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SUBSTITUTION OF TOLYLTRIAZOLE FOR MERCAPTOBENZOTHIAZOLE IN MILITARY COOLANT INHIBITOR FORMULATIONS

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The object of this study was to determine the feasibility of substituting tolyltriazole (TT) for mercaptobenzothiazole (MBT) in the corrosion inhibitor package used in military coolants.

ASTM Glassware Corrosion Tests (D 1384) and Simulated Service Tests (D 2570) were conducted on various blends of antifreeze inhibitors with different percentages of sodium tolyltriazole (NaTT). The NaTT caused foaming in the tests, but a silicone type antifoam agent was found which controlled the foaming. 26

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Results of these tests were correlated with similar tests containing the amount of MBT recommended in coolant specifications (0.4% of the sodium salt). 0.15% was found to be the optimum percentage of NaTT.

Further studies are recommended including vehicle field tests.

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I. INTRODUCTION

For many years mercaptobenzothiazole (MBT) has been used in coolants to inhibit corrosion of metals in the cooling system. It has been found that MBT is easily oxidized to the terminal molecule of benzothiazyl disulfide (BTD) by way of a free radical mechanism and that this conversion is irreversible in coolant media. BTD is insoluble in most coolants and separates as a solid. This could cause clogging. Light, air, or a combination of these maybe the initiator of a molecular homolysis of water or glycol which proceeds, depending on the initiator, by different paths of formation to a peroxy or alkoxy radical which subsequently activiates the MBT. These reactions are further accelerated by the presence of heat (reference 2).

A search was conducted for a comparable substitute that would not oxidize so readily under the conditions that exist in the coolant system. The triazoles were considered to be likely candidates.

Benzotriazole (BT) was substituted for MBT and subjected to the ASTM Glassware Corrosion Test (D 1384) and Simulated Service Tests (D 2570). It was found that BT contributed to pitting of the aluminum in both tests and also caused excessive foaming in the simulated service test, so this inhibitor was judged unsatisfactory.

Tolyltriazole was obtained in two forms, a solid (TT) and a 50% sodium hydroxide solution (NaTT). Glassware Bench Corrosion Tests (ASTM D 1384) were conducted on various percentages of TT and NaTT. The more promising blends were then subjected to the Simulated Service Test (D 2570). The results were compared to those received in tests using MBT.

II. DETAILS OF TEST

A. Test Solutions

Tests were conducted on solutions of 50% ethylene glycol, 30% ethylene glycol, and 100% water. Both distilled and ASTM Corrosive Water was used to prepare the test solutions. Inhibitor formulae were prepared using as base materials the quantities of sodium tetraborate (4.0%), sodium phosphate (0.3%), and MBT (0.4% of the sodium salt) found in MIL-A-46153, or the amount specified in O-I-490A. (See Table 1) Weight percentages of tolyltriazole were substitued for MBT ranging from 0.05 to 0.25%. Various percentages of antifoam agents were added to the test solutions.

B. Glassware Corrosion Tests

Glassware Corrosion tests were carried out in duplicate or triplicate in accordance with ASTM D 1384.

C. Simulated Service Tests

Simulated service tests were conducted on a 50/50 corrosive H_2O and MIL-A-46153 blend (with NaTT and TT substituted for MBT) in accordance with ASTM D-2750.

D. Tolyltriazole

Two different samples of tolyltriazole were used to check their relative purity. These samples were prepared by the same manufacturer but at different times. To aid in solubility, a 50% sodium hydroxide solution of TT was used in most tests.

E. Anti-Foam Agents

(A1) Varpol 61, Polypropylene Glycol (Northern Petrochemical Co.).

(A2) 2025 Polypropylene Glycol (Union Carbide).

(B) Y-30 Silicone (Dow Corning).

(C) Jet Dye, Silicone (Dow Corning).

(E) X2-3010, Silicone (Dow Corning).

F. Corrosion Rating System

A numerical rating system was used to compare the results of test (Table I A).

