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INTERIM REPORT

INHIBITION OF LOW TOXICITY CARBON LOOSENER

(P-C-111b) PLUS SEAL

BY

MARY JOANN CARROLL

AUGUST 1968

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INHIBITION OF LOW TOXICITY CARBON LOOSENER
(P-C-111b) PLUS SEAL

BY

MARY JOANN CARROLL

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AMCMS CODE NO. 5025.11.29500

DEPARTMENT OF THE ARMY PROJECT NO.
IT024401A329

U. S. ARMY COATING AND CHEMICAL LABORATORY
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ABSTRACT

In order to reduce volume losses of carbon loosener (Federal Specification P-C-111b) by drag out and evaporation and to afford degreasing properties, a seal was developed. However, while neither the carbon loosener nor the seal alone caused corrosion, together they caused gross corrosion of certain metals, especially zinc and magnesium.

The purpose of this study was to alter the inhibitor system to eliminate the problem of corrosion. A satisfactory inhibitor system was devised.

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I. INTRODUCTION

Carbon looseners are designed to remove carbon, gum, and other surface contaminants (except rust and corrosion) from parts of internal combustion engines such as pistons, carburetors, fuel pumps, etc. The main criticism of most commercial and earlier specification looseners was that they contained chlorinated solvents, cresols, phenols or derivatives and are highly toxic.

A formula (Appendix A, Table I) with low vapor phase toxicity was devised and promulgated in Federal Specification P-C-111b issued 7 July 1966. (1) Criticisms by users pointed out that this formulation did not have any degreasing properties and necessitated prior degreasing of parts (involving an additional operation). Since this low toxicity formulation contains both organic solvents and water, evaporation losses must be supplemented with make-up liquid. An organic solvent seal (Appendix A, Table II) was added to provide degreasing properties and to minimize evaporation and drag out losses. However this seal introduced some unexpected corrosion problems. Neither the carbon loosener nor the seal alone caused corrosion, but together they caused gross corrosion of certain metals, especially zinc and magnesium. A suitable inhibitor system was required to make this product utilizable.

II. DETAILS OF TEST

Testing procedures described in P-C-111b were altered to simulate washing in the seal prior to immersion in the loosener and in a second change to simulate immersion of a part into a seal-loosener mixture which would be created by mild agitation. These changes were included to bring out any changes brought about by the introduction of an organic solvent seal (Appendix C).

III. DISCUSSION

The carbon loosener (Federal Specification P-C-111b) and the seal when tested separately displayed no significant corrosion. (Photograph 1).

Previous testing at this laboratory (Ref. 3) had indicated that inclusion of a nonionic detergent did not significantly contribute to effectiveness of the cleaner, hence it was omitted from the formulation of the carbon loosener with seal.

Distinctive patterns of corrosion on magnesium panels caused by the two testing procedures may be seen in Photograph 2. Aluminum panels were very slightly attacked and zinc panels developed a heavy dull coating of corrosion products.

Alteration of original inhibitor (sodium silicate, 40° Baumé) particle size by use of various mixing procedures did not improve inhibitory action. (Photograph 3) Addition of Aerosol OT and sodium stearate to the carbon loosener in increasing amounts proportionally decreased corrosion of test magnesium panels. However, zinc panels tested in the same formulations showed increased corrosion. (Photograph 4) Increasing concentrations of sodium silicate reduced somewhat the corrosion of magnesium. However, higher silica concentrations appeared to enhance corrosion of zinc. (Photograph 5).

According to Bakhvalov and Turkovskaya (Ref. 4) magnesium becomes ennobled in solutions having a pH higher than 11.5. This was not found to be so in the course of testing the carbon loosener with seal. Magnesium was attacked even at pH 12. The hypothesis was offered (Ref. 2) that a corrosion cell was created on the surface of the metal caused by the difference in potential between the metal surface covered by solvent droplets (or emulsified solvent droplets) and the remaining surface in direct contact with the carbon loosener. Accordingly, corrosion inhibition could be attained after removal of the solvent droplets.

The choice of an agent to remove solvent droplets was complicated by two factors. Certain surface active agents tended to displace the inhibitor as well as seal and soil, thus permitting corrosion of the metals. Secondly, since it was essential that the seal remain separate, agents causing emulsification of the seal in the cleaner could not be used. Sodium metasilicate, however, could provide sodium hydroxide to remove solvent droplets from the metal and silica to inhibit attack of the metals by the caustic solution.

Formulations of the carbon loosener with seal having sodium metasilicate concentrations between 1.30% and 2.55% by weight of water in the formulation (pH 12.3 - 13.3) caused no significant corrosion to test metals. Zinc was attacked when the concentration of metasilicate was less than 1.30% (by wt. in water portion) and aluminum was attacked when the concentration was above 2.55%. Tables III and IV present the results of testing with weighed panels for chemical and galvanic corrosion. With the exception of lead, weight losses are negligible. The highest weight loss indicated for lead by the data is 0.011 grams. This would represent removal of 0.00003" of lead from the surface and is much less than usual machine tolerances.

When heated to 130°F for 24 hours, the modified carbon loosener with seal was reduced in volume by 6% whereas the comparison formula was reduced in volume by 23%. When exposed in an open container at room temperature for 14 days, the modified carbon loosener with seal lost 7% of its volume while the comparison formula lost 42.5% of its volume.

After storage stability tests, the modified carbon loosener with seal will be recommended for inclusion in the next revision of Federal Specification P-C-111b.

