14116

05MV-49

Corrosion Preventing Characteristics of Military Hydraulic Fluids

Jill M. Tebbe, Luis A. Villahermosa, and Ralph B. Mowery
US ARMY RDECOM

ABSTRACT

Hydraulic systems are widely used in a variety of military applications such as aircraft, ground vehicles, and weapon systems. The impact of corrosion on hydraulic systems and its components has been identified but is often not recognized[1]. Project collaboration between the U.S. Army Research Lab, U.S. Army Corrosion Office, and Concurrent Technologies Corporation identified the most critical corrosion issues found in hydraulic systems to be hoses, hose end fittings, actuator arms, pistons, cylinders, and rams.

INTRODUCTION

Corrosion, by definition, is the deterioration of a metallic surface by chemical or electrochemical action. Common causes of metal corrosion range from humid air entering a hydraulic system and its subsequent condensation, to the chemistry of the hydraulic fluid, to the interaction of metals with different electrochemical potentials. It is important to note that corrosion and rusting are not interchangeable terms. Corrosion often results in a weight loss and surface pitting which exposes the metal. Thus, the exposed metal can react with water and air to form iron oxides (rust).

There has been some discussion and disagreement among the various Military Service's Subject Matter Experts (SME) about the need for corrosion inhibited hydraulic fluids. It has been shown that corrosion preservatives can cause sticking of critical servo and poppet valves in some aviation systems. Therefore, hydraulic fluids containing corrosion preventatives have been prohibited in aviation hydraulic systems by the US Air Force, US Naval Aviation and in US Army Aviation. However, given the relatively dirty operating environment of Army ground equipment, corrosion inhibited fluids are considered necessary.

To prevent corrosion in hydraulic systems, the Army has specified the use of hydraulic fluids with corrosion preventing and/or rust inhibiting characteristics. The most common corrosion inhibitor currently used in hydraulic fluids is barium dinonyl napthalene sulfonate (BDNS). Corrosion inhibitors typically used in engine oils are unavailable because of inclusion in the proprietary additive package.

Currently, the Army uses two different types of hydraulic fluid and in many instances; engine oil is used as a hydraulic fluid in Army vehicles. To verify the relative corrosion protection performance of the various fluids, the Fuels and Lubricants Technology Team (FLTT) of U.S. Army Tank Automotive Research Development and Engineering Center (TARDEC) initiated an investigation to compare the corrosion preventing characteristics of military hydraulic fluids and engine oils based on standard hydraulic fluid corrosion tests. It is important to determine which fluids will protect the Army's equipment against corrosion and rust since the other services do not promote the use of corrosion inhibiting additives. Additionally, corrosion protection is imperative for the Army's equipment because of the challenging and varied operational environments in which the equipment must operate.

LABORATORY INVESTIGATION

SAMPLE IDENTIFICATION

Five military hydraulic fluids and five engine oils of varying types and grades were chosen to be included in this evaluation:

Hydraulic Fluids

- MIL-PRF-5606 – Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance (Air Force)
- MIL-PRF-6083 – Hydraulic Fluid, Petroleum Base, for Preservation and Operation (Army)
- MIL-PRF-46170 – Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base (Army)
- MIL-PRF-83282 – Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base (Navy)
- MIL-PRF-87257 – Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile (Air Force)

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
04 JAN 2005	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Corrosion Preventing Characteristics of Military Hydraulic Fluids	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Jill M. Tebbe; Luis A. Villahermosa; Ralph B. Mowery	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
USA TACOM 6501 E 11 Mile Road Warren, MI 48397-5000	**14116**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	TACOM TARDEC
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Engine Oils

- MIL-PRF-2104 -- Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service (10W and 15W40)
- MIL-PRF-21260 – Lubricating Oil, Internal Combustion Engine, Preservative Break-In (10W and 15W40)

MIL-PRF-46167 – Lubricating Oil, Internal Combustion Engine, Artic (0W30) was to be included in this evaluation. Unfortunately, the sample was not available at the time of testing. Further investigation related to the corrosive properties of hydraulic fluids and engine oils will include MIL-PRF-46167.

CORROSION TESTING PARAMETERS

At time of publication, three corrosion tests have been performed on the selected hydraulic fluid and engine oils samples per American Society for Testing and Materials (ASTM) methods. The three corrosion tests include Rust Protection by Metal Preservatives in the Humidity Cabinet (ASTM D 1748)[2], Corrosiveness of Lubricating Fluid to Bimetallic Couple (ASTM D 6547)[3], and Rust Preventing Characteristics of Inhibited Oil (ASTM D 665)[4]. While the three tests evaluate the corrosion preventing characteristics of the respective fluids, each test offers a different corrosive environment.

