion is at an acceptable level in all concentrations unless the aluminum is electrically connected to a more noble metal in the liquid so that the aluminum corrosion potential is raised by about 1 1/2 volts. This would increase corrosion by a factor of 10.

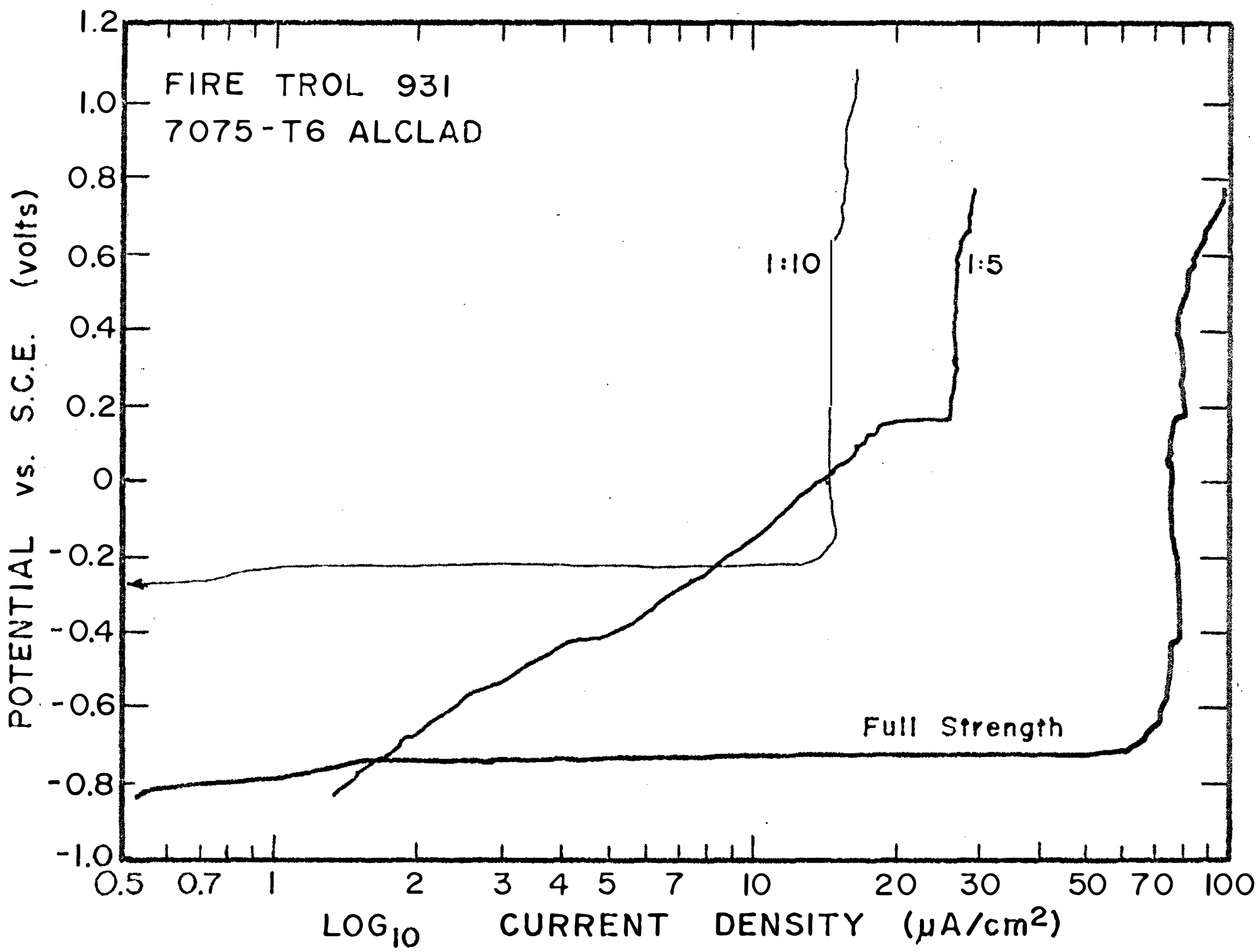


Figure 2. Anodic polarization measurements of Alcladding (commercially pure aluminum) on 7075-T6 aluminum alloy immersed in Firetrol 931. Corrosion in the full-strength retardant would be excessive (approximately 30 mpy) if the solution is only slightly more oxidizing than laboratory conditions, as it might be if well aerated. Dilution makes the situation much safer; at 1:1 dilution a more oxidizing situation will increase the corrosion in a gradual manner, rather than suddenly. Corrosion at 1:10 dilution is extremely low.

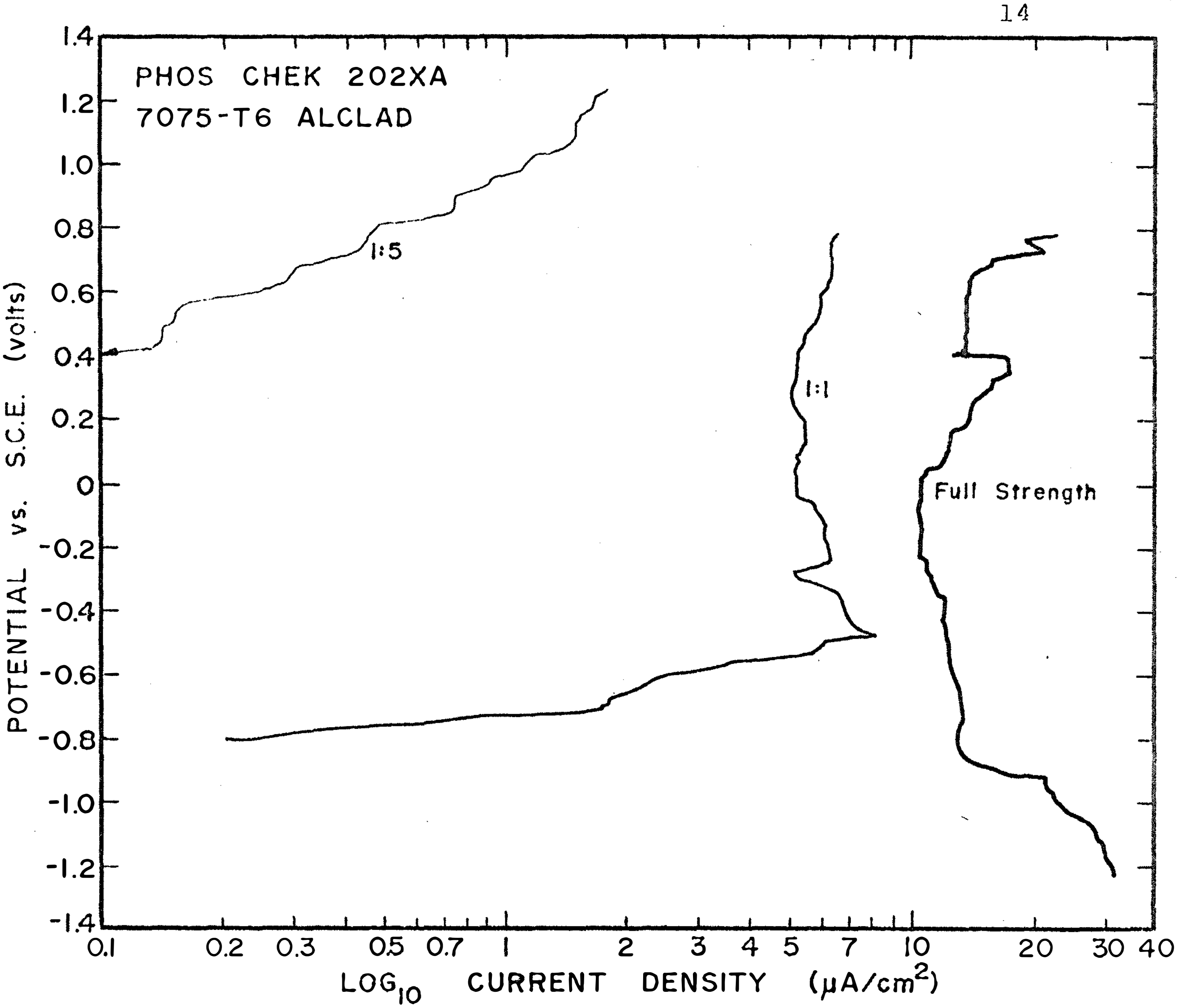


Figure 3. Anodic polarization measurements of Alcladding (commercially pure aluminum) on 7075-T6 aluminum alloy immersed in PhosChek 202XA. Corrosion in the full-strength retardant is borderline (13 mpy) but a washdown that dilutes it 1:1 or 1:5 eliminates corrosion problems. In full-strength retardant the metal will passivate slightly, becoming less corrodible under more oxidizing conditions.