III. RESULTS OF TEST

The 50/50 water/glycol blends listed in Table II, tests 2 thru 4 contain 0.05, 0.15, and 0.25% solid TT plus borax and phosphate found in MIL-A-46153. Test 1 was a blank containing MBT but no TT. The metal test specimens from test 2, 3, and 4 were in excellent conditon with no excessive weight loss on any of the metals. All of these blends foamed excessively during the test procedure so the air flow had to be reduced from 100 ml/min. to 60 ml/min.

Table III, tests 1, 2, and 3 which contained 70% H_2O and 30% glycols and 0.05%, 0.15%, and 0.25% tolyltriazole respectively plus borax and phosphate found in MIL-A-46153 indicated that the aluminum weight loss was greater than in the 50/50 blends listed in Table I. These samples also foamed excessively and again the air flow had to be reduced.

Table IV, tests 1, 2, and 3 were conducted on distilled water and 0.05, 0.15, and 0.25% tolyltriazole plus borax and phosphate found in 0-I-490A. These tests showed a very high aluminum weight loss and this series of tests also foamed.

All the tests listed in Tables II, III, and IV except those containing MBT showed a heavy white precipitate accumulation. This material was found to be an insoluble phosphate.

To eliminate the possibility that the sample of TT was contaminated, a second sample was obtained. The two samples were compared in various blends (Table V). There was no difference noted in the results. The white precipitate remained and the foaming existed.

Tests showed that the obvious problem of foaming had to be eliminated. Several types of anti-foam agents were tried in different proportions including silicone derivatives and polyglycol anti-foams from several sources. (See Table VI) By comparing the results of these tests with those in Tables II and III it is evident that all the anti-foam agents instigated corrosion on all test including those with MBT. Solder and aluminum were the metals most effected. It was found that the rubber stoppers used in these tests were attacked in all cases except with Anti-Foam E.

It was found in tests using silicone type anti-foam agent (B) that a very heavy white precipitate formed. The aluminum and solder weight losses in these tests were high and the antifreeze blend still foamed to a certain extent. Blooming occurred in the solder coupon (Figure 1). Pitting was evident underneath the bloom. A second silicone, anti-foam agent (C) was tried. Table VI shows that this type of anti-foam agent also contributed to high sediment and poor corrosion preventative characteristics. Anti-foam agent (E) (a silicone type) was tested and virtually eliminated the foam until about the 10th day of the test, at which time foam built up to about 1/2" above the test solution. It appeared to stabilize at this point. The effect upon most of the metals was not as severe as was experienced with the other anti-foam agents. This was chosen as the best anti-foam agent for all metals except aluminum. Corrosive water, 0.15% TT and anti-foam agent (E) proved to be comparable with solutions containing MBT and anti-foam (E).

Table VI also shows the results of using solid TT in corrosive water with the anti-foam A^2. The test solutions did not foam. The aluminum showed a hign weight loss.

It was found that 0.05% TT was not sufficient to control the corrosion and 0.25% performed basically the same as the 0.15%. The 0.15% concentration was chosen as the standard percentage for further studies.

The foaming (ASTM D 1881) of the blends containing TT vs MBT are compared in Table XI. This test showed that foaming is greater when TT is used than when MBT is used.

In addition to the metal test specimens the tests listed in Tables VII and VIII containing a sample of original equipment hose. The durometer hardness reading was taken before and after the test. The reading before was 71 points and after 70 points. There was an appreciable difference in the durometer readings for the rubber stoppers in the test apparatus. The samples that contained MBT lost 13 points and those that contained TT (solid) lost 20 points and sloughing occurred. From this test it was concluded that the rubber stopper softening was not a serious problem since a different rubber formula is used in radiator hose. The weight loss on aluminum and solder was high and above the maximum recommended limit.

Tables IX and X contain the results of the Simulated Service Tests. The aluminum weight loss on the test coupons were less using TT than MBT. The brass had a greater weight loss in the TT formulation. The steel and the cast iron weight losses were less with TT. None of the metal coupons were pitted or etched in these tests.

After each Simulated Service Test the water pump was disassembled. Visual examination showed that the internal parts of the pumps were satisfactory condition. During the entire test period (1064 hours @ 190°F.) no coolant was lost from the system.

