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PART II
ASTIA DOCUMENT No. 150977

EFFECT OF METALS ON LUBRICANTS

PART II. CORROSION AND OXIDATION STABILITY AT 400° FAHRENHEIT

JOHN B. CHRISTIAN

MATERIALS LABORATORY

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WRIGHT AIR DEVELOPMENT CENTER

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PROJECT NO. 7331

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Carpenter Litho & Prtg. Co., Springfield, O
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FOREWORD

This report was prepared by the Organic Materials Branch, Materials Laboratory, Directorate of Laboratories, Wright Air Development Center. It is the second part of a series of investigations concerning the effects which lubricants and various metals have on each other.

These investigations were initiated under Project No. 7331, "Hydraulic Fluids," Task No. 73314, "Lubricants," with Mr. John B. Christian acting as project engineer.

This report covers work conducted from April 1956 to July 1957.

ABSTRACT

This report presents data which deals with the general effects which silicates and siloxanes have on various metals; and the effects which these metals have on the fluids under severe conditions.

The corrosion and oxidation stability of a diester blend, a siloxane, and a silicate in the presence of various metal specimens is discussed.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

R. T. Schwartz

R. T. SCHWARTZ
Chief, Organic Materials Branch
Materials Laboratory

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I. INTRODUCTION

One of the most significant factors affecting the deterioration of fluids and lubricants under oxidation conditions is the presence of certain metals in the oxidation system. A number of previous investigations have shown that metals and alloys possess a characteristic catalyzing effect toward the oxidation and thermal decomposition of lubricants with which they might come in contact and the lubricants under these extreme conditions may have a corrosive effect on metals or alloys.

The studies described herein involve the determination of the effects which metals or alloys used in various aircraft systems and the fluids and lubricants employed in these systems have on one another. The data presented in this report were arrived at by conducting oxidation and corrosion tests on the fluids and metals.

The fluids used in these studies have been blended with various additives which improve their viscosity-temperature properties and retard oxidation of the fluid.

The studies involved introduction of dry air, at a flow rate of 5 liters per hour through 100-milliliter samples of the fluids containing single one inch square metal specimens, which had been placed in oxidation-corrosion apparatus. The oxidation system was maintained at a temperature of 400°F for a period of 72 hours.

At the end of the test period the metal specimens were observed for changes in weight, discoloration, corrosion, and etching or pitting. The changes in fluid properties determined were evaporation loss, changes in appearance, neutralization number, and viscosity.

II. DISCUSSION

Sixteen (16) metal specimens comprise the list of those used in obtaining the data shown in the numerous tables in this report. Table XXI lists the metals investigated and the applicable specification.

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The fluids used in conjunction with the metals were OS-45 (ortho-silicate), Oronite 8515 (disiloxane-diester blend), and MLO 8200 (disiloxane), each from various lots.

In all instances the oxidation-corrosion evaluations were conducted in quadruplicate. Each test was comprised of one metal specimen in the fluid.

In order to determine clearly if all of the effects on the fluids were caused by the presence of the metals during the test, a blank run was conducted on each of the fluids with the metal specimens absent.

The color of Oronite 8515 darkened considerably and it had a relatively heavy evaporation loss. Its change in viscosity and neutralization number is much less than those of OS-45 and the MLO 8200. However, OS-45 and MLO 8200 had smaller evaporation losses. (See Table I, Appendix I).

A general picture of the effects of metals on Oronite 8515 is shown in Table II, Appendix I. The metal specimens showing the greatest change in weight were lead, steel, brass, and bronze respectively. Lead, having a 0.63 milligram per square centimeter weight loss, appeared to be the least compatible with Oronite 8515 simultaneously the fluid showed a -55.7% viscosity change. The blend showed a much smaller evaporation loss in the presence of lead than with all other metals tested. Too, the sample containing lead was the only one to yield a negative change in neutralization number.

The viscosity of the Oronite 8515, after having been tested with metals, had changed from 2 to 3 times as much as it had changed after it had been tested in the absence of metals. One of the most significant facts brought out was that evaporation loss in the tests containing metals was generally less than in those with metals absent.

Table III shows the results obtained when MLO 8200 was tested for oxidation-corrosion both in the presence of and in the absence of metals.