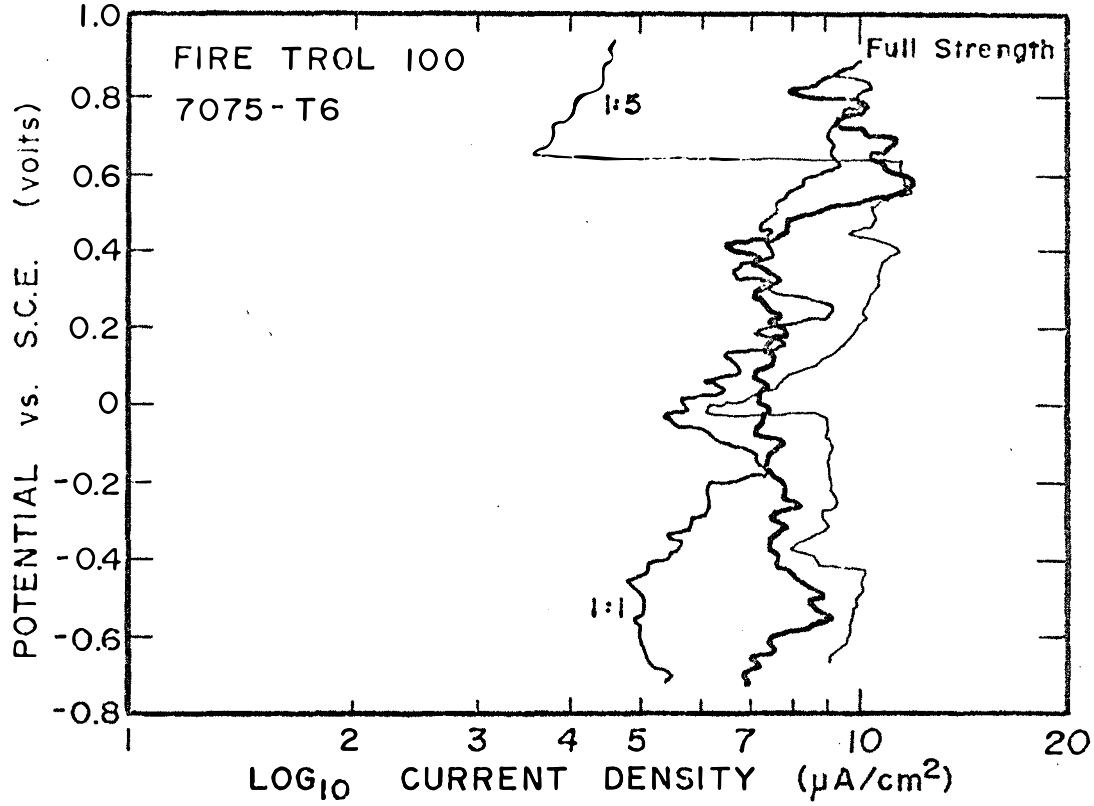


Figure 4. Anodic polarization measurements of aluminum alloy 7075-T6 immersed in Firetrol 100. Corrosion rate is about the same (3 mpy) for all concentrations except that the metal will passivate in the 1:5 dilution at sufficently high potential (>1.5 v). Electrical coupling of the 7075-T6 alloy with a less corrodible metal can reduce the corrosion rate of the aluminum alloy to about half its former value in the retardant diluted 1:5.

The corrosion rates of 7075-T6 in this retardant are over 10 times as great as those of the pure aluminum Alcladding.

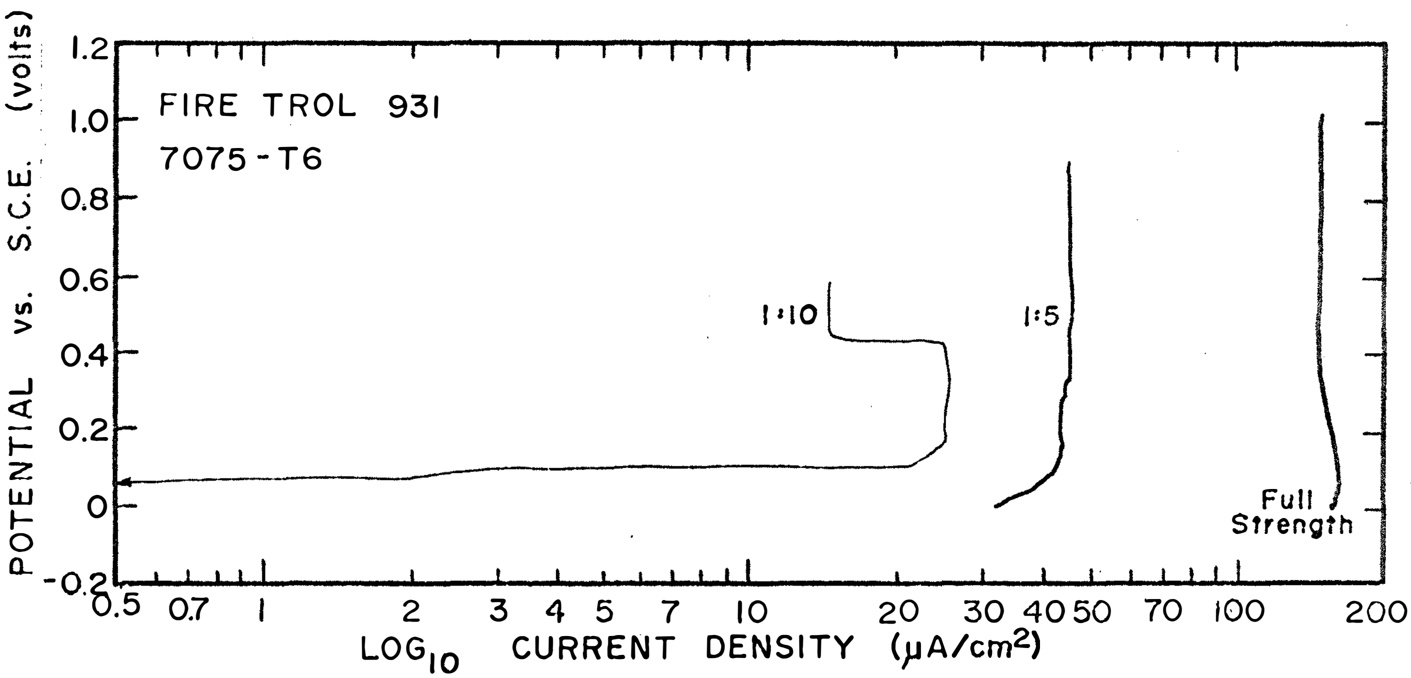


Figure 5. Anodic polarization of aluminum alloy 7075-T6 immersed in Firetrol 931. Curves are shown for potentials greater than 0 volts vs. saturated calomel reference. The corrosion potentials with no applied voltage were about -0.9 volt. Corrosion rates are unacceptably high under very oxidizing conditions, such as when connected to a more noble metal.

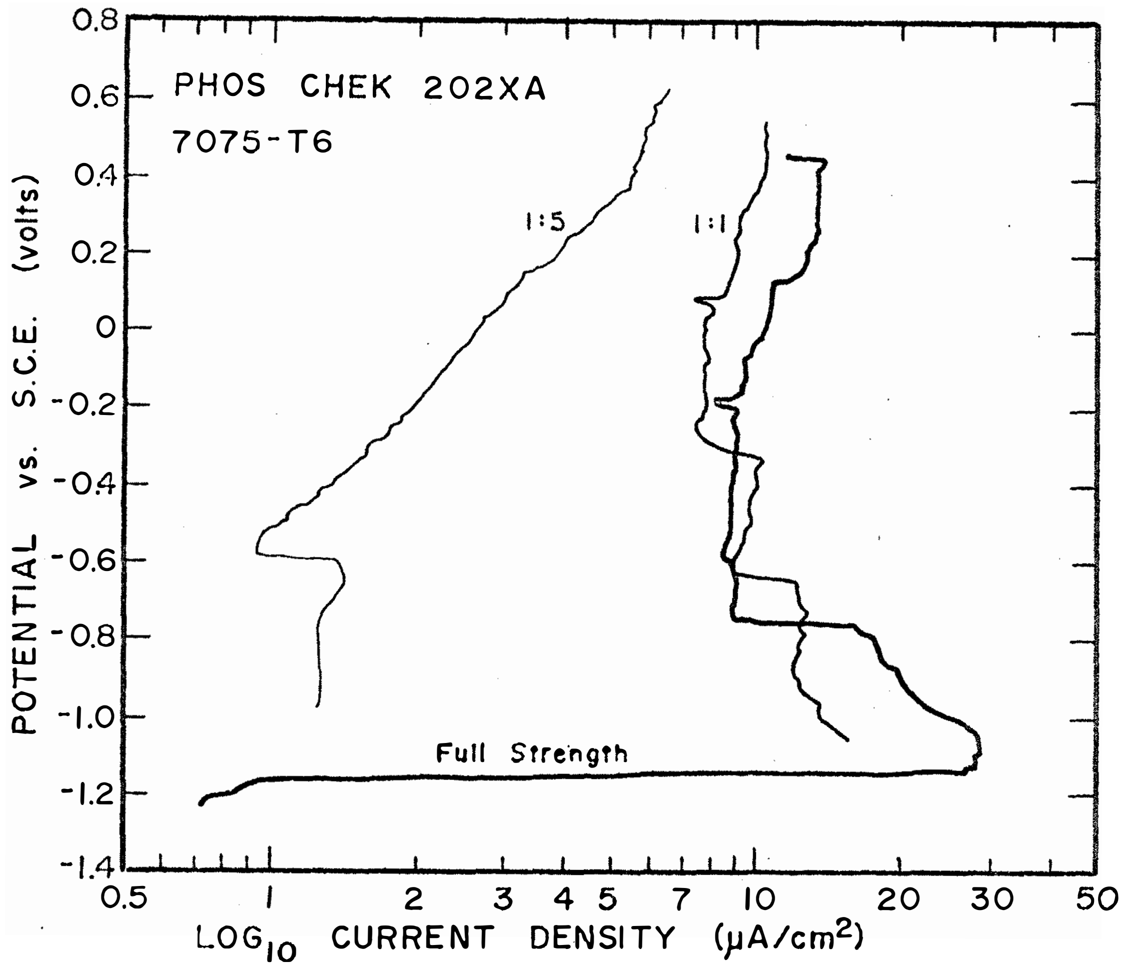


Figure 6. Potentiostatic measurements of aluminum alloy 7075-T6 immersed in PhosChek 202XA. The corrosion rate in the full-strength retardant is lower than for the Alclad metal but increases rapidly under more oxidizing conditions. Any scratch through the thin Alcladding would keep the 7075 alloy cathodically protected in the full-strength solution, but not in the diluted retardants.