IV. CONCLUSIONS

Sodium tolyltriazole (50% aqueous solution) and solid tolyltriazole are comparable with 0.4% MBT in corrosion protection, but both NaTT and solid TT cause foaming. In general the addition of antifoaming agents increases the corrosion of metals in the presence of the TT and NaTT as well as MBT, however, by carefully controlling the amounts of antifoam, optimum conditions can be reached.

Tolyltriazole costs more than mercaptobenzothiazole but the cost is balanced by the fact that lesser quantities of TT are used.

NaTT and TT are more stable to heat, light, and oxidation than MBT.

The silicone antifoam agents in the percentages tested were not stable over a long period of time, but they did not effect the metal coupons as much as the polypropylene glycol antifoam.

It was also concluded that softening of rubber stoppers in the glassware corrosion test was not indicative of adverse effects on vehicle coolant hoses.

V. RECOMMENDATIONS

It is recommended that vehicle field tests be conducted on water and glycol coolants using tolyltriazole as a substitute for mercaptbenzothiazole in the inhibitor formulae.

VI. REFERENCES

1. Federal Specification 0-A-548A Antifreeze Ethylene Glycol Inhibited, Type I, dated 30 December 1958.

2. Federal Specification 0-I-490A, Inhibitor Corrosion Liquid Cooling System, dated 26 April 1965.

3. Military Specification MIL-A-46153, Antifreeze Ethylene Glycol Inhibited, Heavy Duty, Single Package, dated 19 October 1970.

4. ASTM Standard Method D 1881-Test for Foaming Tendencies of Engine Antifreeze in Glassware.

5. ASTM Method D 1384 - Corrosion Test for Engine Antifreeze in Glassware.

6. ASTM Method D 2570 - Simulated Service Corrosion Testing of Engine Coolants.

7. Coating and Chemical Laboratory Report No. 294, entitled "Oxidation of Mercaptobenzothiazole to Benzothiazyl Disulfide in Coolant Media", dated September 1971.

8. Coating and Chemical Laboratory Report No. 210, entitled "Effect of Coolants on Various Types of Aluminum Alloys", dated October 1966.

APPENDIX A

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TABLE I

MILITARY COOLANTS

Composition of Corrosion Inhibitors

	Percent by Weight
A. MIL-A-46153	
Sodium Tetraborate, Decahydrate	4.0 ± 0.2%
Trisodium Phosphate (Calculated as Decahydrate)	0.3 ± 0.04%
Sodium Salt of Mercaptobenzothiazole (50% aqueous solution) (NaMBT)	0.4 ± 0.05%
B. O-I-490a*	
Sodium Tetraborate, Decahydrate	75.7 ± 0.5%
Trisodium Phosphate, Anhydrous	9.2 ± 0.2%
Mercaptobenzothiazole (MBT)	15.1 ± 0.3%

* Amount of inhibitor used is based on concentration of antifreeze.

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TABLE I A

CORROSION RATING SYSTEM FOR LABORATORY BENCH CORROSION TEST

Rating	Weight Loss ($mg./cm^2$)
1	0.00 - 0.10
2	0.11 - 0.20
3	0.21 - 0.30
4	0.31 - 0.40
5	0.41 - 0.50
6	0.51 - 1.0
7	1.1 - 3.0
8	3.1 - 7.0
9	7.1 - 14.0
10	14.1 - 50.0
11	50.1 or above
1	any weight gain

To evaluate the corrosion of metal specimens, corrosion ratings were assigned according to the above table based on weight losses per unit area of each specimens, and a collective rating of each set of specimens, e.e., aluminum, copper, solder, steel and cast iron, assigned by totalling the individual ratings. If the metal shows visual corrosion, e.e., pitting, etching, staining, discoloration, the rating is raised by one point. The higher the numerical rating, the greater the corrosion. A rating of 10 or less indicates a satisfactory composition.

