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TECHNICAL REPORT

SOLID FILM LUBRICANT SUBSTRATES

By

G. P. MURPHY and F. S. MEADE

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Approved by:

A. C. HANSON
Laboratory Director

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Rock Island Arsenal
Rock Island, Illinois

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ABSTRACT

A comparison of the wear life and corrosion protective ability of this Arsenal's recently developed solid film lubricant (RIA Compound 9A) and two commercial solid film lubricants meeting the requirements of Specification MIL-L-8937(ASG), Lubricant, Solid Film, Heat Cured, was made. The substrates to which the solid film lubricants were applied were: (1) grit blasted steel; (2) zinc phosphatized grit blasted steel; (3) zinc phosphatized cadmium plated steel; and (4) sulfuric acid anodized water sealed aluminum.

The following conclusions were produced by this investigation:

(1) The wear life provided by RIA Compound 9A is superior to that provided by the two commercial solid film lubricants on grit blasted zinc phosphatized steel. The wear lives provided by all three lubricants are equivalent on the remaining three substrates.

(2) The corrosion protective ability of RIA Compound 9A is superior to the two commercial solid film lubricants on all four substrates.

(3) If long term corrosion protection is required, anodized and sealed aluminum is the most satisfactory substrate.

(4) RIA Compound 9A provides good wear life even after extended exposure and rusting in a salt fog cabinet. The two commercial materials provided no wear life though exposed to a considerably shorter period in a salt fog cabinet.

(5) If long wear life is required, zinc phosphatized steel is the most satisfactory substrate.

(6) The wear life of RIA Compound 9A was not significantly reduced by an operating temperature of 400°F. The wear life of the two commercial products was reduced about 35% when tested at 400°F.

RECOMMENDATION

It is recommended that solid film lubricants meeting Purchase Description RIAPD-651 be used in all applications for which materials meeting Specification MIL-L-8937(ASG) are currently being specified.

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OBJECT

To compare the wear life and corrosion protective ability of three solid film lubricant coatings applied to substrates commonly used in Army field equipment.

INTRODUCTION

The solid film lubricant specification now in use, MIL-L-8937(ASG)[1] specifies only one substrate, manganese phosphatized steel, for evaluating the wear life of solid film lubricant coatings. Since Army field equipment uses various substrates, information concerning the effect of commonly used substrates on the wear life of solid film lubricants would be of value.

The above mentioned specification contains a corrosion test which uses anodized aluminum as the test substrate. Since the anodized aluminum will resist corrosion for a much longer period of time than the required 500 hours, this corrosion test gives information only as to the possible corrosive properties of the solid film lubricant coating. Information concerning the corrosion protective ability of solid film lubricant coatings applied to various substrates under salt fog and high humidity environments would be of great value.

This Arsenal's solid film lubricant, RIA Compound 9A[2], was tested under MIL-L-22273(Wep)[3] and was found to meet all the requirements of this specification. This specification has been superseded by MIL-L-8937(ASG). There are virtually no differences in the technical requirements of these two specifications. It may therefore be assumed that RIA Compound 9A meets the requirements of MIL-L-8937(ASG). Knowledge of the relative merits of RIA Compound 9A and solid film lubricants meeting the requirements of Specification MIL-L-8937(ASG) would be of great interest and value.

PROCEDURE

This investigation was limited to three solid film lubricant coatings and four substrates. The solid film lubricant coatings consisted of RIA Compound 9A and two commercial proprietary materials, A and B, qualified under Specification MIL-L-8937(ASG).

The four substrates examined were as follows:

1. Grit blasted steel.

2. Grit blasted steel phosphatized in accordance with Specification MIL-P-16232B[4], Type Z, Class 3.

3. Zinc phosphatized cadmium plated steel in accordancd with Specification QQ-P-416a[5], Class 1, Type III.

4. Sulfuric acid anodized and water sealed aluminum in accordance with Specification MIL-A-8625[6], Type II.

The solid film lubricant coatings were applied to the substrates by dipping, allowing the coatings to air dry, and curing for one hour at 400°F for all the substrates except the anodized aluminum. The coatings on this substrate were cured at 300°F for a period of two hours. The film thickness of the cured coatings was 0.0004 to 0.0006 inches.

