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Aberdeen Proving Ground, Maryland 21010

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TECHNICAL REPORT ARCSL-TR-82063

**CORROSION STUDIES OF THE M11 PORTABLE DECONTAMINATION
APPARATUS (PDA) BODY BY AQUEOUS BLEACH**

by

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**Munitions Development Branch
Munitions Division**

April 1983



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| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) It is desirable to be able to use the Portable Decontamination Apparatus (PDA) with dilute aqueous bleach solutions in chemical defense training exercises. The steel body of the PDA, however, is not compatible with the bleach solutions. The test described in this report shows that the corrosion of the PDA is serious, but that a film of oil is sufficient to ameliorate the corrosion. While use of an oil coating or of rinse water containing a rust inhibitor would tend to extend as received PDA service life with dilute aqueous bleach solutions, body wall failure (continued on reverse) | | |

20. ABSTRACT (continued)
would be the ultimate outcome. Further, use of these techniques would place additional responsibility and burden on the user.

PREFACE

The work described in this report was authorized under Project 1L162706A553-J Chemical Training and Trialing Agents and Equipment. This work was started in June 1981 and completed in September 1981. The experimental data are recorded in notebook CSL 810107.

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CORROSION STUDIES OF THE M11 PORTABLE DECONTAMINATION APPARATUS (PDA) BODY BY AQUEOUS BLEACH

1. BACKGROUND AND OBJECTIVES

1.1 Background.

Consideration is being given to using aqueous sodium hypochlorite (ASH) as a simulant decontamination solution in chemical defense training exercises. It is known that ASH will quench the fluorescence of Tinopal CBS[®] or of sodium fluorescein in Polyethylene Glycol 200 (PEG 200) solutions of these fluorescent tracers. PEG 200 tracer mixes are used to simulate liquid chemical agent contamination in training exercises.

For training purposes it is desirable to be able to use ASH with the standard M11 1½-Quart Portable Decontamination Apparatus (PDA). It is known that ASH corrodes the cold-rolled steel body of the PDA. Presumably, some amount of corrosion could be tolerated in training use with ASH; however, severe corrosion, or no practical way of ameliorating such corrosion, during service with ASH would render such use of the PDA impractical.

1.2 Objectives.

The objectives of the work described in this report were to:

- Assess the nature and extent of corrosion of the PDA body from exposure to ASH, as would occur with repeated training use.
- Make a cursory assessment of possible means of ameliorating corrosion of the PDA body in service with ASH.

2. MATERIALS

In performing the work described in this report, the following materials were used:

- M11 Portable Decontamination Apparatus (PDA), NSN 4230-720-1618.
- Clorox[®] I, common household bleach, 5% aqueous sodium hypochlorite
- Epoxy paint, MIL-P-52192B.
- SAE 30-weight oil.
- Inhibitor, corrosion, liquid cooling system, DSA-400-71-C-2993.
- Metallograph, aus JENA Neophot 2, USA 06-06-013796.
- Tensile machine, Southwark-Tate-Emery, USA 06-06-001979.
- Analytic balance, Ainsworth Right-a-Weigh, to ±0.1 mg, USA-06-07-008278.

3. PROCEDURES

3.1 Sample Preparation.

Unused PDA bodies were cut into pieces of such a size that they would easily fit into 40 ml volume test tubes. There were two types of body samples, namely:

- Samples 1 through 14: Approximately 33 mm long by 14 mm wide, cut perpendicular to the body axis and containing the body wall welded seam.
- Samples A through N: Approximately 76 mm long by 14 mm wide, cut parallel to the body axis and not including the body wall welded seam.

The inside surface of each sample (the wetted surface) was masked with tape and two coats of epoxy paint were applied to the edges and back of each sample. The paint was allowed to air dry after each coat, and, after the second coat had dried, the masking tape was removed. The samples were then desiccated and weighed, until a constant weight (± 1.0 mg) was obtained.

The following two compositions of ASH solution were used:

- Solution A: 2/1 (V/V) Water/Clorox[®]I
- Solution B: 8/1 (V/V) Water/Clorox[®]I.

3.2 Test Methods.

PDA samples were subjected to cyclic exposure to ASH solutions by the schedule given in table 1. The steps in the exposure cycle were selected to simulate the treatment the PDA might receive in training use with ASH, and the steps in each cycle were as follows:

(a) Each sample was submerged in a fresh aliquot of the assigned ASH solution in a test tube for one hour at room temperature.

(b) After one hour the ASH solution was poured out of the test tube, and the sample was soaked in air (in the test tube) for an additional hour at room temperature while wet with residual bleach.

