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WATER SOLUBLE CORROSION INHIBITORS TO PROTECT IMMERSSED
STEEL AND ALUMINUM(U) ARMY ARMAMENT RESEARCH
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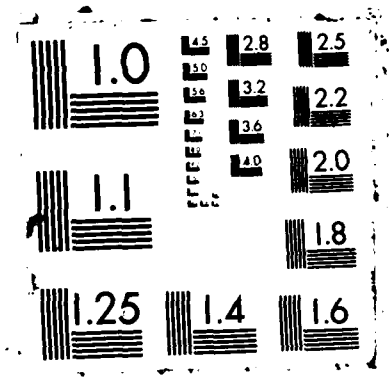
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MEMORANDUM REPORT ARPAD-MR-87001

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IMMERSED STEEL AND ALUMINUM

HENRY HARTMANN

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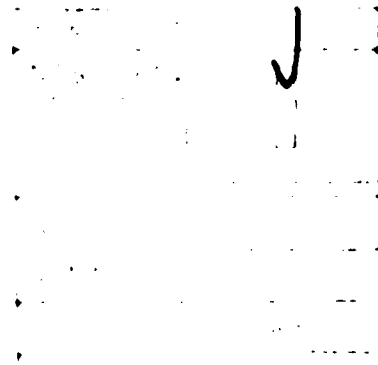
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INTRODUCTION

Much of the nondestructive test (NDT) work at Picatinny Arsenal involves ultrasonic testing under water. A corrosion inhibitor is dissolved in the holding tank water to protect all the metal in the tank structure as well as any metal placed within. In question is the proper concentration of corrosion inhibitor to provide complete protection of all immersed metal. At times technicians have thrown in a handful or half a cup of corrosion inhibitor without bothering to figure out the proper amount. The purpose of this report is to evaluate the effectiveness of two common corrosion inhibitors, sodium nitrite and sodium silicate, and to determine minimum concentrations of each in distilled water for complete protection of immersed steel and aluminum.

TEST DESIGN

Metals

Since most of the materials placed into our ultrasonic test tank are high strength steel and high strength aluminum, these are the two metals to be evaluated for corrosion protection. However, the shape the metal samples should be in is a problem. Investigation revealed that steel wool is an excellent material for revealing corrosion. It was decided to insert a good size ball of steel wool into a 5-oz plastic cup about three quarters full of water for a period of 3 days. About three quarters of the steel wool was submerged in water with the remaining quarter above the water surface.

Treating an aluminum sample was more difficult. Aluminum foil was tried but the finely finished surfaces resisted corrosion. Finally, a target BASE from a 155-mm carrier projectile was taken to the machine shop and 1/4 mm (0.0625 in.) thick chips were sheared from the BASE on a shaper metal working machine. The chips were curled with one surface crimped while the opposite surface was bright. The material was high strength aluminum alloy 2024-T6. One chip was completely submerged in a 5-oz plastic glass.

Corrosion Inhibitors

A previous report¹ revealed that the most common corrosion inhibitors in use are sodium nitrite and sodium silicate. These inhibitors were selected for trial as both chemicals are strictly regulated and sold in a number of commercially available, specially formulated solutions for which treatment instructions and data are available. Sodium nitrite is commonly used in these solutions. For example, a common 10% solution of sodium nitrite by weight.

¹ "Materials, Design, and Corrosion Inhibitors," prepared by the Army Research Office, Picatinny Arsenal, Dover, NJ, 1971.

Concentration in Distilled Water

It was decided to measure by cubic centimeters both the corrosion inhibitors and distilled water. In this way, mixing various concentrations will be simple. It was also planned to start with a maximum concentration of 0.01, that is, one volume of corrosion inhibitor dissolved in 100 volumes of distilled water. Concentrations decreased in equal steps starting from 0.01 to 0.005, 0.001, 0.0005, 0.0001, 0.00005, and finally 0.00001.