The wear life provided by the lubricant coatings was determined with a Falex Lubricant Tester, following the procedure outlined in Specification MIL-L-8937(ASG). For substrates 3 and 4 listed above, a lighter test load was used due to the low yeild strength of the substrate.

Falex wear tests were also made on the solid film lubricant coatings applied to zinc phosphatized steel followed by exposure for various periods of time in a salt spray cabinet.

The corrosion protective ability of the solid film lubricant coatings on the various substrates was determined by the use of both the 20% salt spray test, Method 4001 of Federal Test Method Standard No. 791[7], and the humidity cabinet test specified in Specification MIL-L-8937(ASG).

RESULTS AND DISCUSSION

The results of the Falex wear tests for the various lubricant - substrate combinations are given in Table I. It will be noted that the test load for the cadmium plated steel and anodized aluminum substrates was reduced from the normal 1000 pound test load due to the previously mentioned low yield strength of these two substrates. The wear life values given are the average value for three tests.

TABLE I

FALEX WEAR TESTS

Metal Substrates	Test Temp	Gage Load (Lbs.)	Approx. Initial Load (PSI)	Average Wear Life (Minutes) RIA Comp 9A	Lubricant A	Lubricant B
Steel, grit blasted	Room	1000	50,000	173	88	173
Steel, zinc phosphatized	Room	1000	50,000	500	200	120
Steel, zinc phosphatized	400°F	1000	50,000	454	109	68
Steel, cadmium plate + Zn. Phos	Room	60	3000	275	286	135
Aluminum, H_2SO_4 anodized	Room	25	1250	305	225	313

This data shows the following facts:

1. The wear life provided by the solid film lubricants was improved considerably when the lubricants were applied over a zinc phosphatized steel surface rather than over a grit blasted steel surface in the case of two of the three lubricants studied.

2. The wear life provided by RIA Compound 9A is considerably superior to that provided by the two commercial products when applied to zinc phosphatized steel

3. The wear life provided by RIA Compound 9A was not reduced significantly when the wear life test was conducted at 400°F. However there was a rather large reduction in the wear life of the two commercial materials under the same test conditions.

4. If a solid film lubricant provides a superior wear life on one substrate, there is no assurance that it will also provide a superior wear life on another substrate.

In order to determine the relative corrosion protective ability of the solid film lubricant coating under a salt fog environment, tests were made in a salt spray cabinet. A 20% sodium chloride solution was used and the cabinet was operated at a temperature of 95° ± 2°F with a collection rate of 1cc salt fog per hour. The edges of the coated test panels were coated with petrolatum to prevent corrosion rundown. Table II gives the results of the salt spray test. The criterion for failure in this test was the time necessary for the appearance of 3 corrosion dots on at least two of the three test panels.

This data shows that for any given substrate, the individual solid film lubricant coatings have a great effect on the test results. RIA Compound 9A was far superior to the two commercial solid film lubricants A and B on all substrates tested. This data also shows that a solid film lubricant coating which passes the corrosion test of Specification MIL-L-8937(ASG) may offer no corrosion protection to the substrate. The failure time of solid film lubricants A and B on grit blasted steel and zinc phosphatized steel is no longer than for the uncoated substrates.

If the time required to produce initial corrosion is considered, (for zinc phosphatized cadmium plated steel white corrosion is considered initial corrosion), the best substrate is sulphuric acid anodized and water sealed aluminum. This does not hold true for all solid film lubricant however. Lubricant A applied to the sulphuric acid anodized water sealed aluminum gave a salt spray life no longer than that obtained using the same lubricant coating applied to zinc phosphatized cadmium plated steel.