III. CONCLUSIONS

Elimination of the corrosion problem will permit procurement of a low toxicity carbon loosener which is economical, easy to use, and has slight evaporation and drag out losses.

IV. REFERENCES

- (1) Federal Specification P-C-111b, "Carbon Removing Compound", General Services Administration, 7 July 1966.
- (2) M. Rosenfeld, Coating and Chemical Laboratory, Aberdeen Proving Ground, Md., Private Communication
- (3) E. A. Banks, Laboratory Notebook No. 600, Coating and Chemical Laboratory, Aberdeen Proving Ground, Md.
- (4) G. T. Bakhvalov and A.V. Turkovskaya, Corrosion and Protection of Metals, Pergamon Press, New York, 1965, page 213.

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APPENDIX A

TABLE I

COMPOSITION OF P-C-111b COMPARISON FORMULA (TYPE II)

<u>COMPONENT</u>	<u>PERCENT BY VOLUME</u>
Ethylene glycol monobutyl ether (1)	7.7
Diethylene glycol diethyl ether (2)	6.7
Diethylene glycol monobutyl ether (3)	3.9
Diethylene glycol monomethyl ether (4)	2.0
Detergent, nonionic (5)	1.8
Oleic acid (6)	2.0
Monoethanolamine (7)	20.3
Sodium silicate solution (8)	55.6

Mix all ingredients together (In the order shown) except the sodium silicate solution. Stir the mixture into the sodium silicate solution.

Caution: Use goggles and avoid skin contact.

(1) Federal Specification TT-E-776 - Ethylene Glycol Monobutyl Ether (for Use in Organic Coatings), General Services Administration.

(2) Specific gravity 0.906 - 0.911 at 20/20°C.; boiling range 180° - 190°C. at 760 mm. Hg.; acidity not over 0.02% as acetic acid.

(3) Specific gravity 0.953 - 0.958 at 20/20°C.; boiling range 220° - 235°C at 760 mm. Hg., acidity not over 0.02% as acetic acid.

(4) Specific gravity 1.025 - 1.031 at 20/20°C., boiling range 188° - 198°C. at 760 mm. Hg.; acidity not over 0.02% as acetic acid.

(5) Federal Specification MIL-D-16791, Detergents, General Purpose, Liquid, Nonionic, Type I, General Services Administration.

(6) Technical grade.

(7) Specific Gravity 1.017 - 1.027 at 20/20°C.; boiling range 160° - 176°C at 760 mm. Hg.

(8) 0.25% by volume of 40° Baume solution in distilled water.

TABLE II

PROPERTIES OF DEGREASING SOLVENT (SEAL)

<u>PHYSICAL PROPERTIES</u>	<u>TEMPERATURE °F</u>
API Gravity 10.2	60
Specific Gravity 0.9986	60
Aniline Cloud Pint, Mixed	56.0
Flash Point (Pensky Martin Cosed Cup)	250
<u>Distillation Range</u>	
Initial Boiling Point	505
50%	542
ASTM End Point	660

TABLE III

Chemical Corrosion Test Results for
Modified Carbon Loosener with Seal

Metal Tested	$\% \text{Na}_2\text{SiO}_3$ ¹	Test Procedure ²	Avg. Wt. Chg., mg.	Confidence Limits 95%, mg. ³	Expected Max. Metal Penetration, millionths of an inch ⁴	
Aluminum	1.30	P 1	-0.1	+0.3 to -0.5	4	
		P 2	-0.1	+0.3 to -0.5	4	
	1.65	P 1	+0.1	+0.7 to -0.5	4	
		P 2	-0.2	+0.1 to -0.5	4	
	2.10	P 1	-0.1	+0.5 to -0.7	5	
		P 2	-0.4	-0.3 to -0.5	4	
	2.55	P 1	-0.2	+0.4 to -0.8	6	
		P 2	-0.2	+0.1 to -0.5	4	
	Brass	P-C-111b Comparison Formula, Type II		+0.1	+0.5 to -0.3	3
		1.30	P 1	-0.4	+0.1 to -0.9	3
P 2			-0.5	-0.4 to -0.6	1	
1.65		P 1	-0.7	-0.6 to -0.8	2	
		P 2	-0.6	-0.2 to -1.0	2	
2.10		P 1	-0.6	-0.3 to -0.9	2	
		P 2	-0.6	-0.2 to -1.0	2	
2.55		P 1	-0.6	-0.5 to -0.7	2	
		P 2	-0.6	-0.3 to -0.9	2	
Bronze		P-C-111b Comparison Formula, Type II		-0.5	-0.1 to -0.9	2
	1.30	P 1	-0.4	0.0 to -0.8	2	
		P 2	-0.5	-0.3 to -0.7	2	
	1.65	P 1	-0.6	-0.3 to -0.9	2	
		P 2	-0.7	-0.1 to -1.3	3	
	2.10	P 1	-0.2	+0.1 to -0.5	2	
		P 2	-0.9	-0.6 to -1.2	3	
	2.55	P 1	-0.8	-0.4 to -1.2	3	
		P 2	-0.8	-0.3 to -1.3	3	
	P-C-111b Comparison Formula, Type II		-0.8	+0.3 to -1.9	5	

¹Based on weight of water in formulation of carbon loosener.