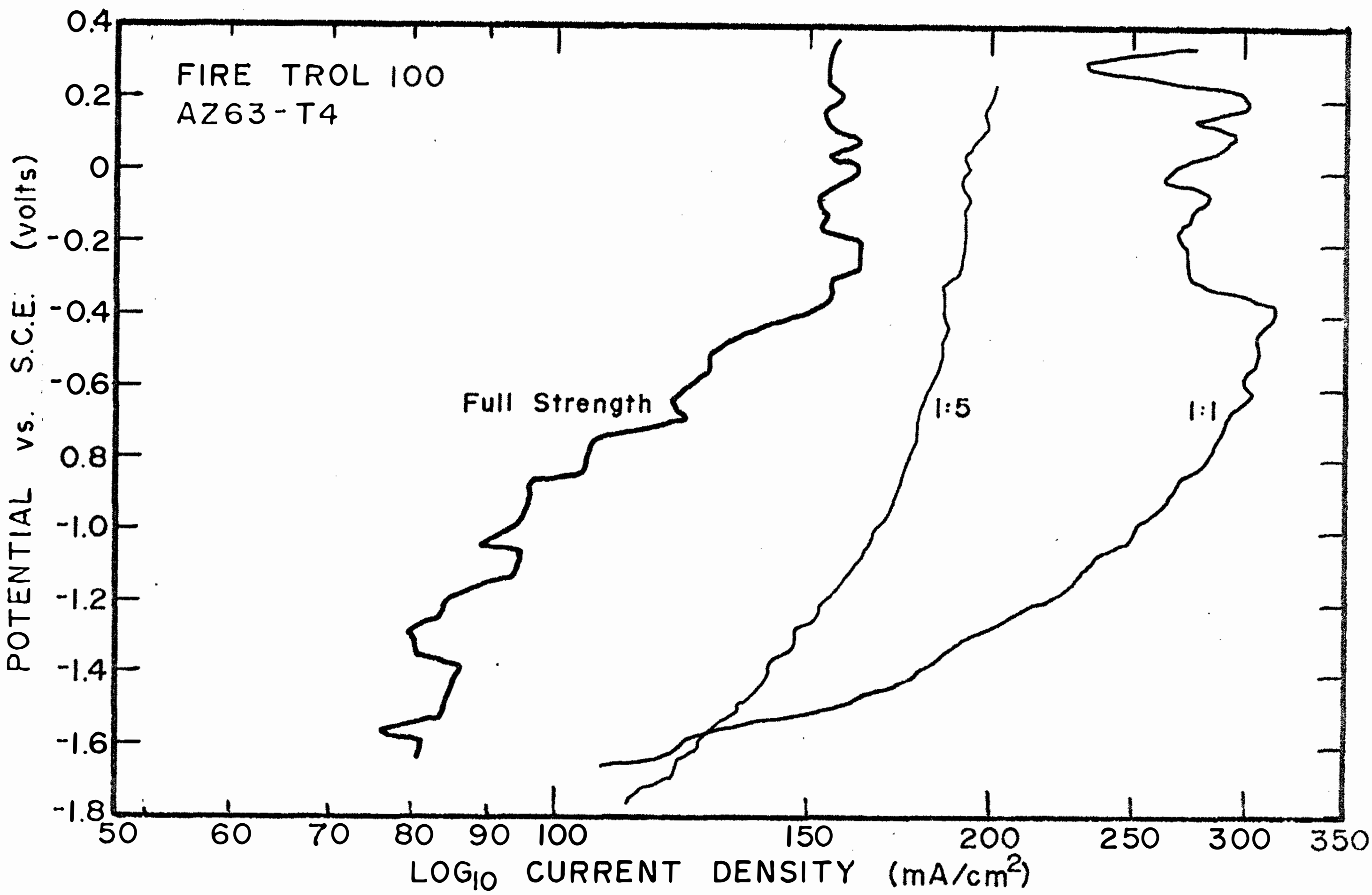


Figure 7. Potentiostatic measurements of magnesium alloy AZ63-T4 immersed in Firetrol 100. Initial corrosion rates are fantastically high (50-60 inches/year). Note that diluting the retardant with water makes the corrosion worse. Under more oxidizing conditions, such as high aeration or connection to a more noble metal, the situation becomes worse. The metal never passivates.

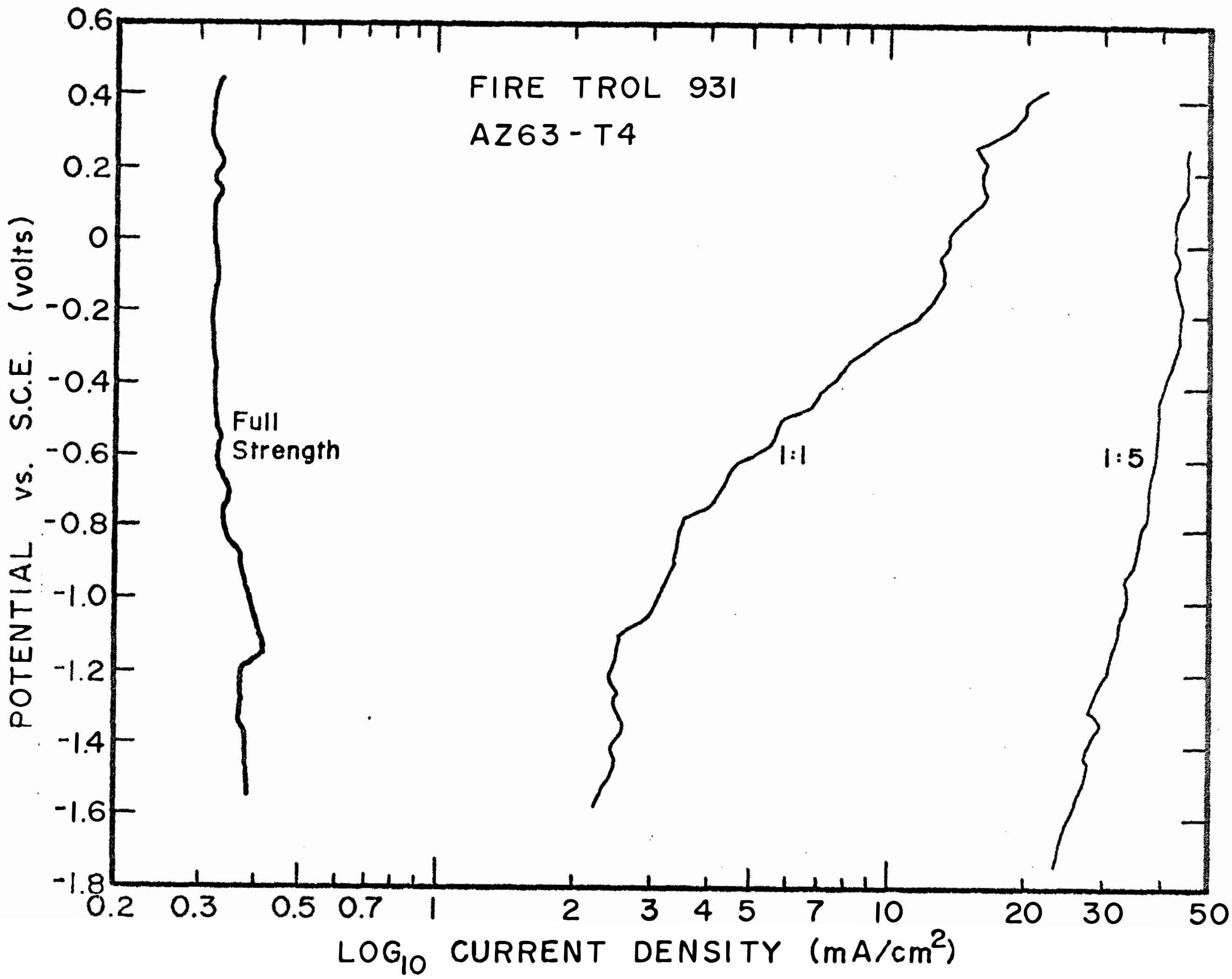


Figure 8. Potentiostatic measurements of magnesium alloy AZ63-T4 immersed in Firetrol 931. Corrosion rate of the alloy in the full strength retardant is over 200 mpy and diluting it makes it much worse (about 15,000 mpy in 1:5 dilution). These corrosion rates are better than for Firetrol 100 but still completely intolerable. It should be remembered that these tests are on bare, unoxidized metal such as might be exposed by a scratch. The metal does not passivate at any potential in this retardant so the only method of protection is with a coating that provides a barrier to the corrosive liquid.

