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EVALUATION OF DRY FILM LUBRICANTS ON ALUMINUM AND MAGNESIUM

REPORT A262 SERIAL NO. 12

MCDONNELL

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CODE (Lub-3)(IV-e)(V-a,e)

FINAL REPORT

LABORATORY: Structures

EVALUATION OF DRY FILM LUBRICANTS ON ALUMINUM AND MAGNESIUM

ABSTRACT

Vendors' literature has recommended the application of dry film lubricants to various aluminum and magnesium alloys. In order to evaluate these recommendations, combinations of several dry film lubricants applied to representative aluminum and magnesium alloys with various surface preparation procedures were tested.

Of the combinations tested, the optimum combination of surface pretreatment and dry film lubricant in the case of 7075-T6 aluminum alloy was found to be Electrofilm 5396 lubricant applied to a hard coated surface. When testing HK31A magnesium alloy, the optimum combination was that of Electrofilm 5396 applied to a surface pretreated with a Dow 17 Type I coating, followed by Everlube 620 lubricant applied to the same pretreated surface.

-A

Prepared by M. S. Tucker Jr., Test Engineer
Approved by K. Swanekamp, Senior Engineer - Lab

Approved by W. E. Vogel, Chief, Structures Lab
Approved by E. A. Fuqua, Lab Project Engineer

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1. INTRODUCTION

A need has developed for test data concerning the performance to be expected from dry film lubricants when applied to aluminum and magnesium alloys. Recommendations for these applications have appeared in some recent vendors' literature. Tests were conducted at room temperature and at 250F with 3 dry film lubricants applied to an aluminum and a magnesium alloy, each with various surface preparations.

These tests were performed by the Structures Laboratory of McDonnell Aircraft Corporation during the period 5 March through 11 September 1962.

2. DESCRIPTION OF TEST ARTICLES

The test cups and riders were fabricated to the configuration shown in Figures 1 and 2 on page 8 . Nine of the test cups were made of 7075-T6 aluminum alloy and 6 of HK31A magnesium alloy. The riders were of 52100 steel (R$_C$58), and were drilled to provide a thermocouple well to be used in elevated temperature testing. -A

Three of the aluminum alloy test cups were subjected to each of the following surface preparation methods: Hard coat 0.002-inch thick per PS 13208, alodine per PS 13209, and anodize per PS 13201. Three of the magnesium alloy cups were surface-conditioned by each of the following methods: Dow 17 coating, Type I , per PS 13217, and HAE Type II coating performed by an outside vendor. -A

The dry film lubricants included in the tests, Molykote X-106, Electrofilm 5396, and Everlube 620, were applied to the test cups by spraying. Micrometer measurements were conducted before and after spraying to assure uniform lubricant thickness.

Table 1 on page 5 summarizes the surface preparation and lubricant applied to each of the test cups.

3. TEST PROCEDURE

All tests were conducted on a McMillan wear tester shown in Figure 3 on page 9 , equipped with a heating element and pyrometer for elevated temperature testing. A cutoff switch, activated by the input of a strain gage, was employed to stop the test when the coefficient of friction reached 0.2. The strain gages were attached to the oscillating linkage arm, as shown in Figure 4 on page 10, and were calibrated to relate the strain in the linkage arm to a coefficient of friction of 0.2.

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3. TEST PROCEDURE (CONTINUED)

If this point was not attained, the test was discontinued after 50 hours.

The test cups were rotated with an oscillating motion through an arc of approximately 45°. This resulted in a test length of about 0.75 inch and allowed 4 tests per cup, 2 at room temperature followed by 2 at 250F. The position of the test cup relative to the rider is shown in Figure 5 on page 11 . -A

The normal load applied to the test surface was calculated from the weight applied to the load pan, plus that of the pan and linkage arm, reacting through a linkage arm ratio of 29.5. Normal loads of 99 pounds were applied to the magnesium alloy surfaces, and of 187.5 pounds to the aluminum alloy test surfaces. In each case, the load was applied in increments to prevent premature failure because of possible damage to the test surface caused by sudden loading. The timer was started after loading was completed, and subsequent inspections performed to assure even contact between the test cups and riders.

4. TEST RESULTS

The oscillatory motion was applied at a rate of 193 cycles per minute; after measuring the time to failure, the number of cycles sustained before failure was calculated. In several cases, failure occurred during loading and the cycles to failure values was taken as zero.

The test results are tabulated for the aluminum alloy, 7075-T6 and the magnesium alloy, HK31A, in Tables 2 and 3 on pages 6 and 7 , respectively.

5. DISCUSSION OF TEST RESULTS

Of the various combinations of base metal alloy, surface preparation, and dry film lubricant tested, either at room temperature or at 250F, none approached the 50 hour maximum test period. Considerable scatter in the test results was encountered; frequently one test condition would yield comparatively good results and an identical test would result in failure before the load was completely applied. The photomacrographs presented in Figures 6 through 33 on pages 12 through 39 show the surfaces of each cup section at approximately 4X magnification after test. The results of Test No. 28 were discarded because the contact area was approximately twice as long as those of the other tests.

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6. CONCLUSION

Of the combinations of dry film lubricant and surface pretreatment tested with 7075-T6 aluminum alloy, the optimum combination of surface pretreatment and dry film lubricant application was that of Electrofilm 5396 applied to a surface hard coated in accord with PS 13208. The next 2 most successful combinations were Everlube 620 applied to a hard coated aluminum surface, followed by Electrofilm 5396 applied to a surface alodined per PS 13209.

In testing HK31A magnesium alloy cups, the optimum surface preparation dry film lubricant combination was found to be Electrofilm 5396 lubricant applied to a Dow 17 Type I surface, followed by Everlube 620 applied to the magnesium alloy of the same surface preparation. -A

TABLE 1

PREPARATION OF TEST CUPS

TEST CUP	MATERIAL	PRE-TREAT	DRY FILM LUBRICANT
1	ALUMINUM	ALODINE	EVERLUBE 620
2	"	"	MOLYKOTE X-106
3	"	"	ELECTROFILM 5396
4	"	ANODIZE	EVERLUBE 620
5	"	"	MOLYKOTE X-106
6	"	"	ELECTROFILM 5396
7	"	HARD COAT	EVERLUBE 620
8	"	"	MOLYKOTE X-106
9	"	"	ELECTROFILM 5396
10	MAGNESIUM	DOW 17	EVERLUBE 620
11	"	"	MOLYKOTE X-106
12	"	"	ELECTROFILM 5396
13	"	HAE TYPE II	EVERLUBE 620
14	"	"	MOLYKOTE X-106
15	"	"	ELECTROFILM 5396

