

AD-A205 635

EVALUATION OF POTENTIAL ENGINE OILS FOR USE IN ADMINISTRATIVE VEHICLES OPERATING ON M85 METHANOL FUEL

**INTERIM REPORT
BFLRF No. 260**

By

B.B. Baber

**Belvoir Fuels and Lubricants Research Facility (SwRI)
Southwest Research Institute
San Antonio, Texas**

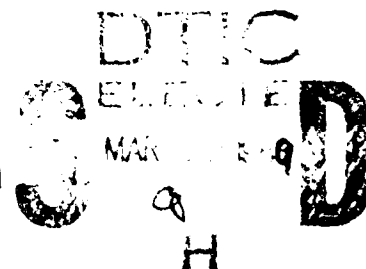
Under Contract to

**U.S. Army Belvoir Research, Development
and Engineering Center
Materials, Fuels and Lubricants Laboratory
Fort Belvoir, Virginia**

Contract No. DAAK70-87-C-0043

Approved for public release; distribution unlimited

December 1988



Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Trade names cited in this report do not constitute an official endorsement or approval of the use of such commercial hardware or software.

DTIC Availability Notice

Qualified requestors may obtain copies of this report from the Defense Technical Information Center, Cameron Station, Alexandria, Virginia 22314.

Disposition Instructions

Destroy this report when no longer needed. Do not return it to the originator.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified			1b. RESTRICTIVE MARKINGS None	
2a. SECURITY CLASSIFICATION AUTHORITY N/A			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A				
4. PERFORMING ORGANIZATION REPORT NUMBER(S) BFLRF No. 260			5. MONITORING ORGANIZATION REPORT NUMBER(S)	
6a. NAME OF PERFORMING ORGANIZATION Belvoir Fuels and Lubricants Research Facility (SwRI)		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS (City, State, and ZIP Code) Southwest Research Institute San Antonio, Texas 78234			7b. ADDRESS (City, State, and ZIP Code)	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Belvoir Research, Development and Engineering Center		8b. OFFICE SYMBOL (If applicable) STRBE-VF	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAAK70-85-C-0007; DAAK70-87-C-0043, WD 6	
8c. ADDRESS (City, State, and ZIP Code) Fort Belvoir, VA 22060-5606			10. SOURCE OF FUNDING NUMBERS	
			PROGRAM ELEMENT NO. 63001D	PROJECT NO. IL263001 D150
			TASK NO. 07(3)	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) Evaluation of Potential Engine Oils for Use in Administrative Vehicles Operating on M85 Methanol Fuel (U)				
12. PERSONAL AUTHOR(S) Baber, Burl B.				
13a. TYPE OF REPORT Interim		13b. TIME COVERED FROM July 85 TO Nov 88		14. DATE OF REPORT (Year, Month, Day) 1988 December
15. PAGE COUNT 98				
16. SUPPLEMENTARY NOTATION Appendices A and B have not been included in all copies of this report. Complete reports, including the Appendices, may be obtained from the Defense Technical Information Center.				
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB-GROUP	Lubricating Oils Methanol Fuel Test Methods	
			Lubricants M85 Methanol	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)				
Six lubricants, comprised of various lubricant formulations, were evaluated to determine which potential engine oil would provide more wear and/or corrosion protection for administrative-type vehicle engines operating on M85 methanol fuel. The six lubricants were first evaluated using a modified ASTM V-D cyclic test procedure. The three best oils were then evaluated in a second test series using steady-state/cold test conditions. These three oils provided the same order of protection from wear and corrosion in the steady-state/cold test conditions as they provided using the cyclic test conditions. All three lubricants coded AL-15427-L, AL-16155-L, and AL-15610-L are recommended for use in administrative-type vehicle engines when operating on M85 methanol fuel.				
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT X UNCLASSIFIED/UNLIMITED SAME AS RPT. DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL T.C. Bowen			22b. TELEPHONE (Include Area Code) (703) 664-3576	22c. OFFICE SYMBOL STRBE-VF

EXECUTIVE SUMMARY

Problems and Objectives: The U.S. Army Methanol-Fueled Administrative Vehicle Demonstration Program was conducted as the result of a request by Vice President Bush to Secretary Weinberger and legislative directives contained in FY85 Department of Energy Authorization bill, Section 202, PL 98-525. The purpose of the demonstration program was to establish the feasibility of using methanol as an alternative fuel for administrative-type vehicles. The phase of the program discussed in this report was concerned with the evaluation of various lubricant formulations for potential engine oils that would provide more wear and/or corrosion protection needed for engines operating on M85 methanol fuel than is currently afforded by existing MIL-L-46152 oils.

Importance of Project: The use of methanol fuel in engines designed for gasoline results in increased wear and corrosion to vital engine parts. One method of decreasing this wear and corrosion is the use of a lubricant formulated to offset the deleterious actions of the fuel. This program evaluated several possible lubricants to determine the best lubricant to use in any future Government programs related to M85 methanol-fueled engines.

Technical Approach: A number of organizations were invited to submit oils that they believed would provide the added protection required for M85-fueled engines. As a result of the requests, six oils were evaluated in an initial test series using modified ASTM V-D cyclic test conditions. The three best oils were determined, based upon wear metal debris in the used oil samples. A second test series was conducted on these three selected oils using steady-state/cold test conditions. Under these conditions, test variables such as decline in engine response and other factors can increase the difficulty in differentiating among test results. Therefore, "bracketing" the test runs with reference runs was performed in both test matrices. This bracketing procedure allows for normalization of the test results to a common baseline.

Accomplishments: Based upon the data obtained in this phase of the Army Methanol-Fueled Administrative Vehicle Demonstration Program, three lubricants were recommended for use in administrative-type methanol-fueled vehicle engines. These three lubricants provided the same order of protection from wear and corrosion in the steady-state/cold test conditions as they provided using the cyclic test conditions.

Military Impact: In the event of a gasoline shortage, an alternative fuel must be utilized by the military's fleet of spark-ignition engine vehicles. The most likely candidate to stretch out the gasoline supply is a methanol/gasoline blend. However, the use of this blend, M85, may result in increased wear, corrosion, and other maintenance problems for the military's administrative vehicles. To help offset these maintenance problems, resulting in increased downtime and logistics burden, a specially formulated lubricant may be used in the vehicles. The most likely candidates were evaluated, and recommendations were made as to the three best methanol-resistant lubricants to use in any future Government programs related to M85 methanol-fueled engines.

A-1

FOREWORD

This work was conducted at the Belvoir Fuels and Lubricants Research Facility (BFLRF) located at Southwest Research Institute (SwRI), San Antonio, TX under Contract Nos. DAAK70-85-C-0007 and DAAK70-87-C-0043 during the period July 1985 through November 1988. The work was funded by the U.S. Army Belvoir Research, Development and Engineering Center (Belvoir RDE Center), Ft. Belvoir, VA, with Messrs. F.W. Schaekel and T.C. Bowen (STRBE-VF), as the contracting officer's representatives and Mr. M.E. LePera, chief of Fuels and Lubricants Division (STRBE-VF), as the project technical monitor.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
I. INTRODUCTION AND BACKGROUND	1
II. PROGRAM OBJECTIVE	i
III. EXPERIMENTAL APPROACH	1
A. Test Engine	2
B. Test Fuel	3
C. Test Procedures	4
D. Candidate Oils	5
IV. DISCUSSION OF RESULTS	6
A. V-D Cyclic Test Conditions	6
B. Steady-State/Cold Test Conditions	8
V. CONCLUSIONS	10
VI. RECOMMENDATIONS	12
APPENDICES	
A. Individual Summary Data Sheets for Each Test Conducted Using the Modified V-D (Cyclic) Test Conditions	13
B. Individual Summary Data Sheets for Each Test Conducted Using the Steady-State (Cold) Test Conditions)	69

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Page</u>
1 White Emulsion-Type Sludge in Valve Cover Before and After Flush for Test No. 20	11

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1 V-D Cyclic Test Conditions - 24 Hours	4
2 Steady-State/Cold Test Conditions - 24 Hours	4
3 Analysis of Test Oils	5
4 Summary of the Total Net Used Oil Wear Metal Data for Each Test Conducted in Test Matrix 1	7
5 Average Normalized Percent of Reference Oil	7
6 Summary of the Total Net Used Oil Wear Metal Data for Each Test Conducted in Test Matrix 2	8
7 Average Normalized Percent of Reference Oil	9
8 Sludge Ratings	10

I. INTRODUCTION AND BACKGROUND

The U.S. Army Methanol-Fueled Administrative Vehicle Demonstration Program was conducted as the result of a request by Vice President Bush to Secretary Weinberger and legislative directives contained in FY85 DOE Authorization bill, Section 202, PL 98-525. The purpose of the demonstration program was to establish the feasibility of using methanol as an alternative fuel for administrative-type vehicles.

One phase of this program was concerned with the evaluation of various lubricant formulations for potential engine oils that would provide more wear and/or corrosion protection needed for engines operating on M85 methanol fuel than is currently afforded by existing MIL-L-46152 oils.

II. PROGRAM OBJECTIVE

The results from this phase of the program will be used to recommend an oil(s) that appears to be the most suitable for inclusion in any future Government programs related to M85 methanol-fueled engines.

III. EXPERIMENTAL APPROACH

A letter was distributed in mid-1985 to twelve organizations known to have a "methanol lubricant," or that had shown earlier interests in developing a suitable formulation. The organizations were invited to submit an oil(s) that they believed would provide the added protection required for M85-fueled engines. A total of five special lubricants were submitted by the invited organizations. In addition, one fully formulated oil for use in gasoline-fueled vehicles was selected by Belvoir Fuels and Lubricants Research Facility (BFLRF) at Southwest Research Institute (SwRI) and was included in the program. The six oils were evaluated in an initial test series using modified ASTM V-D cyclic test conditions. The three best oils were determined, based upon wear metal debris in the used oil samples. A second test series was conducted on these selected oils using steady-state/cold test conditions.

A. Test Engine

A new Ford 2.3L, four-cylinder overhead cam engine was used for each test matrix. The engines were built according to ASTM Sequence V-D specifications except that ring gaps were adjusted for this methanol application and a modified electroless nickel-plated carburetor is used. Piston rings from an ASTM Sequence V-D parts kit were used (top ring, molybdenum and second ring, cast iron).

1. Engine Test Stand Configuration

The test engine was mounted on an SwRI test stand that was configured to conduct Sequence V-D tests. The exceptions to the standard Sequence V-D procedure were as follows:

- An oil filter was installed for all test work.
- A special oil changing and flushing system was used for this technique. Basically, it is a system that can efficiently change the oil consistently and save much time. This system is described in more detail in the next subsection.
- A carburetor was specially modified to accommodate the methanol fuel. These modifications included main jet and air bleed changes to provide near stoichiometric air/fuel ratios.
- The engine test stand was plumbed to both methanol and Phillips "J" fuel with provisions for quick changeovers.

2. Oil Flush/Changes (Flying Flush)

A special oil changing and flushing procedure that has proven to be effective and consistent was used in this program. The system provides for performing oil changes/flushes with the engine running. A special detergent oil, SwRI oil code LO-12119, was used as a part of each test to remove effects of previous oils. Details of the flushing technique are included in the following listing:

<u>Time, hr:min</u>	<u>Action</u>
0:00	● Shut engine down ● Determine oil level ● Change to "J" carburetor ● Change to "J" fuel ● Purge fuel line ● Change fuel filter ● Change oil filter
0:30	● Start engine ● Flush three times with flush oil ● After the third flush, run engine under Sequence V-D Stage II test conditions
2:00	● Shut engine down ● Change to methanol carburetor ● Change to methanol fuel ● Purge fuel line ● Change fuel filter ● Remove oil filter ● Install oil filter cap
2:30	● Start engine ● Flush three times with candidate oil
2:50	● Shut engine down ● Remove oil filter cap ● Install new oil filter filled with candidate oil
2:55	● Start engine
3:00	● Start test

B. Test Fuel

The test fuel was commercial grade, 200 proof methanol plus 15 vol% Phillips "J" gasoline (Batch 28). Water, chlorine, and sodium content of the fuel were determined. SwRI methanol code AIS-22 was used. The analysis results are shown in the following listing:

AIS-SwRI-M-D-04-03-84

Sample A: 0.047 wt% H₂O

Sample B: 0.078 wt% H₂O

Sample C: 0.059 wt% H₂O

Methanols were mixed, blended with Phillips "J" fuel, and placed into a holding tank. Composite samples were tested for sodium and chlorine, with the following results:

<u>Sample</u>	<u>Sodium, ppm</u>	<u>Chlorine, wt%</u>
05-14-87	3	0.005
06-10-87	2	0.017

C. Test Procedures

After reviewing the literature and the candidate oil test data provided by the suppliers of the candidate oils, it was apparent that two general types of laboratory engine wear screener test procedures (cyclic and steady state) have been used for oil evaluations as shown in TABLES 1 and 2.