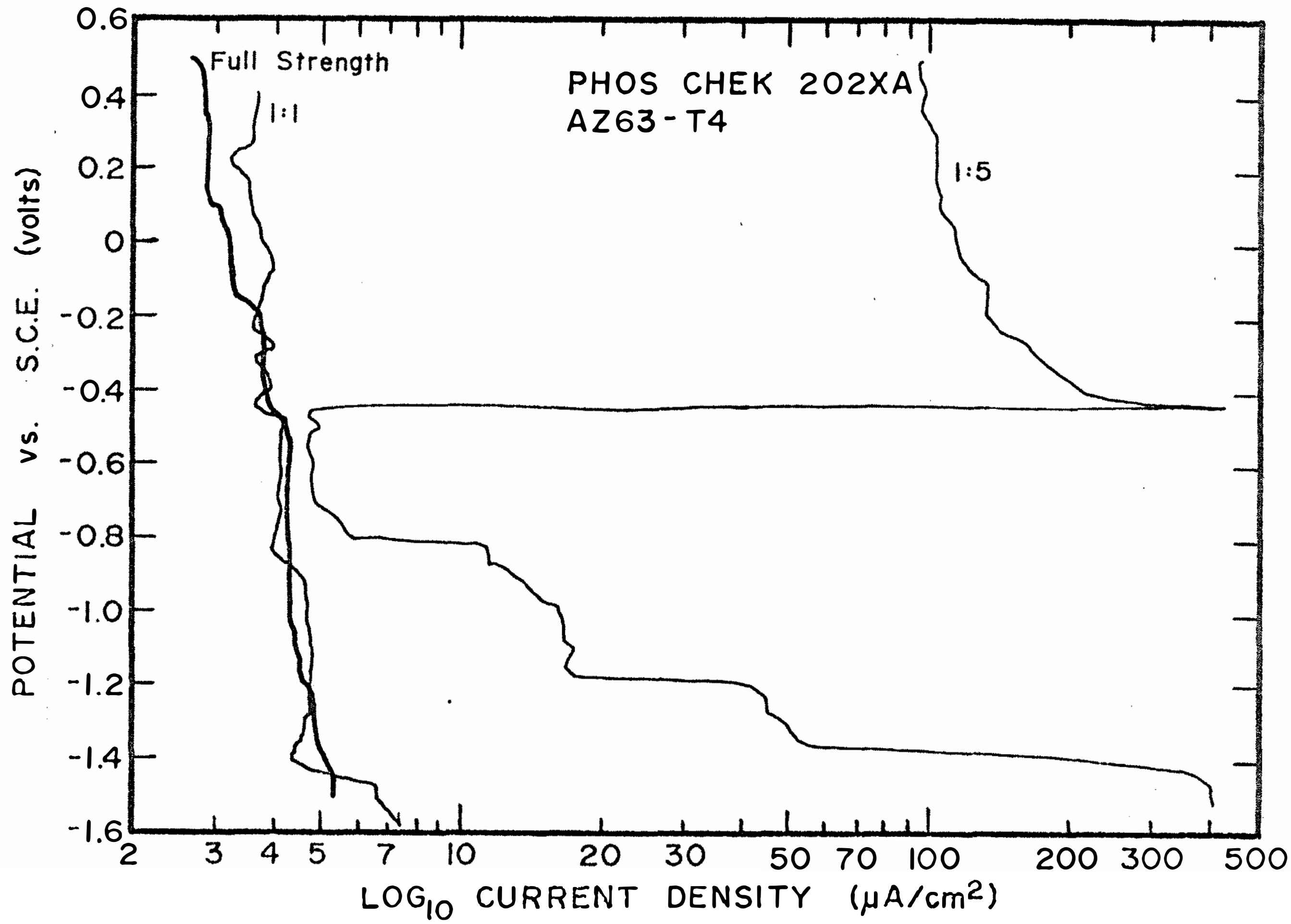


Figure 9. Potentiostatic measurements of magnesium alloy AZ63-T4 immersed in PhosChek 202XA. Corrosion in the full-strength retardant is at an acceptable level. It seems questionable whether the curve for the 1:5 dilution is correct or not. If it is correct, the high initial corrosion rate may produce a protective film to passivate the magnesium alloy.

TABLE 2

INITIAL CORROSION RATES

(Calculated from Current of Potentiostatic Tests)

| Retardant | Dilution | Metal | Corrosion Rate (mpy) |
|---|---|---|---|
| Firetrol 100 | full strength | Mg alloy | 51,000 |
| | 1 : 1 | AZ63-T4 | 68,000 |
| | 1 : 5 | | 43,000 |
| Firetrol 931 | full strength | Mg alloy | 240 |
| | 1 : 1 | AZ63-T4 | 1,400 |
| | 1 : 5 | | 15,000 |
| PhosChek 202XA | full strength | Mg alloy | 3.4 |
| | 1 : 1 | AZ63-T4 | 4.9 |
| | 1 : 5 | | 260 (?) |
| Firetrol 100 | full strength | Al alloy | 2.9 |
| | 1 : 1 | 7075-T6 | 2.2 |
| | 1 : 5 | | 3.7 |
| PhosChek 202XA | full strength | Al alloy | 0.30 |
| | 1 : 1 | 7075-T6 | 6.4 |
| | 1 : 5 | | 0.52 |
| Firetrol 100 | full strength | Alcladding | 0.21 |
| | 1 : 1 | (commercially | 0.16 |
| | 1 : 5 | pure Al) | 0.0 |
| Firetrol 931 | full strength | Alcladding | 0.22 |
| | 1 : 1 | (commercially | 0.56 |
| | 1 : 5 | pure Al) | 0.0 |
| PhosChek 202XA | full strength | Alcladding | 13. |
| | 1 : 1 | (commercially | 0.09 |
| | 1 : 5 | pure Al) | 0.0 |

C. Weight Loss Measurements.

The Corrater tests on magnesium alloy AZ63-T4 showed such extremely high corrosion rates that it seemed advisable to check them by actual weight-loss tests, while at the same time determining the average corrosion rate over a 24-hour period.

1. Apparatus and Materials.

The magnesium alloy AZ63-T4 samples were machined from a cast aircraft wheel. The samples were weighed before and after the tests on a Sartorius analytical balance, accurate to $\pm$ 0.0001 gram. Sample dimensions were measured with a caliper to $\pm$ 0.001 inch. The turntable stirrers were the same as those used for the Corrater tests.

2. Procedure.

The samples were polished to a mirror finish, measured, rinsed in alcohol and acetone, and weighed. They were again rinsed in alcohol and acetone, and immersed in the retardant. All samples remained in the retardant for 24 hours with a stirring rate of 1 rpm. Upon removal from the retardants, the samples were rinsed with water and placed in boiling 15% chromic acid for 15 minutes to remove all corrosion products without removing metal. The samples were then rinsed with water, alcohol and acetone, and reweighed.

3. Results.

Corrosion rates of the magnesium alloy in each of the retardants and their dilutions are given in Table 3 on page 24. The results are consistently higher than the Corrater figures because the weight loss is the average over the 24-hour period and includes the very high initial weight losses. The Corrater, on the other hand, gives instantaneous corrosion rates after an eight-hour conditioning period.

The corrosion rates in Table 3 are expressed in both milligrams per square decimeter per day (mdd) and in mils per year (mpy). They show that the magnesium alloy will lose approximately 0.01 inch from its surface in a 24-hour exposure to Fire Trol 100, and about 0.001 inch in Fire Trol 931. These figures confirm the Corrater and potentiostatic results that show greatly excessive corrosion rates of the bare magnesium alloy in these retardants.

TABLE 3

24-Hour Corrosion Tests
on Magnesium Alloy AZ63-T4

| Retardant | Dilution | Corrosion Rate mdd | Corrosion Rate mpy |
|---|---|---|---|
| Firetrol 100 | full strength | 4740 | 3700 |
| Firetrol 100 | 1 : 1 | 4520 | 3530 |
| Firetrol 100 | 1 : 5 | 4570 | 3560 |
| Firetrol 931 | full strength | 402 | 313 |
| Firetrol 931 | 1 : 1 | 399 | 311 |
| Firetrol 931 | 1 : 5 | 82.3 | 64.1 |
| PhosChek 202XA | full strength | 471(?) | 368(?) |
| PhosChek 202XA | 1 : 1 | 19.7 | 15.4 |
| PhosChek 202XA | 1 : 5 | 21.1 | 16.4 |

Note: Corrosion rates determined by weight loss of samples immersed in retardant stirred at 1 rpm.

D. Intermittent Immersion Tests.

Tests were conducted to determine the susceptibility of Alclad aluminum alloy 7075-T6 to intergranular attack, stress corrosion cracking, and crevice corrosion. The susceptibility of this alloy to intergranular attack by salt water has been reported and studied extensively. For metal subjected to tensile or bending stress the intergranular corrosion may develop into a crack that can cause sudden and unpredicted failure of the part. The intergranular corrosion is especially likely to start in oxygen-starved areas of stagnant, concentrated solution such as under rivet heads, in rivet holes, and under lapped joints of sheet metal--common construction methods for aircraft.

The intermittent immersion test used is a particularly severe test for metal to undergo, consisting of alternate wetting and drying of the metal. The test is commonly used as a rapid method of rejecting metals that might be susceptible to intergranular attack, but in this case it is probably also a pretty good simulation of actual operating conditions that the aluminum might be subjected to when in contact with the fire retardants.

1. Apparatus and Materials.

An intermittent immersion machine was designed and constructed to give a two-hour cycle of alternate submersion and emersion: a two-minute exposure to the retardant and a 1 hour 58 minute drying time. By means of an electric timer, a motor was started which operated a cam and lowered the specimens into the retardant. After two minutes, the cam raised the samples out of the retardant and the motor was automatically shut off. A counting device recorded the number of immersions.

A bending apparatus was constructed to bend the sheet specimens uniformly around a one-inch diameter mandrel without bending the legs of the U-bend sample.

Tests were conducted with 0.032 inch Alclad 7075-T6 sheet samples 6.5 inches long and 1 inch wide sheared parallel to the rolling direction. Pairs of strips were bolted together face-to-face to form a crevice between them with the bolts 1/2 inch from each end of the pair. The coupled pair was then bent in the bending apparatus to form a U-bend specimen. The legs of the U-bend specimens were fastened together with another bolt one inch from the ends to create a tensile stress of either 80% or 100% of the tensile yield strength on the outer surfaces of the specimens.