No solid film lubricant coating - substrate combination, no matter how effective it is, will prevent corrosion indefinitely. Therefore, information is desirable concerning what effect corrosion products have on the wear life of solid film lubricant coatings. A short investigation was made to determine this effect. A number of zinc phosphatized Falex test pins coated with solid film lubricants RIA Compound 9A, lubricant A, and lubricant B were placed in a 20% salt spray cabinet. Periodically, test pins were removed from the cabinet and Falex wear tests made on them. The amount of rust on the test pins after the salt spray exposure is given in Table III and the wear test results are given in Table IV.

TABLE II

SALT SPRAY CORROSION TEST

Metal Substrates	Appearance of Corrosion Products	Hours to Failure: Solid Film Lubricant RIA Comp. 9A	Solid Film Lubricant A	Solid Film Lubricant B
Steel, grit blasted	Rust	4	1/2	1/2
Steel, zinc phosphatized	Rust	120	4	4
Steel, cadmium plated + zinc phosphatized	White	700	48	48
Steel, cadmium plated + zinc phosphatized	Rust	>2200	568	760
Aluminum, H_2SO_4 anodized and sealed	White	1672	48	1100

Note: White corrosion products appear on cadmium plated zinc phosphatized surfaces prior to the appearance of rust.

TABLE III

TEST PINS AFTER SALT SPRAY EXPOSURE

	Solid Film Lubricant	20% Salt Spray Exposure (Hours) 240 (10 Days)	480 (20 Days)	960 (40 Days)	1440 (60 Days)	3120 (130 Days)
Appearance of Pins	RIA Comp. 9A	No rust	5% light rust	5% light rust	30% moderate rust	50% moderate rust
	A	95% heavy rust	100% heavy rust	100% heavy rust	-	-
	B	80% moderate rust	95% heavy rust	100% heavy rust	-	-

TABLE IV

FALEX WEAR LIFE AFTER SALT SPRAY EXPOSURE

	Solid Film Lubricant	20% Salt Spray Exposure (Hours) 0	240 (10 Days)	480 (20 Days)	960 (40 Days)	1440 (60 Days)	3120 (130 Days)
Minutes to Failure (Average)	RIA Comp. 9A	500	-	415	480	482	414
	A	200	98	7	0	-	-
	B	120	59	43	0	-	-

Table III shows that the two commercial solid film lubricant coated test pins rusted at an extremely rapid rate as compared to RIA Compound 9A coated test pins.

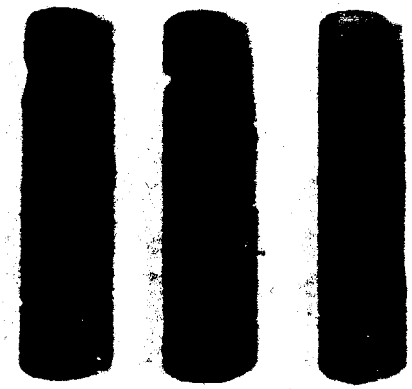
Table IV shows the drastic effect of rust on the wear life of the two commercial products as compared to the effect of rust on the wear life provided by RIA Compound 9A.

During the wear life tests made on the rusted test pins, it was noticed that large pieces of coating flaked off the test pins coated with the commercial lubricants A and B. This flaking indicates that the adhesion of the coating to the substrate was adversly affected by the rusting. RIA Compound 9A showed no evidence of flaking, indicating that the rust was mainly superficial. The wear life tests show that this superficial rust was not detrimental to the lubricant as the wear life after 3120 hours salt spray exposure was only slightly reduced from the original wear life.