TABLE II

GLASSWARE BENCH CORROSION TESTS
(ASTM D-1384)

TOLYLTRIAZOLE VS MBT IN 50% MIL-A-46153

Test Number	1	2	3	4
Coolant Solution	Distilled H_2O 50/50 MIL-A-46153 (MBT Standard)	Distilled H_2O 50/50 MIL-A-46153 0.05% Tolyltri-azole Substituted for MBT	Distilled H_2O 50/50 MIL-A-46153 0.15% Tolyltri-azole Substituted for MBT	Distilled H_2O 50/50 MIL-A-46153 0.25% Tolytri-azole Substituted for MBT
pH Before	7.6	7.65	7.65	7.65
pH After	7.45	7.45	7.5	7.5
	Weight Change mg/sq cm			
Aluminum	0.09	0.03	0.16	0.04
Copper	0.03	0.02	0.02	0.01
Solder	0.003	0.05	0.02	0.06
Brass	0.02	0.01	0.02	0.02
Steel	0.007	0.01	0.003	0.006
Cast Iron	0.03	0.02	0.03	0.02
Rating	6	6	7	6

TABLE III

GLASSWARE BENCH CORROSION TESTS
(ASTM D-1384)

TOLYLTRIAZOLE SUBSTITUTED FOR MBT IN 30% MIL-A-46153

Test Number	1		2		3		4
Coolant Solution	70% Distilled H_2O 30% MIL-A-46153 0.05% Tolyltriazole Substituted for MBT		70% Distilled H_2O 30% MIL-A-46153 0.15% Tolyltriazole Substituted for MBT		70% Distilled H_2O 30% MIL-A-46153 0.25% Tolyltriazole Substituted for MBT		70% Distilled H_2O 30% MIL-A-46153 (MBT-Standard)
pH Before	7.95		7.95		8.0		8.0
pH After	7.9		7.9		8.0		7.9
Weight Change mg/sq cm							
Aluminum	0.16	0.23	0.15	0.26	0.38	0.37	0.05
Copper	0.08	0.03	0.04	0.03	0.03	0.05	0.04
Solder	0.11	0.06	0.01	0.05	0.05	0.09	0.05
Brass	0.03	0.02	0.05	0.04	0.03	0.05	0.03
Steel	0.05	0.04	0.06	0.04	0.03	0.04	0.005
Cast Iron	0.02	0.03	0.03	0.01	0.03	0.02	0.1
Rating	8	8	7	8	9	9	

TABLE IV

GLASSWARE BENCH CORROSION TESTS
(ASTM D-1384)

TOLYLTRIAZOLE SUBSTITUTED FOR MBT IN O-I-490a

Test Number	1		2		3		4
Coolant Solution	100% Distilled H_2O 0.05% Tolyltriazole Substituted for MBT		100% Distilled H_2O 0.15% Tolyltriazole Substituted for MBT		100% Distilled H_2O 0.25% Tolyltriazole Substituted for MBT		100% Distilled H_2O O-I-490a (MBT-Standard)
pH Before	9.55		9.45		9.55		9.1
pH After	9.5		9.4		9.5		9.1
	Weight Change mg/sq cm						
Aluminum	5.17	4.59	5.22	5.43	4.54	6.24	6.37
Copper	0.07	0.02	0.05	0.03	0.002	0.001	0.28
Solder	0.08	0.05	0.24	0.09	0.002	0.12	1.1
Brass	0.05	0.002	0.002	0.01	0	0.01	0.25
Steel	+ 0.14	+ 0.08	+ 0.07	+ 0.11	+ 0.02	0.01	0.08
Cast Iron	0.29	+ 0.23	+ 0.26	0.03	+ 0.18	+ 0.04	0.02
Rating	15	13	15	13	12	14	

TABLE V

GLASSWARE BENCH CORROSION TESTS
(ASTM D-1384)

OLD TOLYLTRIAZOLE VS NEW TOLYLTRIAZOLE

Test Number	1	2	3		4	
Coolant Solution	Old Tolyltriazole 50% H_2O 50% MIL-A-46153 - 0.15% Tolyltriazole Substituted for MBT	Old Tolyltriazole 70% H_2O 30% MIL-A-46153 - 0.15% Tolyltriazole Substituted for MBT	New Tolyltriazole 50% H_2O 50% MIL-A-46153 - 0.15% Tolyltriazole Substituted for MBT		New Tolyltriazole 70% H_2O 30% MIL-A-46153 - 0.15% Tolyltriazole Substituted for MBT	
pH Before	7.6	8.05	7.65		8.1	
pH After	7.6	8.1	7.5		8.1	
Weight Change mg/sq cm						
Aluminum	0.106	0	0.088	0.096	0.045	0.029
Copper	0.049	0.059	0.074	0.067	0.053	0.102
Solder	0.79	0.053	0.9	0.535	0.046	0.042
Brass	0.053	0.021	0.003	0.038	0.063	0.088
Steel	0.063	0.070	0.035	0.031	0.042	0.085
Cast Iron	0.179	0.094	0.104	0.117	0.127	0.221
Rating	13	6	11	12	7	8