TABLE 1. V-D Cyclic Test Conditions - 24 Hours

<u>Stage</u>	<u>Rpm</u>	<u>Bhp</u>	<u>Oil Temp, °F (°C)</u>	<u>Coolant Temp, °F (°C)</u>	<u>Time, minutes per cycle</u>
I	2500	33.5	175 (79)	135 (57)	120
II	2500	33.5	187 (86)	155 (68)	75
III	1500	1.0	120 (49)	120 (49)	45

TABLE 2. Steady-State/Cold Test Conditions - 24 Hours

<u>Rpm</u>	<u>Bhp</u>	<u>Oil Temp, °F (°C)</u>	<u>Coolant Temp, °F (°C)</u>
2500	33.5	125 (52)	115 (46)

Two test matrices were conducted. The first test matrix used the cyclic test conditions given in TABLE 1 and included all six test oils involved in the program. The second test

matrix, using the steady-state/cold test conditions given in TABLE 2, was conducted using the three best oils as determined from the first test matrix. Since test variables such as decline in engine response and other factors can increase the difficulty in differentiating among test results, "bracketing" test runs with reference runs (using one of the candidate oils as the reference oil) was included in both test matrices. This bracketing procedure allows for normalization of the test results to a common baseline.

D. Candidate Oils

The following six candidate oils were received for evaluation in this program. Analysis results of the lubricants are shown in TABLE 3.

TABLE 3. Analysis of Test Oils

<u>BFLRF Oil Code</u>	<u>Viscosity at 40°C, cSt, D 445</u>	<u>Viscosity at 100°C, cSt, D 445</u>	<u>VI, D 2270</u>	<u>TAN, D 664</u>	<u>TBN, D 664</u>
AL-14965-L	136.6	14.0	100	2.68	10.5
AL-14966-L	137.8	14.2	100	2.86	10.4
AL-15427-L	72.0	11.1	145	3.42	7.4
AL-15610-L	118.2	14.1	119	3.49	6.6
AL-16155-L	82.7*	10.4	104	2.49	15.0
AL-16156-L	78.8	10.0	107	2.45	14.5

* This candidate oil was used as the baseline "reference" oil in Test Matrices 1 and 2 to facilitate normalization of the test results. SwRI oil code LO-12119 was used as the flush oil for all tests.

For each test, a new oil sample as well as used oil samples were taken after each 8-, 16-, 20-, and 24-hr operating period. Samples were analyzed for the following metals by Inductively Coupled Plasma (ICP) analyses:

- Iron (Fe)
- Chromium (Cr)
- Aluminum (Al)
- Copper (Cu)

- Tin (Sn)
- Lead (Pb)
- Silicon (Si)
- Molybdenum (Mo)

The wear data from the intermediate samples taken after 16-, 18-, and 20-hr operating periods were reviewed to ensure that no catastrophic wear was occurring during each test. Data from the 24-hr sample were used to determine the total net wear obtained for each test.

IV. DISCUSSION OF RESULTS

A. V-D Cyclic Test Conditions

TABLE 4 presents a summary of the wear metal data obtained for the Test Matrix 1 using the modified V-D cyclic test conditions. All six candidate oils were included in Test Matrix 1. Individual operational summary data sheets and metal determinations from the used oil samples for each test in Test Matrix 1 are included in Appendix A. The total net used oil wear metal data for each are summarized in TABLE 4. The net used oil wear metal data used in this report are the sums of the 24-hr sample wear metals in ppm less the sums of the new sample wear metals for each individual test. TABLE 4 also presents the normalized reference oil comparison data and the normalized percent of reference oil for each test.

Even though silicon was included in each of the individual used oil analyses, it was not included in the comparisons of new and used oil samples. The silicon appears to be part of an additive package for two of the candidate lubricants and, therefore, was not considered as a wear metal element. The remaining seven wear metals were included in the wear metal comparisons presented in TABLE 4.

The average normalized percents of reference oil were calculated for the six candidate oils and are presented in TABLE 5 in the order of protection from wear and corrosion provided by the six individual oils. Oil AL-15427-L generated the least amount of net total wear metals, thereby providing the best protection against wear and corrosion when evaluated using the V-D cyclic test conditions for 24 hours. The reference oil, AL-

**TABLE 4. Summary of the Total Net Used Oil Wear Metal Data for
Each Test Conducted in Test Matrix 1*
(Cyclic Test Conditions)**

<u>Test Sequence No.</u>	<u>BFLRF Oil Code</u>	<u>Total Net, Wear Metal, ppm</u>	<u>Reference Oil Comparison Data</u>	<u>Normalized Percent of Reference Oil</u>
1(a)	AL-16155-L	19	--	--
2	AL-16155-L(b)	116	116.0	100.0
3	AL-14965-L	134	116.3	115.2
4	AL-15427-L	107	116.6	91.8
5	AL-16155-L(b)	117	117.0	100.0
6	AL-16156-L	150	115.8	129.5
7	AL-15610-L	144	114.5	125.8
8	AL-14965-L	253	113.2	223.5
9	AL-16155-L(b)	112	112.0	100.0
10	AL-15427-L	82	100.5	81.6
11	AL-15610-L	98	89.0	110.1
12	AL-16156-L	104	77.5	134.2
13	AL-16155-L(b)	66	66.0	100.0
14	AL-14965-L	165	63.0	261.9
15	AL-15610-L	82	60.0	136.7
16	AL-14966-L	98	57.0	171.9
17	AL-16155-L(b)	54	54.0	100.0
18	AL-14966-L	63	51.0	123.5

* Total net wear metal equals 24-hr sample total data less new sample total data.

(a) Test conducted using Phillips "J" unleaded gasoline. All other tests conducted using M85 methanol fuel.

(b) Reference oil test.

**TABLE 5. Average Normalized Percent of Reference Oil
(Cyclic Test Conditions)**

<u>BFLRF Oil Code</u>	<u>Average Normalized Percent of Reference Oil</u>
AL-15427-L	86.7
AL-16155-L	100.0*
AL-15610-L	124.2
AL-16156-L	131.8
AL-14966-L	147.7
AL-14965-L	200.2

* Reference oil for all tests.

16155-L, provided the next best protection under the V-D cyclic test conditions, with oil AL-14965-L providing the least protection of the six candidate oils included in the program.

It should be mentioned that approximately 81.2 percent of the total net wear metals for the 17 tests using M85 fuel was generated from iron, and approximately 6.7 percent was observed for molybdenum. Chromium accounted for only 1.4 percent of the wear metals noted with aluminum, copper, tin, and lead all being approximately 2.6 percent each.

B. Steady-State/Cold Test Conditions

Evaluation of the three best lubricants as determined using the V-D cyclic test conditions was then continued using steady-state/cold test conditions. Test oils AL-15427-L, AL-16155-L (reference oil for all tests in Test Matrices 1 and 2), and AL-15610-L were evaluated in Test Matrix 2 (steady-state/cold test conditions). TABLE 6 presents a summary of the total net used oil wear data obtained for Test Matrix 2. Individual summary operational data sheets and element determinations for oil samples for each test in Test Matrix 2 are included in Appendix B. As in the wear summaries of Test Matrix 1, silicon was not included in the comparisons of the new and used oil samples taken in Test Matrix 2.

TABLE 6. Summary of the Total Net Used Oil Wear Metal Data for Each Test Conducted in Test Matrix 2* (Steady-State/Cold Test Conditions)

<u>Test Sequence No.</u>	<u>BFLRF Oil Code</u>	<u>Total Net, Wear Metal, ppm</u>	<u>Reference Oil Comparison Data</u>	<u>Normalized Percent of Reference Oil</u>
19(a)	AL-16155-L	35	--	--
20	AL-16155-L(b)	341	341.0	100.0
21	AL-15427-L	264	290.3	90.9
22	AL-15610-L	209	239.7	87.2
23	AL-16155-L(b)	189	189.0	100.0
24	AL-15427-L	167	182.4	91.6
25	AL-15610-L	240	175.7	136.6
26	AL-16155-L(b)	169	169.0	100.0

* Total net wear metal equals 24-hr sample total data less new sample total data.

(a) Test conducted using Phillips "J" unleaded gasoline. All other tests conducted using M85 methanol fuel.

(b) Reference oil test.

The average normalized percents of reference oil were calculated for the three candidate oils and are presented in TABLE 7 in the order of protection from wear and corrosion provided by the three remaining candidate oils. It will be noted that these three candidate oils provided the same order of protection from wear and corrosion in the steady-state/cold test conditions as they provided using the cyclic test conditions.

TABLE 7. Average Normalized Percent of Reference Oil
(Steady-State/Cold Test Conditions)

<u>BFLRF Oil Code</u>	<u>Average Normalized Percent of Reference Oil</u>
AL-15427-L	91.3
AL-16155-L	100.0*
AL-15610-L	111.9

* Reference oil for all tests.

It should be noted that in all tests conducted in Sequence 2 except No. 19 (which was run on Phillips "J" gasoline), a "white emulsion" type sludge formed on the rocker arm cover and cam baffle. This type sludge was reported by S.E. Schwartz*, et al., in an earlier program, and was determined to be composed of methanol, water, and engine oil. This same emulsion would also clog the blowby condenser, causing an increase in crankcase pressure. The operator had to use compressed air to "blow-down" the passages in the condenser. All oils exhibited this same tendency. Incidences of "blow-down" varied somewhat, but were not significantly different from test-to-test. After each test and prior to the initial flush, the rocker arm cover and valve deck were rated for sludge. This sludge was then physically removed prior to the flush. Sludge ratings are presented in TABLE 8.

The valve deck was practically clean when compared with the area between the rocker arm cover and the baffle for all three oils tested. The average sludge rating for the rocker arm cover and baffle varied from 7.39 for the cleanest oil tested (AL-15610-L) to

* Schwartz, Shirley E., Smolenski, Donald J., and Clark, Sidney L., "Entry and Retention of Methanol Fuel in Engine Oil," SAE Technical Paper Series 880040, February 29, 1988.

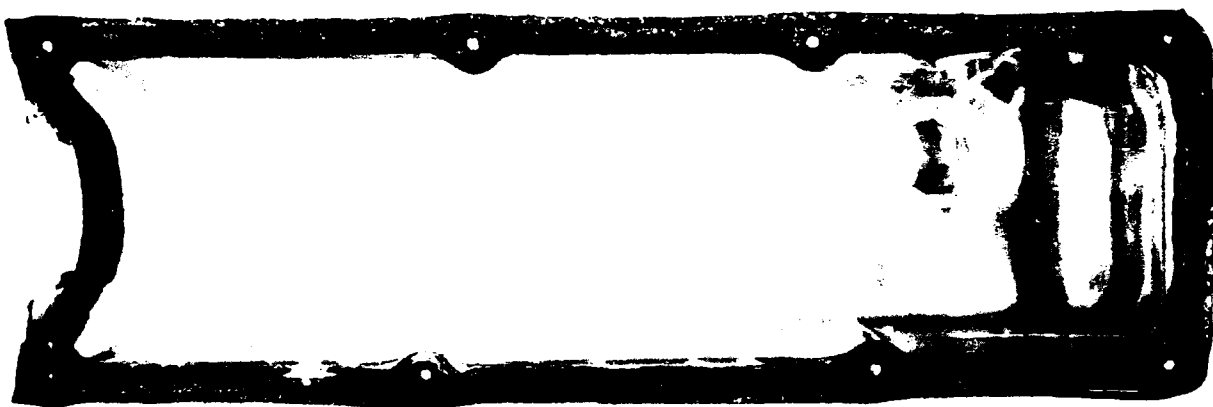
TABLE 8. Sludge Ratings

Test No. Sequence 2	BFLRF Oil Code	Average Sludge (10 = Clean)	
		Rocker Arm Cover & Baffle	Valve Deck
19	AL-16155-L	--	--
20	AL-16155-L	2.91	9.57
21	AL-15427-L	5.18	9.58
22	AL-15610-L	8.32	9.45
23	AL-16155-L	2.90	9.37
24	AL-15427-L	5.64	9.46
25	AL-15610-L	6.43	9.35
26	AL-16155-L	1.92	9.32

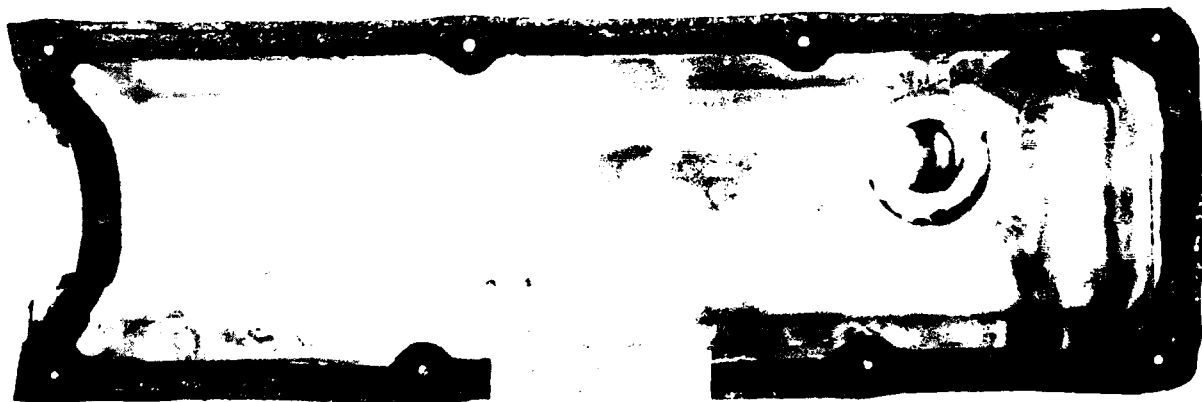
2.57 for AL-16155-L, the reference oil used in both Sequence 1 and Sequence 2 tests. Test oil AL-15427-L provided an average midrange number of 5.41 for the sludge between the rocker arm cover and baffle. Photographs from Test No. 20, before and after the normal flush following the 24-hr test, are presented in Fig. 1. After noting that all sludge was not removed from the rocker arm cover and the cam baffle during the normal flushing procedure, it was decided to physically remove all "white" sludge after each test prior to the normal flushing for the next test. This procedure was followed for all the remaining tests in Sequence 2.