(c) The sample was rinsed with tap water, excess water was poured out and the sample was soaked in air (in the test tube) at room temperature while wet with residual tap water until the start of the next cycle. After each odd-numbered cycle, the samples sat for 2 hours. After each even-numbered cycle, the samples sat overnight, except after the 10th and 20th cycles, wherein samples designated for additional exposure cycles sat over the weekends.

There were two sample replicates for each combination of factors. After 10 cycles, samples A, B, G, H, 1, 2, 7, and 8 were dried in a desiccator. Photographs of the corroded samples were taken and the corrosion products were scraped off with a steel spatula. The scraped samples were then rephotographed, desiccated, and reweighed.

Table 1. Weight Change Data

| Sample | Number of Cycles/ Solution Strength* | Initial Weight | Final Weight | Weight Loss | Exposed Sample Area | Weight Loss Per Unit Area |
|--------|---|-------------------|-----------------|----------------|---------------------------|------------------------------|
| | | g | g | g | cm ² | mg/cm ² |
| A | 10/A | 13.9453 | 13.6947 | 0.2506 | 9.0 | 27.8 |
| B | 10/B | 13.6397 | 13.4414 | 0.1983 | 7.6 | 26.1 |
| G | 10/B | 11.6325 | 11.4800 | 0.1525 | 6.8 | 22.4 |
| H | 10/B | 11.7525 | 11.5814 | 0.1711 | 7.3 | 23.4 |
| C | 20/A | 13.6928 | 13.2264 | 0.4664 | 8.8 | 53.2 |
| D | 20/A | 14.2909 | 13.7958 | 0.4951 | 9.1 | 54.4 |
| I | 20/B | 13.9440 | 13.5971 | 0.3469 | 8.9 | 39.0 |
| J | 20/B | 12.3706 | 13.0380 | 0.3326 | 7.1 | 46.8 |
| E | 30/A | 14.1438 | 13.4428 | 0.7010 | 8.6 | 81.5 |
| F | 30/A | 13.6327 | 12.9555 | 0.6772 | 7.9 | 85.7 |
| K | 30/B | 13.8423 | 13.2858 | 0.5565 | 7.5 | 74.2 |
| L | 30/B | 14.0975 | 13.4205 | 0.6770 | 8.6 | 78.4 |
| 1 | 10/A | 6.4568 | 6.3687 | 0.0881 | 3.7 | 23.8 |
| 2 | 10/A | 6.6619 | 6.5666 | 0.0953 | 3.7 | 25.8 |
| 7 | 10/B | 6.7762 | 6.6893 | 0.0869 | 4.0 | 21.7 |
| 8 | 10/B | 6.7452 | 6.6678 | 0.0774 | 3.6 | 21.5 |
| 3 | 20/A | 6.6187 | 6.4264 | 0.1923 | 3.4 | 56.6 |
| 4 | 20/A | 6.4447 | 6.2544 | 0.1903 | 3.4 | 56.0 |
| 9 | 20/B | 6.4290 | 6.2473 | 0.1817 | 3.6 | 50.4 |
| 10 | 20/B | 6.4251 | 6.2632 | 0.1619 | 3.7 | 43.7 |
| 5 | 30/A | 6.7986 | 6.4386 | 0.3600 | 4.0 | 90.0 |
| 6 | 30/A | 6.5116 | 6.2035 | 0.3081 | 3.9 | 79.0 |
| 11 | 30/B | 6.0145 | 5.8069 | 0.2076 | 3.5 | 59.3 |
| 12 | 30/B | 6.0512 | 5.8189 | 0.2323 | 3.4 | 68.3 |
| M | Control | 13.9608 | 13.9764 | 0.0024 | --- | --- |
| N | Control | 14.2047 | 14.2043 | 0.0004 | --- | --- |
| 13 | Control | 5.9839 | 5.9821 | 0.0018 | --- | --- |
| 14 | Control | 5.9869 | 5.9862 | 0.0007 | --- | --- |

*A - 2:1 (V/V, water:bleach) solution.

B - 8:1 (V/V, water:bleach) solution.

The same procedure was followed after 20 and 30 cycles with samples C, D, I, J, 3, 4, 9, and 10, and with samples E, F, K, L, 5, 6, 11, and 12, respectively.

Corresponding control samples, designated M, N, 13, and 14 and not subjected to exposure cycles, were weighed after application of epoxy primer paint, stored over desiccant and reweighed at the same time as the reweighing of the 10, 20, and 30-cycle test samples.

X-ray photographs were taken of each sample. From these photographs the locations of the deepest corrosion pit in each sample were estimated and then marked on the corresponding sample. The sample from each type/cycle group having the deepest pit was sectioned at this pit and mounted in clear optical plastic. Pit depth was measured from a Polaroid photograph taken at X 25 magnification.