To obtain one unit volume of silicon dioxide (this is the active corrosion inhibitor in sodium silicate), six volumes of liquid sodium silicate (water glass) grade 40 are required. The composition of liquid sodium silicate is listed in table 1. Solid silicon dioxide (pure sand) is an abrasive; however, when molecularly combined with sodium oxide, it becomes water soluble and is an excellent corrosion inhibitor.

Findings

All of the corrosion inhibitor data are listed in table 2. Many of the tests were repeated twice. The following results were obtained:

1. Some of the corrosion inhibitors were effective at very dilute concentration.

2. No corrosion took place on steel wool that rose above the level of water containing corrosion inhibitors. On some of the strands of steel wool, tiny amounts of salt were evident.

CALCULATION FOR THE AMOUNT OF CORROSION INHIBITOR NEEDED

There are 4 quarts per gallon, 16 fluid ounces per pint, 2 tablespoons per fluid ounce, and 3 teaspoons per tablespoon, then there are 768 teaspoons per gallon.

Protecting Steel

1. 1 gallon of water
2. 1.7 teaspoons of inhibitor

1.7664 gallons of water, 1.7664 x 768 = 1.3544 teaspoons of inhibitor.

1. 1 gallon of water
2. 1.7 teaspoons of inhibitor

0.00050 silicon dioxide

$t = 0.00050 (768) 6 \text{ g}$

For example: For 30 gallons of water, $t = 0.00050 (768) 6 (30) = 69.1$
teaspoons or 1.4 cups of sodium silicate.

Protecting Aluminum

0.00001 sodium nitrite

$t = 0.00001 (768) \text{ g}$

For example: For 30 gallons of water, $t = 0.00001 (768) 30 = 0.2$ teaspoon of
sodium nitrite.

0.00001 silicon dioxide

$t = 0.00001 (768) 6 \text{ g}$

For example: for 30 gallons of water, $t = 0.00001 (768) 6 (30) = 1.4$
teaspoons of sodium silicate.

EFFECT UPON THE SPEED OF SOUND

Additives to distilled water can affect the speed of sound. A measuring cylinder graduated to 25 cm³ was used to hold either distilled water or corrosion inhibiting solutions, and the time was measured for an ultrasound pulse to pass down through the liquid and bounce back up. The total distance of passage was 37.5 cm (14.8 inches). The estimate for error is 0.001. Time measurements were made on a cathode ray tube screen using distilled water for the calibration checks before and after each of the two tests:

<u>Liquid</u>	<u>Time, cm</u>
Distilled water	10.00
0.01 sodium nitrite solution	10.00
Distilled water	10.00
0.06 sodium silicate solution	9.95
Distilled water	10.00

The concentrations of both corrosion inhibitors were the maximum that were tried. Sodium nitrite had no affect on the speed of sound. Sodium silicate permitted the speed of sound to increase by 1/2 of 1%. Since this increase in speed is probably a linear function, at a concentration of 0.00001 (as compared to 0.01), the increase in the speed of sound should be a negligible 0.0005%. To verify this, the following data were obtained:

<u>Liquid</u>	<u>Time, cm</u>
Distilled water	10.00
0.00006 sodium silicate solution	10.00
Distilled water	10.00

It was observed that substantial ultrasonic noise appeared with the presence of either corrosion inhibitor. This is the sacrifice in ultrasonic signal-to-noise ratio when either corrosion inhibitor is used. However, in actual use, dilute concentrations of corrosion inhibitor should cause little impact upon the ultrasonic signal-to-noise ratio.

COST CALCULATIONS

If purchased in 55 gallon drum quantities, the basic cost of granular sodium nitrite is about \$25 per gallon; whereas, liquid sodium silicate costs about \$2 per gallon. However, Grade 40 degrees sodium silicate contains only 1/6 silicon dioxide by volume; therefore, silicon dioxide costs about \$12 per gallon (6 x 2).³

Protecting steel submerged in 100 gallons of water:

Sodium nitrite, (0.00095) \$25 (100 gallons) = 13¢

Silicon dioxide, (0.0005) \$12 (100 gallons) = 60¢

Protecting 7075-T6 aluminum submerged in 100 gallons of water:

Sodium nitrite, (0.00001) \$25 (100 gallons) = 3¢

Silicon dioxide, (0.00001) \$12 (100 gallons) = 1¢

CONCLUSIONS

1. Both sodium nitrite and silicon dioxide (the active ingredient of sodium silicate) are very effective in preventing corrosion of steel and high strength aluminum alloy #7075-T6 while immersed in water for three days. Minimum concentrations of each corrosion inhibitor for complete protection and the cost of each in 100 gallons of water are:

³All money in this report is in FY87 dollars.