TABLE VI

ANTIFOAM AGENTS USED IN SOLUTIONS CONTAINING TT-NaTT AND MBT

Coolant	% TT	% MBT	Anti-Foam		Mg/sq cm Loss (Rating) Cu	Solder	Brass	Steel	CI	Al	pH Before	After
1	.015	0	(A^1)	.015%	.005 (1)	.89 (7)	.02 (1)	.02 (1)	.19 (2)	.14 (2)	7.5	7.5
1	.15	0	(A^1)	.015%	.005 (1)	1.72 (7)	.04 (1)	.02 (1)	.12 (2)	.17 (2)	7.5	7.5
1	.25	0	(A^1)	.015%	.01 (1)	1.65 (7)	.03 (1)	.01 (1)	.02 (1)	.13 (2)	7.6	7.55
1-Std.	0	.73	(A^1)	.015%	.01 (1)	.01 (1)	.005 (1)	.01 (1)	.19 (2)	.09 (1)	7.6	7.5
2	.015	0	(A^1)	.015%	.01 (1)	.3 (3)	.005 (1)	.03 (1)	.23 (2)	.29 (3)	9.5	9.5
2	.15	0	(A^1)	.015%	.01 (1)	.93 (7)	.01 (1)	.04 (1)	.25 (2)	6.87 (8)	9.5	9.5
2	.25	0	(A^1)	.015%	.004 (1)	.38 (4)	.01 (1)	.08 (1)	.18 (2)	8.25 (9)	9.5	9.5
2-Std.	0	.23	(A^1)	.015%	.02 (1)	.01 (1)	.08 (1)	.06 (1)	.48 (5)	4.04 (8)	9.5	9.5
2	.05	0	(B)	.015%	.11 (1)	.21 (3)	.15 (2)	.06 (1)	.03 (1)	5.0 (8)	9.5	9.5
2	.15	0	(B)	.015%	.16 (2)	.27 (3)	.16 (2)	.11 (2)	.05 (1)	6.81 (8)	9.45	9.4
2	.25	0	(B)	.015%	.01 (1)	1.0 (7)	.19 (2)	.07 (1)	.02 (1)	6.03 (8)	9.3	9.5
2-Std.	0	.23	(B)	.015%	.28 (3)	1.1 (7)	.25 (3)	.08 (1)	.02 (1)	6.37 (8)	9.5	9.5
1	.05	0	(B)	.015%	.10 (1)	1.2 (7)	.2 (2)	.07 (1)	.03 (1)	.04 (1)	7.65	7.5
1	.15	0	(B)	.015%	.11 (2)	1.06 (7)	.14 (2)	.08 (1)	.02 (1)	.04 (1)	7.65	7.5

TABLE VI - ANTIFOAM AGNETS USED IN SOLUTIONS CONTAINING TT-NaTT AND MBT (CONTINUED)