²Explanation of procedures: P 1 - Panels were dipped 10 times into seal prior to addition to the carbon loosener; P 2 - Panels were placed in a shaken mixture of carbon loosener with seal; all panels were heated for 4 hours at $54^\circ \pm 2^\circ \text{C}$. in the carbon loosener.

³Confidence interval based on the observed range of data for each test set.

⁴Weight losses were calculated as metal lost. Weight gains were assumed to be oxygen and the amount of metal necessary to form the oxide was assumed to be attacked. In every case the highest possible loss was chosen. Uniform corrosion was assumed as no pitting was observed.

TABLE III - (Continued)

Chemical Corrosion Test Results for
Modified Carbon Loosener with Seal

Metal Tested	% Na ₂ SiO ₃ ¹	Test Procedure ²	Avg. Wt. Chg., mg.	Confidence Limits 95%, mg. ³	Expected Max. Metal Penetration, millionths of an inch ⁴	
Magnesium ⁵	1.30	P 1	+0.3	+0.2 to +0.4	10	
		P 2	+0.3	+0.1 to +0.5	11	
	1.65	P 1	+0.1	0.0 to +0.2	4	
		P 2	+0.2	+0.1 to +0.3	7	
	2.10	P 1	+0.2	+0.1 to +0.3	7	
		P 2	+0.4	+0.3 to +0.5	11	
	2.55	P 1	+0.3	+0.2 to +0.4	10	
		P 2	+0.4	+0.3 to +0.5	11	
	P-C-111b Comparison Formula, Type II					
	Zinc	1.30	P 1	+0.3	+0.1 to +0.5	11
P 2			-0.2	-0.1 to -0.3	2	
1.65		P 1	0.0	+0.2 to -0.2	5	
		P 2	-0.1	+0.3 to -0.5	10	
2.10		P 1	0.0	+0.4 to -0.4	13	
		P 2	-0.2	0.0 to -0.4	3	
2.55		P 1	0.0	+0.1 to -0.1	3	
		P 2	+0.2	+0.4 to 0.0	13	
P-C-111b Comparison Formula, Type II						
				-9.8	-9.3 to -10.4	83

¹Based on weight of water in formulation of carbon loosener.

²Explanation of procedures: P 1 - Panels were dipped 10 times into seal prior to addition to the carbon loosener; P 2 - Panels were placed in a shaken mixture of carbon loosener with seal; all panels were heated for 4 hours at 54° ± 2° C. in the carbon loosener.

³Confidence interval based on the observed range of data for each test set.

⁴Weight losses were calculated as metal lost. Weight gains were assumed to be oxygen and the amount of metal necessary to form the oxide was assumed to be attacked. In every case the highest possible loss was chosen. Uniform corrosion was assumed as no pitting was observed.

⁵The figures for depth of metal attacked are believed by the author to be high due to the assumption that MgO is the only deposit formed.

TABLE IV

Galvanic Corrosion Test Results for
Modified Carbon Loosener with Seal

Metal Tested	% Na ₂ SiO ₃ ¹	Test Procedure ²	Avg. Wt. Chg., mg.	Confidence Limits 95%, mg. ³	Expected Max. Metal Penetration, millionths of an inch ⁴	
Aluminum	1.30	P 1	+0.1	+0.4 to -0.2	5	
		P 2	+0.1	+0.6 to -0.4	7	
	1.65	P 1	-0.1	+0.3 to -0.5	6	
		P 2	+0.1	No deviation	1	
	2.10	P 1	+0.1	+0.4 to -0.2	5	
		P 2	0.0	+0.5 to -0.5	6	
	2.55	P 1	+0.1	+0.5 to -0.3	5	
		P 2	+0.1	+0.5 to -0.3	5	
	P-C-111b Comparison Formula, Type II			0.0	+0.2 to -0.2	2
	Copper	1.30	P 1	-0.3	+0.3 to -0.9	8
P 2			-0.3	+0.2 to -0.8	5	
1.65		P 1	-0.4	-0.3 to -0.5	2	
		P 2	-0.4	+0.4 to -1.2	11	
2.10		P 1	-0.2	+0.4 to -0.8	11	
		P 2	-0.6	-0.5 to -0.7	2	
2.55		P 1	-0.2	+0.3 to -0.7	8	
		P 2	-0.4	+0.4 to -1.2	11	
P-C-111b Comparison Formula, Type II			-0.6	0.0 to -1.2	4	
Lead		1.30	P 1	-1.2	-2.7 to +0.3	20
	P 2		-1.4	-2.5 to -0.3	7	
	1.65	P 1	-4.2	-6.2 to -2.2	17	
		P 2	-3.5	-4.5 to -2.5	12	
	2.10	P 1	-4.6	-5.3 to -3.9	14	
		P 2	-4.4	-5.3 to -3.5	14	
	2.55	P 1	-5.8	-7.5 to -4.1	20	
		P 2	-7.8	-11.5 to -3.7	31	
	P-C-111b Comparison Formula, Type II			-1.3	-2.9 to +0.4	28

¹Based on weight of water in formulation of carbon loosener.

²Explanation of procedures: P 1 - Panels were dipped 10 times into seal prior to addition to the carbon loosener; P 2 - Panels were placed in a shaken mixture of carbon loosener with seal; all panels were heated for 4 hours at 54 ± 2° C. in the carbon loosener.

³Confidence interval based on the observed range of data for each test set.

⁴Weight losses were calculated as metal lost. Weight gains were assumed to be oxygen and the amount of metal necessary to form the oxide was assumed to be attacked. In every case the highest possible loss was chosen. Uniform corrosion was assumed as no pitting was observed.