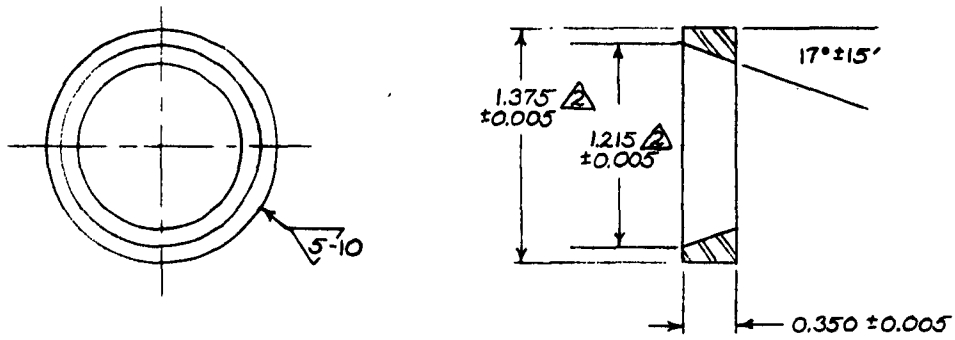
TABLE 2 - ALUMINUM TEST CUPS

Test Cup	Test No.	Surface Pretreatment	Dryfilm Lubricant Applied	Test Temp. (F)	Time to Failure (hr.)	Cycles to Failure
1	1	Alodine	Everlube 620	R.T.	0.0	0
	2			R.T.	2.0	23,160
	3			250	1.3	15,054
	4			250	4.0	46,320
2	5		Molykote X-106	R.T.	0.0	0
	6			R.T.	0.0	0
	7			250	0.0	0
	8			250	0.0	0
3	9		Electrofilm 5396	R.T.	3.0	34,740
	10			R.T.	1.3	15,054
	11			250	3.0	34,740
	12			250	1.1	12,738
4	13	Anodize	Everlube 620	R.T.	2.2	25,476
	14			R.T.	2.9	33,582
	15			250	13.6	157,468
	16			250	0.0	0
5	17		Molykote X-106	R.T.	0.0	0
	18			R.T.	0.0	0
	19			250	0.0	0
	20			250	0.0	0
6	21		Electrofilm 5396	R.T.	2.0	23,160
	22			R.T.	3.0	34,740
	23			250	0.0	0
	24			250	0.0	0
7	25	Hardcoat	Everlube 620	R.T.	5.9	68,322
	26			R.T.	5.4	62,532
	27			250	5.9	68,322
	28			250	28.4	328,872
8	29		Molykote X-106	R.T.	1.0	11,580
	30			R.T.	1.2	13,896
	31			250	1.3	15,054
9	32		Electrofilm 5396	R.T.	11.6	134,328
	33			R.T.	10.3	119,274
	34			250	11.3	130,854
	35			250	11.2	129,696

TABLE 3 - MAGNESIUM TEST CUPS

Test Cup	Test No.	Surface Pretreatment	Dryfilm Lubricant applied	Test Temp. (F)	Time to Failure (hr.)	Cycles to Failure
10	1	Dow 17 type I	Everlube 620	R.T.	18.3	211,914
	2			R.T.	0.6	6,948
	3			250	13.4	155,172
	4			250	6.4	74,112
11	5		Molykote X-106	R.T.	1.5	17,370
	6			R.T.	0.0	0
	7			250	0.1	1,158
	8			250	1.3	15,054
12	9		Electrofilm 5396	R.T.	14.5	167,910
	10			R.T.	3.6	41,688
	11			250	16.4	189,912
	12			250	15.2	176,016
13	13	HAE type II	Everlube 620	R.T.	0.1	1,158
	14			R.T.	0.0	0
	15			250	0.0	0
	16			250	0.0	0
14	17		Molykote X-106	R.T.	0.0	0
	18			R.T.	0.0	0
	19			250	0.3	3,474
	20			250	0.1	1,158
15	21		Electrofilm 5396	R.T.	7.9	91,482
	22			R.T.	1.4	1,621
	23			250	6.1	70,638
	24			250	0.2	2,316

FIGURE 1

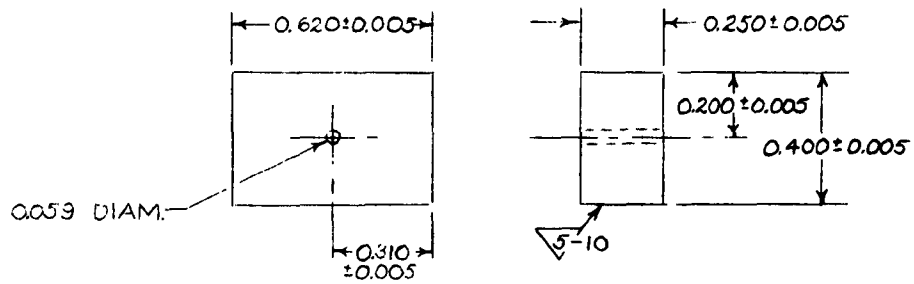


TEST CUP CONFIGURATION

NOTES:

1. EXCEPT AS NOTED IN ▽ SYMBOL, HOLD SURFACE FINISH TO 63 RMS MICROINCHES.
2. CONCENTRICITY OF TAPERED I.D. TO O.D. TO BE WITHIN 0.0003 T.I.R.

FIGURE 2

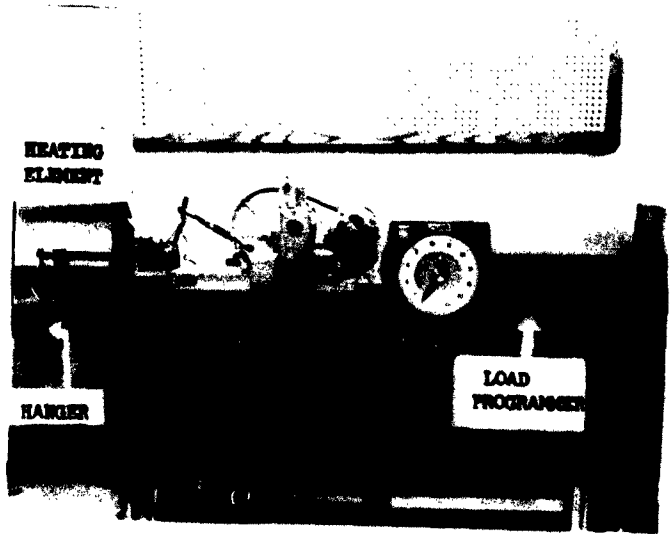


TEST RIDER CONFIGURATION

NOTES:

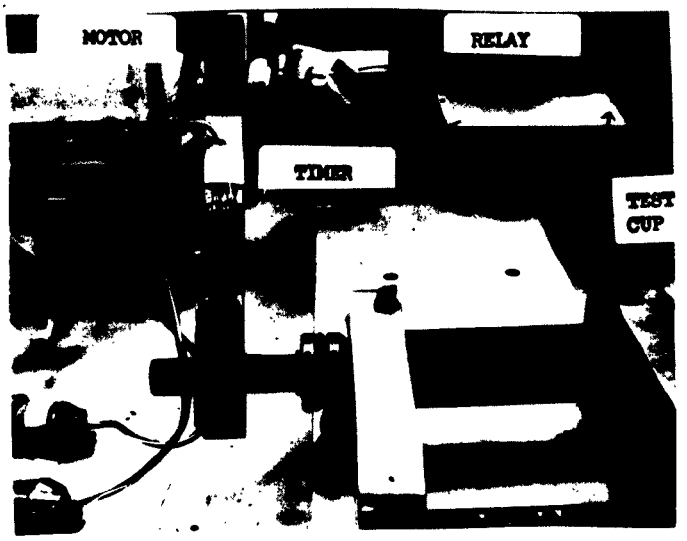
1. TEST RIDER MATERIAL TO BE 52100 STEEL (R_C 30).