Coolant	% TT	% MBT	Anti-Foam	Mg/sq cm Loss (Rating) Cu	Solder	Brass	Steel	CI	Al	pH Before	After
1	.25	0	(B) .015%	.11 (2)	.58 (6)	.14 (2)	.08 (1)	.03 (1)	.04 (1)	7.6	7.5
1-Std.	0	.23	(B) .015%	.21 (3)	.05 (1)	.24 (3)	.08 (1)	.01 (1)	.32 (4)	7.6	7.5
1	.10	0	(C) .015%	.33 (4)	.30 (3)	.30 (3)	.04 (1)	.02 (1)	2.3 (7)	7.6	7.6
1	.15	0	(C) .015%	.4 (4)	.36 (4)	.67 (7)	.05 (1)	.01 (1)	2.4 (7)	7.6	7.6
1-Std.	0	.23	(C) .015%	.42 (5)	.63 (6)	.40 (4)	.07 (1)	.01 (1)	2.7 (7)	7.65	7.6
1-Blank	0	0	(C) .015%	.85 (6)	.72 (6)	.24 (3)	.08 (1)	.01 (1)	106.4 (11)	7.55	7.5
2	.15	0	(E) .005%	.16 (2)	.29 (3)	.16 (2)	.07 (1)	.06 (1)	7.87 (9)	9.45	9.4
1	.15	0	(E) .005%	.16 (2)	.23 (3)	.20 (2)	.06 (1)	.02 (1)	.51 (6)	7.65	7.45
2-Std.	0	.23	(E) .005%	.21 (3)	.11 (2)	.40 (4)	.10 (1)	.01 (1)	2.81 (7)	9.5	9.5
1-Std.	0	.23	(E) .005%	.30 (3)	2.0 (7)	.35 (4)	.04 (1)	.01 (1)	.56 (6)	7.6	7.45
3	.15*	0	(E) .005%	.12 (2)	1.02 (6)	.16 (2)	.03 (1)	.007 (1)	.42 (5)	7.45	7.4
3-Std.	0	.23	(E) .005%	.28 (3)	.37 (4)	.22 (3)	.03 (1)	.01 (1)	.62 (6)	7.5	7.5
4	.15*	0	(E) .005%	.13 (2)	.59 (6)	.16 (2)	.04 (1)	.03 (1)	9.95 (9)	9.0	9.0
4-Std.	0	.23	(E) .005%	.25 (3)	1.75 (7)	.2 (2)	.04 (1)	.01 (1)	10.45 (9)	9.0	9.0
5	.15*	0	(E) .005%	.16 (2)	.63 (6)	.2 (2)	.02 (1)	.01 (1)	7.1 (9)	9.1	9.3

TABLE VI - ANTIFOAM AGENTS USED IN SOLUTIONS CONTAINING TT-NaTT AND MBT (CONTINUED)

Coolant	% TT	% MBT	Anti-Foam	Mg/sq cm Loss (Rating) Cu	Solder	Brass	Steel	Cl	Al	pH Before	After
5-Std.	0	.23	(E) .005%	.25 (3)	1.71 (7)	.2 (2)	.04 (1)	.01 (1)	10.4 (9)	9.0	9.0
5	.15*	0	(E) .005%	.16 (2)	.34 (4)	.81 (9)	.04 (1)	+ .05 (1)	5.9 (8)	9.1	9.1
5	.15*	0	(A^2) .005%	.18 (2)	.40 (4)	.21 (2)	.05 (1)	+ .05 (1)	5.09 (8)	9.1	9.1

* Solid TT used instead of NaTT solution.

Solution 1 - 50/50% Distilled H_2O and MIL-A-46153.

Solution 2 - 100% Distilled H_2O + standard borax and phosphate.

Solution 3 - 50/50% Corrosive water and MIL-A-46153.

Solution 4 - 100% Corrosive water + standard borax and phosphate.

Solution 5 - 100% Corrosive water and O-I-490a.

TABLE VII

GLASSWARE BENCH CORROSION TESTS
(ASTM D-1384)

SILICONE ANTIFOAM IN 0-1-490a FOR EFFECT ON OE-EP HOSE

Test Number	1	2	3
Coolant Solution	100% Corrosive H_2O Antifoam "E" 0.005% 0-1-490a OE-EP Hose	100% Corrosive H_2O Antifoam "E" 0.005% 0-1-490a OE-EP Hose	100% Corrosive H_2O Antifoam "E" 0.005% 0-1-490a OE-EP Hose
pH Before	9.0	9.0	9.0
pH After	9.0	9.0	9.0
RA Before	9.1	9.1	9.1
RA After	9.1	9.1	9.1
Hose Durometer Hardness			
Before	71	71	71
After	70	70	70
	Weight Change mg/sq cm		
Aluminum	4.96	4.81	4.48
Copper	0.29	0.20	0.30
Solder	0.48	0.63	1.12
Brass	0.27	0.30	0.27
Steel	0.03	0.03	0.04
Cast Iron	+ 0.09	+ 0.06	+ 0.13
Rating	21	22	23