TABLE IV - (CONTINUED)

Galvanic Corrosion Test Results for
Modified Carbon Loosener with Seal

Metal Tested	Na ₂ SiO ₃ ¹	Test Procedure ²	Avg. Wt. Chg., mg.	Confidence Limits 95%, mg. ³	Expected Max. Metal Penetration, millionths of an inch ⁴	
Magnesium ⁵	1.30	P 1	+1.1	+1.2 to +1.0	32	
		P 2	+1.1	+1.4 to +0.8	37	
	1.65	P 1	+0.5	+0.9 to +0.1	24	
		P 2	+0.8	+1.6 to 0.0	42	
	2.10	P 1	+0.3	+1.3 to -0.7	34	
		P 2	+0.6	+1.1 to +0.1	29	
	2.55	P 1	+0.3	+0.6 to 0.0	16	
		P 2	+0.5	+1.0 to -0.1	27	
	P-C-111b Comparison Formula, Type II			+0.9	+1.9 to -0.1	51
	Steel	1.30	P 1	-0.1	+0.6 to -0.8	8
P 2			-0.1	+0.3 to -0.5	4	
1.65		P 1	-0.1	+0.3 to -0.5	4	
		P 2	0.0	+0.5 to -0.5	7	
2.10		P 1	-0.1	+0.2 to -0.4	3	
		P 2	+0.1	+0.3 to -0.5	4	
2.55		P 1	-0.1	+0.5 to -0.7	7	
		P 2	-0.1	+0.1 to -0.3	1	
P-C-111b Comparison Formula, Type II			0.0	+0.5 to -0.5	7	

¹Based on weight of water in formulation of carbon loosener.

²Explanation of procedures: P 1 - Panels were dipped 10 times into seal prior to addition to the carbon loosener; P 2 - Panels were placed in a shaken mixture of carbon loosener with seal; all panels were heated for 4 hours at 54 ± 2° C. in the carbon loosener.

³Confidence interval based on the observed range of data for each test set.

⁴Weight losses were calculated as metal lost. Weight gains were assumed to be oxygen and the amount of metal necessary to form the oxide was assumed to be attacked. In every case the highest possible loss was chosen. Uniform corrosion was assumed as no pitting was observed.

⁵The figures for depth of metal attacked are believed by the author to be high due to the assumption that MgO is the only deposit formed.

TABLE V

Composition of Modified Carbon Loosener with Seal

<u>Component</u>	<u>Percent By Volume</u>
Ethylene glycol monobutyl ether ¹	7.8
Diethylene glycol diethyl ether ²	6.7
Diethylene glycol monobutyl ether ³	4.0
Diethylene glycol monomethyl ether ⁴	2.0
Oleic acid ⁵	2.0
Monoethanolamine ⁶	20.7
Aqueous sodium metasilicate solution ⁷	56.7

Mix the first six components together (in the order listed) and stir the mixture into the sodium metasilicate solution. Then add 20% additional (by volume) of the seal to the carbon loosener.

CAUTION: AVOID SKIN CONTACT.

¹Federal Specification TT-E-776 - Ethylene Glycol Monobutyl Ether (for use in Organic Coatings), General Services Administration.

²Specific gravity 0.906 - 0.911 at 20/20°C.; boiling range 180° - 190°C. at 760 mm Hg.; acidity not over 0.02% as acetic acid.

³Specific gravity 0.953 - 0.958 at 20/20°C.; boiling range 220° - 235°C. at 760 mm Hg., acidity not over 0.02% as acetic acid.

⁴Specific gravity 1.025 - 1.031 at 20/20°C., boiling range 188° - 198°C. at 760 mm., acidity not over 0.02% as acetic acid.

⁵Technical grade.

⁶Specific Gravity 1.017 - 1.027 at 20/20°C.; boiling range 160° - 176°C. at 760 mm Hg.

⁷Concentration: 13-25.5 grams Na_2SiO_3 per liter of water.

APPENDIX B

PHOTOGRAPH I CHEMICAL CORROSION TEST
P-C-111b COMPARISON FORMULA TYPE II

MAGNESIUM

ALUMINUM

ZINC

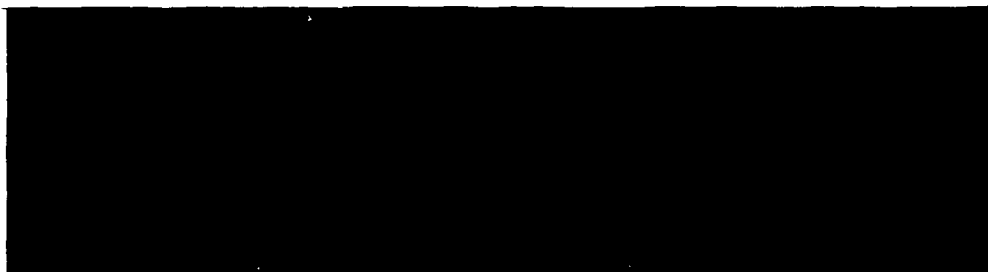


DEGREASING SOLVENT (SEAL)