FIGURE 3 - MC MILLAN DRY FILM LUBRICANT TEST SETUP



D4E-253656

FIGURE 4 - STRAIN GAGED INDICATING ARM



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DATE
REVISED
REVISED D4E-264660

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FIGURE 5 - MOUNTED TEST CUPS SHOWING WORN SURFACES

D4E-253655

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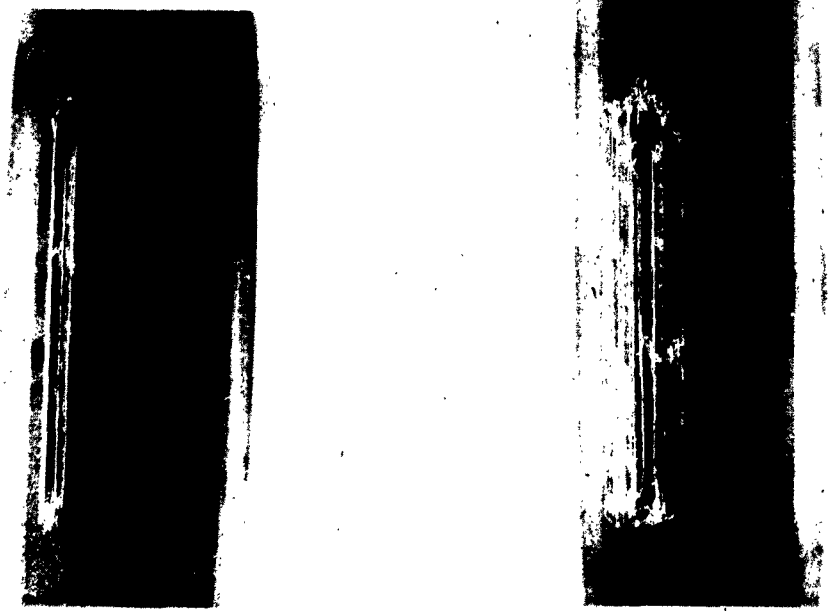
FIGURE 6

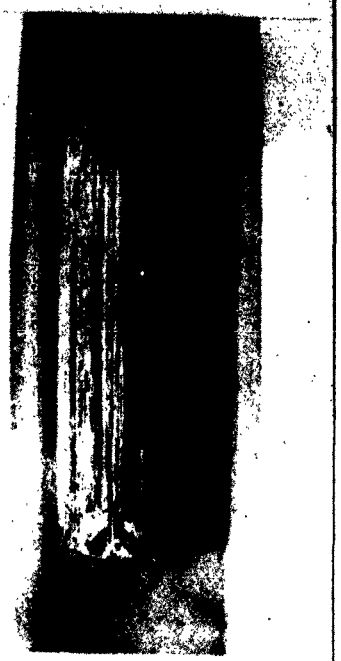


M10527 No. 1 M10528 No. 2

Test Cup 1
Alodine - Everlube 620

FIGURE 7

M10538 No. 3



M10537 No. 4

Test Cup 1
Alodine - Everlube 620

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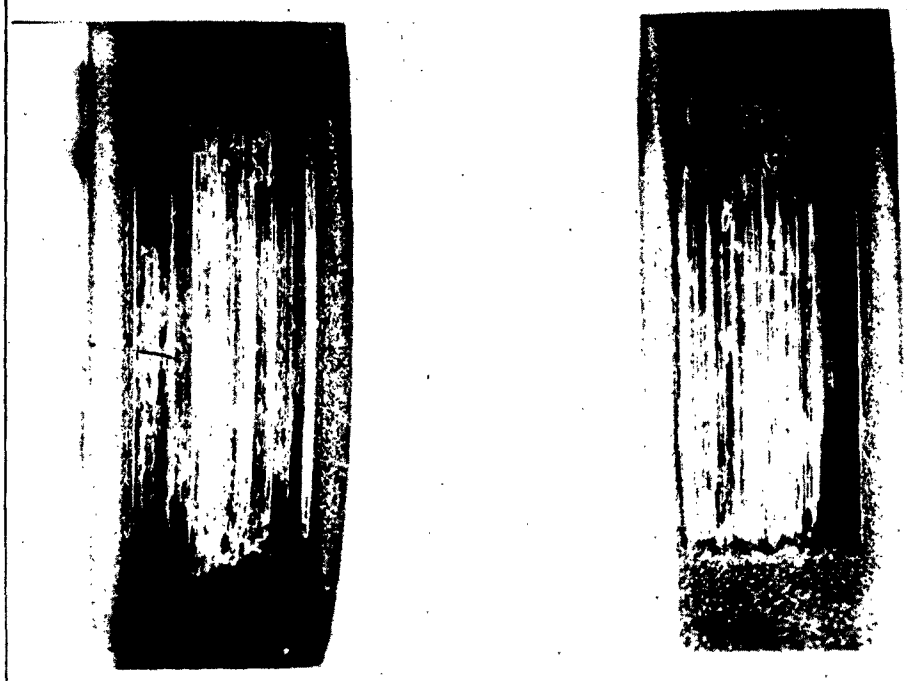
FIGURE 8



M10509 No. 5

M10506 No. 6

Test Cup 2
Alodine - Molykote X-106

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FIGURE 9

M10505 No. 7

M10507 No. 8

Test Cup 2
Alodine - Molykote X-106

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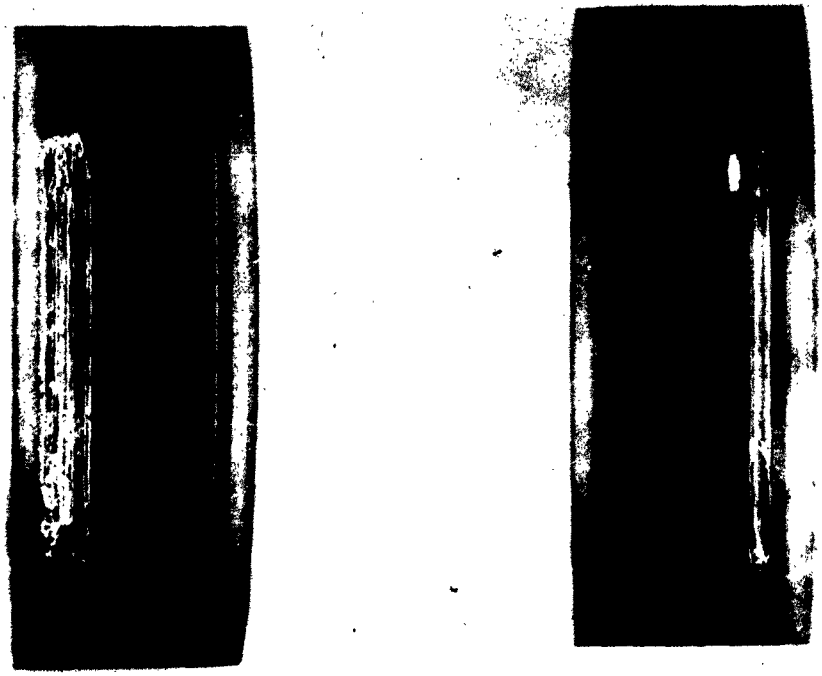
FIGURE 10



M10534 No. 9

M10536 No. 10

Test Cup 3

Alodine - Electrofilm 5396

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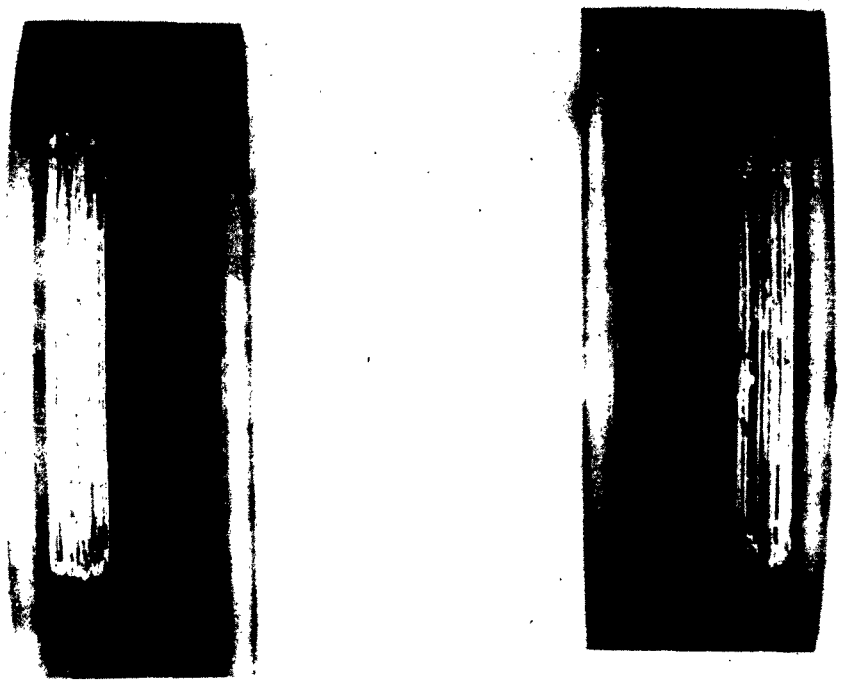
FIGURE 11