2. Procedure.

The test method was essentially that given in Section 4.3.5 of the U.S. Department of Agriculture, Forest Service Interim Specification 5100-00301, with the following differences:

a. the U-bend specimens consisted of pairs of strips with a crevice between them, as described above.

b. The samples were washed off with a strong water spray once every 24 hours to remove the extremely thick build-up of dry retardant which encrusted the specimens. This seemed the best way to keep the test an alternate wetting and drying type.

Eight specimens were tested:

2 samples stressed at 80% of yield strength in Fire Trol 100,

2 samples stressed at 100% of yield strength in Fire Trol 100,

2 samples stressed at 80% of yield strength in PhosChek 202XA, and

2 samples stressed at 100% of yield strength in PhosChek 202XA.

After a test duration of 300 hours, the samples were removed, edges were polished to examine in cross-section for cracks and intergranular penetration, and the sample surfaces were examined visually and under a binocular microscope.

3. Results.

a. Fire Trol 100 Samples.

No cracking or intergranular attack was observed with the reflecting microscope in a study of cross-sections of the samples unetched.

Visual examination showed some discoloration of the immersed surfaces. Under a water spray the Fire Trol 100 came off easily leaving no coating except for a silver-brown tarnish on the outside surfaces of the U-bend specimens. The inside surfaces of the pair were covered with a white adherent coating near the edges and a light brown tarnish in the center section of the specimens. Some pitting on the inside of the bend pairs was apparent.

A binocular microscopic examination at 10X magnification showed approximately 1500 shallow pits per square inch. On the four samples a total of five pits with diameters as large as 0.015 inch was observed. Halos of uncorroded metal approximately three millimeters in diameter surrounded either individual pits or pit clusters.

b. PhosChek 202XA Samples.

No cracking or intergranular penetration was observed with the reflecting optical microscope at high magnifications. Visual examination showed a red, adherent film that could be removed by vigorous scrubbing with a soft brush or cloth in tap water. When the film was removed, the metal was shiny with a fine rippled texture. Inside the U-bend pair, the metal surfaces were stained evenly with a brown tarnish much like the Fire Trol samples but lighter in color.

Binocular microscopic examination showed approximately 1000 pits per square inch on the inner surfaces of the U-bend couples. On the four samples there were seven pits in the size range of 0.015 inch. Halos of uncorroded metal surrounded the pits or pit clusters. The PhosChek samples had fewer but deeper pits than the Fire Trol samples.

E. Conclusions.

From the results of the tests conducted so far, it can be concluded that:

1. Fire Trol 100 will tarnish Alcladding but will not cause general corrosion problems for either Alcladding or 7075-T6. It tends to pit aluminum in crevices such as lapped joints. Diluting the retardant did not cause trouble for Alcladding or aluminum alloy 7075-T6.
2. Corrosion of uncoated magnesium alloy AZ63-T4 in Fire Trol 100 is disastrous, the retardant is difficult to wash off, and dilution makes it worse.
3. Fire Trol 931 does not cause general corrosion problems or pitting of Alcladding or 7075-T6 alloy either in full strength or diluted.
4. Fire Trol 931 severely corrodes magnesium alloy AZ63-T4, and the retardant film is difficult to wash off. Diluting it 1:1 doesn't help but a 1:5

dilution is much better.

5. PhosChek 202XA causes moderate corrosion of Alcladding and 7075-T6 aluminum alloy when in full-strength, with low corrosion when the retardant is diluted. The film formed on the metal is stable and difficult to remove but leaves a bright, shiny surface underneath. The retardant does not cause intergranular attack or stress corrosion cracking of Alcladding although it does pit the metal in crevices.

6. PhosChek 202XA causes some pitting of magnesium alloy AZ63-T4 but general corrosion attack is low.

F. General Comments.

One serious corrosion problem that was brought to light by these experiments is the extremely high rate of attack on the magnesium alloy AZ63-T4 exposed to Fire Trol 100 or Fire Trol 931. This corrosion can be mitigated by a protective coating but the danger is potentially present at every nick or scratch where bare metal might be exposed.

Aluminum and aluminum alloys have a natural film of oxide on the surface which offers some protection. The Fire Trol retardants tarnish the metal, giving it additional protection. PhosChek coats the aluminum with a very adherent film but underneath, the metal is untarnished. From a corrosion point of view, it is best that the tarnish should be left on the aluminum to provide protection. For appearance and air speed it may be desirable to remove the tarnish, though, and since the corrosion of the aluminum and 7075-T6 is not bad in any of the retardants whether the metal is tarnished or clean, no serious problem would result if the metal is kept shined.

When corrosion rates increase drastically as the corrodant is diluted, the presence of an oxidizing passivator such as sodium dichromate is the most likely explanation. Such is the case with Fire Trol 100 and Fire Trol 931. The passivator must be present in sufficient quantity to cause the metal to oxidize and produce a protective oxide layer on its surface. If the passivator is too dilute, the metal oxidizes (corrodes) but a complete protective film never forms and so the corrosion continues unabated at a high rate.

G. Additional Research.

Intermittent corrosion tests on the magnesium alloy AZ63-T4 are now under way to study intergranular attack and susceptibility to stress corrosion cracking in Fire Trol 100 and PhosChek 202XA. The tests are not yet completed so the results will be reported later.

Intermittent immersion tests such as were made on Alclad sheet should also be performed on the 7075-T6 aluminum alloy without cladding to investigate the possibility of a potentially dangerous failure due to stress corrosion cracking if the Alcladding should be removed from areas of the sheet surface by abrasion or corrosion. No intermittent immersion tests have been run in Fire Trol 931, although it appears likely that the results would be similar to those in Fire Trol 100, but this should be verified.

Complete corrosion tests should be made on a high-strength low-alloy steel such as 4340. Since steel is used for key components where strength must be maintained even with the weight penalty, it is important to be alerted to any potential corrosion dangers. Preliminary tests indicate that corrosion rates may be quite high.

Other metals recommended for testing include

aluminum alloy 2024
magnesium alloy AZ91A
martensitic stainless steel
austenitic stainless steel type 304
galvanized (zinc-coated) carbon steel.

These tests would show up any dangerous materials and possibly present suitable alternative materials which could be used with the fire retardants.

# APPENDIX A

Corrater Test Measurements

of Corrosion Rate and Pitting Index

in

Fire Trol 100, Fire Trol 931, and PhosChek 202XA

for

Pure Aluminum, Aluminum Alloy 7075-T6,
and Magnesium Alloy AZ63-T4

at

Retardant Concentrations of
Full Strength, Diluted 1:1, and Diluted 1:5

# Corrater Tests
# on Pure Aluminum in
# Firetrol 100 - Full Strength

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.71 | 0.73 |
| 0 hr. 5 min. | 0.20 | 1.05 |
| 0 hr. 44 min. | 0.07 | 0.84 |
| 2 hr. 24 min. | 0.05 | 0.12 |
| 4 hr. 48 min. | 0.048 | 0.11 |
| 6 hr. 14 min. | 0.08 | 0.10 |
| 7 hr. 24 min. | 0.08 | 0.11 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.03 | 1.22 |
| 8 hr. 25 min. | 0.06 | 1.38 |
| 8 hr. 51 min. | 0.10 | 0.27 |
| 9 hr. 53 min. | 0.11 | 0.41 |
| 12 hr. 24 min. | 0.12 | 0.04 |
| 13 hr. 44 min. | 0.12 | 0.15 |
| 14 hr. 50 min. | 0.08 | 0.11 |
| 15 hr. 41 min. | 0.10 | 0.17 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.26 | 0.10 |
| 16 hr. 14 min. | 0.03 | 0.06 |
| 17 hr. 11 min. | 0.07 | 0.03 |
| 18 hr. 39 min. | 0.02 | 0.06 |
| **19 hr. 0 min. | 0.037 | 0.12 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring was stopped.

## Corrater Tests
## on Pure Aluminum in
## Firetrol 100 - 1:1

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 43 min. | 0.225 | 0.59 |
| 1 hr. 38 min. | 0.18 | 0.59 |
| 3 hr. 7 min. | 0.175 | 0.79 |
| 5 hr. 9 min. | 0.18 | 0.47 |
| 6 hr. 50 min. | 0.23 | 0.74 |
| 7 hr. 51 min. | 0.215 | 0.21 |
| | Gentle rinse & dry | |
| 8 hr. 12 min. | 0.03 | 0.18 |
| 9 hr. 34 min. | 0.18 | 0.01 |
| 10 hr. 38 min. | 0.29 | 0.37 |
| 13 hr. 7 min. | 0.24 | 0.33 |
| 14 hr. 41 min. | 0.20 | 0.28 |
| **16 hr. 0 min. | 0.14 | 0.23 |
| | Hard rinse & dry | |
| 16 hr. 7 min. | 0.01 | 0.20 |
| 17 hr. 1 min. | 0.06 | 0.07 |
| 18 hr. 41 min. | 0.23 | 0.09 |
| **19 hr. 0 min. | 0.27 | 0.12 |

* After conditioning period of 16 hours in stirred corrodant.