Presently, the Corrosiveness and Oxidation Stability of Hydraulic Oils, Aircraft Turbine Engine Lubricants, and Other Highly Refined Oils (ASTM D 4636)[5] has not been completed. This test will examine the sample fluids oxidation and corrosive degradation as well as the interaction with various metals. These metals will include copper, steel, aluminum, magnesium, and cadmium. FLTT plans to continue testing in the near future.

Rust Protection by Metal Preservatives in the Humidity Cabinet (ASTM D 1748)

The rust protection test exposes steel test panels which have been polished, numbered, cleaned, dipped in sample fluid that corresponds to the number on the panel, and allowed to drain for a specified number of hours so the excess sample fluid can drip off. The panels are placed in a humidity cabinet for a minimum of 100 hours at 49°C.

Three test panels were prepared in accordance with ASTM D 1748 for each fluid selected for inclusion in this evaluation. The method stipulates the evaluation of three sand blasted and three aluminum oxide polished panels for each fluid. However, at the time of testing, the panels could not be sandblasted. Therefore, only aluminum oxide polished panels were evaluated.

Due to the large number of fluids (samples) to be evaluated, the test was completed in two stages. Panels treated with MIL-PRF-5606, MIL-PRF-6083, MIL-PRF-46170, MIL-PRF-83282, and MIL-PRF-87257 were tested first. The panels were allowed to remain in the humid environment for approximately 113 hours. At 96 hours, MIL-PRF-6083 and MIL-PRF-46170 did not have any signs of corrosive attack while MIL-PRF-5606, MIL-PRF-83282, and MIL-PRF-87257 were completely covered with corrosion. The panels were re-evaluated and removed from the cabinet at 113 hours. The examination criteria as denoted in ASTM D 1748 defines a panel as passing if the surface does not contain more than three spots of rust, none of which can be larger than 1mm in diameter.

The second set of testing included 10W MIL-PRF-2104, 15W40 MIL-PRF-2104, 10W MIL-PRF-21260, 15W40, and MIL-PRF-21260. The panels remained in the humidity cabinet for 116 hours. The panels were checked after 22 hours; a thick, white, milky-type residue appeared on the panels coated with MIL-PRF-21260. The remaining samples, 10W MIL-PRF-2104 and 15W40 MIL-PRF-2104 had spots on the edges, top, and face of the panels. As time progressed, the corrosive attack worsened. Table 1 lists the final results of the humidity cabinet evaluation.

Table 1: Rust Protection Results.

Sample	Pass	Fail
MIL-PRF-5606		X
MIL-PRF-6083	X	
MIL-PRF-46170	X	
MIL-PRF-83282		X
MIL-PRF-87257		X
10W MIL-PRF-2104		X
15W40 MIL-PRF-2104		X
10W MIL-PRF-21260	X	
15W40 MIL-PRF-21260	X	

Based solely upon the results from this test, the likelihood of corrosive attack is increased if non-ARMY hydraulic fluids as well as MIL-PRF-2104 and MIL-PRF-46167 engine oils are used in corrosion favorable environments.

The following figures exemplify the amount of corrosion that is likely to occur in hydraulic systems which operate in high humidity environments. Figure 1 displays the corrosive attack experienced by the steel panel treated with MIL-PRF-87257 (Air Force) after 113 hours in the

humidity cabinet. Similar results were experienced for MIL-PRF-5606.

Figure 1: MIL-PRF-87257

Figure 2 displays the corrosion attack for MIL-PRF-2104 10W engine oil after 116 hours in the humidity cabinet. The severity of attack is a great deal less than that of the hydraulic fluids that do not contain corrosion inhibitors; as was expected since the engine oils do contain corrosion inhibitors. Unfortunately, the corrosion inhibitors of the engine oils do not meet the standards for Army hydraulic fluid corrosion protection.

Figure 2: MIL-PRF-2104

Figure 3 displays the corrosive attack (or lack there of) of the steel panels after treated with MIL-PRF-46170. The panels were clean and free from any attack after 113 hours in the humidity cabinet. MIL-PRF-6083 results were similar to MIL-PRF-46170.

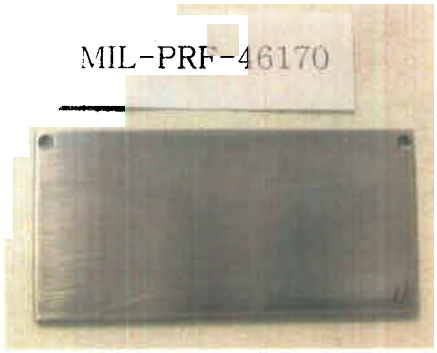

Figure 3: MIL-PRF-46170

Figure 4 presents the three steel panels with varying degrees of corrosion together.