TABLE VIII

GLASSWARE BENCH CORROSION TESTS
(ASTM D-1384)

SILICONE ANTIFOAM IN O-I-490a - SOLID TOLYLTRIAZOLE SUBSTITUTED FOR MBT FOR EFFECT ON OE-EP HOSE

Test Number	1	2	3
Coolant Solution	100% Corrosive H_2O Antifoam "E" 0.005% Tolyltriazole 0.15% Substituted for MBT	100% Corrosive H_2O Antifoam "E" 0.005% Tolyltriazole 0.15% Substituted MBT	100% Corrosive H_2O Antifoam "E" 0.005% Tolytriazole 0.15% Substituted MBT
pH After	9.1	9.1	9.1
RA Before	9.0		
RA After	9.1	9.1	9.1
Hose Durometer Hardness			
Before	71	71	71
After	70	70	70
		Weight Change mg/sq cm	
Aluminum	5.7	4.84	7.32
Copper	0.16	0.16	0.16
Solder	0.33	0.34	0.74
Brass	8.8	7.5	8.1
Steel	0.03	0.07	0.04
Cast Iron	+ 0.02	+ 0.06	+ 0.05
Rating	25	25	28

TABLE IX

SIMULATED SERVICE TEST - ASTM D-2570

Test Number	1	2	3
	50% Corrosive H_2O 50% MIL-A-46153 Antifoam "E" 0.005% (MBT)	50% Corrosive H_2O 50% MIL-A-46153 Antifoam "E" 0.005% (MBT)	50% Corrosive H_2O 50% MIL-A-46153 Antifoam "E" 0.005% (MBT)
pH Before	7.5	7.5	7.5
pH After	7.6	7.6	7.6
RA Before	8.0	8.0	8.0
RA After	8.7	8.7	8.7
	Weight Change mg/sq cm		
Aluminum	0.72	0.61	0.80
Copper	0.71	0.80	0.78
Solder	0.76	0.38	0.99
Brass	0.38	0.44	0.43
Steel	0.40	0.36	0.35
Cast Iron	0.3	0.23	0.23
Rating	29	28	30

TABLE X

SIMULATED SERVICE TEST - ASTM D-2570

Test Number	1	2	3
Coolant Solution	50% Corrosive H_2O 50% MIL-A-46153 Antifoam "E" 0.005% - 0.15% Tolyltriazole Substituted for MBT	50% Corrosive H_2O 50% MIL-A-46153 Antifoam "E" 0.005% - 0.15% Tolyltriazole Substituted for MBT	50% Corrosive H_2O 50% MIL-A-46153 Antifoam "E" 0.005% - 0.15% Tolyltriazole Substituted for MBT
pH Before	7.5	7.5	7.5
pH After	7.4	7.4	7.4
RA Before	8.0	8.0	8.0
RA After	8.8	8.8	8.8
	Weight Change mg/sq cm		
Aluminum	0.32	0.52	0.42
Copper	0.98	1.11	1.02
Solder	0.76	0.73	1.48
Brass	0.82	0.74	0.84
Steel	0.08	0.10	0.12
Cast Iron	0.003	0.009	0.02
Rating	24	27	27

TABLE XI

TEST FOR FOAMING TENDENCIES OF ENGINE ANTIFREEZES IN GLASSWARE ASTM D-1881

Sample	Temperature °F.	Avg. Foam Vol. @ 5 Min.	Break Time
Sodium MBT	190°	285 ml.	8.1 Sec.
Old Sodium Tolyltriazole	190°	321 ml.	7.8 Sec.
New Sodium Tolyltriazole	190°	286 ml.	9.5 Sec.
MBT	190°	138 ml.	6.6 Sec.
Sodium MBT	160°	81.6 ml.	4.9 Sec.
Old Sodium Tolyltriazole	160°	165 ml.	7.7 Sec.
New Sodium Tolyltriazole	160°	147 ml.	7.7 Sec.
MBT	160°	136 ml.	7.7 Sec.