The remaining samples were subjected to tensile strength test. A pencil mark was made at 3/8 inch from each end of each sample. Samples containing welds were pressed in a vise before tensile test to eliminate curvature. The tensile machine jaws were secured to each sample to obtain a bite of 3/8 inch on each end, and load was applied at a draw rate of 0.02 inches per second until sample failure.

A set of six additional samples (A1 through A6) was painted and weighed as described previously. Four of these samples (A1 through A4) were used to assess corrosion-inhibiting methods, while the other two (A5 and A6) were used as exposed controls. All samples were subjected to 10 exposure cycles and each cycle consisted of one hour soak in a fresh aliquot of ASH, and overnight standing damp with residual water in air in test tubes after rinse with water and draining. After the third and seventh cycles the samples sat for 3 days rather than overnight before the next cycle. Samples A1 and A2 were coated with SAE 30-weight oil before exposure to ASH solution in each cycle. With samples A3 and A4 corrosion inhibitor was included in the rinse water. After 10 cycles, the corrosion products were scraped off and the samples were desiccated and weighed.

4. RESULTS AND DISCUSSION

4.1 Weight Loss.

Data pertaining to sample weight loss due to cyclic exposure to ASH solutions for the first set of samples are given in table 1 and figures 1 and 2. The condition of the 30-cycle treatment samples before and after scraping is shown in figures 3 and 4, respectively. Samples exhibited general corrosion with a linear weight loss trend as a function of the number of exposure cycles and with a rate of weight loss dependent on ASH solution strength. A maximum weight loss of approximately 5% was observed in samples exposed to 30 cycles with ASH solution A.

4.2 Corrosion Depth.

Data pertaining to sample corrosion depth are given in table 2 and the deepest penetration in samples G and E is shown in figures 5 and 6, respectively. In samples containing the welded seam the deepest penetration occurred in the heat-affected zone adjacent to the weld. A maximum penetration of approximately 40% of the body wall thickness was observed in samples after 30 exposure cycles.