** After stirring was stopped.

Corrater Tests on
Pure Aluminum in
Firetrol 100 - 1:5

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.10 | 0.23 |
| 1 hr. 1 min. | 0.15 | 0.25 |
| 1 hr. 59 min. | 0.21 | 0.22 |
| 3 hr. 0 min. | 0.235 | 0.13 |
| 4 hr. 52 min. | 0.23 | 0.04 |
| 5 hr. 57 min. | 0.22 | 0.02 |
| 7 hr. 8 min. | 0.21 | 0.08 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.035 | 0.11 |
| 9 hr. 49 min. | 0.06 | 0.06 |
| 10 hr. 40 min. | 0.10 | 0.0 |
| 13 hr. 4 min. | 0.19 | 0.02 |
| 14 hr. 44 min. | 0.19 | 0.04 |
| 15 hr. 46 min. | 0.255 | 0.09 |
| **16 hr. 0 min. | 0.21 | 0.16 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.017 | 0.07 |
| 17 hr. 32 min. | 0.027 | 0.02 |
| 18 hr. 32 min. | 0.06 | 0.03 |
| **19 hr. 0 min. | 0.06 | 0.07 |

* After conditioning period of 16 hours in stirred corrodant.

** After stirring was stopped.

Corrater Tests on
Aluminum Alloy 7075-T6 in
Firetrol 100 - Full Strength

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.70 | 1.68 |
| 0 hr. 10 min. | 0.61 | 0.59 |
| 0 hr. 49 min. | 0.05 | 0.10 |
| 2 hr. 15 min. | 0.45 | 0.19 |
| 4 hr. 48 min. | 0.04 | 0.12 |
| 6 hr. 20 min. | 0.08 | 0.12 |
| 7 hr. 30 min. | 0.08 | 0.12 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.075 | 0.17 |
| 8 hr. 21 min. | 0.17 | 1.94 |
| 8 hr. 50 min. | 0.26 | 1.16 |
| 9 hr. 52 min. | 0.27 | 0.70 |
| 12 hr. 22 min. | 0.11 | 0.19 |
| 13 hr. 54 min. | 0.11 | 0.01 |
| 14 hr. 48 min. | 0.10 | 0.0 |
| 15 hr. 39 min. | 0.10 | 0.17 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.15 | 0.03 |
| 16 hr. 19 min. | 0.01 | 0.03 |
| 17 hr. 16 min. | 0.01 | 0.02 |
| 18 hr. 42 min. | 0.005 | 0.01 |
| **19 hr. 0 min. | 0.005 | 0.01 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring is stopped.

Corrater Tests on
Aluminum Alloy 7075-T6
in Firetrol 100 - 1:1

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 50 min. | 0.27 | 0.37 |
| 1 hr. 45 min. | 0.265 | 2.47 |
| 3 hr. 13 min. | 0.26 | 2.94 |
| 5 hr. 15 min. | 0.35 | 1.93 |
| 6 hr. 56 min. | 0.38 | 0.39 |
| 7 hr. 57 min. | 0.305 | 0.27 |
| | Gentle rinse & dry | |
| 8 hr. 18 min. | 0.02 | 0.03 |
| 9 hr. 40 min. | 0.24 | 0.06 |
| 10 hr. 44 min. | 0.44 | 0.10 |
| 13 hr. 13 min. | 0.38 | 0.30 |
| 14 hr. 14 min. | 0.31 | 0.37 |
| **16 hr. 0 min. | 0.18 | 0.52 |
| | Hard rinse & dry | |
| 16 hr. 14 min. | 0.04 | 0.26 |
| 17 hr. 8 min. | 0.127 | 0.28 |
| 18 hr. 47 min. | 0.30 | 0.05 |
| **19 hr. 0 min. | 0.16 | 0.81 |

* After conditioning period of 16 hours in stirred corrodant.

** After stirring was stopped.

Corrater Tests on
Aluminum Alloy 7075-T6 in
Firetrol 100 - 1:5

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.08 | 0.20 |
| 1 hr. 2 min. | 0.24 | 0.51 |
| 1 hr. 59 min. | 0.28 | 0.65 |
| 3 hr. 1 min. | 0.26 | 0.43 |
| 4 hr. 53 min. | 0.29 | 0.06 |
| 5 hr. 57 min. | 0.26 | 0.31 |
| 7 hr. 2 min. | 0.32 | 0.36 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.68 | 3.06 |
| 9 hr. 48 min. | 0.42 | 0.59 |
| 10 hr. 40 min. | 0.42 | 0.38 |
| 13 hr. 4 min. | 0.34 | 0.27 |
| 14 hr. 45 min. | 0.31 | 0.18 |
| 15 hr. 31 min. | 0.385 | 0.03 |
| **16 hr. 0 min. | 0.30 | 0.16 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.18 | 1.41 |
| 17 hr. 32 min. | 0.10 | 0.03 |
| 18 hr. 33 min. | 0.185 | 0.07 |
| **19 hr. 0 min. | 0.13 | 0.02 |

* After conditioning period of 16 hours in <u>stirred</u> corrodant.

** After stirring was stopped.

Corrater Tests on
Magnesium Alloy AZ63-T4 in
Firetrol 100 - Full Strength

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 3300 | 4174 |
| 0 hr. 28 min. | 1556 | 754 |
| 2 hr. 2 min. | 1214 | 185 |
| 4 hr. 33 min. | 927 | 895 |
| 6 hr. 2 min. | 830 | 500 |
| 7 hr. 14 min. | 833.5 | 341 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | >10,000 | -- |
| 8 hr. 25 min. | 3202 | 7697 |
| 8 hr. 56 min. | >10,000 | -- |
| 9 hr. 57 min. | 2737 | 3865 |
| 12 hr. 26 min. | 1189 | 19 |
| 13 hr. 50 min. | 1102 | 100 |
| 14 hr. 53 min. | 1010 | 187 |
| 15 hr. 46 min. | 972 | 185 |
| | Hard rinse & dry | |
| 16 hr. 0 min, | 625 | 950 |
| 16 hr. 10 min. | 2733 | 3787 |
| 17 hr. 10 min. | >10,000 | -- |
| 18 hr. 36 min. | 3880 | 6506 |
| **19 hr. 0 min. | 2066 | 3234 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring was stopped.

Corrater Tests on
Magnesium Alloy AZ63-T4 in
Firetrol 100 - 1:1

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 37 min. | 503 | 494 |
| 1 hr. 31 min. | 522 | 408 |
| 3 hr. 1 min. | 533 | 490 |
| 5 hr. 3 min. | 531 | 416 |
| 6 hr. 44 min. | 622 | 492 |
| 7 hr. 44 min. | 512.5 | 471 |
| | Gentle rinse & dry | |
| 8 hr. 6 min. | 174 | 147 |
| 9 hr. 28 min. | 523 | 94 |
| 10 hr. 32 min. | 536.5 | 327 |
| 13 hr. 1 min. | 542 | 321 |
| 14 hr. 34 min. | 518 | 215 |
| **16 hr. 0 min. | 465 | 178 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 150 | 15 |
| 16 hr. 55 min. | 408.5 | 441 |
| 18 hr. 35 min. | 426 | 73 |
| **19 hr. 0 min. | 377 | 21 |

* After conditioning period of 16 hours in stirred corrodant.

** After stirring was stopped.

Corrater Tests on
Magnesium Alloy AZ63-T4 in
Firetrol 100 - 1:5

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 427 | 333 |
| 1 hr. 1 min. | 456 | 366 |
| 1 hr. 58 min. | 458 | 240 |
| 3 hr. 0 min. | 453.5 | 279 |
| 4 hr. 52 min. | 436.5 | 195 |
| 5 hr. 56 min. | 435 | 252 |
| 7 hr. 8 min. | 418 | 207 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 143 | 281 |
| 9 hr. 51 min. | 218 | 143 |
| 10 hr. 42 min. | 240 | 244 |
| 13 hr. 6 min. | 289 | 185 |
| 14 hr. 46 min. | 299 | 135 |
| 15 hr. 45 min. | 337 | 178 |
| **16 hr. 0 min. | 330 | 291 |
| | Gentle rinse & dry | |
| 16 hr. 0 min. | 149 | 3 |
| 17 hr. 31 min. | 228 | 97 |
| 18 hr. 32 min. | 281 | 107 |
| **19 hr. 0 min. | 292.5 | 137 |

* After conditioning period of 16 hours in stirred corrodant.

** After stirring was stopped.

Corrater Tests
on Pure Aluminum in
Firetrol 931 - Full Strength

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.62 | 0.02 |
| 0 hr. 57 min. | 0.65 | 0.0 |
| 1 hr. 58 min. | 0.67 | 0.04 |
| 4 hr. 22 min. | 0.61 | 0.0 |
| 5 hr. 50 min. | 0.60 | 0.0 |
| 6 hr. 55 min. | 0.60 | 0.01 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.015 | 0.01 |
| 9 hr. 6 min. | 0.113 | 0.11 |
| 11 hr. 15 min. | 0.18 | 0.06 |
| 13 hr. 10 min. | 0.245 | 0.09 |
| 14 hr. 6 min. | 0.23 | 0.07 |
| 15 hr. 21 min. | 0.205 | 0.15 |
| **16 hr. 0 min. | 0.145 | 0.18 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.047 | 0.13 |
| 17 hr. 1 min. | 0.105 | 0.01 |
| 18 hr. 4 min. | 0.16 | 0.02 |
| 18 hr. 41 min. | 0.175 | 0.05 |
| **19 hr. 0 min. | 0.19 | 0.05 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring was stopped.