APPENDIX B

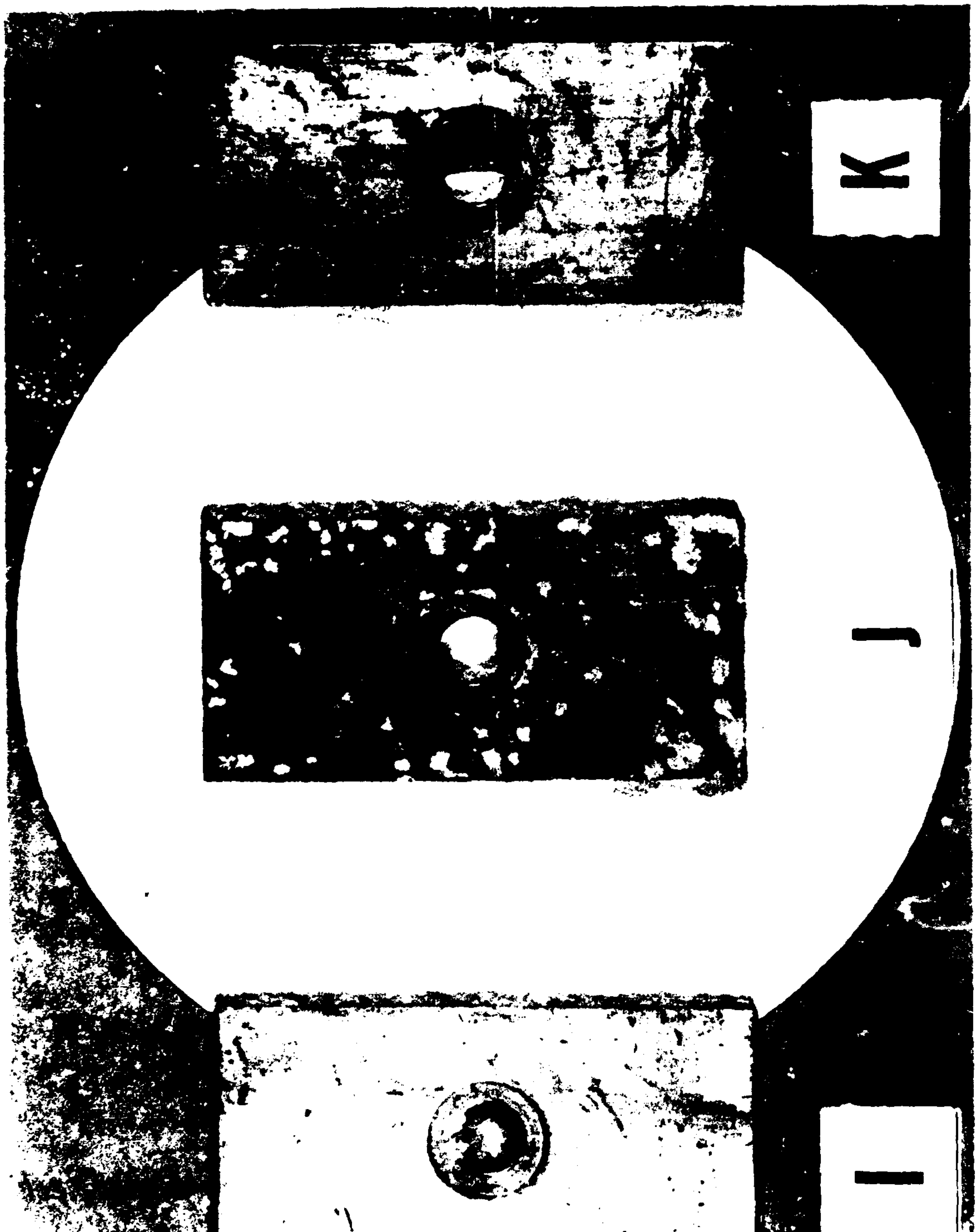
FIGURE # 1

ALUMINUM TEST SPECIMENS FROM GLASSWARE CORROSION TEST - (MIL-A-46153 with NaTT Substituted for MBT plus .015% Silicone Type Antifoam)

I - New Specimen

J - Exposed Specimen (With Blooming)

K - Exposed Specimen (Blooming Removed - Note Pitting)


K
J
I