MAGNESIUM

ALUMINUM

ZINC



COMPARISON STANDARD - FRESHLY POLISHED PANELS

MAGNESIUM

ALUMINUM

ZINC



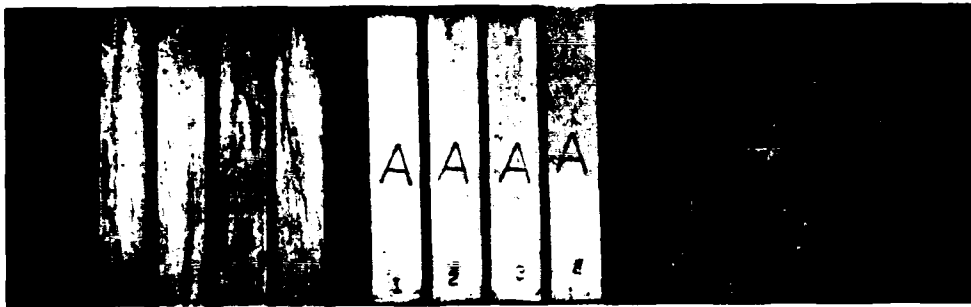
PHOTOGRAPH 2 CHEMICAL CORROSION TEST
EFFECT OF MIXING P-C-111b COMPARISON FORMULA
(CARBON LOOSENER, TYPE 11) WITH SEAL (DEGREASING
SOLVENT)

GROUP 1 PANELS DIPPED INTO SEAL PRIOR TO BEING
PLACED IN SEAL - CARBON LOOSENER MIXTURE

MAGNESIUM

ALUMINUM

ZINC



GROUP 2 PANELS PLACED IN SHAKEN MIXTURE

MAGNESIUM

ALUMINUM

ZINC



PHOTOGRAPH 3 CHEMICAL CORROSION TEST

EFFECT ON MAGNESIUM PANELS OF MIXED SEAL (DEGREASING SOLVENT) AND P-C-111b COMPARISON FORMULA (CARBON LOOSENER, TYPE II, WITHOUT NONIONIC DETERGENT) PREPARED BY VARIOUS MIXING PROCEDURES (APPENDIX C)

PROCEDURE A

PROCEDURE B



PROCEDURE C



Panels numbered 1, 2, 3, and 4 were dipped into the seal prior to being placed in the carbon loosener with seal.

Panels numbered 5, 6, 7, and 8 were placed in the shaken mixture.

PHOTOGRAPH 4 (CONTINUED) CHEMICAL CORROSION

**EFFECTS OF MIXING SEAL (DEGREASING SOLVENT) AND
MODIFIED P-C-111b COMPARISON FORMULA (CARBON LOOSENER,
TYPE II) CONTAINING VARYING AMOUNTS OF AEROSOL OT AND
SODIUM STEARATE**

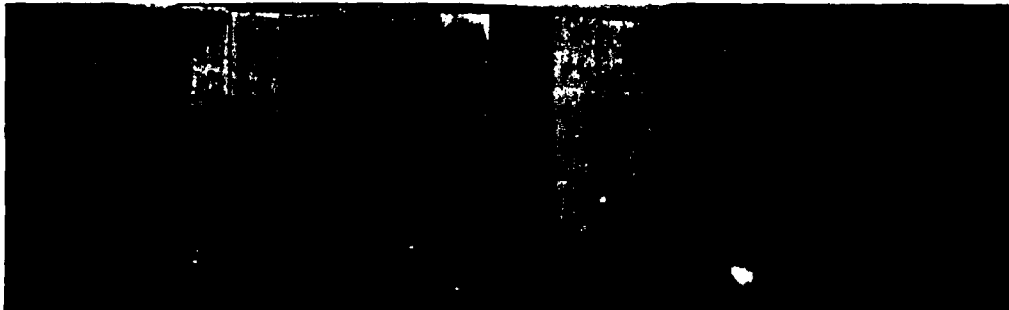
AEROSOL OT 0.1 % by wt. in H₂O
SODIUM STEARATE 0.5% by wt. in H₂O

MAGNESIUM

ZINC



AEROSOL OT 0.2 % by wt. in H₂O
SODIUM STEARATE 0.5 % by weight in H₂O



Panels numbered 1, 2, 3, and 4 were dipped into the seal prior to being placed in the carbon loosener with seal
Panels numbered 5,6,7, and 8 were placed in the shaken mixture.

PHOTOGRAPH 5 CHEMICAL CORROSION TEST

EFFECTS OF INCREASING PRESENT SPECIFICATION INHIBITOR
CONCENTRATION IN CARBON LOOSENER WITH SEAL MIXTURE

1.26% 40° Baume sodium silicate
solution in H₂O

MAGNESIUM

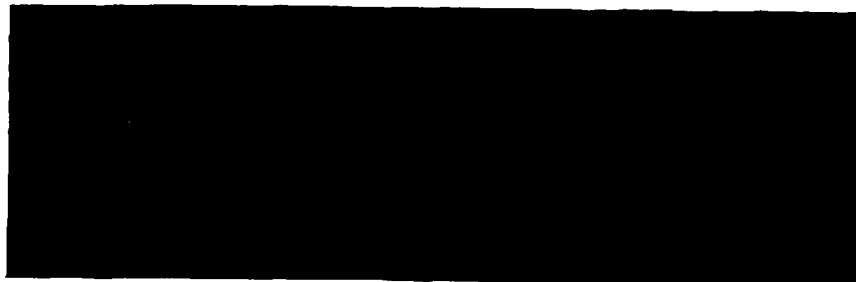
ZINC



2.5% 40° Baume sodium silicate
solution in H₂O



3.25% 40° Baume sodium silicate
solution in H₂O



Panels numbered 1, 2, 3, and 4, were dipped into the seal prior to being placed in the carbon loosener with seal.
Panels numbered 5, 6, 7, and 8 were placed in the shaken mixture.