Corrater Tests
on Pure Aluminum in
Firetrol 931 - 1:1

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.66 | 0.08 |
| 1 hr. 17 min. | 0.67 | 0.09 |
| 2 hr. 15 min. | 0.67 | 0.07 |
| 2 hr. 53 min. | 0.665 | 0.07 |
| 4 hr. 54 min. | 0.67 | 0.07 |
| 6 hr. 0 min. | 0.67 | 0.06 |
| 7 hr. 3 min. | 0.67 | 0.08 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.01 | 0.02 |
| 9 hr. 3 min. | 0.17 | 0.06 |
| 10 hr. 9 min. | 0.30 | 0.01 |
| 12 hr. 44 min. | 0.44 | 0.06 |
| 14 hr. 2 min. | 0.475 | 0.05 |
| 15 hr. 37 min. | 0.50 | 0.02 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.01 | 0.02 |
| 17 hr. 8 min. | 0.105 | 0.01 |
| 18 hr. 13 min. | 0.20 | 0.0 |
| 18 hr. 45 min. | 0.21 | 0.02 |
| **19 hr. 0 min. | 0.51 | 0.01 |

* After conditioning period of 16 hours in stirred corrodant.

** After stirring was stopped.

Corrater Tests
on Pure Aluminum in
Firetrol 931 - 1:5

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.96 | 2.85 |
| 1 hr. 5 min. | 0.94 | 3.00 |
| 2 hr. 18 min. | 0.95 | 2.92 |
| 2 hr. 59 min. | 1.485 | 2.97 |
| 4 hr. 59 min. | 0.92 | 2.82 |
| 6 hr. 9 min. | 0.90 | 2.92 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.02 | 0.08 |
| 8 hr. 58 min. | 0.03 | 0.10 |
| 10 hr. 5 min. | 0.07 | 0.12 |
| 13 hr. 0 min. | 0.327 | 0.05 |
| 13 hr. 55 min. | 0.357 | 0.11 |
| 15 hr. 46 min. | 0.41 | 0.18 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.007 | 0.02 |
| 16 hr. 56 min. | 0.01 | 0.02 |
| 18 hr. 3 min. | 0.04 | 0.04 |
| 18 hr. 53 min. | 0.11 | 0.20 |

* After conditioning period of 16 hours in <u>stirred</u> corrodant.

Corrater Tests on
Aluminum Alloy 7075-T6 in
Firetrol 931 - Full Strength

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.72 | 0.08 |
| 0 hr. 57 min. | 0.74 | 0.20 |
| 1 hr. 55 min. | 0.77 | 0.20 |
| 4 hr. 22 min. | 0.71 | 0.19 |
| 5 hr. 51 min. | 0.70 | 0.19 |
| 6 hr. 55 min. | 0.68 | 0.15 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.185 | 0.17 |
| 9 hr. 7 min. | 0.20 | 0.34 |
| 10 hr. 15 min. | 0.41 | 0.41 |
| 13 hr. 10 min. | 0.50 | 0.16 |
| 14 hr. 6 min. | 0.525 | 0.15 |
| 15 hr. 22 min. | 0.535 | 0.15 |
| **16 hr. 0 min. | 0.48 | 0.07 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.25 | 0.68 |
| 17 hr. 2 min. | 0.57 | 0.62 |
| 18 hr. 4 min. | 0.79 | 0.54 |
| 18 hr. 41 min. | 0.83 | 0.59 |
| **19 hr. 0 min. | 0.74 | 0.47 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring is stopped.

Corrater Tests on
Aluminum Alloy 7075-T6 in
Firetrol 931 - 1:1

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.62 | 0.16 |
| 1 hr. 15 min. | 0.62 | 0.16 |
| 2 hr. 17 min. | 0.62 | 0.16 |
| 2 hr. 54 min. | 0.63 | 0.14 |
| 4 hr. 57 min. | 0.63 | 0.14 |
| 6 hr. 1 min. | 0.64 | 0.12 |
| 7 hr. 1 min. | 0.64 | 0.12 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.285 | 0.51 |
| 9 hr. 3 min. | 0.225 | 0.15 |
| 10 hr. 5 min. | 0.60 | 0.81 |
| 12 hr. 42 min. | 0.685 | 0.47 |
| 14 hr. 2 min. | 0.68 | 0.35 |
| 15 hr. 36 min. | 0.66 | 0.30 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.115 | 0.19 |
| 17 hr. 7 min. | 0.15 | 0.10 |
| 18 hr. 11 min. | 0.45 | 0.07 |
| 18 hr. 35 min. | 0.51 | 0.0 |
| **19 hr. 0 min. | 0.51 | 0.01 |

* After conditioning of 16 hours in <u>stirred</u> corrodant.

** After stirring is stopped.

# Corrater Tests on Aluminum Alloy 7075-T6 in Firetrol 931 - 1:5

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.43 | 0.60 |
| 1 hr. 5 min. | 0.425 | 0.59 |
| 2 hr. 18 min. | 0.42 | 0.56 |
| 2 hr. 58 min. | 0.42 | 0.56 |
| 4 hr. 59 min. | 0.415 | 0.51 |
| 5 hr. 7 min. | 0.37 | 0.52 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.067 | 0.09 |
| 8 hr. 59 min. | 0.15 | 0.14 |
| 10 hr. 2 min. | 0.17 | 0.28 |
| 13 hr. 0 min. | 0.35 | 0.70 |
| 13 hr. 55 min. | 0.38 | 0.68 |
| 15 hr. 44 min. | 0.345 | 0.69 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.07 | 0.35 |
| 16 hr. 50 min. | 0.15 | 0.32 |
| 17 hr. 57 min. | 0.14 | 0.24 |
| 17 hr. 44 min. | 0.20 | 0.18 |

* After conditioning period of 16 hours in <u>stirred</u> corrodant.

Corrater Tests on
Magnesium Alloy AZ63-T4 in
Firetrol 931 - Full Strength

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 53.2 | 82.6 |
| 1 hr. 13 min. | 129 | 215 |
| 2 hr. 11 min. | 105 | 257 |
| 4 hr. 42 min. | 105 | 216 |
| 5 hr. 59 min. | 100 | 216 |
| 7 hr. 5 min. | 89.2 | 170.4 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 126.9 | 48.1 |
| 9 hr. 7 min. | 144 | 97 |
| 10 hr. 16 min. | 140 | 72 |
| 12 hr. 11 min. | 104.5 | 29 |
| 13 hr. 7 min. | 94.5 | 13 |
| 14 hr. 23 min. | 92 | 22 |
| **16 hr. 0 min. | 61.5 | 28 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.365 | 3.56 |
| 17 hr. 0 min. | 65 | 132 |
| 18 hr. 2 min. | 73 | 196 |
| 18 hr. 40 min. | 78 | 239 |
| **19 hr. 0 min. | 49 | 170 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring was stopped.

Corrater Tests on
Magnesium Alloy AZ63-T4 in
Firetrol 931 - 1:1

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 9.2 | 18.53 |
| 1 hr. 20 min. | 10.1 | 15.4 |
| 2 hr. 18 min. | 8.75 | 10.9 |
| 2 hr. 57 min. | 8.25 | 12.3 |
| 4 hr. 57 min. | 8.23 | 13.7 |
| 6 hr. 3 min. | 8.367 | 16.6 |
| 7 hr. 7 min. | 7.3 | 14.57 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.07 | 3.06 |
| 9 hr. 2 min. | 2,25 | 21.65 |
| 10 hr. 6 min. | 28.6 | 68.4 |
| 12 hr. 41 min. | 12.2 | 134.2 |
| 14 hr. 1 min. | 26.9 | 148.5 |
| 15 hr. 36 min. | 15.7 | 76.8 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.38 | 0.08 |
| 17 hr. 8 min. | 1.50 | 4.47 |
| 18 hr. 12 min. | 7.4 | 85.2 |
| 18 hr. 45 min. | 7.7 | 117.2 |
| **19 hr. 0 min. | 6.7 | 86.7 |

* After conditioning period of 16 hours in stirred corrodant.

** After stirring was stopped.

Corrater Tests on
Magnesium Alloy AZ63-T4 in
Firetrol 931 - 1:5

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 35 min. | 4.64 | 1.99 |
| 1 hr. 40 min. | 3.74 | 2.74 |
| 2 hr. 54 min. | 3.545 | 2.11 |
| 3 hr. 36 min. | 5.08 | 1.72 |
| 5 hr. 36 min. | 3.32 | 2.18 |
| 6 hr. 44 min. | 3.28 | 2.15 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.97 | 1.21 |
| 8 hr. 57 min. | 3.06 | 1.53 |
| 10 hr. 3 min. | 3.25 | 0.01 |
| 12 hr. 59 min. | 3.51 | 1.22 |
| 13 hr. 54 min. | 3.59 | 1.34 |
| 15 hr. 46 min. | 3.61 | 1.86 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.34 | 0.69 |
| 16 hr. 12 min. | 1.34 | 1.15 |
| 16 hr. 55 min. | 4.16 | 7.35 |
| 18 hr. 3 min. | 4.615 | 4.39 |
| 18 hr. 54 min. | 4.26 | 7.85 |

* After conditioning period of 16 hours in stirred corrodant.

Corrater Tests
on Pure Aluminum in
PhosChek 202XA - Full Strength

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 2.42 | 5.40 |
| 0 hr. 56 min. | 2.85 | 6.81 |
| 1 hr. 53 min. | 3.085 | 6.65 |
| 4 hr. 54 min. | 2.75 | 3.28 |
| 6 hr. 2 min. | 2.90 | 2.26 |
| 7 hr. 18 min. | 2.73 | 2.02 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 1.15 | 3.03 |
| 9 hr. 12 min. | 3.06 | 6.54 |
| 10 hr. 23 min. | 3.76 | 2.02 |
| 11 hr. 4 min. | 4.377 | 5.92 |
| 13 hr. 32 min. | 5.02 | 4.36 |
| 14 hr. 25 min. | 4.41 | 4.25 |
| 15 hr. 32 min. | 4.68 | 2.15 |
| **16 hr. 0 min. | 4.01 | 1.33 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.165 | 0.47 |
| 16 hr. 53 min. | 3.19 | 4.64 |
| 18 hr. 8 min. | 5.217 | 6.61 |
| **19 hr. 0 min. | 4.31 | 5.99 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring was stopped.