Figure 4: Corrosion of steel panels.

Corrosiveness of Lubricating Fluid to Bimetallic Couple (ASTM D 6547)

The corrosiveness test examines the corrosive characteristics of the sample fluid when exposed to a steel and brass fitting. The sample fluid (2 drops) is placed on the cleaned and polished steel disks. An acid washed brass clip is then placed on the steel disk directly over the sample fluid. This galvanic couple is then placed in a 50% relative humidity environment for 10 days. Figure 5 illustrates the galvanic couple assembly.

Figure 5: Illustration of galvanic couple assembly.

Three steel disks and three brass clips were prepared for each test fluid in accordance with ASTM D 6547. Once the discs and clips were assembled, they were placed into a desiccator containing saturated aqueous calcium nitrate tetrahydrate which produces 50% relative humidity. At the conclusion of the 10 day test period, the assemblies were taken apart and examined for signs of discoloration, etching, pitting, or other signs of corrosion. Table 2 lists the final results of the galvanic corrosion test.

Table 2: Corrosiveness of Lubricating Fluid to Bimetallic Couple Results.

Sample	Pass	Fail
MIL-PRF-5606	X	
MIL-PRF-6083	X	
MIL-PRF-46170	X	
MIL-PRF-83282	X	
MIL-PRF-87257	X	
10W MIL-PRF-2104	X	
15W40 MIL-PRF-2104	X	
10W MIL-PRF-21260	X	
15W40 MIL-PRF-21260	X	

Based solely upon the test results from this test, there appears to be no increased risk of corrosive attack from the interaction of metals, such as steel and brass, with the sample fluids.

Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water (ASTM D 665)

This test procedure takes into account the rust preventing characteristics of a sample fluid on ferrous materials should the sample fluid become mixed with water. Table 3 lists the results from the rust-preventing characteristics of inhibited oils in the presence of water. Two steel test rods were prepared according to ASTM D 665 for each test fluid. ASTM D 665 provides two test procedures, Procedure A is for distilled water and Procedure B is for synthetic sea water. FLTT chose to use Procedure A as Army equipment is not normally subject to sea water. The test was run for 4 hours at 60°C.

Table 3: Rust-preventing characteristics of inhibited oils in the presence of water results.

Sample	Pass	Fail
MIL-PRF-5606	X	
MIL-PRF-6083	X	
MIL-PRF-46170	X	
MIL-PRF-83282	X	
MIL-PRF-87257	X	
10W MIL-PRF-2104	X	
15W40 MIL-PRF-2104	X	
10W MIL-PRF-21260	X	
15W40 MIL-PRF-21260	X	
Distilled Water		X

Based solely on the test results of this test, there is no increased risk of corrosive attack on the system relative to the fluid.

CONCLUSION

The preliminary test results show all of hydraulic fluids and engine oils are capable of preventing corrosive attack against steel and brass couples (under certain conditions) as well as ferrous materials exposed to fluids that have become mixed with water. However, high humidity situations often encountered by Army equipment presented a challenge for some of the test fluids. MIL-PRF-6083 and MIL-PRF-46170 (Army hydraulic fluids) provide better corrosion protection than the other military hydraulic fluids as well as the some of the engine oils.

ACKNOWLEDGMENTS

The authors would like to acknowledge Cary Xiong for her dedication and professionalism in conducting the laboratory evaluation.

REFERENCES

1. Mason, Robert B. (2004). Corrosion of Hydraulics. Retrieved April 28, 2004 from http://www.armycorrosion.com/past_summits/summit2004/presentations.cfm.
2. ASTM D 1748-02, *Standard Test Method for Rust Protection by Metal Preservatives in the Humidity Cabinet*, American Society for Testing and Materials, West Conshohocken, PA, November 2002.
3. ASTM D 6547-00, *Standard Test Method for Corrosiveness of Lubricating Fluid to Bimetallic Couple*, American Society for Testing and Materials, West Conshohocken, PA, April 2000.
4. ASMT D 665-03, *Standard Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water*, American Society for Testing and Materials, West Conshohocken, PA, November 2003.
5. ASTM D 4636-99(2004)e1, *Standard Test Method for Corrosiveness and Oxidation Stability of Hydraulic Oils, Aircraft Turbine Engine Lubricants, and Other Highly Refined Oils*, American Society for Testing and Materials, West Conshohocken, PA, November 2003.