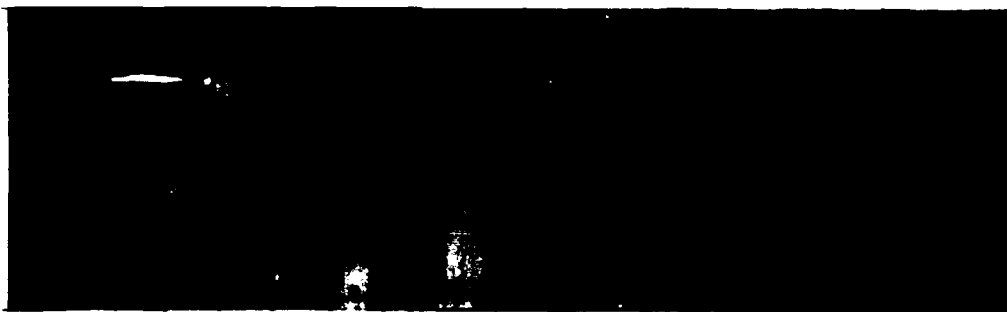
PHOTOGRAPH 6 CHEMICAL CORROSION TEST

**EFFECTS OF REPLACEMENT INHIBITOR AT DIFFERENT pH LEVELS
IN CARBON LOOSENER WITH SEAL MIXTURE**

pH 11.7
0.44 % Na_2SiO_3 by wt. in H_2O

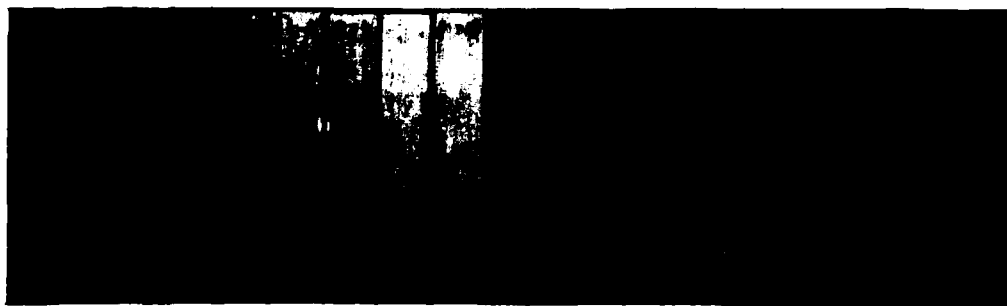
MAGNESIUM

ZINC



pH 12.0
2.5% 40° Baume sodium silicate
soln. in H_2O
0.44% Na_2SiO_3 by wt. in H_2O