V. CONCLUSIONS

The degree of protection from wear and corrosion provided by six different engine oils formulated for use with M85 fuel indicated the best protection was obtained when using lubricant AL-15427. The least protection was provided by lubricant AL-14965-L. The three lubricants providing the best protection, in the order of protection from wear and corrosion, were AL-15427-L, AL-16155-L, and AL-15610-L. These three lubricants provided the same order of protection from wear and corrosion in the steady-state/cold test conditions as they provided using the cyclic test conditions.



Test No. 20, before flush



Test No. 20, after flush

Figure 1. White emulsion-type sludge in valve cover
before and after flush for Test No. 20

VI. RECOMMENDATIONS

Based upon the data obtained in this phase of the Army Methanol-Fueled Administrative Vehicle Demonstration Program, three lubricants coded AL-15427-L, AL-16155-L, and AL-15610-L are recommended for use in administrative-type vehicle engines. It is believed worthy of mention that two of these three oils are known to have been used in the fleet test portion of the program with no lubricant-related problems occurring during the program.

APPENDIX A

**Individual Summary Data Sheets for Each
Test Conducted Using the Modified
V-D (Cyclic) Test Conditions**

WEAR SCREENER TEST

OIL CODE	<u>AL-16155-L</u>
SWRI NO.	<u>LO-34026</u>
DATE	<u>05-19-87</u>
TEST NO.	<u>31-01-237-84-3</u>
ENGINE NO.	<u>237</u>
TOTAL ENG HRS	<u>5</u>
FUEL	<u>Phillips "J"</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>5 Hours*</u>

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)

- 8, 16, 20, 24 hours

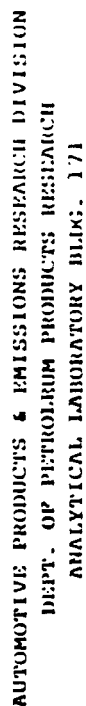
- "New" Oil

* Included 2 hour V-D break-in and coolant flush.

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER			DATE COMPLETED		
31-01-237-84-3			05-20-87		
CLIENT OIL CODE			SWRI OIL CODE		
AL-16155-L			LO-34026		
			STAGE I		
			STAGE II		
			STAGE III		
			MAX	MIN	AVG
			MAX	MIN	AVG
			MAX	MIN	AVG
Speed, rpm			2508	2501	2504
Load, bhp			33.9	33.4	33.6
Oil	Cooler into engine, °F		176	170	175
	Engine ΔT(Out-In), °F		6	2	3
	Pump Gallery, psi		63.0	60.0	60.9
	Engine Gallery, psi		58.0	54.0	55.2
	ΔP (Pump-Engine), psi		6.0	5.0	5.7
	Cyl. Head Gallery, psi		55.0	51.0	53.4
	ΔP (Engine-Head), psi		4.5	0.3	1.9
	Cooling, min		-----	-----	-----
Water	Jacket Outlet, °F		136	124	133
	ΔT (Out-In), °F		15	13	14
	Flow, gpm		15.4	14.7	15.1
	Blowby Heat Exch., °F		131	119	128
	Marine Manifold, °F		149	137	146
Carb.	Temperature, °F		81	78	80
Air	Humidity, grains/lb		79.2	79.2	79.2
	Pressure, in. H ₂ O		0.24	0.22	0.23
Blowby Temperature, °F			130	120	127
Blowby Rate, cfm			1.81	1.65	1.70
Crankcase Pressure, in. H ₂ O			0.01	0.00	0.00
Ignition Timing, °BTDC			46	46	46
Intake Manifold Vacuum, in. Hg			8.1	7.4	7.9
Fuel Flow, lb/hr			---	---	---
Exhaust Back Press., in. H ₂ O			13.2	8.9	11.0
Exhaust	O ₂ , %		1.17	0.91	1.02
Gas	CO, %		0.35	0.16	0.21
Analysis	NOx, ppm		-----	-----	3250

Southwest Research Institute
Testing Laboratory



AL-16155-I.

2016

31-011-157-88.1 }

DATE:

SAMPLE.B:

SWRI CODE: 10-34026

CHARGE NO. :

METALS IN PPM

● ●
● ●

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE	<u>AL-16155-L</u>
SWRI NO.	<u>LO-34026</u>
DATE	<u>05-20-87</u>
TEST NO.	<u>31-02-237-84-3</u>
ENGINE NO.	<u>237</u>
TOTAL ENG HRS	<u>32</u>
FUEL	<u>M-85 Tank # 105</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>3 Hours</u>

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)

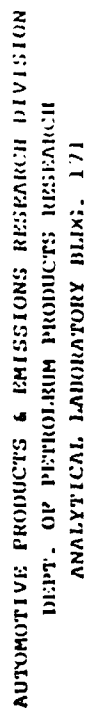
- 8, 16, 20, 24 hours

- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-02-237-84-3				05-22-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-16155-L				LO-34026								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2510	2496	2506	2512	2497	2503	760	746	754
Load, bhp				33.7	33.2	33.5	33.8	33.3	33.6	1.00	0.57	0.85
Oil	Cooler into engine, °F			177	172	174	187	185	186	121	119	120
	Engine ΔT(Out-In), °F			4	2	3	5	3	4	2	1	2
	Pump Gallery, psi			63.0	62.0	62.6	61.0	60.0	60.5	58.7	57.0	58.0
	Engine Gallery, psi			57.5	56.0	57.0	56.0	54.0	54.8	55.0	54.0	54.5
	ΔP (Pump-Engine), psi			6.5	5.0	5.7	6.0	5.0	5.7	5.2	3.0	3.8
	Cyl. Head Gallery, psi			57.4	54.0	56.1	54.5	52.0	53.4	55.5	52.0	54.0
	ΔP (Engine-Head), psi			3.0	0.0	0.8	4.0	0.0	1.4	2.0	0.0	1.2
	Cooling, min			35	25	30	35	25	30	35	25	30
Water	Jacket Outlet, °F			136	133	134	156	155	156	122	119	121
	ΔT (Out-In), °F			14	12	13	13	12	13	15	11	13
	Flow, gpm			15.4	14.7	15.1	15.3	14.8	15.0	11.4	11.3	11.4
	Blowby Heat Exch., °F			130	127	128	149	147	148	114	113	114
	Marine Manifold, °F			150	147	149	169	167	168	136	132	133
Carb.	Temperature, °F			82	79	81	81	80	81	85	80	82
Air	Humidity, grains/lb			79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.24	0.22	0.23	0.24	0.22	0.22	0.26	0.20	0.24
Blowby Temperature, °F				128	125	127	147	140	143	113	113	113
Blowby Rate, cfm				1.68	1.55	1.62	1.68	1.55	1.62	1.68	1.55	1.62
Crankcase Pressure, in. H ₂ O				1.80	0.01	0.50	1.70	0.01	0.70	1.10	0.01	0.40
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				9.2	8.5	8.8	9.0	7.7	8.5	15.6	11.1	14.4
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				11.2	9.5	10.4	11.3	9.4	10.4	2.8	2.4	2.6
Exhaust	O ₂ , %			1.19	0.88	1.07	1.11	1.00	1.06	0.85	0.15	0.30
	CO, %			0.70	0.25	0.49	0.65	0.26	0.51	6.90	6.40	6.66
Analysis	NOx, ppm			---	---	---	---	---	2390	---	---	---

Southwest Research Institute
Testing Laboratory



FORMER CODE: AL-16155-1.

THEOREM 3.1

DATA:

EXAMPLE:

ISSN CODE: 10-34026

CHARGE NO.:

METALS IN PPM

[illegible]

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-14965-L
SWRI NO. LO-34460
DATE 05-24-87
TEST NO. 31-03-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 59
FUEL M-85 (Tank # 105)
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)

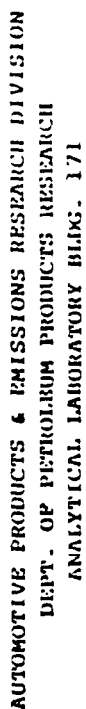
- 8, 16, 20, 24 hours

- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				31-03-237-84-3				DATE COMPLETED				05-26-87			
CLIENT OIL CODE				AL-14965-L				SWRI OIL CODE				LO-34460			
				STAGE I			STAGE II			STAGE III					
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG			
Speed, rpm				2508	2499	2503	2508	2500	2504	764	756	759			
Load, bhp				33.8	33.3	33.6	33.5	33.4	33.5	1.2	0.7	1.0			
Oil	Cooler into engine, °F			176	174	175	187	185	186	122	118	121			
	Engine ΔT(Out-In), °F			7	4	5	6	4	5	1	0	1			
	Pump Gallery, psi			66.0	61.0	65.0	64.0	63.4	63.7	59.4	58.3	58.9			
	Engine Gallery, psi			61.0	59.7	60.0	58.4	57.9	58.2	55.6	54.3	55.1			
	ΔP (Pump-Engine), psi			5.6	1.0	4.8	5.6	5.0	5.4	4.0	3.5	3.8			
	Cyl. Head Gallery, psi			59.4	57.5	58.6	57.3	56.0	56.7	55.2	53.5	54.5			
	ΔP (Engine-Head), psi			3.0	0.7	1.5	3.0	0.5	1.3	1.5	0.3	0.8			
	Cooling, min			14	13	14									
Water	Jacket Outlet, °F			135	134	135	155	154	155	122	118	121			
	ΔT (Out-In), °F			14	12	13	13	12	13	12	11	12			
	Flow, gpm			15.2	14.6	15.0	15.0	14.8	14.9	116	113	115			
	Blowby Heat Exch., °F			129	127	128	149	145	147	135	132	133			
	Marine Manifold, °F			151	148	150	170	167	169	84	80	81			
Carb.	Temperature, °F			82	80	81	81	78	80	84	80	81			
Air	Humidity, grains/lb			79.5	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2			
	Pressure, in. H ₂ O			0.24	0.20	0.22	0.22	0.20	0.22	0.26	0.24	0.25			
Blowby Temperature, °F				130	127	128	148	146	146	117	113	115			
Blowby Rate, cfm				1.78	1.63	1.68	0.60	0.01	0.17	0.10	0.00	0.06			
Crankcase Pressure, in. H ₂ O				0.70	0.01	0.15	0.60	0.01	0.17	0.10	0.00	0.06			
Ignition Timing, °BTDC				46	46	46	10	10	10						
Intake Manifold Vacuum, in. Hg				8.8	8.4	8.6	8.6	8.3	8.5	15.3	14.8	15.0			
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---			
Exhaust Back Press., in. H ₂ O				11.0	9.0	9.9	11.1	9.0	10.0	2.1	1.3	1.6			
Exhaust	O ₂ , %			1.18	0.98	1.06	1.08	0.92	1.00	0.60	0.55	0.58			
Gas	CO, %			0.72	0.59	0.65	0.78	0.61	0.69	0.65	0.60	0.63			
Analysis	NOx, ppm			---	---	---	---	---	2770	---	---	---			

Southwest Research Institute
Testing Laboratory



TEST: 31-03-237-84-3

DATE: _____

SWRI CODE: 10-34460

CHARGE NO. :

METALS IN PPM

[illegible]

•

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-15427-L
SWRI NO. LO-34461
DATE 05-27-87
TEST NO. 31-04-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 86
FUEL M-85 (Tank # 105)
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION

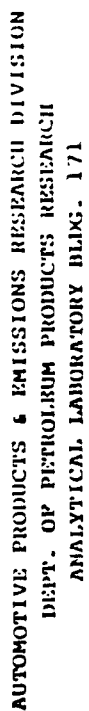
(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)
- 8, 16, 20, 24 hours
- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-04-237-84-3				05-29-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-15427-L				LO-34461								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2510	2490	2499	2509	2490	2502	760	753	758
Load, bhp				33.8	33.0	33.4	33.6	33.5	33.6	1.3	0.8	1.0
Oil	Cooler into engine, °F			176	172	174	187	185	186	123	121	122
	Engine ΔT(Out-In), °F			2	0	1	2	1	2	1	0	0
	Pump Gallery, psi			61.4	60.0	60.9	59.2	58.5	58.9	56.8	56.0	56.2
	Engine Gallery, psi			55.2	54.6	55.0	54.0	52.0	52.8	53.1	52.0	52.6
	ΔP (Pump-Engine), psi			6.2	5.0	5.8	6.5	5.0	6.0	4.0	3.0	3.6
	Cyl. Head Gallery, psi			54.6	51.5	52.7	52.2	49.0	50.8	52.7	50.0	51.0
	ΔP (Engine-Head), psi			3.5	0.4	2.0	4.5	0.3	2.2	3.0	1.0	2.0
	Cooling, min									16	15	16
Water	Jacket Outlet, °F			136	134	135	156	154	155	122	119	121
	ΔT (Out-In), °F			13	12	12	12	11	12	13	11	12
	Flow, gpm			15.2	14.8	15.0	15.2	14.8	15.0			
	Blowby Heat Exch., °F			129	127	128	150	146	148	116	112	113
	Marine Manifold, °F			152	149	151	171	169	170	134	131	132
Carb.	Temperature, °F			82	79	81	81	80	81	82	79	80
Air	Humidity, grains/lb			80.9	79.2	79.2	80.9	79.2	79.5	80.9	79.2	79.5
	Pressure, in. H ₂ O			0.24	0.22	0.23	0.24	0.22	0.23	0.26	0.24	0.25
Blowby Temperature, °F				130	126	128	149	145	147	115	112	113
Blowby Rate, cfm				1.69	1.59	1.62						
Crankcase Pressure, in. H ₂ O				0.10	0.01	0.04	0.10	0.00	0.04	0.10	0.01	0.28
Ignition Timing, °BTDC				46	46	46				10	10	10
Intake Manifold Vacuum, in. Hg				9.60	9.10	9.25	9.20	8.90	9.00	15.6	14.8	15.2
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				11.7	8.3	9.5	10.8	8.7	9.8	1.0	0.1	0.3
Exhaust	O ₂ , %			1.10	0.80	1.00	1.06	0.86	0.97	0.88	0.10	0.61
	CO, %			0.62	0.43	0.53	0.65	0.45	0.57	6.70	6.20	6.50
Analysis	NOx, ppm						2840	2650	2745			

Southwest Research Institute
Testing Laboratory



THESE: 31-(0.4-2)37-134-}

SWRI CODE: IO-34461

CHARGE NO.:

METALS IN PPM

[illegible]

25

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-16155-L
SWRI NO. LO-34026
DATE 05-30-87
TEST NO. 31-05-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 113
FUEL M-85 (Tank # 105)
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION _____

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)

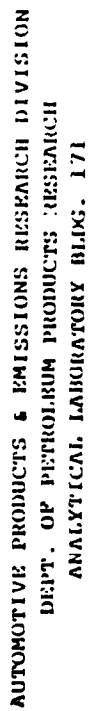
- 8, 16, 20, 24 hours

- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER 31-05-237-84-3			DATE COMPLETED 05-31-87		
CLIENT OIL CODE AL-16155-L			SWRI OIL CODE LO-34026		
			STAGE I		
			MAX	MIN	AVG
Speed, rpm			2506	2498	2503
Load, bhp			33.9	33.2	33.6
Oil	Cooler into engine, °F		177	174	175
	Engine ΔT(Out-In), °F		3	1	2
	Pump Gallery, psi		62.7	62.0	62.3
	Engine Gallery, psi		57.0	56.0	56.8
	ΔP (Pump-Engine), psi		6.0	5.0	5.5
	Cyl. Head Gallery, psi		56.3	54.0	55.2
	ΔP (Engine-Head), psi		7.0	0.0	4.0
	Cooling, min		16	13	14
Water	Jacket Outlet, °F		135	134	135
	ΔT (Out-In), °F		14	12	13
	Flow, gpm		15.0	14.6	14.9
	Blowby Heat Exch., °F		130	128	129
	Marine Manifold, °F		154	150	151
			171	170	170
Carb.	Temperature, °F		81	78	80
Air	Humidity, grains/lb		79.2	79.2	79.2
	Pressure, in. H ₂ O		0.24	0.22	0.23
Blowby Temperature, °F			129	127	128
Blowby Rate, cfm			1.78	1.73	1.76
Crankcase Pressure, in. H ₂ O			0.07	0.01	0.03
Ignition Timing, °BTDC			46	46	46
Intake Manifold Vacuum, in. Hg			9.2	8.6	8.9
Fuel Flow, lb/hr			---	---	---
Exhaust Back Press., in. H ₂ O			11.2	8.9	10.4
Exhaust	O ₂ , %		1.18	1.00	1.11
Gas	CO, %		0.68	0.40	0.53
Analysis	NOx, ppm		---	---	2180

Southwest Research Institute
Testing Laboratory



REF: 31-01137-334-3

21.11.11

SWRI CODE: 10-34026

CHARGE NO.:

METALS IN PPM

三三三

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE	<u>AL-16156-L</u>
SWRI NO.	<u>LO-33993</u>
DATE	<u>06-01-87</u>
TEST NO.	<u>31-06-237-84-3</u>
ENGINE NO.	<u>237</u>
TOTAL ENG HRS	<u>140</u>
FUEL	<u>M-85 (Tank # 105)</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>3 Hours</u>

DISCUSSION

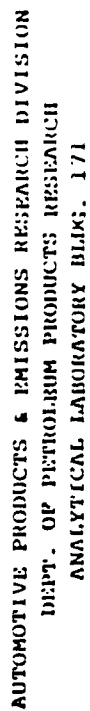
(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)
- 8, 16, 20, 24 hours
- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-06-237-84-3				06-02-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-16156-L				LO-33993								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2514	2491	2503	2512	2501	2506	757	750	753
Load, bhp				33.6	33.2	33.4	33.8	33.6	33.7	1.1	0.8	1.0
Oil	Cooler into engine, °F			177	174	176	188	185	187	122	118	120
	Engine ΔT(Out-In), °F			3	0	1	3	2	2	5	0	3
	Pump Gallery, psi			62.6	62.0	62.1	61.0	60.0	60.3	59.0	58.0	58.4
	Engine Gallery, psi			57.0	56.0	56.7	54.5	54.0	54.2	56.0	54.2	55.0
	ΔP (Pump-Engine), psi			6.0	5.0	5.4	7.0	5.5	6.1	4.4	3.0	3.4
	Cyl. Head Gallery, psi			57.0	53.0	54.7	54.0	51.0	52.3	56.0	52.2	53.5
	ΔP (Engine-Head), psi			3.5	0.0	2.0	3.5	0.0	1.9	2.5	0.0	1.5
	Cooling, min			177	174	176	188	185	187	122	118	120
Water	Jacket Outlet, °F			136	134	135	155	153	154	122	107	119
	ΔT (Out-In), °F			15	12	14	14	12	13	15	11	13
	Flow, gpm			15.2	14.8	15.1	15.1	14.8	15.1	15.2	14.8	15.1
	Blowby Heat Exch., °F			130	128	129	149	147	148	115	100	111
	Marine Manifold, °F			153	148	150	171	168	169	134	118	130
Carb.	Temperature, °F			81	78	80	81	80	80	81	80	81
Air	Humidity, grains/lb			79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.26	0.22	0.23	0.24	0.20	0.22	0.26	0.22	0.24
Blowby Temperature, °F				130	128	129	148	145	146	115	98	110
Blowby Rate, cfm				1.88	1.70	1.74	1.88	1.70	1.74	1.88	1.70	1.74
Crankcase Pressure, in. H ₂ O				0.90	0.01	0.14	0.60	0.01	0.01	0.10	0.01	0.04
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				8.9	8.3	8.6	8.7	8.3	8.5	15.2	14.5	14.8
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				10.7	9.0	10.1	11.4	9.1	10.6	3.0	2.2	2.6
Exhaust	O ₂ , %			1.15	1.03	1.08	1.12	0.93	1.04	0.37	0.04	0.22
Gas	CO, %			0.63	0.32	0.47	0.65	0.32	0.50	7.00	6.50	6.70
Analysis	NOx, ppm			---	---	---	---	---	2360	---	---	---

Southwest Research Institute
Testing Laboratory



CHARGE NO.:

METALS IN PPM

[illegible]

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE	<u>AL-15610-L</u>
SWRI NO.	<u>LO-34579</u>
DATE	<u>06-03-87</u>
TEST NO.	<u>31-07-237-84-3</u>
ENGINE NO.	<u>237</u>
TOTAL ENG HRS	<u>167</u>
FUEL	<u>M-85 (Tank # 105)</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>3 Hours</u>

DISCUSSION

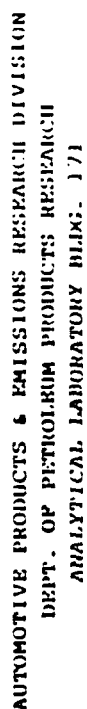
(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)
- 8, 16, 20, 24 hours
- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-07-237-84-3				06-04-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-15610-L				LO-34579								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2508	2494	2501	2505	2496	2500	760	750	753
Load, bhp				33.8	33.4	33.6	33.8	33.3	33.6	1.2	0.8	1.1
Oil	Cooler into engine, °F			177	171	175	187	185	187	120	119	120
	Engine ΔT(Out-In), °F			6	1	3	2	1	2	3	0	1
	Pump Gallery, psi			64.4	63.5	64.0	62.6	62.0	62.2	59.4	58.0	59.0
	Engine Gallery, psi			58.8	58.0	58.3	56.8	56.0	56.4	55.2	54.7	55.0
	ΔP (Pump-Engine), psi			6.0	5.3	5.7	8.5	5.4	6.3	4.7	3.0	4.0
	Cyl. Head Gallery, psi			58.6	55.5	57.3	56.4	54.0	55.1	55.7	53.0	54.6
	ΔP (Engine-Head), psi			3.0	0.1	1.0	2.8	0.2	1.4	2.0	0.5	1.2
	Cooling, min			14	13	14	15	14	15	20	14	16
Water	Jacket Outlet, °F			135	133	134	155	154	155	122	119	120
	ΔT (Out-In), °F			14	13	14	15	13	13	14	11	12
	Flow, gpm			15.3	15.0	15.1	15.2	15.0	15.1	15.3	15.0	15.1
	Blowby Heat Exch., °F			129	127	128	148	147	148	114	112	113
	Marine Manifold, °F			153	148	150	170	169	169	132	122	129
Carb.	Temperature, °F			82	79	80	80	80	80	82	80	80
Air	Humidity, grains/lb			79.2	77.8	78.9	79.2	79.2	79.2	79.2	76.4	78.6
	Pressure, in. H ₂ O			0.26	0.22	0.23	0.24	0.22	0.23	0.26	0.24	0.25
Blowby Temperature, °F				128	125	127	145	143	144	113	111	112
Blowby Rate, cfm				1.83	1.71	1.76	1.83	1.71	1.76	1.83	1.71	1.76
Crankcase Pressure, in. H ₂ O				1.00	0.01	0.27	0.70	0.01	0.23	1.00	0.01	0.24
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				8.8	8.4	8.6	8.7	8.4	8.6	15.5	15.0	15.2
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				10.6	8.3	9.6	10.4	8.4	9.2	1.4	0.5	1.1
Exhaust	O ₂ , %			1.14	0.85	1.04	1.15	0.96	1.04	0.48	0.18	0.30
	CO, %			0.43	0.22	0.28	0.46	0.23	0.35	7.00	6.40	6.60
Analysis	NOx, ppm			1.14	0.85	1.04	---	---	2150	1.14	0.85	1.04

Southwest Research Institute
Testing Laboratory



SPONSOR CODE:

SAMPLE.B:

31-07-237-13.1-3

DATA:

SWRI CODE: IAD-34579

CHARGE NO.:

METALS IN PPM

[illegible]

ISI:

URGENCY DATE:

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-14965-L
SWRI NO. LO-34460
DATE 06-08-87
TEST NO. 31-08-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 194
FUEL M-85 (Tank # 105)
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

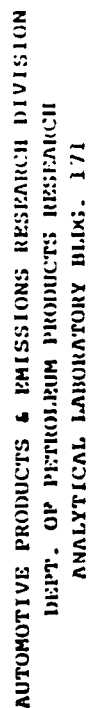
DISCUSSION _____

- (1) Take 2 ounce Oil Sample: _____
- End of candidate flush ("0" hour) _____
- 8, 15, 20, 24 hours _____
- "New" Oil _____