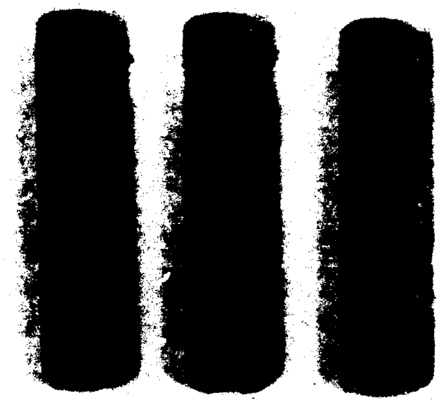
The wear life test data after salt spray exposure (Table IV) correlates with the salt spray data given in Table III. The data in these two tables indicates that the better the corrosion protection ability of the solid film lubricant, the less will be the deleterious effect of corrosion products on wear life.

The above data covering the effect of rust on the wear life provided by solid film lubricants has far reaching implications. If the proper solid film lubricant is used, moderate rusting on military equipment may not render the equipment inoperative. Moderate rusting, though undesirable from the preservation point of view, may not necessarily be fatal to the equipment.

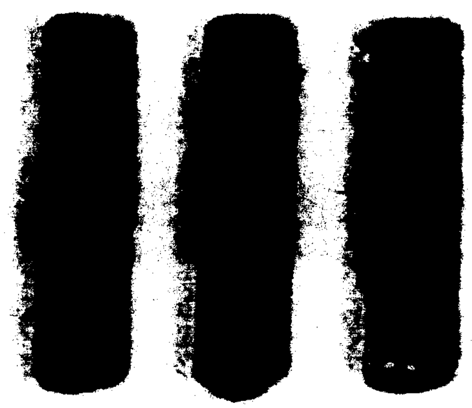
Figure 1 shows the appearance of test pins coated with RIA Compound 9A and lubricant A after the salt spray exposure. It is readily seen that the pins coated with RIA Compound 9A are considerably less rusted after 60 days exposure than are the pins coated with lubricant A after 20 days exposure. Test pins coated with solid film lubricant B were not photographed, however the data in Table III indicates that the pins coated with lubricant A and pins coated with lubricant B have a similar appearance after salt spray exposure. The reason that the pins coated with lubricant A are not rusted over the complete surface of the pin is that the top of the pin in the vicinity of the hole was covered with petrolatum. This was necessary to prevent rust rundown from the top edge of the pin and also from the hole.



R.I.A. COMPOUND 9A
(20 DAYS EXPOSURE)



R.I.A. COMPOUND 9A
(60 DAYS EXPOSURE)



LUBRICANT "A"
(20 DAYS EXPOSURE)

SOLID FILM LUBRICANT COATED SPECIMENS AFTER
SALT SPRAY EXPOSURE

FIGURE 1

In addition to information concerning the salt spray corrosion protection provided by the solid film lubricants, it was desirable to obtain information concerning the corrosion protective ability of the coatings under humid conditions. The humidity test used was that described in Specification MIL-L-8937(ASG) in which coated test panels in direct contact with uncoated panels of the same substrate material were sandwiched together in a jig under a pressure of 25 PSI. The coated panels were placed in the jig assembly in such a manner that the test surface of the top panel faced upward and the bottom panel faced downward. The number of hours to failure for each coated panel is given in Table V. Also given is the hours to failure for the uncoated control panels.

This data shows that, with the exception of the grit blasted substrate, the test is more severe on the top test panel than the bottom one. This may be due to the fact that the moisture condensed and was held more readily on the top panel. The bottom panel also may have been in a more protected position in the cabinet. The data also shows that for applications of solid film lubricants if only one surface is to be coated it should be the least protected surface.

Despite the difference in severity of the test on the top and bottom test panels, the solid film lubricant coatings were rated about the same on both panels. The agreement between the humidity cabinet and salt spray tests was good. RIA Compound 9A was again superior to the MIL-L-8937(ASG) lubricants A and B on the top test panels. The same probably would be true for the bottom test panels had the test been allowed to run to failure for the bottom test panels.