Corrater Tests
on Pure Aluminum in
PhosChek 202XA - 1:1

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.185 | 0.11 |
| 0 hr. 55 min. | 0.37 | 0.32 |
| 2 hr. 6 min. | 0.53 | 0.06 |
| 2 hr. 57 min. | 0.59 | 0.05 |
| 4 hr. 35 min. | 0.75 | 0.16 |
| 6 hr. 3 min. | 0.81 | 0.04 |
| 7 hr. 43 min. | 0.83 | 0.02 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.18 | 0.0 |
| 8 hr. 8 min. | 0.31 | 0.31 |
| 9 hr. 8 min. | 0.60 | 0.60 |
| 10 hr. 6 min. | 0.88 | 0.69 |
| 12 hr. 40 min. | 0.91 | 0.52 |
| 14 hr. 13 min. | 0.89 | 0.39 |
| 15 hr. 39 min. | 0.86 | 0.58 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.09 | 0.09 |
| 16 hr. 22 min. | 0.55 | 1.26 |
| 18 hr. 26 min. | 0.925 | 0.21 |
| **19 hr. 0 min. | 1.39 | 0.52 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring was stopped.

Corrater Tests
on Pure Aluminum in
PhosChek 202XA - 1:5

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.415 | 0.16 |
| 1 hr. 22 min. | 0.485 | 0.15 |
| 3 hr. 59 min. | 0.46 | 0.08 |
| 5 hr. 24 min. | 0.48 | 0.08 |
| 6 hr. 55 min. | 0.47 | 0.07 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.345 | 0.69 |
| 9 hr. 39 min. | 0.12 | 0.04 |
| 11 hr. 30 min. | 0.51 | 0.08 |
| 13 hr. 50 min. | 0.56 | 0.24 |
| 15 hr. 26 min. | 0.59 | 0.20 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.02 | 0.28 |
| 19 hr. 0 min. | 0.57 | 0.19 |

* After conditioning period of 16 hours
in stagnant corrodant.

Corrater Tests on
Aluminum Alloy 7075-T6 in
PhosChek 202XA - Full Strength

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 2.78 | 0.09 |
| 1 hr. 0 min. | 3.48 | 0.64 |
| 1 hr. 55 min. | 3.565 | 0.63 |
| 4 hr. 55 min. | 3.447 | 0.68 |
| 6 hr. 3 min. | 3.49 | 0.04 |
| 7 hr. 18 min. | 3.34 | 0.12 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.089 | 0.31 |
| 9 hr. 13 min. | 2.70 | 4.06 |
| 10 hr. 24 min. | 3.975 | 0.31 |
| 11 hr. 5 min. | 3.63 | 2.62 |
| 13 hr. 32 min. | 3.90 | 2.39 |
| 14 hr. 25 min. | 3.76 | 1.47 |
| 15 hr. 33 min. | 3.51 | 1.28 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.15 | 0.23 |
| 16 hr. 55 min. | 6.46 | 1.06 |
| 18 hr. 13 min. | 5.715 | 0.28 |
| **19 hr. 0 min. | 3.18 | 0.87 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring is stopped.

Corrater Tests on
Aluminum Alloy 7075-T6 in
PhosChek 202XA - 1:1

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.32 | 0.14 |
| 0 hr. 53 min. | 0.35 | 0.15 |
| 2 hr. 4 min. | 0.30 | 0.14 |
| 2 hr. 57 min. | 0.43 | 0.10 |
| 4 hr. 37 min. | 0.40 | 0.04 |
| 6 hr. 5 min. | 0.39 | 0.05 |
| 7 hr. 43 min. | 0.35 | 0.02 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.03 | 0.03 |
| 8 hr. 11 min. | 0.35 | 0.48 |
| 9 hr. 11 min. | 0.75 | 0.22 |
| 10 hr. 20 min. | 0.83 | 0.76 |
| 12 hr. 44 min. | 0.55 | 0.16 |
| 14 hr. 18 min. | 0.47 | 0.15 |
| 15 hr. 45 min. | 0.45 | 0.18 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.02 | 0.18 |
| 16 hr. 22 min. | 0.16 | 0.28 |
| 18 hr. 27 min. | 0.55 | 0.0 |
| **19 hr. 0 min. | 0.82 | 1.04 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring is stopped.

Corrater Tests on
Aluminum Alloy 7075-T6 in
PhosChek 202XA - 1:5

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.40 | 0.04 |
| 3 hr. 57 min. | 0.406 | 0.05 |
| 5 hr. 22 min. | 0.45 | 0.08 |
| 6 hr. 52 min. | 0.45 | 0.10 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.19 | 0.15 |
| 9 hr. 35 min. | 0.08 | 0.02 |
| 11 hr. 24 min. | 0.50 | 0.18 |
| 13 hr. 46 min. | 0.50 | 0.09 |
| 15 hr. 20 min. | 0.51 | 0.10 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.037 | 0.08 |
| 19 hr. 0 min. | 0.52 | 0.70 |

* After conditioning period of 16 hours in stagnant corrodant.

Corrater Tests on
Magnesium Alloy AZ63-T4 in
PhosChek 202XA - Full Strength

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.07 | 0.14 |
| 0 hr. 56 min. | 0.075 | 0.15 |
| 1 hr. 55 min. | 0.075 | 0.13 |
| 4 hr. 56 min. | 0.075 | 0.15 |
| 6 hr. 5 min. | 0.075 | 0.13 |
| 7 hr. 22 min. | 0.075 | 0.15 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.03 | 0.31 |
| 9 hr. 13 min. | 0.045 | 0.11 |
| 10 hr. 24 min. | 0.05 | 0.12 |
| 11 hr. 31 min. | 0.047 | 0.12 |
| 13 hr. 58 min. | 0.047 | 0.13 |
| 14 hr. 52 min. | 0.043 | 0.13 |
| 15 hr. 58 min. | 0.045 | 0.13 |
| **16 hr. 0 min. | 0.043 | 0.13 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.03 | 0.20 |
| 16 hr. 52 min. | 0.007 | 0.01 |
| 18 hr. 9 min. | 0.013 | 0.01 |
| **19 hr. 0 min. | 0.02 | 0.02 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring was stopped.

Corrater Tests on
Magnesium Alloy AZ63-T4 in
PhosChek 202XA - 1:1

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.18 | 0.0 |
| 0 hr. 56 min. | 0.17 | 0.04 |
| 2 hr. 5 min. | 0.17 | 0.04 |
| 2 hr. 58 min. | 0.16 | 0.04 |
| 4 hr. 36 min. | 0.16 | 0.04 |
| 6 hr. 6 min. | 0.155 | 0.03 |
| 7 hr. 44 min. | 0.10 | 0.01 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.89 | 0.43 |
| 8 hr. 5 min. | 0.28 | 0.57 |
| 9 hr. 8 min. | 0.02 | 0.03 |
| 10 hr. 7 min. | 0.013 | 0.0 |
| 12 hr. 40 min. | 0.013 | 0.01 |
| 14 hr. 11 min. | 0.01 | 0.0 |
| 15 hr. 59 min. | 0.01 | 0.0 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 0.68 | 4.06 |
| 16 hr. 22 min. | 0.11 | 0.21 |
| 18 hr. 27 min. | 0.0 | 0.0 |
| **19 hr. 0 min. | 0.0 | 0.0 |

* After conditioning period of 16 hours in stagnant corrodant.

** After stirring was stopped.

Corrater Tests on
Magnesium Alloy AZ63-T4 in
PhosChek 202XA - 1:5

| Time* | Corrosion Rate (mpy) | Pitting Index |
|---|---|---|
| 0 hr. 0 min. | 0.03 | 0.20 |
| 1 hr. 20 min. | 0.04 | 0.22 |
| 3 hr. 56 min. | 0.01 | 0.20 |
| 5 hr. 22 min. | 0.10 | 0.04 |
| 6 hr. 53 min. | 0.025 | 0.15 |
| | Gentle rinse & dry | |
| 8 hr. 0 min. | 0.12 | 1.03 |
| 9 hr. 39 min. | 0.16 | 0.08 |
| 11 hr. 31 min. | 0.04 | 0.35 |
| 13 hr. 47 min. | 0.007 | 0.33 |
| 15 hr. 26 min. | 0.015 | 0.19 |
| | Hard rinse & dry | |
| 16 hr. 0 min. | 1.68 | 7.47 |
| 19 hr. 0 min. | 0.05 | 0.10 |

* After conditioning period of 16 hours in stagnant corrodant.

Samuel A. Bradford

1973. Corrosion of aircraft metals in fire retardants.

Information Report NOR-X-66; 60 pp.; Northern Forest Research Centre, Canadian Forestry Service, Environment Canada, Edmonton, Alberta, T6H 3S5

Samuel A. Bradford

1973. Corrosion of aircraft metals in fire retardants.

Information Report NOR-X-66; 60 pp.; Northern Forest Research Centre, Canadian Forestry Service, Environment Canada, Edmonton, Alberta, T6H 3S5

Copies of this publication (if still in stock) may be obtained from:

Information Officer
Northern Forest Research Centre
Canadian Forestry Service
Department of the Environment
5320 - 122 Street
Edmonton, Alberta, Canada
T6H 3S5