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-08-237-84-3				06-09-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-14965-6				L0-34460								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2510	2498	2504	2507	2500	2503	763	748	753
Load, bhp				33.7	33.2	33.4	33.6	33.2	33.4	1.2	1.0	1.1
Oil	Cooler into engine, °F			176	174	175	187	185	186	122	118	121
	Engine ΔT(Out-In), °F			6	3	5	4	3	4	7	2	4
	Pump Gallery, psi			65.8	65.0	65.2	64.4	63.0	63.6	60.0	59.0	59.6
	Engine Gallery, psi			69.7	59.0	60.9	59.0	58.0	58.4	56.1	55.4	55.9
	ΔP (Pump-Engine), psi			6.0	4.0	5.0	5.7	5.0	5.2	4.3	3.0	3.8
	Cyl. Head Gallery, psi			59.5	57.0	58.1	57.0	55.8	56.5	55.6	53.0	54.4
	ΔP (Engine-Head), psi			4.0	0.0	2.2	3.0	1.0	1.9	3.0	1.0	1.9
	Cooling, min			15	13	14	15	13	14	15	13	14
Water	Jacket Outlet, °F			136	134	135	156	155	155	121	120	120
	ΔT (Out-In), °F			15	12	14	14	13	13	13	12	13
	Flow, gpm			15.1	14.7	14.9	15.0	14.8	14.9	114	113	114
	Blowby Heat Exch., °F			130	128	129	149	148	148	114	113	114
	Marine Manifold, °F			152	149	150	171	169	170	134	130	132
Carb.	Temperature, °F			81	80	80	81	80	80	83	80	81
Air	Humidity, grains/lb			79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.24	0.21	0.22	0.22	0.21	0.22	0.24	0.24	0.24
Blowby Temperature, °F				129	127	128	147	146	146	114	112	113
Blowby Rate, cfm				1.78	1.71	1.74	1.78	1.71	1.74	1.78	1.71	1.74
Crankcase Pressure, in. H ₂ O				0.09	0.01	0.02	0.04	0.01	0.02	1.00	0.01	0.02
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				8.8	7.5	8.2	8.6	7.8	8.3	15.1	14.6	14.9
Fuel Flow, lb/hr				0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Exhaust Back Press., in. H ₂ O				11.7	9.4	10.6	10.9	9.0	10.1	1.2	0.0	0.7
Exhaust	O ₂ , %			2.60	1.02	1.34	2.20	1.06	1.30	0.25	0.17	0.21
Gas	CO, %			0.50	0.12	0.29	0.42	0.18	0.34	7.00	6.40	6.60
Analysis	NOx, ppm			2340	2340	2340	2340	2340	2340	2340	2340	2340

Southwest Research Institute
Testing Laboratory



REF: 31-08-237-84-3

DATE: _____

SWRI CODE: IO-34460

CHARGE NO.:

METALS IN PPM

[illegible]

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE	<u>AL-16155-L</u>
SWRI NO.	<u>LO-34026</u>
DATE	<u>06-10-87</u>
TEST NO.	<u>31-09-237-84-3</u>
ENGINE NO.	<u>237</u>
TOTAL ENG HRS	<u>221</u>
FUEL	<u>M-85 Tank = 105</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>3 Hours</u>

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)

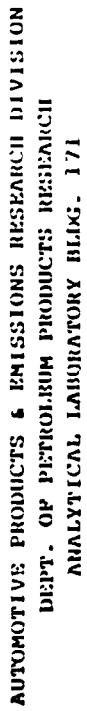
- 8, 16, 20, 24 hours

- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-09-237-84-3				06-11-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-16155-L				LO-34026								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2510	2490	2499	2510	2490	2501	765	751	759
Load, bhp				33.7	33.1	33.4	33.8	33.2	33.6	1.1	0.6	0.8
Oil	Cooler into engine, °F			176	174	175	186	185	186	122	118	120
	Engine ΔT(Out-In), °F			2	0	1	3	2	2	5	2	4
	Pump Gallery, psi			62.8	62.0	62.3	60.9	60.5	60.7	58.7	58.0	58.4
	Engine Gallery, psi			58.0	56.7	57.1	55.2	54.8	55.0	55.4	55.0	55.1
	ΔP (Pump-Engine), psi			6.0	4.0	5.2	6.0	5.5	5.6	3.6	3.0	3.4
	Cyl. Head Gallery, psi			56.5	54.0	54.8	54.4	52.0	53.1	55.0	52.0	53.6
	ΔP (Engine-Head), psi			4.0	0.6	2.3	3.0	0.5	1.8	3.0	0.1	1.5
	Cooling, min			15	14	15	15	14	15	15	14	15
Water	Jacket Outlet, °F			136	133	134	155	154	155	122	121	122
	ΔT (Out-In), °F			15	13	14	14	13	14	13	11	12
	Flow, gpm			15.1	14.8	15.0	15.0	14.8	14.9	15.1	14.8	15.0
	Blowby Heat Exch., °F			130	127	128	148	147	148	116	113	115
	Marine Manifold, °F			151	147	149	170	169	169	134	132	133
Carb.	Temperature, °F			81	79	80	81	80	80	81	80	81
Air	Humidity, grains/lb			82.1	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.22	0.18	0.20	0.22	0.18	0.20	0.24	0.22	0.23
Blowby Temperature, °F				129	127	127	146	145	146	115	112	114
Blowby Rate, cfm				1.90	1.72	1.85	1.90	1.72	1.85	1.90	1.72	1.85
Crankcase Pressure, in. H ₂ O				0.11	0.01	0.06	0.80	0.01	0.27	0.10	0.01	0.06
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				9.1	8.7	8.8	8.9	8.4	8.6	15.6	15.1	15.3
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				10.9	8.8	10.1	10.9	9.3	10.1	0.1	0.0	0.3
Exhaust Gas Analysis	O ₂ , %			1.18	0.15	1.00	1.20	0.99	1.11	1.10	0.23	0.57
	CO, %			4.80	0.07	0.73	0.52	0.07	0.34	6.80	6.00	6.40
Analysis NOx, ppm				2080	2080	2080	2080	2080	2080	2080	2080	2080

Southwest Research Institute
Testing Laboratory



TEST: 31-09-237-84-3

SWRI CODE: 1.0-34026

SWRI CODE: _____

CHARGE NO. :

[illegible]

41

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE	<u>AL-15427-L</u>
SWRI NO.	<u>LO-34461</u>
DATE	<u>06-12-87</u>
TEST NO.	<u>31-10-237-84-3</u>
ENGINE NO.	<u>237</u>
TOTAL ENG HRS	<u>248</u>
FUEL	<u>M-85 Tank # 105</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>3 Hours</u>

DISCUSSION

(1) Take 2 ounce Oil Sample

- End of candidate flush ("0" hour)

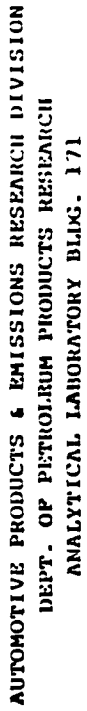
- 8, 16, 20, 24 hours

- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-10-237-84-3				06-13-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-15427-L				LO-34461								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2512	2494	2503	2508	2498	2503	748	733	741
Load, bhp				33.8	33.5	33.6	33.7	33.2	33.5	1.4	1.0	1.2
Oil	Cooler into engine, °F			177	173	175	186	186	186	121	119	120
	Engine ΔT(Out-In), °F			2	0	1	1	1	1	4	2	3
	Pump Gallery, psi			60.2	58.9	59.6	58.4	57.3	58.0	56.0	55.0	55.2
	Engine Gallery, psi			56.8	53.1	54.4	52.5	51.2	52.0	52.5	50.8	51.7
	ΔP (Pump-Engine), psi			6.6	5.0	5.8	6.2	5.9	6.0	4.6	3.0	3.7
	Cyl. Head Gallery, psi			53.8	50.5	52.3	51.1	49.0	50.0	51.5	49.0	50.3
	ΔP (Engine-Head), psi			4.5	0.4	1.7	3.0	0.3	1.7	3.0	0.1	1.2
	Cooling, min			14.0	14.0	14.0	14.0	14.0	14.0	16	12	14
Water	Jacket Outlet, °F			136	133	134	155	154	154	122	120	121
	ΔT (Out-In), °F			14	13	14	14	12	13	14	12	13
	Flow, gpm			15.1	14.8	14.9	15.0	14.8	14.9	14.0	14.0	14.0
	Blowby Heat Exch., °F			130	127	128	148	147	148	115	113	114
	Marine Manifold, °F			152	147	149	170	166	168	133	132	132
Carb.	Temperature, °F			82	78	81	81	80	80	82	79	80
Air	Humidity, grains/lb			88.2	79.2	80.1	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.22	0.18	0.20	0.20	0.18	0.19	0.24	0.22	0.24
Blowby Temperature, °F				129	126	127	146	144	145	114	112	113
Blowby Rate, cfm				1.92	1.83	1.88	1.92	1.83	1.88	1.92	1.83	1.88
Crankcase Pressure, in. H ₂ O				0.90	0.10	0.50	0.60	0.10	0.40	1.00	0.10	0.60
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				9.2	8.7	9.0	9.0	8.9	8.9	15.8	14.8	15.1
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				11.7	8.4	10.3	11.6	10.0	10.9	0.8	0.1	0.4
Exhaust	O ₂ , %			1.20	0.97	1.08	1.10	0.93	1.04	0.46	0.30	0.38
Gas	CO, %			0.49	0.15	0.36	0.53	0.21	0.36	7.00	6.50	6.70
Analysis	NO _x , ppm			---	---	---	---	---	2110	---	---	---

Southwest Research Institute
Testing Laboratory



31-10-237-84-3

CHARGE NO.:

SAMPLEB:

[illegible]

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE	<u>AL-15610-L</u>
SwRI NO.	<u>LO-34579</u>
DATE	<u>06-18-87</u>
TEST NO.	<u>31-11-237-84-3</u>
ENGINE NO.	<u>237</u>
TOTAL ENG HRS	<u>275</u>
FUEL	<u>M-85 Tank # 105</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>3 Hours</u>

DISCUSSION

(1) Record extra temperatures and note Phase

- Oil Sump

- Intake Manifold and #4 Runner

- Water Pump

(2) Take 2 ounce Oil Sample

- End of candidate flush ("0" hour)

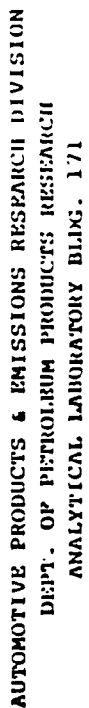
- 8, 16, 20, 24 hours

- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-11-237-84-3				06-20-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-15610-L				LO-34579								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2513	2498	2506	2508	2491	2503	773	752	764
Load, bhp				33.8	29.7	33.2	33.8	33.6	33.7	1.3	0.1	0.8
Oil	Cooler into engine, °F			176	173	175	187	185	186	121	119	120
	Engine ΔT(Out-In), °F			7	2	4	5	2	3	3	0	2
	Pump Gallery, psi			64.8	64.0	64.3	62.8	62.0	62.4	59.9	59.0	59.6
	Engine Gallery, psi			59.8	58.0	58.9	57.3	57.0	57.2	56.1	54.0	55.5
	ΔP (Pump-Engine), psi			6.0	5.0	5.4	5.6	5.0	5.3	5.0	3.5	4.0
	Cyl. Head Gallery, psi			55.3	54.0	54.8	53.7	51.9	52.7	52.0	50.0	51.1
	ΔP (Engine-Head), psi			5.7	3.0	4.1	5.3	3.4	4.4	6.0	3.0	4.4
	Cooling, min			20	14	16	20	14	16	20	14	16
Water	Jacket Outlet, °F			135	133	134	155	154	154	121	119	120
	ΔT (Out-In), °F			15	13	14	14	12	13	13	12	12
	Flow, gpm			15.2	14.9	15.0	15.1	14.9	15.0	15.2	14.9	15.0
	Blowby Heat Exch., °F			130	128	128	148	146	148	115	112	113
	Marine Manifold, °F			151	149	150	169	168	169	133	130	132
Carb.	Temperature, °F			78	81	80	79	81	80	84	79	81
Air	Humidity, grains/lb			79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.26	0.20	0.23	0.24	0.22	0.23	0.26	0.24	0.25
Blowby Temperature, °F				129	127	128	147	145	146	114	111	113
Blowby Rate, cfm				2.08	1.90	1.97	2.08	1.90	1.97	2.08	1.90	1.97
Crankcase Pressure, in. H ₂ O				0.60	0.10	0.20	0.20	0.10	0.10	0.20	0.10	0.10
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				9.0	8.4	8.7	8.7	8.4	8.5	15.3	14.6	15.0
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				10.9	8.4	10.2	11.6	10.8	11.1	0.7	0.1	0.5
Exhaust	O ₂ , %			1.16	1.01	1.10	1.09	1.00	1.06	0.44	0.07	0.27
	CO, %			0.60	0.34	0.50	0.55	0.39	0.50	6.90	6.20	6.60
Analysis	NO _x , ppm			---	---	---	---	---	2200	---	---	---

Southwest Research Institute
Testing Laboratory



TEST: 31-11-237-84-3

DATE: _____

SWRI CODE: IO-34579

CHARGE NO. :

METALS IN PPM

[illegible]

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-16156-L
SWRI NO. LO-33993
DATE 06-21-87
TEST NO. 31-12-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 302
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION

(1) Take 2 ounce Oil Sample

- End of candidate flush ("0" hour)