MAGNESIUM

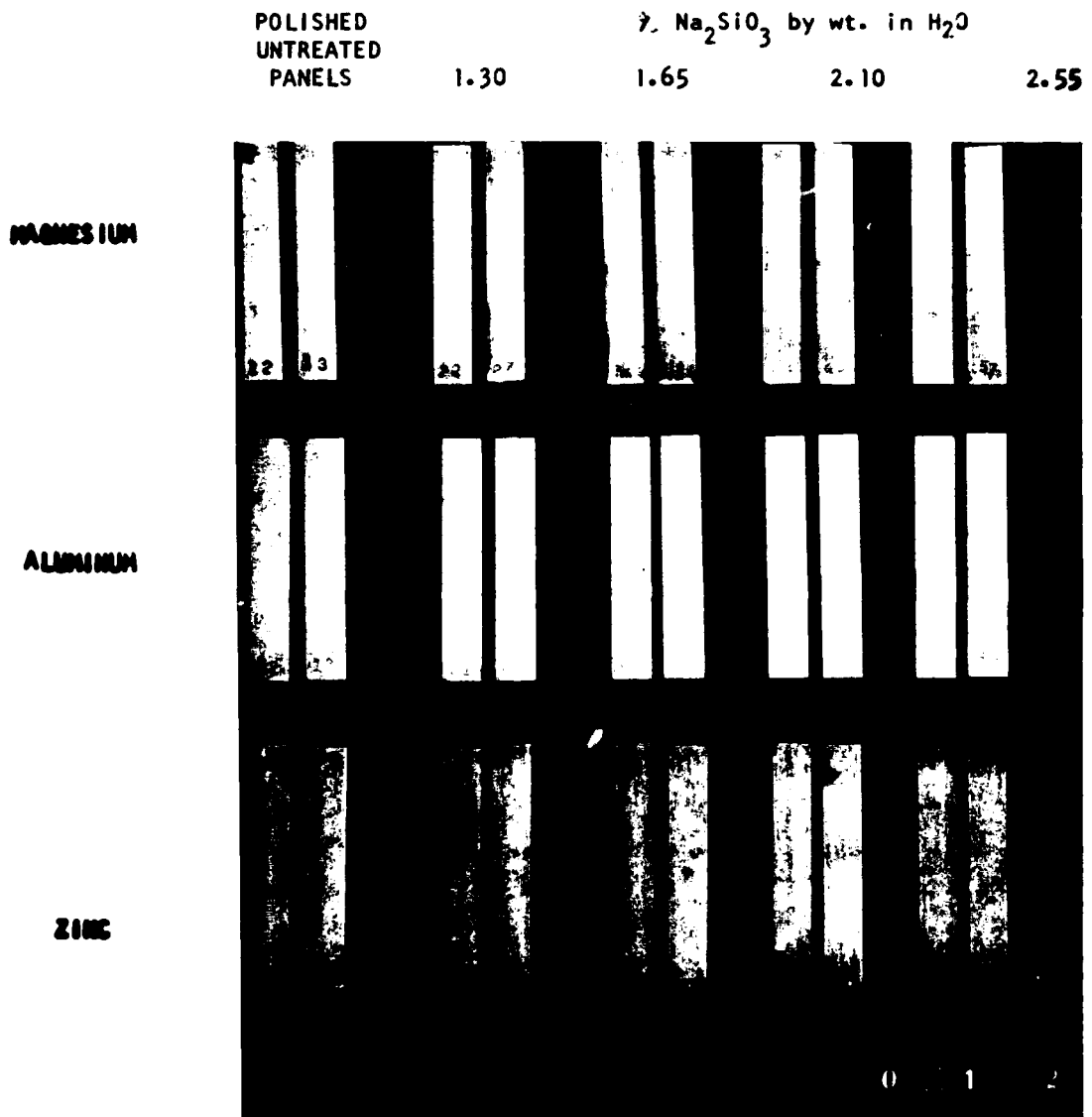


Panels numbered 1,2,2, and 4 were dipped into the seal prior to being placed in the carbon loosener with seal.

Panels numbered 5, 6, 7, and 8 were placed in the shaken mixture.

PHOTOGRAPH 7A CHEMICAL CORROSION

EFFECT ON TEST PANELS OF VARYING THE CONCENTRATION
OF REPLACEMENT INHIBITOR IN THE FORMULATION OF THE
CARBON LOOSENER WITH SEAL



PHOTOGRAPH 7B CHEMICAL CORROSION TEST

EFFECTS ON TEST PANELS OF VARYING THE CONCENTRATION OF REPLACEMENT INHIBITOR IN THE FORMULATION OF THE CARBON LOOSENER WITH SEAL

ZINC PANELS ONLY

% Na_2SiO_3 by weight in H_2O

0.70

0.95

1.30

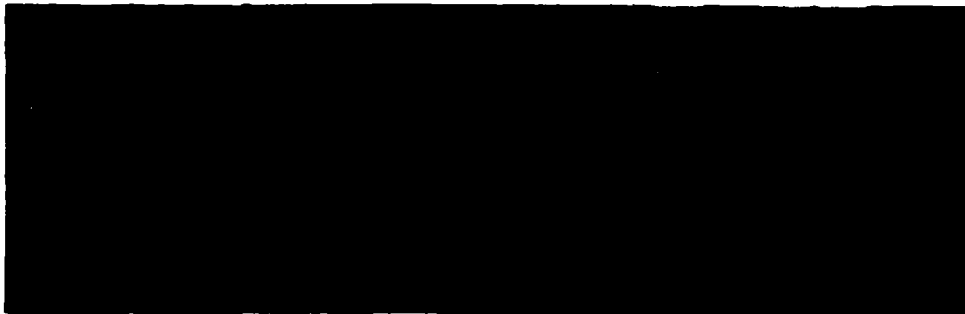


ALUMINUM PANELS ONLY

% Na_2SiO_3 by weight in H_2O

4.00

3.00



APPENDIX C - Test Procedures

Testing procedures described in Federal Specification P-C-111b were altered to simulate washing in the seal prior to immersion in the loosener and in a second change to simulate immersion of a part into a seal-loosener mixture which would be created by mild agitation. These modifications were included to bring out any changes brought about by the introduction of an organic solvent seal.

Panels used in chemical and galvanic corrosion testing were prepared as follows: Test panels of alloys specified by Federal Specification P-C-111b were prepared by polishing each face with #100 aluminum oxide cloth followed by #240 aluminum oxide paper. Mill finish and surface tarnish were removed, exposing a smooth surface. Edges were polished smooth. The panels were washed with ethanol and dried with paper towels.

For each metal tested for chemical corrosion, 25 ml. of sample carbon loosener mixed with seal was transferred to each of eight test tubes approximately 19 mm. x 150 mm. in size. In addition, 25 ml. of P-C-111b comparison formula type II was transferred to each of four test tubes of the same size as a control. The tubes were loosely stoppered and heated for one hour at $54^{\circ} \pm 2^{\circ}\text{C}$. Each of four panels of each metal being tested was slowly dipped ten times into the seal and then added to unshaken preheated carbon loosener with seal. (Procedure 1). Four panels of each metal being tested were placed in separate tubes of the thoroughly shaken preheated mixture (Procedure 2).

Tubes were restoppered and heated in an oven at $54^{\circ} \pm 2^{\circ}\text{C}$. for four hours, after which the panels were removed, washed successively with water, acetone, ethanol, and dried with paper toweling. For preliminary testing, the panels were appraised visually, but for final testing of the modified carbon loosener with seal, weight losses or gains were tabulated.

Panels used in galvanic corrosion testing were weighed to the nearest 0.1 mg. and tied with cotton string as described in Federal Specification P-C-111b making sure of good contact between the metals. There was no direct contact between magnesium and lead or between aluminum and copper.

Four 250 ml. beakers per sample were filled to the 220 ml. mark with cleaner-seal mixture and this was permitted to form two layers. Four sets of the galvanically coupled metals were each dipped ten times into the seal alone and then one set was placed in each beaker so that no portion of the solvent seal layer touched the metals. (Procedure 1).