Generally the MLO 8200 had no effect on the metal specimens with the exception of lead, which had a weight loss of 1.27 milligrams per square centimeter, and strong evidence of etching. The evaporation loss of the fluid with metals present was less than with them absent from the test. Silver and vanadium tool steel formed the two exceptions. With these metals present, evaporation loss was 8.73% and 12.55% respectively compared with the 8.60% evaporation loss of the test sample without metal specimens.

The neutralization number of the MLO 8200 increased most in tests in which there were no metals present. There was a striking change in viscosity when lead was present during the test; the viscosity decreased by 65.0%.

The oxidation and corrosion test results involving OS-45 tested with metals are shown in Table IV.

There was a marked weight loss only with the specimens of magnesium, lead, bronze, and steel. The evaporation and neutralization number of the oil with metals present was generally as high as the oxidized oil without metals. Chrome molybdenum steel gave an extremely low change in neutralization number (+0.5) and an evaporation of only 0.63%.

The changes in viscosity were in a general trend with only minor variations; there were two exceptions - chrome plated steel and copper brought about an increase in viscosity while the viscosity decreased with all other metals present.

Tables V through XX show how each individual specimen is affected by and how it affects each of the fluids tested.

Aluminum retained its freshly polished finish, lost no weight, and showed no pitting or etching. It was unaffected by all of the fluids tested with it. It had little or no effect on any of the fluids (See Table V).

Brass was slightly etched and discolored by Oronite 8515 (note the pink color and -0.25 milligram per square inch weight change).

There was very slight evidence of etching with OS-45. MLO 8200 had no apparent affect on brass. None of the fluids showed evidence of having been significantly changed by the presence of brass (Table VI).

Bronze exhibited a significant weight loss only with OS-45. MLO 8200 and Oronite 8515 had abnormally high viscosity changes; nevertheless, evaporation was relatively low (Table VII).

Cast iron showed a 0.17 milligram per square centimeter weight loss. However, there was no evidence of etching in OS-45 whose viscosity changed only -9.1%. Oronite 8515 and MLO 8200 showed no extreme effects (Table VIII).

Chrome molybdenum steel was relatively unchanged by all of the fluids except for discolorations. OS-45's evaporation was extremely low, while the viscosity of MLO 8200 changed an abnormal -30.4% (Table IX).

Chrome plated steel was practically unchanged after the tests; it maintained its shiny, freshly polished surface and exhibited only minor changes in weight. OS-45, the only fluid showing evidence of changing in the presence of chrome plated steel, had an evaporation loss of 15.77% (Table X).

OS-45 had a slight etching effect on copper, leaving it a dull pink surface. Oronite 8515 and the siloxane were, in general, stable with copper (Table XI).

The appearance of copper-beryllium ranged from dull pink to dark brown in the test fluids. There was practically no change in weight in all tests, which accounted for the smooth surface of the specimens. All three fluids had relatively high viscosity changes (Table XII).

Lead appeared to be incompatible with all three of the test fluids. In the 8515 fluid signs of having been pitted along with a considerable weight loss occurred. The fluid itself showed an immense decrease in viscosity. Its neutralization number, however, decreased.

With MLO 8200 lead exhibited an even greater degree of pitting and weight loss, and a more pronounced decrease in viscosity of the fluid resulted.

Lead apparently had little effect on OS-45. However, it caused considerable pitting and weight loss to the lead specimen (Table XIII).

Magnesium had no really adverse effects on any of the fluids; the viscosity of Oronite 8515 and MLO 8200 was relatively high. OS-45 brought about a considerable degree of etching and pitting of the magnesium specimen, resulting in a heavy weight loss (Table XIV).

Monel was unchanged by all the fluids except for slight discoloration by OS-45. Oronite 8515 and the MLO 8200 had a slightly abnormal decrease in viscosity. Generally, monel and the three fluids are compatible (Table XV).

Silver itself was almost unchanged by the test fluids. OS-45 showed a large percentage evaporation. Both OS-45 and Oronite 8515 had a sizeable increase in their neutralization number (Table XVI).

Stainless steel was unaffected by all three fluids. Oronite 8515 had a slightly high neutralization number and a high viscosity change. OS-45 showed only a high neutralization number (Table XVII).

MLO 8200 and steel showed evidence of being compatible. There was only a 0.03 milligram per square centimeter increase in the specimen, while the fluid had only a 7.10% evaporation loss and a 21.2% decrease in viscosity. The steel specimens showed moderate and heavy weight losses in Oronite 8515 and OS-45. Viscosity changes in the latter two fluids were moderately severe (Table XVIII).