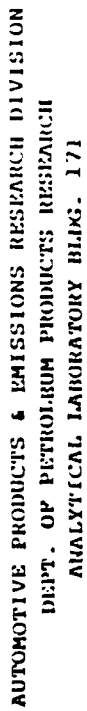
- 8, 16, 20, 24 hours

- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-12-237-84-3				06-23-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-16156-L				L0-33993								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2510	2498	2504	2509	2501	2505	759	752	756
Load, bhp				33.7	33.3	33.5	33.7	33.3	33.6	1.2	0.9	1.0
Oil	Cooler into engine, °F			177	174	175	187	186	187	122	120	121
	Engine ΔT(Out-In), °F			4	0	2	3	0	2	6	2	4
	Pump Gallery, psi			63.1	62.0	62.5	61.0	60.9	61.0	59.0	58.0	58.4
	Engine Gallery, psi			57.6	57.0	57.2	55.0	56.0	55.4	55.4	54.0	54.6
	ΔP (Pump-Engine), psi			5.7	5.0	5.3	6.0	5.0	5.6	4.4	3.0	3.8
	Cyl. Head Gallery, psi			53.1	52.0	52.5	51.0	50.0	50.8	51.0	50.0	50.5
	ΔP (Engine-Head), psi			5.5	4.0	4.7	5.1	4.0	4.5	5.0	3.0	4.1
	Cooling, min			17	14	15	17	14	15	17	14	15
Water	Jacket Outlet, °F			136	134	135	155	155	155	122	119	120
	ΔT (Out-In), °F			14	13	14	13	12	13	14	12	13
	Flow, gpm			15.3	15.0	15.1	15.3	15.0	15.1	15.3	15.0	15.1
	Blowby Heat Exch., °F			130	128	129	149	148	148	115	112	113
	Marine Manifold, °F			153	149	150	170	169	170	133	130	131
Carb.	Temperature, °F			82	79	80	82	79	81	85	80	83
Air	Humidity, grains/lb			79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.24	0.20	0.22	0.24	0.20	0.21	0.26	0.23	0.24
Blowby Temperature, °F				130	128	129	147	146	146	115	112	113
Blowby Rate, cfm				2.08	1.93	2.00	2.08	1.93	2.00	2.08	1.93	2.00
Crankcase Pressure, in. H ₂ O				0.20	0.10	0.10	0.20	0.10	0.10	0.20	0.10	0.10
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				8.8	8.3	8.6	8.6	8.4	8.5	15.3	14.7	15.0
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				11.8	9.2	10.8	11.5	9.3	10.4	0.8	0.0	0.3
Exhaust	O ₂ , %			1.15	1.00	1.06	1.05	0.96	1.02	0.34	0.25	0.27
	CO, %			0.59	0.33	0.44	0.50	0.43	0.47	6.50	6.30	6.40
Analysis	NOx, ppm			---	---	---	---	---	2730	---	---	---

Southwest Research Institute
Testing Laboratory



2531. $\{1, 2, 7, 8\}$

DATE: _____

SWRI CODE: 10-33993

CHARGE NO.:

METALS IN PPM

三三

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-16155-L
SWRI NO. LO-34026
DATE 06-23-87
TEST NO. 31-13-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 329
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION _____

(1) Take 2 ounce Oil Sample: _____

- End of candidate flush ("0" hour) _____

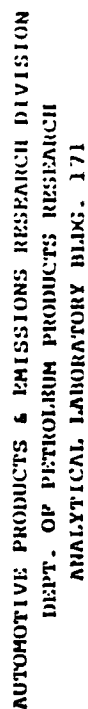
- 8, 16, 20, 24 hours _____

- "New" oil _____

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-13-237-84-3				06-25-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-16155-L				LO-34026								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2510	2494	2502	2503	2498	2500	763	748	755
Load, bhp				33.8	33.3	33.6	33.8	33.3	33.5	1.4	0.7	1.1
Oil	Cooler into engine, °F			177	173	175	187	185	186	121	118	120
	Engine ΔT(Out-In), °F			3	1	2	4	2	2	6	3	4
	Pump Gallery, psi			63.2	62.0	62.5	61.0	60.6	60.9	59.0	58.7	58.9
	Engine Gallery, psi			58.0	56.0	57.2	56.0	55.0	55.2	55.5	54.0	54.8
	ΔP (Pump-Engine), psi			6.0	4.0	5.2	6.0	5.0	5.7	5.0	3.3	4.1
	Cyl. Head Gallery, psi			54.5	53.0	53.6	52.2	51.0	51.5	52.5	50.0	51.4
	ΔP (Engine-Head), psi			5.0	2.4	3.6	4.1	2.9	3.6	4.3	2.7	3.4
	Cooling, min			16	13	15	16	13	15	16	13	15
Water	Jacket Outlet, °F			135	133	134	155	154	154	122	118	120
	ΔT (Out-In), °F			14	13	14	14	13	13	14	12	13
	Flow, gpm			15.3	15.1	15.2	15.2	14.9	15.1	15.2	14.9	15.1
	Blowby Heat Exch., °F			130	127	129	149	147	148	115	112	113
	Marine Manifold, °F			150	148	150	170	168	169	134	129	132
Carb.	Temperature, °F			81	80	80	81	79	80	85	80	83
Air	Humidity, grains/lb			79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.24	0.20	0.22	0.24	0.22	0.23	0.26	0.23	0.24
Blowby Temperature, °F				130	127	129	148	145	147	115	111	113
Blowby Rate, cfm				2.04	1.91	1.96	2.04	1.91	1.96	2.04	1.91	1.96
Crankcase Pressure, in. H ₂ O				0.40	0.10	0.10	0.40	0.10	0.20	1.00	0.10	0.30
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				8.8	8.7	8.7	8.8	8.5	8.7	15.2	14.8	15.0
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				11.5	10.1	10.8	11.2	9.2	10.0	0.6	0.0	0.2
Exhaust	O ₂ , %			1.06	0.92	1.01	1.01	0.93	0.99	0.46	0.40	0.42
Gas	CO, %			0.51	0.28	0.38	0.50	0.25	0.38	6.90	6.40	6.60
Analysis	NOx, ppm			2450	2210	2330	2450	2210	2330	2450	2210	2330

Southwest Research Institute
Testing Laboratory



TEST: 31-13-237--84-3

DATE: _____ IO-34026
SWRI CODE:

METALS IN PPM

[illegible]

53

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-14965-L
SWRI NO. LO-34460
DATE 07-14-87
TEST NO. 31-14-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 356
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)

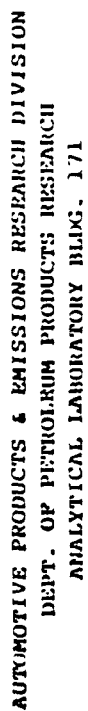
- 8, 16, 20, 24 hours

- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER 31-14-237-84-3				DATE COMPLETED 07-15-87					
CLIENT OIL CODE AL-14965L				SWRI OIL CODE L0-34460					
				STAGE I			STAGE II		
				MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2509	2493	2503	2510	2498	2507
Load, bhp				33.7	33.0	33.3	33.8	33.1	33.4
Oil	Cooler into engine, °F	177	174	175	188	186	187	122	119
	Engine ΔT(Out-In), °F	7	3	5	8	4	5	7	3
	Pump Gallery, psi	67.2	66.0	66.6	65.1	64.7	64.9	60.8	60.0
	Engine Gallery, psi	61.4	60.0	61.0	60.0	59.0	59.3	57.2	55.0
	ΔP (Pump-Engine), psi	6.1	5.0	5.6	6.0	5.0	5.6	5.0	3.4
	Cyl. Head Gallery, psi	57.4	55.0	56.3	58.8	54.0	55.3	52.0	50.0
	ΔP (Engine-Head), psi	6.1	4.2	5.0	6.0	0.3	4.1	6.6	4.0
	Cooling, min	15	13	14					
Water	Jacket Outlet, °F	135	134	135	156	154	155	122	119
	ΔT (Out-In), °F	14	13	14	13	13	13	14	11
	Flow, gpm	15.3	14.9	15.2	15.3	14.7	15.0		
	Blowby Heat Exch., °F	130	128	129	150	148	149	115	113
	Marine Manifold, °F	150	149	150	171	169	170	134	132
Carb.	Temperature, °F	81	80	81	81	80	81	82	80
Air	Humidity, grains/lb	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O	0.22	0.20	0.22	0.22	0.20	0.21	0.26	0.24
Blowby Temperature, °F				130	127	129	148	145	146
Blowby Rate, cfm				2.15	1.92	2.08			
Crankcase Pressure, in. H ₂ O				0.90	0.10	0.50	0.80	0.10	0.40
Ignition Timing, °BTDC				46	46	46			
Intake Manifold Vacuum, in. Hg				8.6	7.9	8.4	8.7	8.3	8.5
Fuel Flow, lb/hr				---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				11.4	9.3	10.4	10.8	9.8	10.4
Exhaust	O ₂ , %	1.40	1.06	1.20	1.34	1.00	1.16	0.54	0.16
Gas	CO, %	0.95	0.40	0.71	0.97	0.47	0.72	6.90	6.30
Analysis	NOx, ppm				2300	2300	2300		

Southwest Research Institute
Testing Laboratory



DATE: 07-16-87

SWRI CODE: IO-34460

CHARGE NO. :

METALS IN PPM

151

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE	<u>AL-15610-L</u>
SWRI NO.	<u>LO-34579</u>
DATE	<u>07-16-87</u>
TEST NO.	<u>31-15-237-84-3</u>
ENGINE NO.	<u>237</u>
TOTAL ENG HRS	<u>383</u>
FUEL	<u>M-85 Tank # 105</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>3 Hours</u>

DISCUSSION

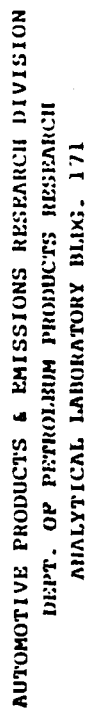
(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)
- 8, 16, 20, 24 hours
- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-15-237-84-3				07-17-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-15610-L				L0-34579								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2513	2496	2506	2514	2505	2508	768	755	762
Load, bhp				33.7	33.3	33.5	33.7	33.4	33.5	1.2	1.0	1.1
Oil	Cooler into engine, °F			177	175	176	187	186	186	122	120	121
	Engine ΔT(Out-In), °F			7	3	5	4	2	3	3	2	2
	Pump Gallery, psi			65.0	64.0	64.6	63.6	63.0	63.3	59.8	59.0	59.5
	Engine Gallery, psi			59.2	59.0	59.0	57.6	57.0	57.4	56.2	54.0	55.4
	ΔP (Pump-Engine), psi			6.9	5.0	6.0	6.2	6.0	6.0	5.0	3.2	3.9
	Cyl. Head Gallery, psi			57.4	56.0	56.8	55.0	54.0	54.6	54.0	53.1	53.6
	ΔP (Engine-Head), psi			3.8	1.6	2.5	3.0	2.4	2.7	3.1	0.0	1.8
	Cooling, min			15	14	15	15	14	15	15	14	15
Water	Jacket Outlet, °F			136	134	134	155	154	155	122	120	121
	ΔT (Out-In), °F			14	13	14	14	13	13	14	11	12
	Flow, gpm			15.2	15.0	15.1	15.2	15.0	15.1	15	14	15
	Blowby Heat Exch., °F			130	128	129	148	147	148	115	113	114
	Marine Manifold, °F			150	147	149	170	168	169	134	131	132
Carb.	Temperature, °F			81	78	80	82	78	80	83	80	82
Air	Humidity, grains/lb			79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.22	0.20	0.21	0.22	0.20	0.21	0.26	0.24	0.25
Blowby Temperature, °F				130	128	129	147	146	146	114	113	113
Blowby Rate, cfm				2.37	2.13	2.24	2.37	2.13	2.24	2.37	2.13	2.24
Crankcase Pressure, in. H ₂ O				1.00	0.10	0.60	0.80	0.10	0.50	1.20	0.10	0.60
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				9.0	8.6	8.8	8.9	8.6	8.8	15.2	14.6	14.9
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				11.7	10.5	11.0	11.4	10.3	11.0	3.0	1.4	1.9
Exhaust Gas Analysis	O ₂ , %			1.17	0.96	1.05	1.19	0.85	1.04	0.40	0.15	0.22
	CO, %			0.85	0.60	0.74	0.81	0.70	0.75	6.90	6.40	6.70
NOx, ppm				2000	2000	2000	2000	2000	2000	2000	2000	2000

Southwest Research Institute
Testing Laboratory



THE
31-15-237-81--3

DATE:

SWRI CODE: I.O-34579

AMPL.B:

CHARGE NO.:

METALS IN PPM

50

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-14966-L
SWRI NO. LO-35235
DATE 07-24-87
TEST NO. 31-16-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 410
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION

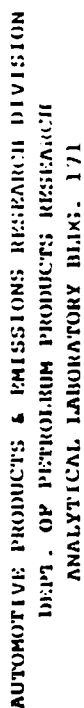
(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)
- 8, 16, 20, 24 hours
- "New" Oil