M10529 No. 11 M10535 No. 12

Test Cup 3
Alodine - Electrofilm 5396

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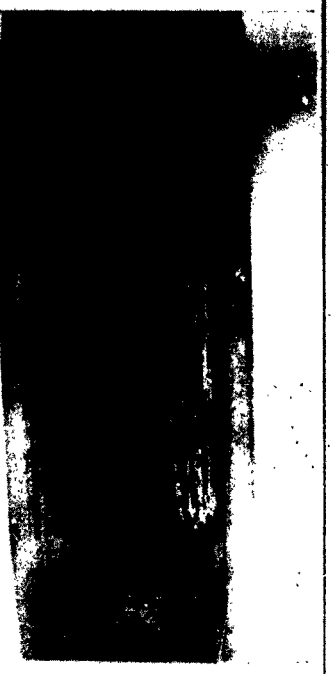
FIGURE 12

M10532 No. 13



M10533 No. 14

Test Cup 4
Anodize - Everlube 620

FIGURE 13

M10530 No. 15 M10530 No. 16

Test Cup 4
Anodize - Everlube 620

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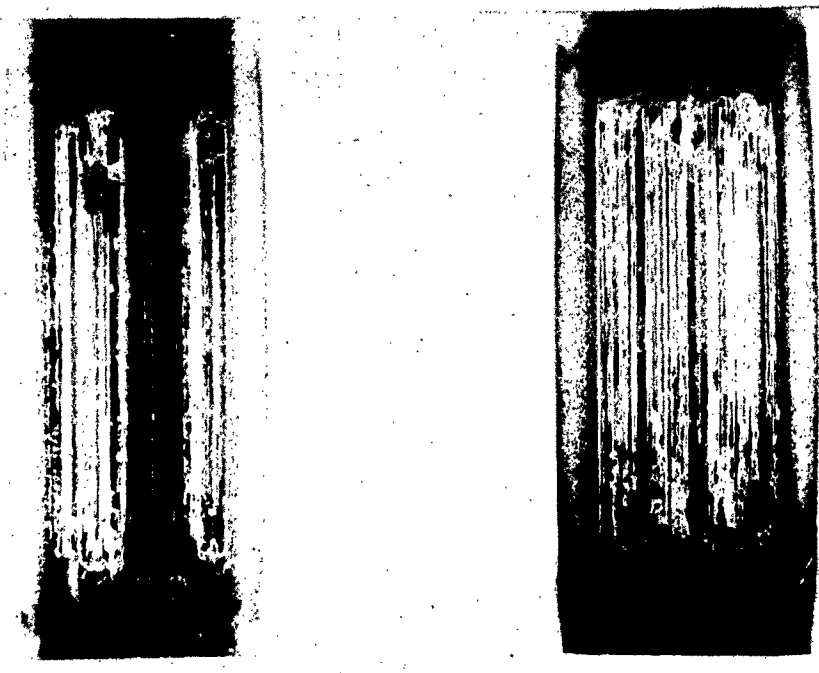
FIGURE 14



M10514 No. 17 M10512 No. 18

Test Cup 5
Anodize - Molykote X-106

DATE

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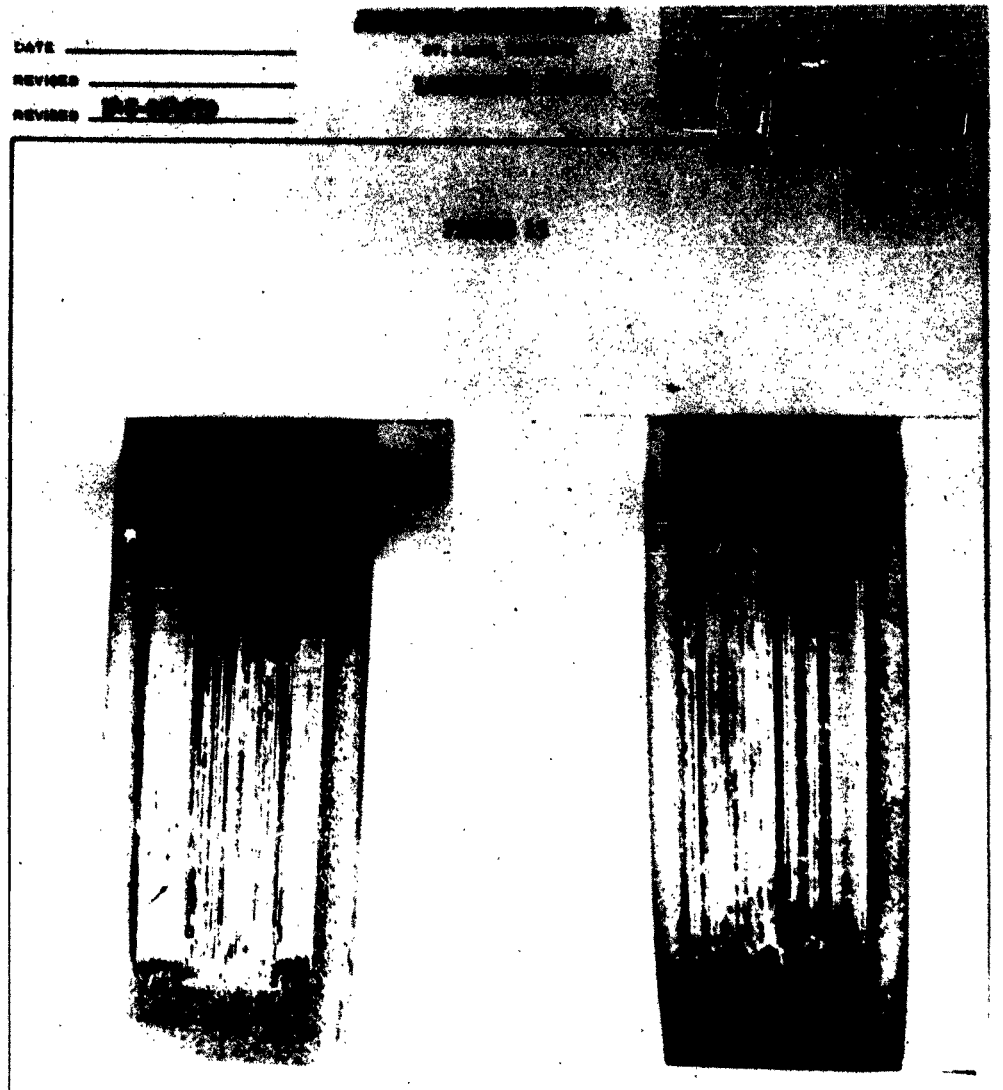
REVISED [redacted]