Four 250 ml. beakers were filled to the 220 ml. mark with thoroughly mixed cleaner-seal combination and one set of the galvanically coupled metals was immediately added to each beaker. (Procedure 2).

As a control, four 250 ml. beakers were filled to the 200 ml. mark with comparison formula as described in Table I and one set of the galvanically coupled metals was placed in each beaker.

The beakers were covered with watch glasses and placed in an air oven at $54^{\circ} \pm 2^{\circ}\text{C}$. for 24 hours. The panel sets were then removed from the beakers and washed with running water. The panel sets were separated and each metal was placed in a separate beaker of acetone. The panels were removed from the acetone, washed with ethanol, dried with paper toweling and reweighed. Discoloration, pitting, etching and weight changes were noted.

To test for cleaning ability, heavily soiled aluminum pistons (from internal combustion engines) were cut into 12 sections leaving an uncut center section approximately $1/2$ to $3/4$ inch in diameter as described in Federal Specification P-C-111b. The uncut center section was placed in soil control compound as described in Federal Specification P-C-111b. One section of each piston trio was dipped ten times into the seal solvent and then placed in a beaker of carbon loosener with seal. Another section of each piston trio was placed in a beaker of thoroughly mixed carbon loosener with seal. The center section of each piston trio was placed in a beaker of comparison formula. The same amount of each compound was used and each section was completely submerged and held off the bottom by small glass rods. Each trio was kept as a separate unit. After 4 hours at $54^{\circ}\text{C} \pm 2^{\circ}\text{C}$, the sections were removed and scrubbed with a hard bristle under cool (about 30°C .) running water, then air dried.

The center section cleaned in the soil control formulation was compared with the sections cleaned in the comparison formula. If it was cleaned as well as the section cleaned in the comparison formula, the piston was discarded to eliminate data from pistons capable of being cleaned with inferior cleaners.

The sections cleaned in the carbon loosener with seal were then compared with the center section tested in the comparison formula. The sections were rated inferior, superior, or equal.

The sample was considered equal in cleaning ability to the comparison formula unless two or more sections in a piston were rated at one extreme and were not balanced by an equal number of sections rated at the other extreme. In that case the piston was rated at the extreme. Six pistons were used for each test and the different procedures were evaluated separately. The cleaner was rated over all as equal to the comparison formula unless two or more pistons were rated at one extreme and were not balanced by an equal number of pistons at the other extreme. In that case, the sample was rated over all as either superior or inferior.

This test was also conducted at room temperature using a 16 hour immersion time.

Mixing Procedures

Carbon looseners prepared by the various mixing procedures all conform in composition to P-C-111b comparison formula (Type II) with the nonionic detergent omitted.

Procedure A:

The following were prepared:

Solution 1 - containing 1/3 the required water mixed with all the required sodium silicate.

Solution 2 - containing 1/3 the required water mixed with all the monoethanolamine.

Solution 3 - containing 1/3 the required water mixed with the remaining organic components.

Solution 2 was stirred into to solution 1. Solution 3 was stirred into the the mixture of 1 and 2. Twenty percent (by volume) seal was added to this.

Procedure B:

The following were prepared:

Solution 1 - containing 1/10 the required water mixed with all the required sodium silicate.

Solution 2 - containing the remaining water and other components required.

Solution 2 was stirred into solution 1. Twenty percent (by volume) seal was added to this.

Procedure C:

The sodium silicate solution was prepared as described in Federal Specification P-C-111b. The required amount of monoethanolamine was added drop wise to this solution. The remainder of the components were added drop wise to the silicate-water-monoethanolamine mixture. The entire procedure was done in a CO₂ free atmosphere. Twenty percent (by volume) seal was added to this.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified.)

1 ORIGINATING ACTIVITY (Corporate author) U. S. Army Coating and Chemical Laboratory Aberdeen Proving Ground, Maryland 21005		2a REPORT SECURITY CLASSIFICATION Unclassified	
2b GROUP			
3 REPORT TITLE INHIBITION OF LOW TOXICITY CARBON LOOSENER (P-C-111b) PLUS SEAL			
4 DESCRIPTIVE NOTES (Type of report and inclusive dates) Interim Report			
5 AUTHOR(S) (Last name, first name, initial) CARROLL, MARY JOANN			
6 REPORT DATE		7a TOTAL NO OF PAGES 26	7b NO OF REFS 4
8a CONTRACT OR GRANT NO AMCMS Code No. 5025.11.29500		9a ORIGINATOR'S REPORT NUMBER(S) CCL No. 256	
b PROJECT NO IT024401A329		9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
10 AVAILABILITY LIMITATION NOTICES Qualified requestors may obtain copies of this report from Defense Documentation Center. Distribution of this document is unlimited.			
11 SUPPLEMENTARY NOTES		12 SPONSORING MILITARY ACTIVITY U. S. Army Materiel Command Washington, D. C.	
13 ABSTRACT In order to reduce volume losses of carbon loosener (Feder Specification P-C-111b) by drag out and evaporation and to afford degreasing properties, a seal was developed. However, while neither the carbon loosener nor the seal alone caused corrosion, together they caused gross corrosion of certain metals, especially zinc and magnesium. The purpose of this study was to alter the inhibitor system to eliminate the problem of corrosion. A satisfactory inhibitor system was devised.			