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-16-237-84-3				07-26-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-14966-L				LO-35235								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2510	2497	2502	2506	2500	2504	763	756	760
Load, bhp				33.8	33.2	33.5	33.8	33.4	33.6	1.1	0.9	1.0
Oil	Cooler into engine, °F			177	173	176	188	186	187	121	118	120
	Engine ΔT(Out-In), °F			9	4	6	7	4	6	7	3	5
	Pump Gallery, psi			66.6	66.3	66.4	65.0	64.6	64.7	60.7	60.1	60.4
	Engine Gallery, psi			60.9	60.6	60.7	59.2	58.8	58.9	56.6	55.4	55.8
	ΔP (Pump-Engine), psi			5.8	5.6	5.7	5.9	5.7	5.8	5.3	3.9	4.6
	Cyl. Head Gallery, psi			60.2	59.0	59.6	58.2	56.8	57.6	55.8	54.7	55.4
	ΔP (Engine-Head), psi			1.7	0.6	1.1	2.2	1.0	1.4	1.9	0.2	0.6
	Cooling, min			15	12	14	15	12	14	15	12	14
Water	Jacket Outlet, °F			136	133	135	155	154	154	120	122	121
	ΔT (Out-In), °F			14	13	13	13	12	13	13	11	12
	Flow, gpm			15.2	15.0	15.1	15.5	14.7	15.1	15.5	14.7	15.1
	Blowby Heat Exch., °F			130	127	129	149	147	148	116	113	114
	Marine Manifold, °F			152	148	150	171	169	170	134	113	129
Carb.	Temperature, °F			81	78	80	81	79	80	81	79	80
Air	Humidity, grains/lb			79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.18	0.17	0.18	0.18	0.14	0.16	0.24	0.20	0.22
Blowby Temperature, °F				130	128	129	147	145	146	115	112	114
Blowby Rate, cfm				2.16	1.93	2.07	2.16	1.93	2.07	2.16	1.93	2.07
Crankcase Pressure, in. H ₂ O				0.60	0.10	0.20	0.40	0.10	0.30	1.10	0.10	0.30
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				9.0	8.4	8.6	8.8	8.6	8.7	15.5	15.0	15.2
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				11.6	9.8	10.8	11.8	10.0	10.8	1.9	0.1	1.2
Exhaust	O ₂ , %			1.16	1.01	1.09	1.12	0.93	1.02	0.23	0.11	0.18
	CO, %			0.79	0.64	0.71	0.82	0.70	0.76	6.60	6.20	6.40
Analysis	NOx, ppm			2010	2010	2010	2010	2010	2010	2010	2010	2010

Southwest Research Institute
Testing Laboratory



DATE:

SWRI CODE: 1.0-35235

CHARGE NO.:

METALS IN PPM

11

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-16155-L
SWRI NO. LO-34369
DATE 07-26-87
TEST NO. 31-17-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 437
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION _____

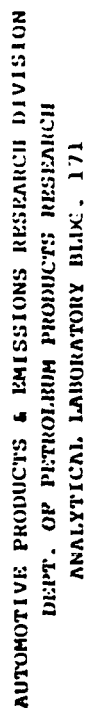
(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)
 - 8, 16, 20, 24 hours
 - "New" Oil
- _____

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED						
31-17-237-84-3				07-28-87						
CLIENT OIL CODE				SWRI OIL CODE						
AL-16155-L				LO-34369						
		STAGE I			STAGE II			STAGE III		
		MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm		2511	2501	2505	2512	2504	2507	763	752	756
Load, bhp		33.7	33.4	33.6	33.7	33.2	33.5	1.0	0.8	0.9
Oil	Cooler into engine, °F	177	174	175	187	186	187	120	119	120
	Engine ΔT(Out-In), °F	4	2	3	4	3	4	5	4	5
	Pump Gallery, psi	63.8	62.9	63.5	61.8	61.0	61.5	59.6	58.8	59.1
	Engine Gallery, psi	57.8	57.0	57.5	55.7	55.0	55.4	55.4	54.0	55.0
	ΔP (Pump-Engine), psi	6.2	5.7	6.0	6.2	6.0	6.1	5.0	3.5	4.2
	Cyl. Head Gallery, psi	56.6	56.0	56.4	54.4	53.9	54.1	54.8	54.0	54.5
	ΔP (Engine-Head), psi	1.3	1.0	1.1	1.6	1.0	1.2	1.4	0.0	0.7
	Cooling, min	16	13	14	16	13	14	16	13	14
Water	Jacket Outlet, °F	136	134	135	156	155	156	122	119	120
	ΔT (Out-In), °F	14	13	13	13	12	12	12	10	11
	Flow, gpm	15.3	15.0	15.1	15.0	14.9	15.0	15.0	14.9	15.0
	Blowby Heat Exch., °F	131	129	129	150	149	150	116	112	114
	Marine Manifold, °F	150	150	150	171	169	170	133	129	131
Carb.	Temperature, °F	81	80	80	81	79	80	81	79	80
Air	Humidity, grains/lb	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O	0.18	0.14	0.17	0.18	0.14	0.17	0.24	0.21	0.23
Blowby Temperature, °F		130	128	129	149	146	148	115	112	113
Blowby Rate, cfm		2.48	2.08	2.26	2.48	2.08	2.26	2.48	2.08	2.26
Crankcase Pressure, in. H ₂ O		1.00	0.30	0.80	0.90	0.30	0.60	1.30	0.80	1.00
Ignition Timing, °BTDC		46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg		9.1	8.8	8.9	9.0	8.8	8.8	15.7	15.5	15.6
Fuel Flow, lb/hr		---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O		11.0	9.1	10.2	12.0	9.6	10.5	1.0	0.6	0.8
Exhaust Gas Analysis	O ₂ , %	1.18	0.96	1.08	1.16	0.93	1.02	0.60	0.22	0.36
	CO, %	0.96	0.70	0.81	0.87	0.70	0.80	6.70	6.40	6.60
NOx, ppm		2050	2050	2050	---	---	2050	2050	2050	2050

Southwest Research Institute
Testing Laboratory



REF: 31-17-237-44-3

DATE:

SWRI CODE: 1.0-34369

SAMPLE.B:

CHARGE NO.:

METALS IN PPM

三

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-14966-L
SWRI NO. LO-35235
DATE 07-31-87
TEST NO. 31-18-237-84-3
ENGINE NO. 237
TOTAL ENG HRS 464
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

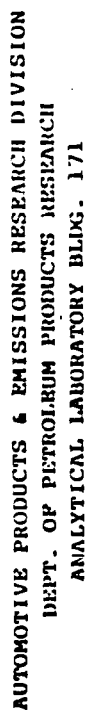
DISCUSSION _____

- (1) Take 2 ounce Oil Sample: _____
- End of candidate flush ("0" hour) _____
 - 8, 16, 20, 24 hours _____
 - "New" Oil _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____
- _____

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED						
31-18-237-84-3				07-31-87						
CLIENT OIL CODE				SWRI OIL CODE						
AL-14966-L				LO-35235						
		STAGE I			STAGE II			STAGE III		
		MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm		2512	2508	2509	2525	2509	2513	766	751	755
Load, bhp		33.7	33.1	33.5	33.7	33.4	33.5	1.0	0.8	1.0
Oil	Cooler into engine, °F	177	175	176	189	185	187	122	119	121
	Engine ΔT(Out-In), °F	7	4	6	7	4	6	6	4	5
	Pump Gallery, psi	66.6	66.0	66.4	65.2	64.0	64.7	60.5	60.0	60.2
	Engine Gallery, psi	60.9	60.0	60.6	59.4	58.7	59.0	56.6	55.0	56.0
	ΔP (Pump-Engine), psi	6.4	5.6	6.0	6.3	5.0	5.8	6.0	4.1	4.8
	Cyl. Head Gallery, psi	59.9	58.0	59.4	57.7	57.0	57.4	56.0	54.0	55.2
	ΔP (Engine-Head), psi	2.0	0.7	1.3	2.4	1.1	1.8	1.4	0.0	0.8
	Cooling, min	15	13	14	15	13	14	15	13	14
Water	Jacket Outlet, °F	135	133	134	155	155	155	122	119	120
	ΔT (Out-In), °F	14	13	13	14	12	13	13	11	12
	Flow, gpm	15.3	14.9	15.1	15.2	14.8	15.0	15.3	14.9	15.1
	Blowby Heat Exch., °F	130	128	129	149	148	149	116	112	114
	Marine Manifold, °F	150	149	150	171	169	170	142	130	133
Carb.	Temperature, °F	82	79	81	82	80	81	83	80	81
Air	Humidity, grains/lb	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O	0.18	0.17	0.17	0.18	0.15	0.17	0.24	0.22	0.23
Blowby Temperature, °F		130	128	129	149	147	148	115	112	113
Blowby Rate, cfm		2.18	2.05	2.14	2.18	2.05	2.14	2.18	2.05	2.14
Crankcase Pressure, in. H ₂ O		0.80	0.20	0.40	0.40	0.20	0.30	1.10	1.00	1.00
Ignition Timing, °BTDC		46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg		8.9	8.4	8.6	8.8	8.5	8.6	15.2	15.1	15.2
Fuel Flow, lb/hr		---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O		11.7	10.0	10.7	11.7	8.6	10.3	1.1	0.1	0.7
Exhaust Gas Analysis	O ₂ , %	1.18	1.00	1.10	1.05	0.95	1.00	0.65	0.19	0.46
	CO, %	0.97	0.80	0.87	0.95	0.80	0.85	6.70	6.20	6.40
NOx, ppm		---	---	---	---	---	2350	---	---	---

Southwest Research Institute
Testing Laboratory



SPONSOR CODE: A1.-14966-1.

TK51:
31-18-237-884- }

DATE: 07-30-87

SAMPLEB:

SWRI CODE: 1.0-35235

CHARGE NO.:

METALS IN PPM

[illegible]

APPENDIX B

**Individual Summary Data Sheets for Each
Test Conducted Using the Steady-State
(Cold) Test Conditions**

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-16155-L
SWRI NO. LO-34369
DATE 08-26-87
TEST NO. 31-01-10-85-3
ENGINE NO. 10
TOTAL ENG HRS 5
FUEL Phillips "J"
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 5 Hours*

DISCUSSION _____

(1) Take 2 ounce Oil Sample: _____

- End of candidate flush ("0" hour) _____

- 8, 16, 20, 24 hours _____

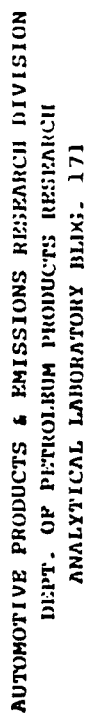
- "New" Oil _____

*Includes 2-hour V-D break-in and coolant flush.

SEQUENCE V-D
OPERATIONAL SUMMARY

TEST NUMBER				DATE COMPLETED								
31-01-10-85-3				08-27-87								
CLIENT OIL CODE				SWRI OIL CODE								
AL-16155-L				LO-34369								
				STAGE I			STAGE II			STAGE III		
				MAX	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG
Speed, rpm				2511	2501	2505	2513	2506	2509	756	747	752
Load, bhp				33.8	33.2	33.5	33.9	33.3	33.6	1.4	1.2	1.3
Oil	Cooler into engine, °F			176	173	175	187	186	186	132	118	121
	Engine ΔT(Out-In), °F			4	2	3	3	2	2	1	0	0
	Pump Gallery, psi			61.5	58.0	59.2	57.5	56.0	56.7	58.8	57.0	58.2
	Engine Gallery, psi			54.0	50.0	51.6	51.0	48.0	49.1	54.0	52.0	53.1
	ΔP (Pump-Engine), psi			8.3	6.5	7.6	8.1	6.5	7.5	5.7	4.5	5.2
	Cyl. Head Gallery, psi			51.4	48.0	48.9	47.0	45.0	45.9	52.0	42.0	49.6
	ΔP (Engine-Head), psi			4.0	2.0	2.7	4.0	3.0	3.5	3.5	1.2	2.0
	Cooling, min			15	12	14	15	12	14	15	12	14
Water	Jacket Outlet, °F			135	133	134	156	155	156	122	118	119
	ΔT (Out-In), °F			15	14	15	15	13	14	15	9	13
	Flow, gpm			15.3	14.8	15.0	15.2	14.8	15.1	15.3	14.8	15.0
	Blowby Heat Exch., °F			131	128	130	152	150	151	119	102	113
	Marine Manifold, °F			150	147	149	171	169	170	137	121	131
Carb.	Temperature, °F			81	78	80	81	79	80	86	81	82
Air	Humidity, grains/lb			79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2	79.2
	Pressure, in. H ₂ O			0.26	0.22	0.24	0.26	0.20	0.24	0.28	0.23	0.26
Blowby Temperature, °F				133	130	132	152	150	151	118	102	112
Blowby Rate, cfm				2.33	2.03	2.15	2.33	2.03	2.15	2.33	2.03	2.15
Crankcase Pressure, in. H ₂ O				0.03	0.01	0.02	0.02	0.01	0.01	0.09	0.01	0.04
Ignition Timing, °BTDC				46	46	46	46	46	46	10	10	10
Intake Manifold Vacuum, in. Hg				8.8	8.2	8.6	8.7	8.2	8.5	15.7	15.1	15.5
Fuel Flow, lb/hr				---	---	---	---	---	---	---	---	---
Exhaust Back Press., in. H ₂ O				11.2	9.3	10.3	10.7	10.0	10.4	1.1	0.1	0.7
Exhaust	O ₂ , %			1.16	0.96	1.05	1.10	0.95	1.02	0.52	0.43	0.48
Gas	CO, %			0.43	0.28	0.36	0.40	0.33	0.36	4.0	3.2	3.6
Analysis	NOx, ppm			3560	3560	3560	3560	3560	3560	3560	3560	3560