M10511 No. 19

M10510 No. 20

Test Cup 5
Anodize - Molykote X-10[illegible]

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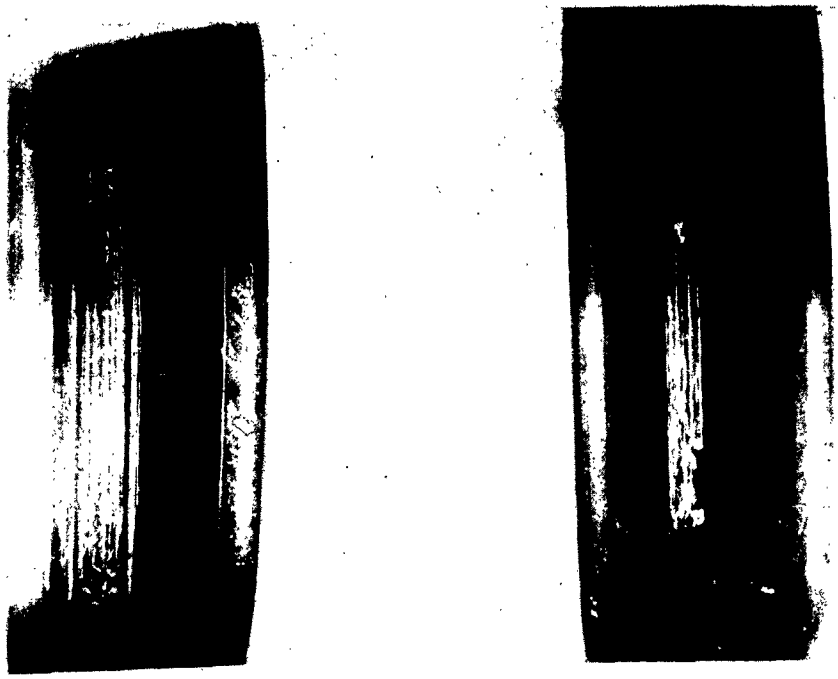
FIGURE 16



M10438 No. 21 M10440 No. 22

Test Cup 6
Anodize - Electrofilm 539

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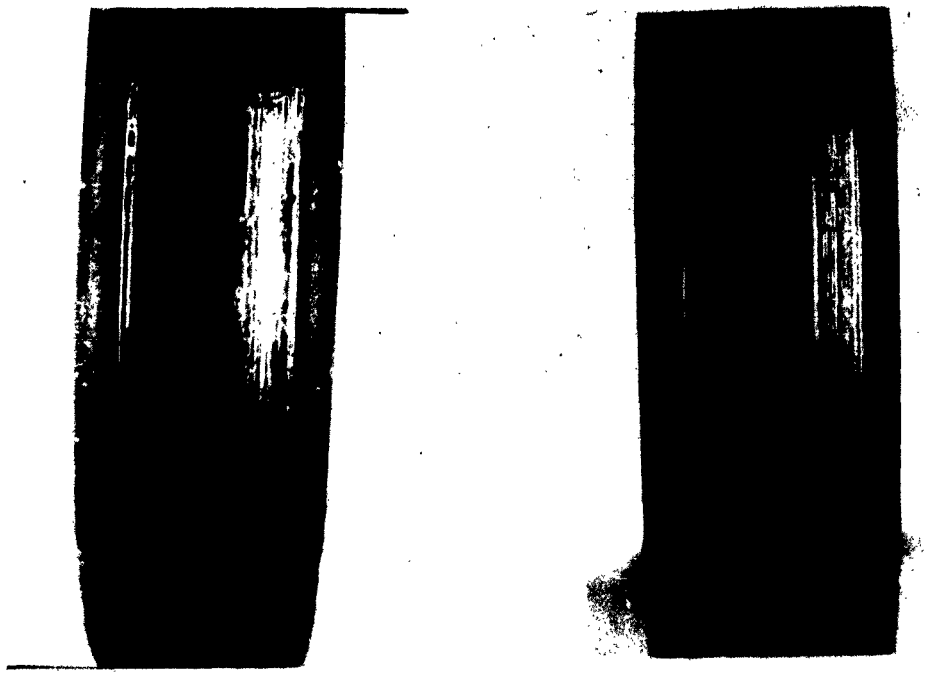
FIGURE 17



M10431 No. 23 M10430 No. 24

Test Cup 6
Anodize - Electrofilm 538

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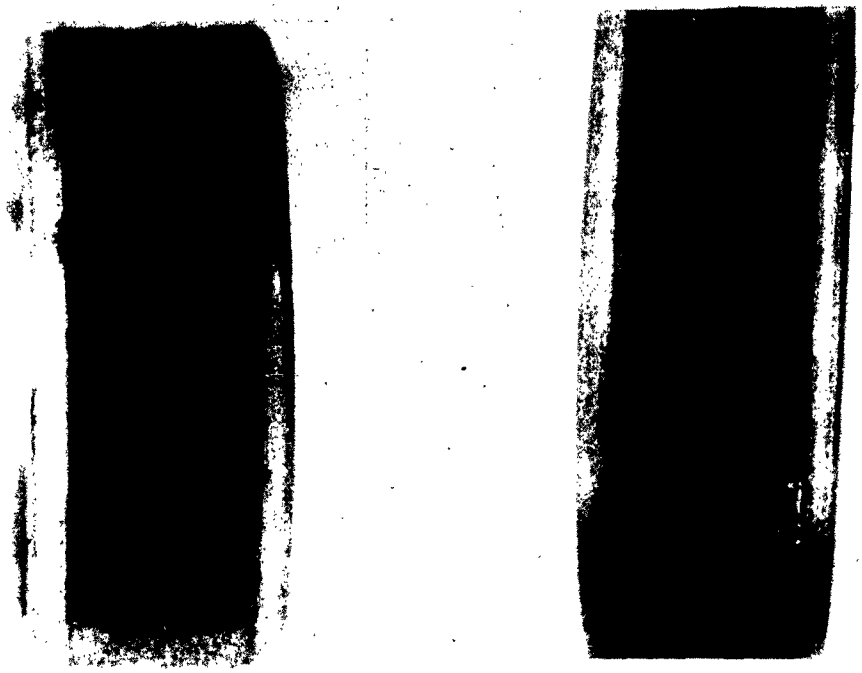
FIGURE 18



M10436 No. 25 M10439 No. 26

Test Cup 7
Hardcoat - Everlube 620

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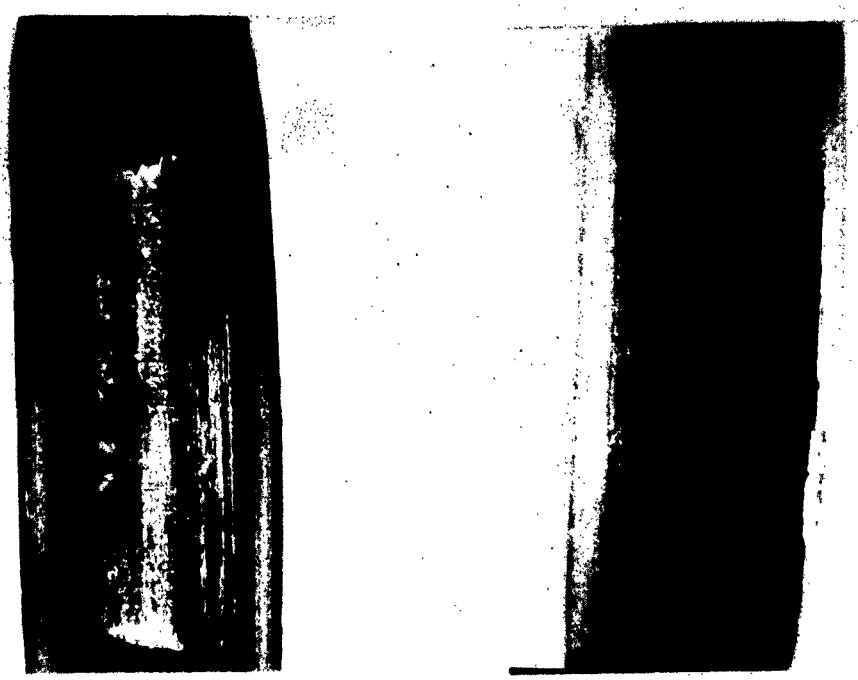
FIGURE 19