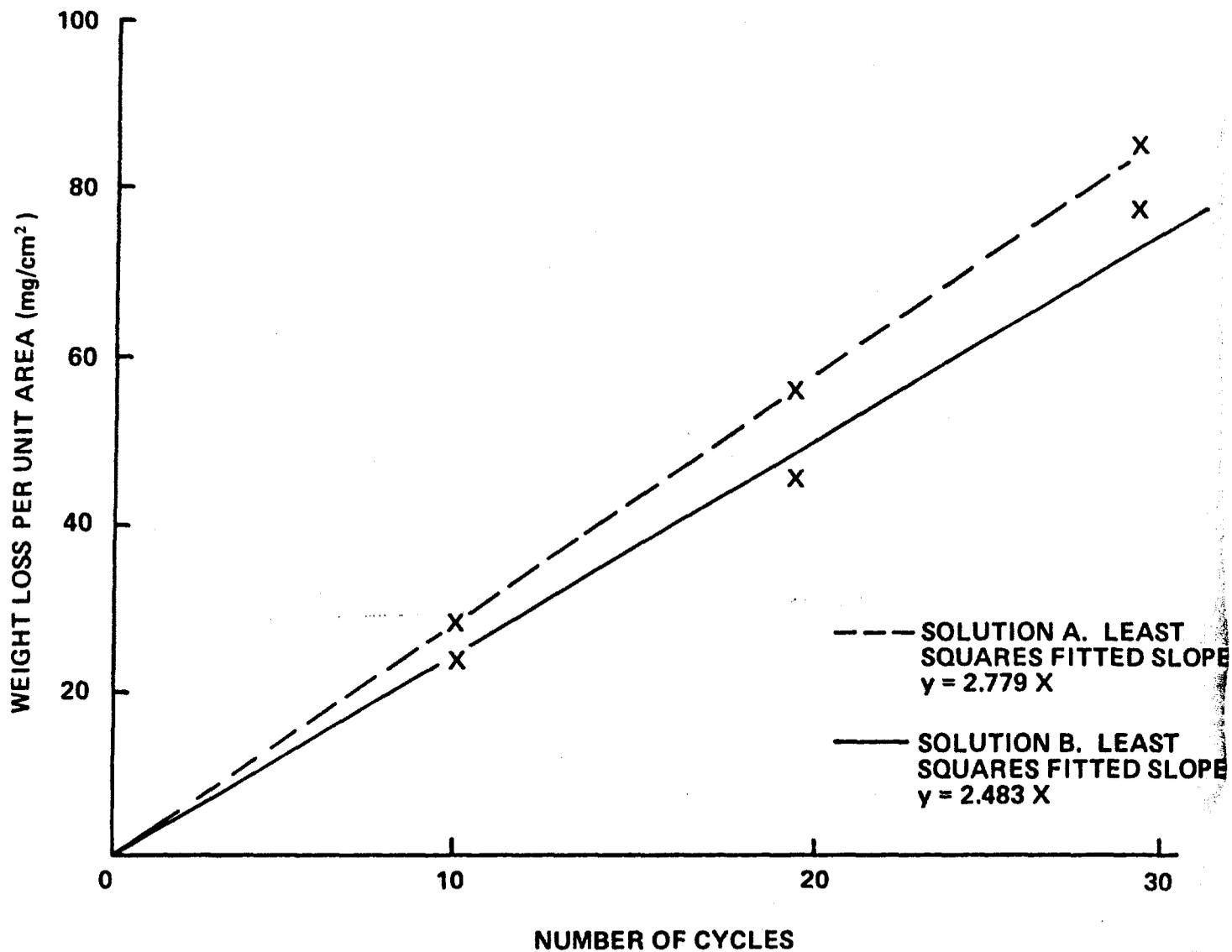


Figure 1. Average Weight Change Unwelded samples (Data points are the average value for those samples which have the same number of cycles and solution strength.)

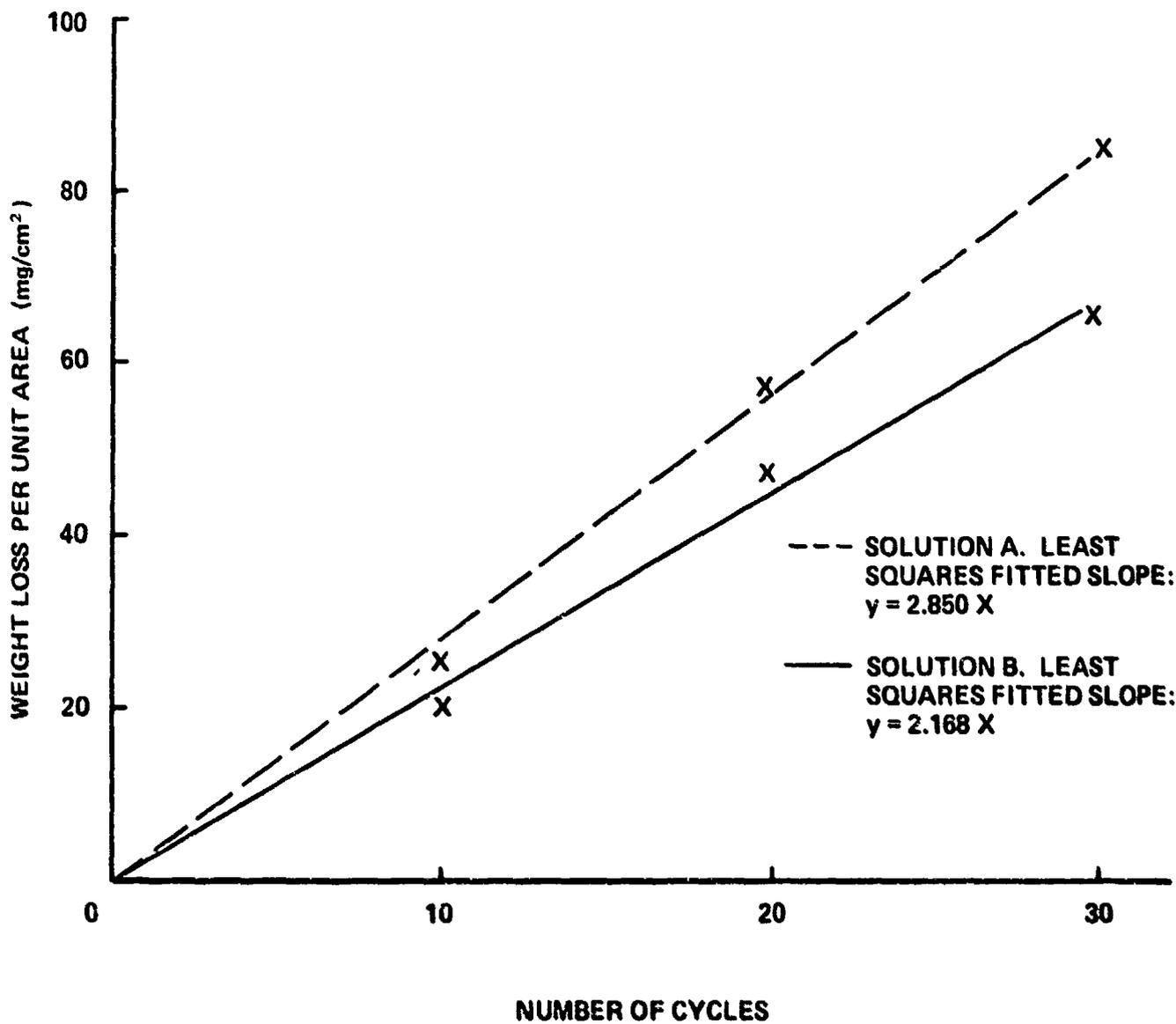


Figure 2. Average Weight Change Welded Samples (Data points are the average value for those samples which have the same number of cycles and solution strength.)