Titanium was practically unchanged by the fluids. There was only slight staining on the surfaces of the specimens. Two of the fluids - Oronite 8515 and OS-45 - had slightly high viscosity changes (Table XIX).

Vanadium tool remained almost totally unchanged in the fluids except for the acquisition of very deep purple and blue stains. Viscosity wise, all of the fluids showed evidence of being stable with vanadium tool, but all the fluids had excessive evaporation losses (Table XX).

III. CONCLUSIONS

Silicates and siloxanes change greatly in viscosity and neutralization number during the oxidation-corrosion test, both in the presence of, and in the absence of metals. High evaporation losses also occur. The greatest evaporation loss occurred in Oronite 8515. The silicate and siloxane showed the greatest changes in viscosity and neutralization number.

The diester was affected greatest by lead and silver; Oronite 8515 attacked lead, steel, and brass more than any of the other metals. It can be considered compatible with all of the other metals tested.

The siloxane had a corrosive effect on lead only, causing gross etching and pitting and consequent weight loss. Lead was the only metal tested that had an outstandingly maleffect on the siloxane.

The silicate attacked four metals viciously; they were magnesium, lead, bronze, and steel. Moderately heavy weight losses were noted in copper, cast iron, silver, and chrome molybdenum steel. All other metals were essentially unharmed by the silicate. A neutralization number change of +4.00 or greater occurred in seven tests; involved were aluminum, brass, chrome plated steel, copper, copper-beryllium, silver, and stainless steel. A decrease of 25% or greater in viscosity occurred in four tests - lead, stainless steel, steel, and titanium.

The silicate proved to be incompatible with the greatest number of metals; it caused weight losses ranging from 0.17 to 1.94 milligrams per square centimeter.

The other two fluids proved to be compatible with all metals except lead.

Lead was the only metal that was attacked by all of the fluids tested; too, lead was the only metal which caused significantly noticeable changes in the three fluids.

Aluminum was the only metal among the 16 tested that was totally unchanged, and brought about only minor changes in all three fluids.

With the exception of lead and other minor exceptions, the fluids and metals used in this report may be considered compatible under the conditions set forth.

APPENDIX I

TEST DATA

TABLE I

OXIDATION-CORROSION OF ORONITE 8515, MLO 8200, AND OS-45 WITH NO METALS PRESENT FOR 72 HOURS AT 400°F

Sample	Appearance Before	Appearance After	% Evaporation	Neut. No. Original	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515								
Lot 1	Light Brown	Dark Brown	12.6	0.10	+2.30	8.06	7.12	-11.7
Lot 2	Light Brown	Dark Brown	12.6	0.10	+2.30	8.78	7.75	-11.7
OS-45								
Lot 1	Light Pink	Medium Brown	8.5	0.00	+4.10	3.86	2.99	-22.5
Lot 2	Light Pink	Medium Brown	8.4	0.00	+4.10	3.90	3.03	-22.3
Lot 3	Light Pink	Medium Brown	8.6	0.00	+4.10	3.97	3.07	-22.7
MLO 8200								
Lot 1	Medium Brown	Dark Brown	8.6	0.00	+3.51	10.07	7.69	-23.5
Lot 2	Medium Brown	Dark Brown	8.6	0.00	+3.50	11.58	8.87	-23.4

Note: In all tables viscosities are expressed in centistokes, and neutralization numbers in mg of KOH per 100 ml.

TABLE II

OXIDATION-CORROSION OF ORONITE 8515 WITH METALS (400°F, 72 HOURS)