There is also a strong indication that, with the exception of the grit blasted steel substrate, the MIL-L-8937(ASG) solid film lubricants may cause corrosion. Although both of these MIL-L-8937(ASG) lubricants passed the specification corrosion test, it is seen that when the test is extended beyond the required 500 hours, both materials for the most part fail before the controls for the top set of test panels.

The data obtained in this investigation shows that when everything is taken into consideration RIA Compound 9A is superior to the two qualified MIL-L-8937(ASG) solid film lubricants. The wear life and corrosion tests in this specification are not sufficiently stringent to guarantee the purchase of a solid film lubricant having suitable wear life and corrosion protection for Army equipment to be used for extended period of time in the

TABLE V

HUMIDITY CABINET TEST RESULTS

	Solid Film Lubricant	Grit Blasted Steel Panel		Zinc Phosphatized Steel Panel		Zinc Phosphatized Cadmium Plated Steel Panel		Sulfuric Acid Anodized Aluminum Panels	
		Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Hours to Failure	RIA Comp. 9A	1310	>3350	1632	>3600	>3600	>3600	>3600	>3600
	A	168	168	192	672	792	>3600	1464	>3600
	B	8	8	504	792	1968	>3600	1968	>3600
	Control	<4	<4	360	1000	>3600	>3600	2290	>3600

ıield. A specification has been written by Rock Island Arsenal which has a 450 minute Falex Wear Test requirement and also a 100 hour 20% salt spray corrosion test requirement. The substrate for both tests is zinc phosphatized steel. The specification is being coordinated at the present time.

To summarize briefly, this investigation shows:

(1) RIA Compound 9A is superior to the qualified MIL-L-8937(ASG) solid film lubricants tested (2) corrosion products formed in a salt spray atmosphere does not substantially reduce the wear life of RIA Compound 9A (3) For maximum corrosion protection, sulphuric acid anodized and water sealed aluminum is the best substrate for solid film lubricant coatings. (4) For maximum wear life, zinc phosphatized steel is the best substrate. (5) The wear life of RIA Compound 9A is insignificantly affected by a 400°F operating temperature.

LITERATURE REFERENCES

1. Military Specification MIL-L-8937(ASG), Lubricant, Solid Film, Heat Cured.

2. Meade, F. S., and Murphy, G. P., "A Corrosion Protecting Resin Bonded Dry Film Lubricant with Good Wear Life". Rock Island Arsenal Laboratory Report No. 61-4164, November 1961.

3. Military Specification MIL-L-22273, Lubricant, Solid Film, Dry.

4. Military Specification MIL-P-16232B, Phosphate Coatings, Heavy, Manganese or Zinc Base (For Ferrous Metals).

5. Federal Specification QQ-P-416A, Plating, Cadmium (Electrodeposited).

6. Military Specification MIL-A-8625A, Anodic Coatings for Aluminum and Aluminum Alloys.

7. Federal Test Method Standard No. 791a, Lubricants, Liquid Fuels, and Related Products; Methods of Testing.

LIST OF PRIOR REPORTS

RIA LAB NO.	DATE ISSUED	TITLE
52-4224	10-3-52	Evaluation of Certain Dry Lubricants
58-1134	5-14-58	Evaluation of Bonded Dry Lubricants
59-1515	6-4-59	Investigation of Resin Systems as Bonding Agents for Dry Lubricants
60-1308	5-26-60	A Study of the Lubricity of a Sulphurized Coating
60-2192	7-15-60	Development of An Improved Resin Bonded Dry Film Lubricant
61-4164	11-16-61	A Corrosion Protecting Resin Bonded Dry Film Lubricant With Good Wear Life
62-652	2-20-62	The Effect of Vapor Degreasing on Wear Life and Salt Spray Life of Resin Bonded Solid Film Lubricants
62-4056	12-5-62	Dry Lubricants and Corrosion
63-959	3-26-63	The Effect of Cure Conditions on Wear Life and Corrosion Protection of A Resin Bonded Solid Film Lubricant