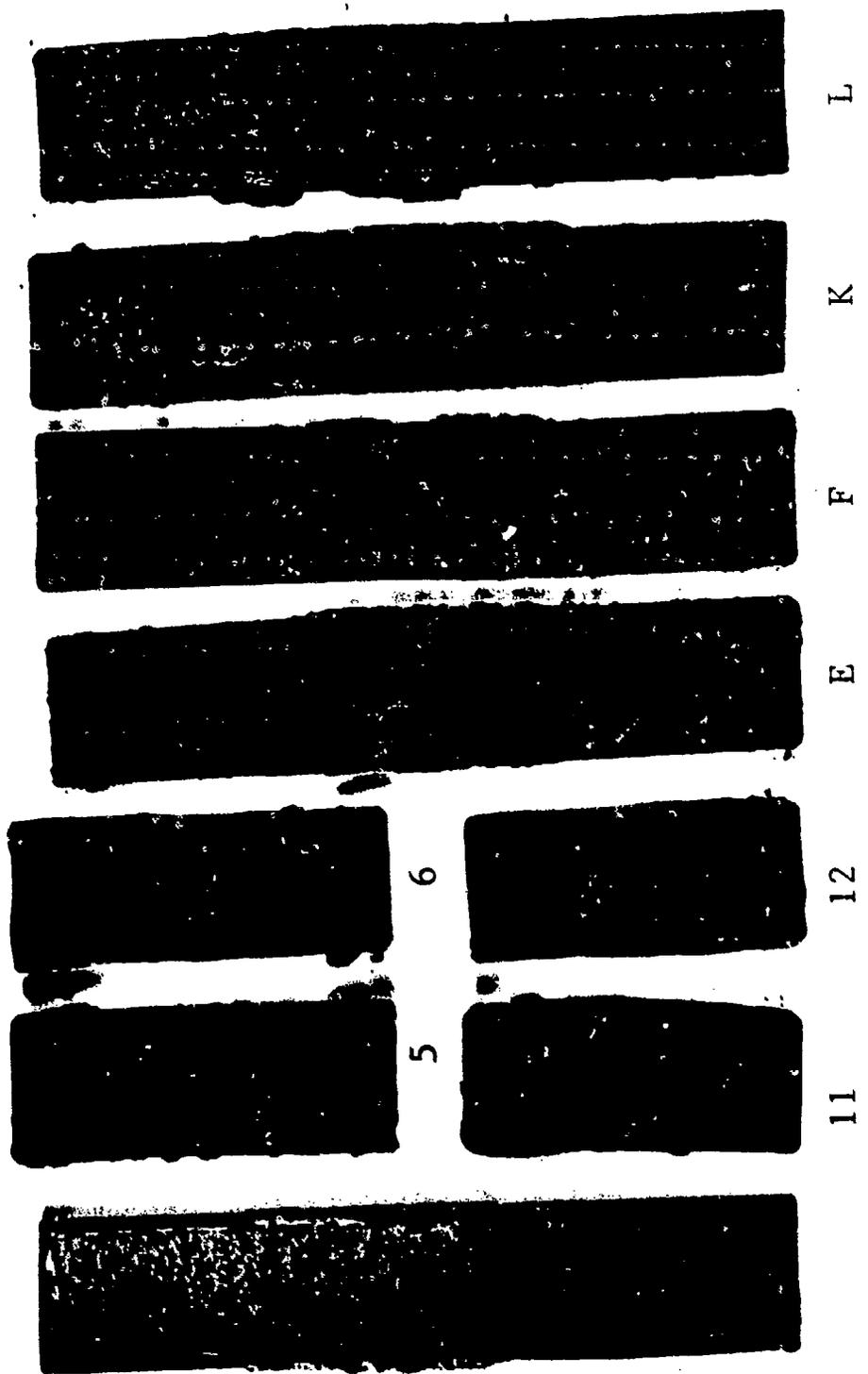


Figure 3. Condition of 30-Cycle Treatment Samples Before Scraping

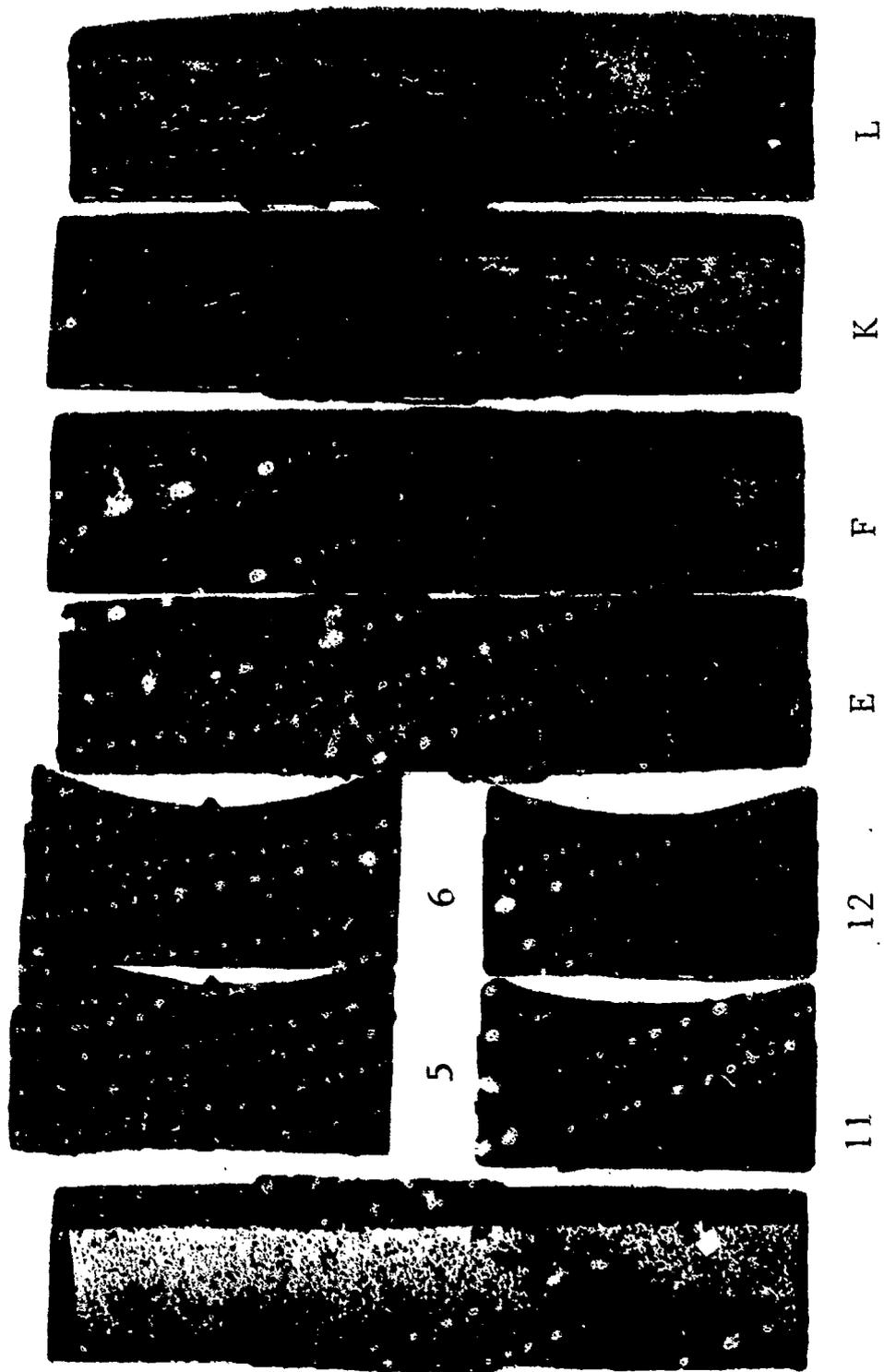


Figure 4. Condition of 30-Cycle Treatment Samples After Scraping

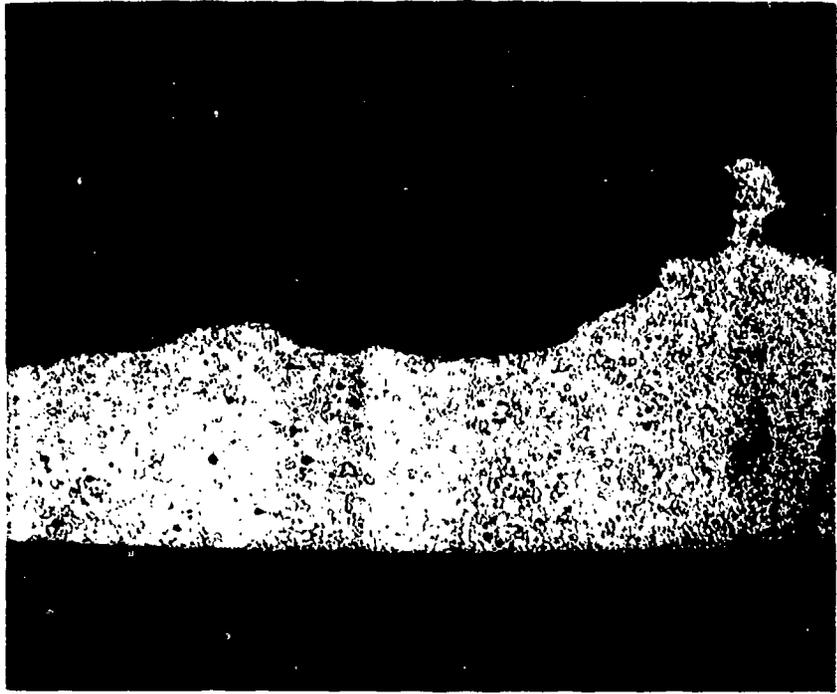


Figure 5. Corrosion Penetration in Sample 6

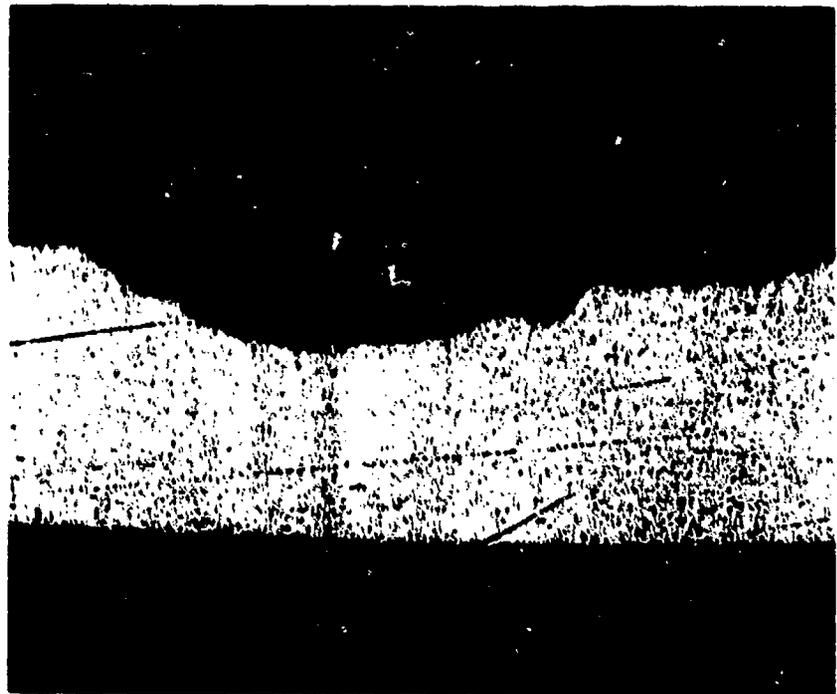


Figure 6. Corrosion Penetration in Sample E

Table 2. Corrosion Depth Data

| Sample | Number of Cycles/ Solution Strength* | Thickness of Sample inches | Depth of Greatest Penetration inches | Percentage Depth Penetration |
|--------|---|----------------------------------|--|---------------------------------|