M10439 No. 27 M10437 No. 28

Test Cup 7
Hardcoat - Everlube 620

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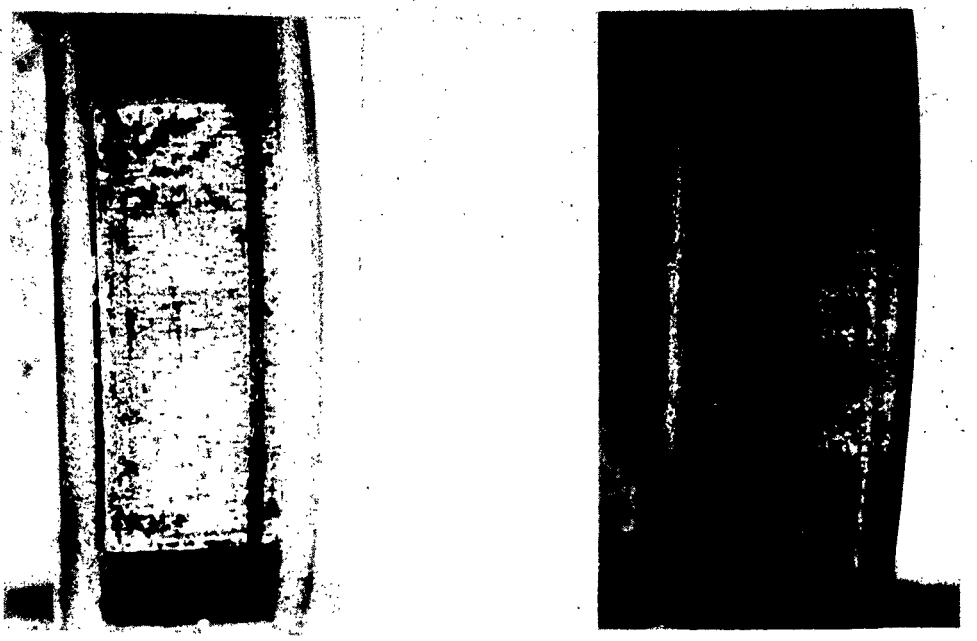
FIGURE 20



M10547 No. 29

M10550 No. 30

Test Cup 8

Hardcoat - Molykote X-106

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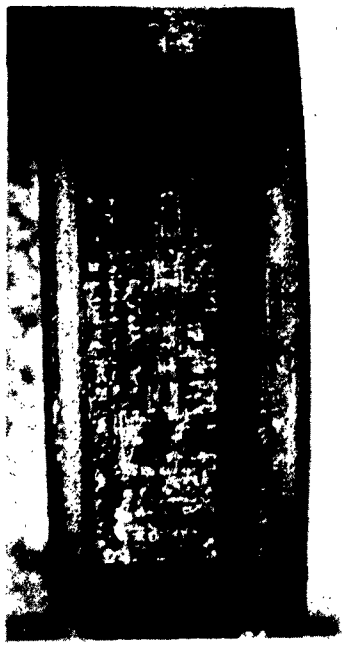
FIGURE 21



M10940 No. 31

No. 32 - No test due to unavailability of surface

Test Cup 8
Haricoat - Molykote X-106

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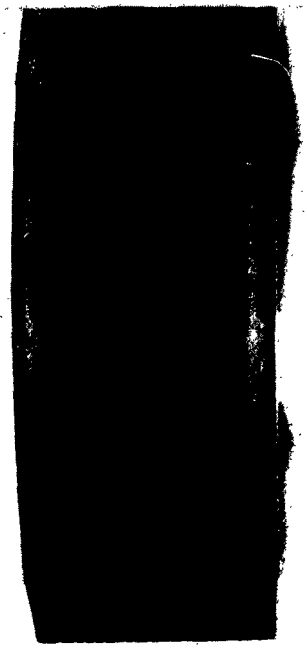
FIGURE 22

M10517 No. 33



M10434 No. 34

Test Cup 9
Hardcoat - Electrofilm 5396

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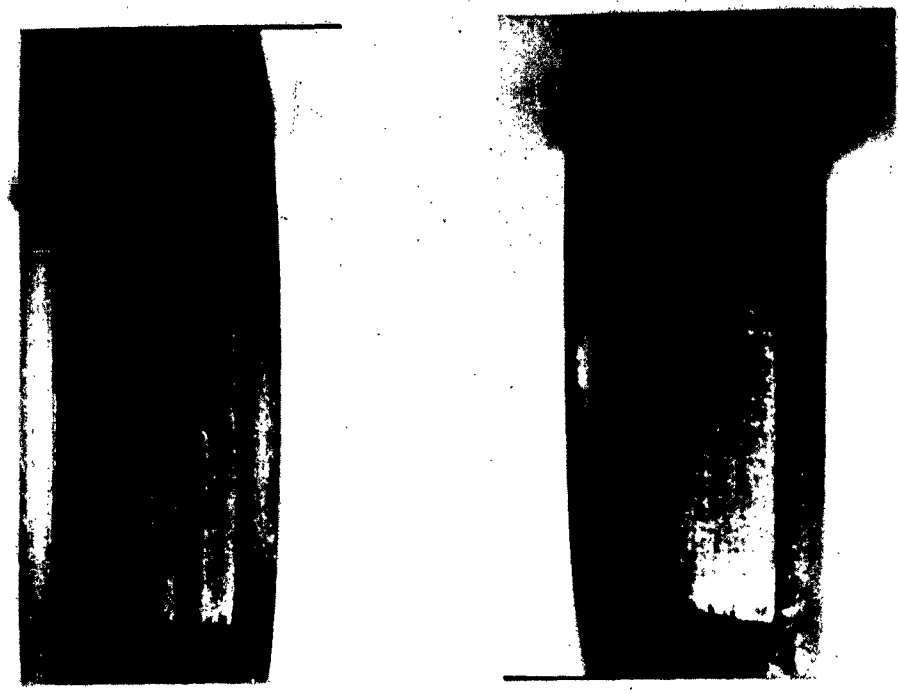
FIGURE 23



M10433 No. 35 M10432 No. 36

Test Cup 9
Hardcoat - Electrofilm 338

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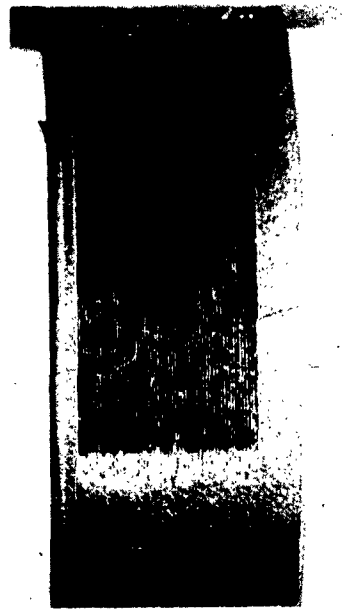
FIGURE 24