Specimen	*Specimen Wt. Change	Specimen Appearance	Oil Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Aluminum	0	Shiny	Dark	6.2	3.33	8.78	6.36	-21.8
Lead	-0.63	Fitted Brown	Dark Brown	1.5	-0.10	8.06	3.57	-55.7
Magnesium	-0.08	Light Gray	Dark Brown	10.9	+2.10	8.06	5.77	-28.4
Silver	-0.03	Shiny	Dark Brown	7.77	+7.05	8.06	5.96	-26.1
Titanium	-0.02	Slight Stain	Dark Brown	10.4	+2.15	8.78	6.41	-27.1
Brass	-0.25	Pink Etched	Dark Brown	10.9	+0.60	8.78	6.20	-29.4
Bronze	-0.11	Dark Brown	Dark Brown	4.2	+0.61	8.78	5.77	-34.3
Copper	-0.05	Medium Brown	Dark Brown	4.2	0.00	8.06	6.05	-24.9
Copper-Beryllium	-0.02	Pink-Brown	Dark Brown	2.7	+1.08	8.06	5.49	-31.9
Cast Iron	0	Slight Stain	Dark Brown	10.4	+1.79	8.06	6.34	-21.3
Chrome Moly Steel	-0.01	Light Blue	Dark Brown	9.3	+2.30	8.06	6.14	-23.8
Chrome Plated Steel	0	Shiny	Medium Brown	9.5	+1.79	8.06	6.42	-20.3
Monel	-0.03	Shiny	Dark Brown	4.6	+2.50	8.06	5.63	-30.1
Stainless Steel	-0.02	Shiny	Dark Brown	9.6	+3.50	8.78	5.98	-31.9
Steel	-0.28	Light Brown	Dark Brown	11.5	+0.67	8.78	5.50	-36.4
Vanadium Tool	0	Purple	Dark Brown	11.1	+1.78	8.06	6.17	-23.4

* Specimen weight changes are expressed in milligrams per square centimeter.

TABLE III

OXIDATION-CORROSION OF MLO 8200 WITH METALS (400°F, 72 HOURS)

Specimen	*Specimen Wt. Change	Specimen Appearance	Oil Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Aluminum	0	Shiny	Dark Brown	5.34	+1.02	11.58	7.53	-35.0
Lead	-1.27	Gray Pitted	Medium Brown	3.84	+0.25	11.58	4.05	-65.0
Magnesium	-0.02	Shiny	Medium Brown	5.75	+2.00	10.07	7.45	-26.0
Silver	+0.08	Shiny	Medium Brown	8.73	+3.25	10.07	8.08	-19.8
Titanium	+0.02	Slight Tarnish	Medium Brown	5.03	+2.50	10.07	7.52	-25.3
Brass	-0.01	Dark Brown	Dark Brown	2.83	+1.02	11.58	7.67	-33.8
Bronze	-0.01	Dark Brown	Dark Brown	3.88	+1.27	11.58	7.86	-32.1
Copper	0	Dark Brown	Dark Brown	2.56	+1.02	11.58	8.24	-28.8
Copper-Beryllium	+0.04	Dark Brown	Dark Brown	2.88	+0.50	11.58	8.08	-30.2
Cast Iron	-0.04	Blue-Brown	Medium Brown	7.94	+1.54	10.07	7.07	-29.8
Chrome Moly Steel	+0.02	Dark Blue	Medium Brown	5.47	+0.76	11.58	8.06	-30.4
Chrome Plated Steel	+0.01	Shiny	Medium Brown	7.03	+4.00	10.07	7.65	-24.0
Monel	-0.02	Shiny	Medium Brown	5.11	+1.75	10.07	6.67	-33.8
Stainless Steel	+0.03	Shiny	Medium Brown	5.32	+2.04	10.07	7.41	-26.1
Steel	+0.03	Light Brown	Medium brown	7.10	+1.50	10.07	7.94	-21.2
Vanadium Tool	-0.07	Blue	Medium Brown	12.55	+1.42	10.07	8.32	-17.4

* Specimen weight changes are expressed in milligrams per square centimeter.

TABLE IV

OXIDATION-CORROSION OF OS-45 WITH METALS (400°F, 72 HOURS)