| A | 10/A | 0.061 | 0.0063 | 10% |
| 8 | 10/B | 0.061 | 0.0066 | 10% |
| D | 20/A | 0.061 | 0.0189 | 31% |
| 4 | 20/A | 0.061 | 0.0128 | 21% |
| 6 | 30/A | 0.061 | 0.0256 | 42% |
| E | 30/A | 0.061 | 0.0226 | 37% |

*A - 2:1 (V/V, water:bleach) solution.

B - 8:1 (V/V, water:bleach) solution.

4.3 Tensile Strength.

Data pertaining to sample tensile strength are given in table 3. It should be noted this test did not conform to any standard tensile strength test procedure, i.e., specimens did not conform to a standard pattern. Tensile strength for all samples was computed on the basis of as received body wall thickness. By inspection of the data, no significant reduction in the tensile strength of samples exposed to ASH appears to have occurred. Tensile strength at failure for all samples exceeded the computed maximum wall hoop stress, resulting from pressurizing a fully loaded PDA with two nitrogen cylinders, by a factor of 4 to 5.

4.4 Corrosion Inhibition.

Data pertaining to samples which were treated to inhibit corrosion are given in table 4. In terms of sample weight loss, pre-exposure treatment with oil or use of rust inhibitor in the rinse water inhibited corrosion by about 90% and about 50%, respectively. No penetration or tensile strength data were collected from these samples.