Test Cup No. 10, Runs 1-4, was not available for photomacrographs

M10548 No. 5



M10547 No. 6

Test Cup 11
Dow 17 - Molykote X-106

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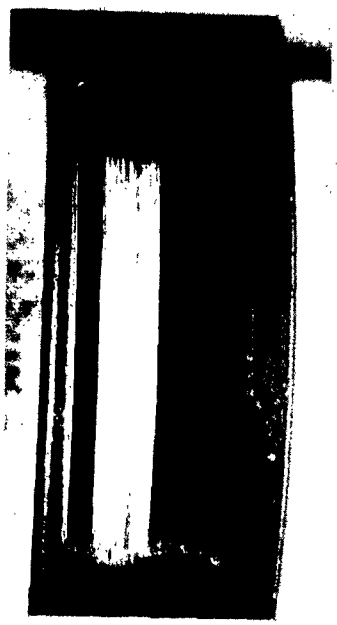
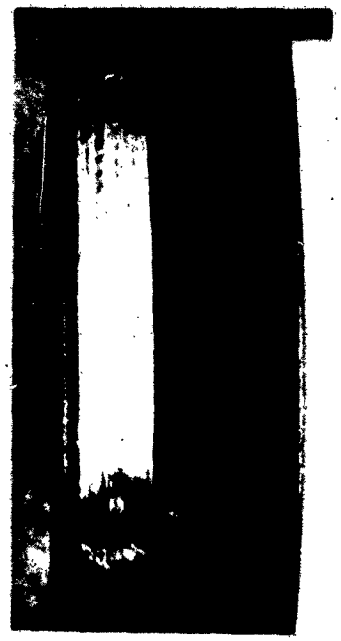
FIGURE 25

Test Cup No. 10, Runs 1-4, was not available for photomacrographs



M10550 No. 7



M10549 No. 8

Test Cup 11
Dow 17 - Molykote X-106

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FIGURE 26

M10546 No. 9 M10543 No. 10

Test Cup 12
Dow 17 - Electrofilm 5396

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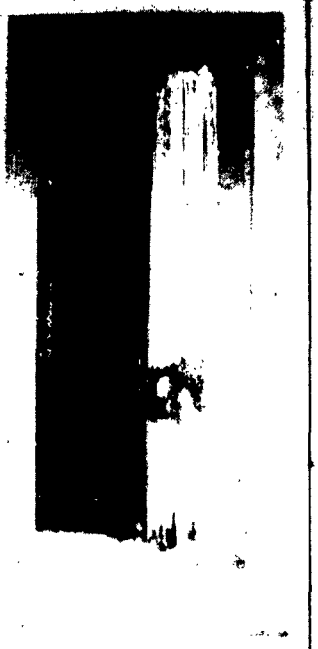
FIGURE 27

M10544 No. 11



M10548 No. 12

Test Cup 12
Dow 17 - Electrofilm 5396

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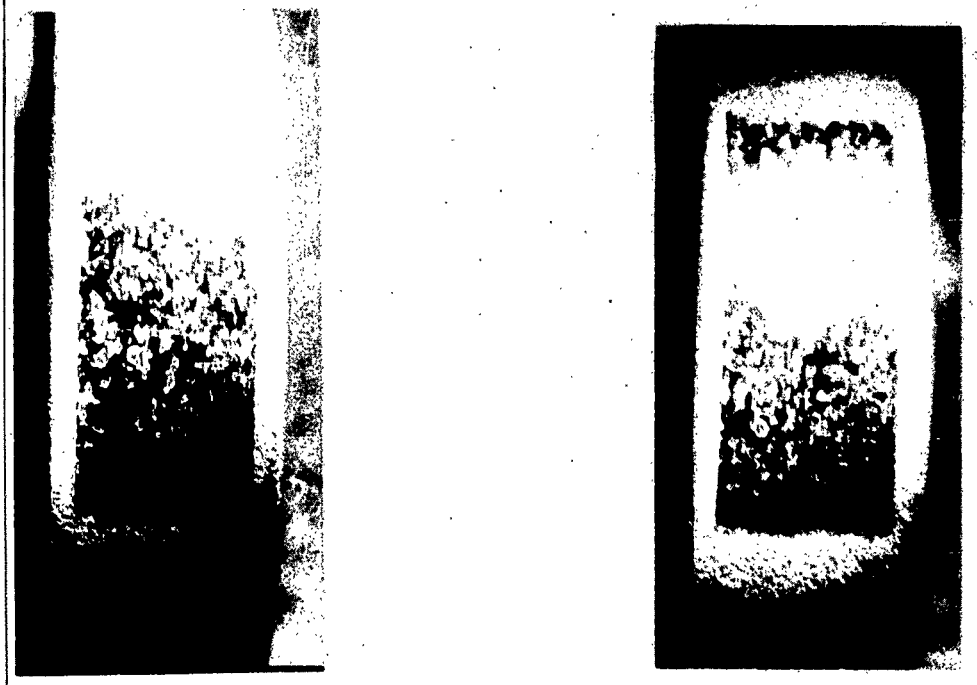
FIGURE 28



M9435 No. 13

M9434 No. 14

Test Cup 13
HAE Type II Everlube 620

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FIGURE 29

M9433 No. 15

M9432 No. 16

Test Cup 13
HAE Type II Everlube 620

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FIGURE 30

M10544 No. 17

M10545 No. 18

Test Cup 14
HAE Type II Molykote X-106

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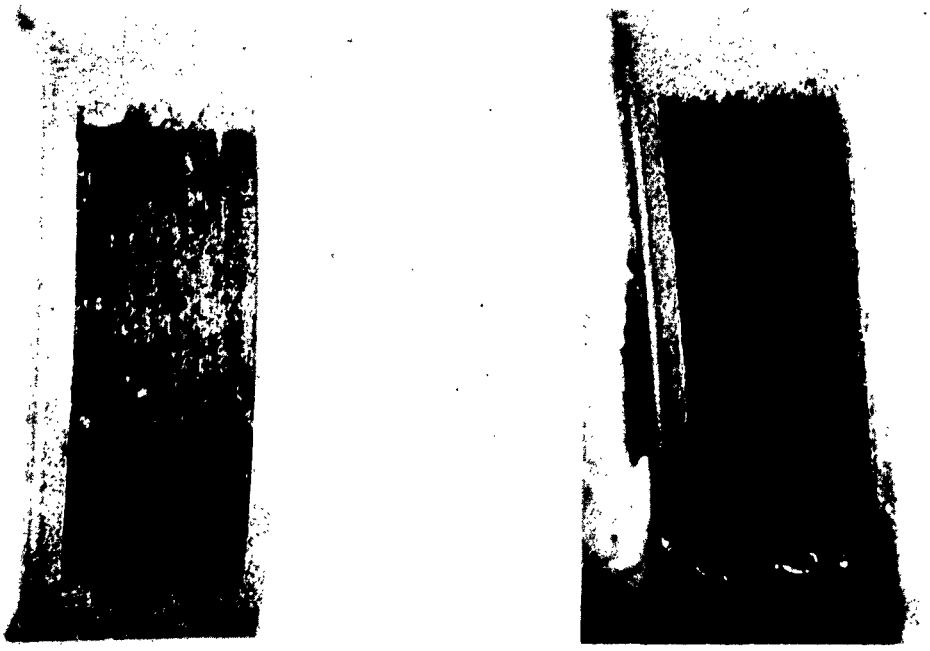
FIGURE 31



M10546 No. 19 M10543 No. 20

Test Cup 14
HAE Type II Molykote X-106

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FIGURE 32

M10664 No. 21

M10662 No. 20

Test Cup 15
MAE Type II Electrofilm 5390

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FIGURE 33

M10665 No. 23

M10663 No. 24

Test Cup 15
HAE Type II Electrofilm 5396

MAC 1900 (REV. 26 JAN. 59)
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TEST REQUEST

PAGE 40
REPORT A262

TITLE Evaluation of Dry Film Lubricants on Aluminum and Magnesium

LABORATORY OR DEPT. RESPONSIBLE FOR TEST	MODEL
D25-2	Misc.
TEST PARTS ON ISN ☐; ON TPL NO. ____ PRODUCTION PARTS FOR TEST NOT REQUIRED ☑	ACCT. None

WORK REQUESTED

OBJECTIVE (GIVE PURPOSE OF TEST, WORK AND DATA REQUIRED, INCLUDING SERVICE HISTORY AND BACKGROUND INFORMATION)

OK for IDEP

1.0 OBJECT

To evaluate several dry film lubricants for wear life on aluminum and magnesium at room temperature and 250°F.