Specimen	*Specimen Wt. Change	Specimen Appearance	Oil Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Aluminum	0	Shiny	Dark Brown	9.97	+5.01	3.86	2.96	-23.3
Lead	-1.23	Shiny Pitted	Dark Brown	7.70	+1.81	3.86	2.78	-28.0
Magnesium	-1.94	Gray	Dark Brown	9.20	+3.72	3.86	3.10	-19.7
Silver	-0.14	Shiny	Dark Brown	11.00	+4.33	3.86	3.21	-16.8
Titanium	-0.03	Slight Stain	Light Brown	9.60	+3.11	3.90	2.62	-32.8
Brass	-0.07	Pink Pitted	Dark Brown	11.27	+4.00	3.86	3.07	-20.5
Bronze	-0.80	Pink Pitted	Dark Brown	9.30	+2.30	3.86	3.16	-18.1
Copper	-0.20	Pink Etched	Dark Brown	9.26	+4.21	3.86	4.16	+7.8
Copper-Beryllium	-0.04	Pink	Dark Brown	7.50	+4.41	3.86	2.90	-24.9
Cast Iron	-0.17	Slight Stain	Dark Brown	10.83	+2.36	3.97	3.61	-9.1
Chrome Moly Steel	-0.12	Gray-Brown	Medium Brown	0.63	+0.50	3.86	3.02	-21.8
Chrome Plated Steel	-0.05	Shiny	Medium Brown	15.77	+5.60	3.97	4.76	+19.9
Monel	-0.04	Gray	Dark Brown	7.45	+2.83	3.86	2.94	-23.8
Stainless Steel	+0.03	Slight Tarnish	Dark Brown	8.90	+4.48	3.86	2.89	-25.1
Steel	-0.55	Gray	Dark Brown	9.30	+1.60	3.90	2.75	-29.5
Vanadium Tool	-0.03	Blue	Dark Brown	11.40	+2.37	3.97	3.20	-19.4

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE V

ALUMINUM VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	0	Shiny	Dark Brown	6.20	+3.33	8.78	6.36	-21.8
MLO 8200	0	Shiny	Dark Brown	5.34	+1.02	11.58	7.53	-35.0
OS-45	0	Shiny	Dark Brown	8.97	+5.01	3.86	2.96	-23.3

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE VI

BRASS VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.25	Pink Etched	Dark Brown	10.90	+0.60	8.78	6.20	-29.4
MLO 8200	-0.01	Dark Brown	Dark Brown	2.83	+1.02	11.58	7.67	-33.8
OS-45	-0.07	Pink Pitted	Dark Brown	11.27	+4.00	3.86	3.07	-20.5

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE VII

BRONZE VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.11	Brown	Dark Brown	4.20	+0.61	8.78	5.77	-34.3
MLO 8200	-0.01	Dark Brown	Dark Brown	3.88	+1.27	11.58	7.81	-32.1
OS-45	-0.80	Pink Etched	Dark Brown	9.30	+2.30	3.86	3.16	-18.1

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE VIII

CAST IRON VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	0	Slight Stain	Dark Brown	10.30	+1.79	8.06	6.34	-21.3
MLO 8200	-0.04	Blue-Brown	Medium Brown	7.93	+1.54	10.07	7.07	-29.8
OS-45	-0.17	Slight Stain	Dark Brown	10.83	+2.36	3.97	3.61	-9.1

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE IX

CHROME MOLYBDENUM STEEL VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.01	Light Blue	Dark Brown	9.30	+2.30	8.06	6.14	-23.8
MLO 8200	+0.02	Dark Blue	Medium Brown	5.47	+0.76	11.58	8.06	-30.4
OS-45	-0.12	Gray-Brown	Medium Brown	0.63	+0.50	3.86	3.02	-21.8

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE X

CHROME PLATED STEEL VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	0	Shiny	Medium Brown	9.50	+1.79	8.06	6.42	-20.3
MLO 8200	+0.01	Shiny	Medium Brown	7.03	+4.00	10.07	7.65	-24.0
OS-45	-0.05	Shiny	Medium Brown	15.77	+5.60	3.97	4.76	+19.9

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XI

COPPER VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.05	Medium Brown	Dark Brown	4.20	0	8.06	6.05	-24.9
MLO 8200	0	Dark Brown	Dark Brown	2.56	+1.02	11.58	8.24	-28.8
OS-45	-0.20	Pink Etched	Dark Brown	9.26	+4.21	3.86	4.16	+7.8

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XII

COPPER-BERYLLIUM VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.02	Pink-Brown	Dark Brown	2.70	+1.08	8.06	5.49	-31.9
MLO 8200	+0.04	Dark Brown	Dark Brown	2.88	+0.50	11.58	8.08	-30.2
OS-45	-0.04	Pink	Dark Brown	7.50	+4.41	3.86	2.90	-24.9

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XIII

LEAD VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oromite 8515	-0.63	Pitted	Dark Brown	1.50	-0.10	8.06	3.57	-55.7
MLO 8200	-1.27	Pitted	Medium Brown	3.84	+0.25	11.58	4.05	-65.0
OS-45	-1.23	Pitted Shiny	Dark Brown	7.70	+1.81	3.86	2.78	-28.0