<u>Metal</u>	<u>Portion in water by volume</u>		<u>Cost in 100 gal. of water (\$)</u>	
	<u>Sodium nitrite</u>	<u>Silicon dioxide</u>	<u>Sodium nitrite</u>	<u>Silicon dioxide</u>
Steel wool	0.00005	0.00050	0.12	0.60
7075-T6 aluminum	0.00001	0.00001	0.03	0.01

2. The presence of either corrosion inhibitor at the minimum recommended rates has no significant impact on the speed of sound through the solution.

3. An attractive bronze coating can be obtained over bare aluminum by soaking in a 1% sodium nitrite solution (by volume) for three days.

Table 1. Composition of liquid sodium silicate, grade 40*

	Sodium oxide (Na ₂ O)	Silicon dioxide (SiO ₂)	Water (H ₂ O)
Portion by weight	0.091	0.292	0.617
Specific gravity	2.27	2.32	1.0
Portion by volume	0.05	0.16	0.79

*"Grades of Diamond Liquid Sodium Silicates," Diamond Shamrock Chemicals Co., Technical Bulletin, Painesville, OH, 1985.

Table 2. Effect of two inhibitors on the corrosion of steel and aluminum

<u>Portion by volume of inhibitor in water</u>	<u>Sodium nitrite (NaNO_2)</u>	<u>Silicon dioxide (SiO_2)</u>
		<u>Steel Wool</u>
0.01	No corrosion	No corrosion
0.005	No corrosion	No corrosion
0.001	No corrosion	No corrosion
0.0005	No corrosion	No corrosion
0.0001	No corrosion	Localized dark brown rust of surface
0.00005	No corrosion	Localized dark brown rust of surface
0.00001	Slight rusting	Localized rust near surface about 0.01% of surface
0.00000 (pure water)	Mostly amber but some black rust covering 100 percent of the steel wool surface	
		<u>Aluminum alloy 7075-T6 chips</u>
0.01	No corrosion, microscopic patches of bronze color covering half the surface; overall appearance is a silvery bronze	No corrosion
0.005	No corrosion, lighter bronzing color than above	No corrosion
0.001	No corrosion, barely perceptible bronzing	No corrosion
0.0005	No corrosion, barely perceptible bronzing	No corrosion
0.0001	No corrosion, barely perceptible bronzing	No corrosion
0.00005	No corrosion, no bronzing	No corrosion
0.00001	No corrosion, no bronzing	No corrosion
0.00000 (pure water)	Corrosion consists of considerable hydroxide gel plus many black spots covering	

Corrosion of steel and aluminum while immersed in water for three days

<u>Silicon dioxide (SiO₂)</u>		<u>Combined equal portions of sodium nitrite + silicon dioxide</u>	
<u>Steel Wool</u>			
No corrosion		No corrosion	
No corrosion		No corrosion	
No corrosion		No corrosion	
No corrosion		No corrosion	
Localized dark brown rust over about 0.25% of surface		Two localized rust spots just beginning	
Localized dark brown rust over about 0.25% of surface		Very, very light rust covering 100% of surface	
Localized rust near surface of water covering about 0.01% of surface		Very light rusting covering 100% of surface	

percent of the steel wool surface

Aluminum alloy 7075-T6 chips

lor	No corrosion	No corrosion, no bronzing
is		
e	No corrosion	No corrosion
	No corrosion	No corrosion, no bronzing
	No corrosion	No corrosion, no bronzing
	No corrosion	No corrosion, no bronzing
	No corrosion	No corrosion, no bronzing
	No corrosion	No corrosion, no bronzing

el plus many black spots covering the rough surface, bright surface unscathed

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