2.0 JUSTIFICATION

F6675-040 REV. B ADDT.

Existing vendor data recommends use of dry film lubricants on aluminum and magnesium. However, no testing has been conducted at MAC to substantiate the vendor data. Several recent production problems have indicated a need for test data to permit making reliable recommendations regarding lubrication of MAC products.

3.0 MATERIALS

for "A" see pg 3

3.1 7075-T6 aluminum Spec. QQ-A-282 Cond. T6
Size: 1.5"dia. rod x 12.0"

3.2 HM31A-F Magnesium Spec. AMS 4388
Size: 1.5"dia. rod x 8.0"

~~3.3 4130 Steel Spec. MIL-S-6758 Cond C Size: .375" x 1.00" x 10.0"~~

3.3 Modified MacMillan Tester for oscillatory motion and 250°F temperature.

4.0 SPECIMEN PREPARATION

~~4.1 Heat treat 4130 steel per P.S. 15013.~~

4.1 Manufacture 10 test cups from 7075-T6 aluminum and 7 test cups from HM31A-F magnesium. The test cups will be manufactured per Figure I.

4.2 Manufacture 15 riders of ~~4130~~ 52100 steel (R_c = 30) per Figure II.

* 1020 Summary Sheet & Volum Copy of Spt Rpt'd

REFERENCES OR ENCLOSURES

REV. B CHARGE NO. REVISED AS PER MEMO MP 62-282

REV C ADD ACTUALS
2-1-63

4.0 SPECIMEN PREPARATION (Continued)

4.4 Pretreatments (5 specimens per pretreat).

4.4.1 Aluminum

(a) Hard coat .002 inches thick per P.S. 13208.
(b) Alodine per P.S. 13209.
(c) Anodize per P.S. 13201.

4.4.2 Magnesium

(a) Dow 17 per P.S. 13217.
(b) ~~HAE per P.S. 13212.~~ HAE Type III coating. Send to Brooks & Perkins, 1420 W. Fort St Detroit 16, Mich

4.5 One specimen per pretreatment shall be coated with each of the following lubricants:

4.5.1 Molykote X-106 per P.B. 841 of P.S. 1802.

4.5.2 Electrofilm 99A applied at Dynacraft, St. Louis.

4.5.3 Everlube 620 applied at Edco-Apex Testing Lab, St. Louis (bake: 2 hrs. @ 225°F).

5.0 TESTING

5.1 Test motion shall be oscillatory (210 cpm) resulting in (4) four testing surfaces per specimen, 2 tests at room temperature and 2 tests at 250°F.

5.2 Testing shall continue until the coefficient of friction (f) = 0.2, or until 50 hours has elapsed, whichever occurs first.

5.3 Loads shall be applied per MIL-L-25504.

5.4 Aluminum

5.4.1 Test each specimen at room temperature with 10 lb. on the hanger on two (2) separate surfaces.

5.4.1 Test each specimen at 250°F with 3 lb. on the hanger on two (2) separate surfaces.

5.5 Magnesium

5.5.1 Test each specimen at room temperature with 5 lb. on the hanger on two (2) separate surfaces.

5.5.2 Test each specimen at 250°F with 3 lb. on the hanger on two (2) separate surfaces.

NOTE: Sequence of testing shall be:

1. Room temperature tests of hard coated aluminum with Molykote X-106 lubricant.
2. Room temperature test of anodized aluminum with Molykote X-106 lubricant.
3. Sequence unimportant after above testing is completed.

6.0 DATA REQUIRED

6.1 Report the number of cycles to failure (f = 0.2), or whether the specimen lasted 50 hours.

6.2 Photomicrographs of typical failures at 20X.

Rev "A" — Misalignment of the electrofilm wear testing machine resulted in questionable data — M/hrs requested are for correcting alignment & re-runs Approved S. Clubb/kmp 4/30/62
Authorized C. L. Szabo 5/3/62
per pink (C)

TEST REQUEST

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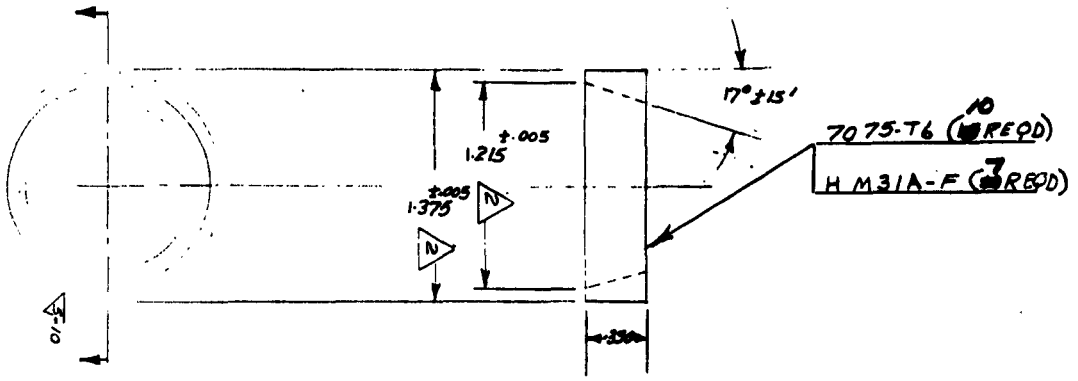

FIGURE I

1. EXCEPT AS NOTED IN ▽ SYMBOL HOLD SURFACE TO 63 RMS MICROINCHES
2. CONCENTRICITY OF TAPERED DIA TO OD TO BE WITHIN .0003 T.I.R
3. BREAK ALL SHARP CORNERS

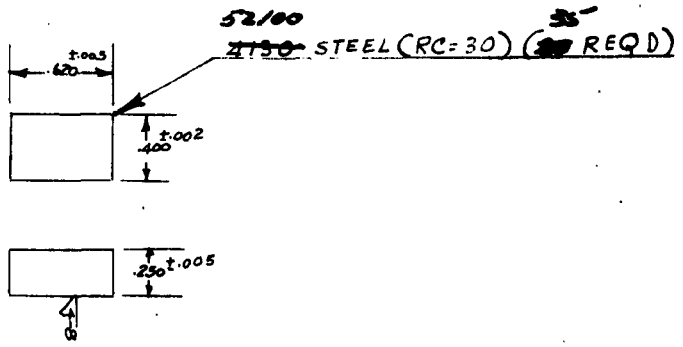

FIGURE II

1. THE .250 INCH DIMENSION SHALL BE PARALLEL TO THE AXIS OF THE CUP WITHIN ±.001 T.I.R

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