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XIV

MAGNESIUM VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.08	Light Gray	Dark Brown	10.90	+2.10	8.06	5.77	-28.4
MLO 8200	-0.02	Shiny	Medium Brown	5.75	+2.00	10.07	7.45	-26.0
OS-45	-1.94	Gray Etched	Dark Brown	9.20	+3.72	3.86	3.10	-19.7

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XV

MONEL VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.03	Shiny	Dark Brown	4.60	+2.50	8.06	5.63	-30.1
MLO 8200	-0.02	Shiny	Medium Brown	5.11	+1.75	10.07	6.67	-33.8
OS-45	-0.04	Gray	Dark Brown	7.45	+2.83	3.86	2.94	-23.8

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XVI

SILVER VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.03	Shiny	Dark Brown	7.70	+7.05	8.06	5.96	-26.1
MLO 8200	+0.08	Shiny	Medium Brown	8.73	+3.25	10.07	8.08	-19.8
OS-45	-0.14	Shiny	Dark Brown	11.00	+4.33	3.86	3.21	-16.8

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XVII

STAINLESS STEEL VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.02	Shiny	Dark Brown	9.60	+3.50	8.78	5.98	-31.9
MLO 8200	+0.03	Shiny	Medium Brown	5.32	+2.04	10.07	7.41	-26.4
OS-45	+0.03	Slight Stain	Dark Brown	8.90	+4.48	3.86	2.89	-25.1

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XVIII

STEEL VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.28	Light Brown	Dark Brown	11.50	+0.67	8.78	5.58	-36.4
MLO 8200	+0.03	Light Brown	Medium Brown	7.10	+1.50	10.07	7.94	-21.2
OS-45	-0.55	Gray	Dark Brown	9.30	+1.60	3.90	2.75	-29.5

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XIX

TITANIUM VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	-0.02	Slight Stain	Dark Brown	10.40	+2.15	8.78	6.41	-27.1
MLO 8200	+0.02	Very Slight Stain	Medium Brown	5.03	+2.50	10.07	7.52	-25.3
OS-45	-0.03	Slight Stain	Light Brown	9.60	+3.11	3.90	2.62	-32.8

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XX

VANADIUM TOOL VERSUS FLUIDS AT 400°F FOR 72 HOURS

Oil Sample	*Specimen Wt. Change	Specimen Appearance	Sample Appearance	% Evaporation	Neut. No. Change	Viscosity Original	Viscosity After	Viscosity % Change
Oronite 8515	0	Purple	Dark Brown	11.10	+1.78	8.06	6.17	-23.4
MLO 8200	-0.07	Blue	Medium Brown	12.55	+1.42	10.07	8.32	-17.4
OS-45	-0.03	Blue	Dark Brown	11.40	+4.10	3.86	2.99	-22.5

*Specimen weight changes are expressed in milligrams per square centimeter.

TABLE XXI

OXIDATION-CORROSION TEST (72 hrs., 400°F)

	Oronite 8515	OS-45	MLO 8200
Susceptible Metals			
Brass	-0.25	-0.07	-0.01
Lead	-0.63	-1.23	-1.27
Steel	-0.28	-0.55	+0.03
Magnesium	-0.08	-1.94	-0.02
Non-Susceptible Metals			
Aluminum	0.00	0.00	0.00
Cast Iron	0.00	-0.04	-0.17
Vanadium Tool	0.00	-0.07	-0.03
Chrome Molybdenum Steel	-0.01	+0.02	-0.12
Stainless Steel	-0.02	+0.03	+0.03
Titanium	-0.02	+0.02	-0.03
Chrome Plated Steel	0.00	-0.01	-0.05
Monel	-0.03	-0.02	-0.04

TABLE XXII

METALS USED IN FLUID DETERIORIATION STUDIES

Specimen	Specification
Aluminum	24S-T3
Brass	QQ-B-611
Bronze	QQ-B-/46
Cast Iron	Meehanite, Type GA
Chrome Molybdenum Steel	AA-QQ-S0685
Chrome Plated Steel	QQ-C-320
Copper	C-511
Copper-Beryllium	QQ-C-530
Lead	Comm. Purity
Magnesium	FS-10-064
Monel	
Silver	Electrode
Stainless Steel	188-302
Steel	1005
Titanium	RC-79
Vanadium Tool, M-10	QQ-S-00779, Grade 3