5. CONCLUSIONS

ASH solutions are incompatible with the as received (AR) PDA body. Although the severity of body corrosion based on overall weight loss or change in tensile strength seems to be minor or negligible from use with ASH, repeated use with ASH would eventually lead to body wall failure, probably through pitting and the appearance of small leaks. Catastrophic pressure failure, once the body wall has become sufficiently corroded and weakened, is a possibility.

While use of an oil coating or of rinse water containing a rust inhibitor would tend to extend AR PDA service life with ASH, body wall failure would still be the ultimate outcome. Further, use of these techniques would place additional responsibility and burden on the user.

Table 3. Tensile Data

| Sample | Solution Strength* | Load to Failure lb | Sample Width inches | Tensile Strength** at Failure lb/in ² |
|--------|--------------------|-----------------------|------------------------|--|
| B | 10/A | 1805 | 0.55 | 52,800 |
| G | 10/B | 1500 | 0.47 | 51,200 |
| H | 10/B | 1400 | 0.47 | 47,800 |
| C | 20/A | 1770 | 0.55 | 51,800 |
| I | 20/B | 1835 | 0.55 | 53,700 |
| J | 20/B | 1530 | 0.51 | 48,200 |
| F | 30/A | 1750 | 0.55 | 51,200 |
| L | 30/B | 1790 | 0.58 | 50,600 |
| 1 | 10/A | 1620 | 0.51 | 51,000 |
| 2 | 10/A | 1640 | 0.51 | 51,700 |
| 7 | 10/B | 1680 | 0.55 | 49,200 |
| 3 | 20/A | 1630 | 0.53 | 49,400 |
| 9 | 20/B | 1525 | 0.51 | 48,000 |
| 10 | 20/B | 1570 | 0.51 | 49,400 |
| 5 | 30/A | 1540 | 0.55 | 45,000 |
| 11 | 30/B | 1665 | 0.51 | 52,400 |
| 12 | 30/B | 1780 | 0.51 | 56,100 |
| M | Control | 1745 | 0.59 | 47,600 |
| N | Control | 1825 | 0.59 | 49,800 |
| 13 | Control | 1800 | 0.51 | 56,700 |
| 14 | Control | 1630 | 0.51 | 51,300 |

*A - 2:1 (V/V, water:bleach) solution.

B - 8:1 (V/V, water:bleach) solution.

**The walls of the PDA would see a hoop stress of approximately 6000 lb/in² after charging with a single nitrogen cylinder (to 190 psig) and 12,000 lb/in² after charging with two (to 360 psig).

Table 4. Inhibited Corrosion Data

| Sample | Treatment* | Initial Weight | Final Weight | Weight Loss | Exposed Sample Area | Weight Loss Per Unit Area |
|--------|------------|----------------|--------------|-------------|---------------------|---------------------------|
| | | g | g | g | cm ² | mg/cm ² |
| A1 | AA | 13.8892 | 13.8593 | 0.0299 | 8.9 | 3.4 |
| A2 | AA | 11.3082 | 11.2922 | 0.0160 | 7.8 | 2.1 |
| A3 | BB | 13.4298 | 13.2821 | 0.1477 | 8.8 | 16.8 |
| A4 | BB | 12.7400 | 12.6025 | 0.1375 | 7.9 | 17.4 |
| A5 | CC | 13.7594 | 13.5266 | 0.2328 | 8.0 | 29.1 |
| A6 | CC | 15.2411 | 14.9845 | 0.2566 | 9.0 | 28.5 |

*AA - Film of SAE 30-weight oil applied before each cycle.

BB - Rinsed with liquid cooling system corrosion inhibitor after each cycle.

CC - No applied rust inhibitor.

With or without service extension methods, some cleanup regimen would have to be followed after use of the AR PDA with ASH to prevent loosely bound corrosion products from obstructing or otherwise interfering with operation of the PDA discharge flow control components. While a malfunction in training use resulting from this aspect would only be a nuisance, malfunction in subsequent combat service use of the PDA with DS2 would be unacceptable.

A PDA modification which would enable dual service with either ASH or DS2, with negligible corrosion or added user burden in either service, is the best approach. From the technical point of view it is probable that something like an epoxy coating of the body wall would suffice for this purpose. The coating method should be simple and foolproof enough to enable in-the-field application. Since not all PDA are used in training, it is only necessary to modify PDA which are to be used with ASH. With modified PDA we must have assurance that subsequent combat service use will not be impaired by the modification. Combat service malfunction risk could of course be avoided completely if it were possible to dedicate a sufficient number of PDA to training use only.

6. RECOMMENDATIONS

Do not use an AR PDA in training service with ASH, where subsequently it might become necessary to use the PDA in combat service with DS2.

Assess the feasibility of using a body wall coating, such as epoxy, to enable dual training or combat service with ASH or DS2, respectively.

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