Southwest Research Institute
Testing Laboratory



31-01-10-85--}

DATE: 08-26-87

SWRI CODE: 1.0-34369

CHARGE NO.:

METALS IN PPM

[illegible]

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-16155-L
SWRI NO. LO-35822
DATE 09-15-87
TEST NO. 31-02A-10-85-3
ENGINE NO. 10
TOTAL ENG HRS 62
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION _____

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)

- 8, 16, 20, 24 hours

- "New" Oil

(2) Note test conditions are "steady state"

OPERATIONAL SUMMARY

Client Oil Code: AL-16155-L

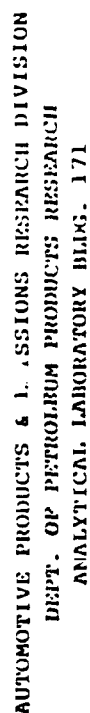
Test Number: 31-02A-10-85-3

Laboratory Oil Code: LO-35822

Date Completed: 09-16-87

		Maximum	Minimum	Average
Speed, rpm		2506	2497	2502
Load, bhp		33.7	33.2	33.5
Oil	Cooler into Engine, °F	126	123	125
	Engine ΔT (Out-In), °F	18	13	15
	Pump Gallery, psi	71.3	69.0	69.7
	Engine Gallery, psi	64.0	62.0	62.8
	ΔP (Pump-Engine), psi	8.0	5.3	6.9
	Cylinder Head Gallery, psi	60.8	58.0	59.8
	ΔP (Engine-Head), psi	4.0	2.5	2.0
	Cooling, minutes	////////	////////	////////
Water	Jacket Outlet, °F	116	113	115
	ΔT (Out-In), °F	10	8	9
	Flow, gpm	15.2	15.0	15.1
	Blowby Heat Exchanger, °F	113	107	111
	Marine Manifold, °F	93	86	90
Carburetor Air	Temperature, °F	82	80	81
	Humidity, grains/lb	79.2	79.2	79.2
	Pressure, in. H ₂ O	2.26	2.21	2.23
Blowby Temperature, °F		118	108	113
Blowby Rate, cfm		2.10	2.02	2.07
Crankcase Pressure, in. H ₂ O		5.0+	1.8	4.5+
Ignition Timing, °BTDC		46	46	46
Intake Manifold Vacuum, in. Hg		9.3	8.6	8.9
Fuel Flow, lbs/hr		---	---	---
Exhaust Back Pressure, in. H ₂ O		10.6	9.5	10.7
Exhaust Gas Analysis	O ₂ , %	1.00	0.52	0.77
	CO, %	0.83	0.60	0.73
	NO _x , ppm	---	---	260

Southwest Research Institute
Testing Laboratory

DATE: 09-15-87

SWRI CODE: 1.0-35822

METALS IN PDM

[illegible]

EMERGENCY DATE:

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE	<u>AL-15427-L</u>
SWRI NO.	<u>LO-34461</u>
DATE	<u>09-17-87</u>
TEST NO.	<u>31-03-10-85-3</u>
ENGINE NO.	<u>10</u>
TOTAL ENG HRS	<u>89</u>
FUEL	<u>M-85 Tank # 105</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>3 Hours</u>

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)

- 8, 16, 20, 24 hours

- "New" Oil

(2) Note test conditions are "steady state"

OPERATIONAL SUMMARY

Client Oil Code: AL-15427-L

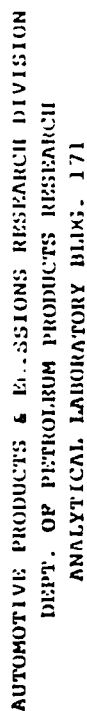
Test Number: 31-03-10-85-3

Laboratory Oil Code: LO-34461

Date Completed: 09-18-87

		Maximum	Minimum	Average
Speed, rpm		2508	2496	2502
Load, bhp		33.7	33.4	33.6
Oil	Cooler into Engine, °F	126	124	126
	Engine ΔT (Out-In), °F	14	11	12
	Pump Gallery, psi	69.6	66.9	68.7
	Engine Gallery, psi	62.0	60.5	61.6
	ΔP (Pump-Engine), psi	7.9	5.0	7.0
	Cylinder Head Gallery, psi	62.0	56.4	58.4
	ΔP (Engine-Head), psi	4.5	1.8	3.4
	Cooling, minutes	////////	////////	////////
Water	Jacket Outlet, °F	116	114	115
	ΔT (Out-In), °F	11	9	10
	Flow, gpm	18.2	15.0	15.4
	Blowby Heat Exchanger, °F	112	109	110
	Marine Manifold, °F	90	83	87
Carburetor Air	Temperature, °F	81	78	80
	Humidity, grains/lb	79.2	79.2	79.2
	Pressure, in. H ₂ O	0.24	0.22	0.24
Blowby Temperature, °F		113	110	112
Blowby Rate, cfm		2.12	2.02	2.09
Crankcase Pressure, in. H ₂ O		1.80	0.19	1.28
Ignition Timing, °BTDC		46	46	46
Intake Manifold Vacuum, in. Hg		9.2	8.8	9.0
Fuel Flow, lbs/hr		---	---	---
Exhaust Back Pressure, in. H ₂ O		11.0	9.9	10.4
Exhaust	O ₂ , %	1.15	0.46	0.91
Gas	CO, %	0.75	0.23	0.43
Analysis	NO _x , ppm	---	---	1980

Southwest Research Institute
Testing Laboratory



TEST: 31-03-10-55-

DATE: 09-17-87

SWRI CODE: I.O-34461

CHARGE NO.:

METALS IN PPM

[illegible]

URGENCY DATE:

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE	<u>AL-15610-L</u>
SwRI NO.	<u>LO-34579</u>
DATE	<u>09-20-87</u>
TEST NO.	<u>31-04-10-85-3</u>
ENGINE NO.	<u>10</u>
TOTAL ENG HRS	<u>116</u>
FUEL	<u>M-85 Tank # 105</u>
TEST HOURS	<u>24</u>
FLUSH OIL	<u>LO-12119</u>
FLUSH OIL FUEL	<u>Phillips "J"</u>
FLUSH TIME	<u>3 Hours</u>

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)
- 8, 16, 20, 24 hours
- "New" Oil

(2) Note test conditions are "steady state"

OPERATIONAL SUMMARY

Client Oil Code: AL-15610-L

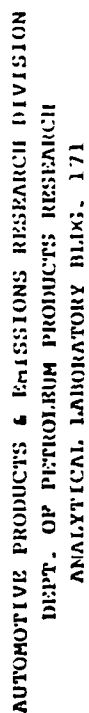
Test Number: 31-04-10-85-3

Laboratory Oil Code: LC-34579

Date Completed: 09-21-87

		Maximum	Minimum	Average
Speed, rpm		2508	2498	2502
Load, bhp		33.7	33.2	33.5
Oil	Cooler into Engine, °F	127	124	126
	Engine ΔT (Out-In), °F	21	18	19
	Pump Gallery, psi	72.6	70.5	71.2
	Engine Gallery, psi	65.1	64.0	64.9
	ΔP (Pump-Engine), psi	8.0	5.5	7.0
	Cylinder Head Gallery, psi	59.8	58.0	59.0
	ΔP (Engine-Head), psi	7.0	5.0	5.9
	Cooling, minutes	////////	////////	////////
Water	Jacket Outlet, °F	116	113	115
	ΔT (Out-In), °F	12	9	10
	Flow, gpm	15.4	14.8	15.0
	Blowby Heat Exchanger, °F	113	107	110
	Marine Manifold, °F	92	87	89
Carburetor Air	Temperature, °F	81	78	80
	Humidity, grains/lb	79.2	79.2	79.2
	Pressure, in. H ₂ O	0.26	0.22	0.24
Blowby Temperature, °F		115	110	112
Blowby Rate, cfm		2.29	1.95	2.10
Crankcase Pressure, in. H ₂ O		5.00	0.08	2.40
Ignition Timing, °BTDC		46	46	46
Intake Manifold Vacuum, in. Hg		8.8	8.4	8.6
Fuel Flow, lbs/hr		---	---	---
Exhaust Back Pressure, in. H ₂ O		11.6	9.3	10.3
Exhaust	O ₂ , %	1.19	0.96	1.09
Gas	CO, %	0.51	0.31	0.42
Analysis	NO _x , ppm	---	---	2100

Southwest Research Institute
Testing Laboratory



THESE: 31-001-10-85--3

DATE: 09-20-87

SWRI CODE: 1.0-34579

CHARGE NO.:

METALS IN PIM

[illegible]

URGENCY DATE:

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-16155-L
SWRI NO. LO-34369
DATE 09-22-87
TEST NO. 31-05-10-85-3
ENGINE NO. 10
TOTAL ENG HRS 143
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)

- 8, 16, 20, 24 hours

- "New" Oil

(2) Note test conditions are "steady state"

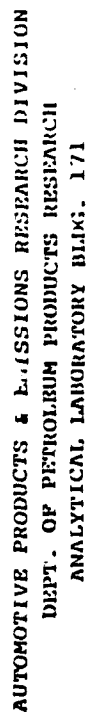
OPERATIONAL SUMMARY

Client Oil Code: AL-16155-L
 Laboratory Oil Code: LO-35822

Test Number: 31-05-10-85-3
 Date Completed: 09-23-87

		Maximum	Minimum	Average
Speed, rpm		2509	2500	2504
Load, bhp		33.7	33.2	33.5
Oil	Cooler into Engine, °F	126	123	125
	Engine ΔT (Out-In), °F	18	14	16
	Pump Gallery, psi	71.0	68.8	70.1
	Engine Gallery, psi	63.5	62.9	63.2
	ΔP (Pump-Engine), psi	3.5	5.8	7.1
	Cylinder Head Gallery, psi	61.6	59.2	60.8
	ΔP (Engine-Head), psi	3.8	1.9	2.3
	Cooling, minutes	////////	////////	////////
Water	Jacket Outlet, °F	116	114	116
	ΔT (Out-In), °F	10	9	10
	Flow, gpm	15.3	15.0	15.1
	Blowby Heat Exchanger, °F	116	112	114
	Marine Manifold, °F	93	85	89
Carburetor Air	Temperature, °F	81	78	80
	Humidity, grains/lb	79.2	79.2	79.2
	Pressure, in. H ₂ O	0.24	0.20	0.23
Blowby Temperature, °F		113	109	111
Blowby Rate, cfm		2.29	2.02	2.10
Crankcase Pressure, in. H ₂ O		2.2	0.6	1.4
Ignition Timing, °BTDC		46	46	46
Intake Manifold Vacuum, in. Hg		9.2	8.8	9.0
Fuel Flow, lbs/hr		---	---	---
Exhaust Back Pressure, in. H ₂ O		11.5	9.7	10.6
Exhaust	O ₂ , %	1.19	1.00	1.06
Gas	CO, %	0.32	0.14	0.22
Analysis	NO _x , ppm	---	---	1950

Southwest Research Institute
 Testing Laboratory



SPONSOR CODE: AL-16155-1.

TEST:

31-05-10-85-3

DATE: 09-22-87

AMPLB:

SWRI CODE: LO-35822

CHARGE NO. :

METALS IN PPM

[illegible]

...

URGPRNCY DATE:

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-15427-L
SWRI NO. LO-34461
DATE 09-24-87
TEST NO. 31-06-10-85-3
ENGINE NO. 10
TOTAL ENG HRS 170
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)
- 8, 16, 20, 24 hours
- "New" Oil

(2) Note test conditions are "steady state"

OPERATIONAL SUMMARY

Client Oil Code: AL-15427-L

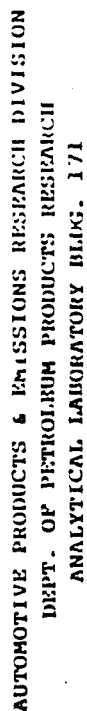
Test Number: 31-06-10-85-3

Laboratory Oil Code: LO-34461

Date Completed: 09-25-87

		Maximum	Minimum	Average
Speed, rpm		2508	2500	2503
Load, bhp		33.8	33.3	33.6
Oil	Cooler into Engine, °F	126	123	125
	Engine ΔT (Out-In), °F	13	10	11
	Pump Gallery, psi	68.6	66.0	67.5
	Engine Gallery, psi	61.5	59.8	60.6
	ΔP (Pump-Engine), psi	8.0	5.8	6.9
	Cylinder Head Gallery, psi	57.7	56.0	57.1
	ΔP (Engine-Head), psi	4.1	2.5	3.5
	Cooling, minutes	////////	////////	////////
Water	Jacket Outlet, °F	117	114	115
	ΔT (Out-In), °F	12	7	9
	Flow, gpm	15.3	14.8	15.0
	Blowby Heat Exchanger, °F	113	108	110
	Marine Manifold, °F	90	85	87
Carburetor Air	Temperature, °F	81	78	79
	Humidity, grains/lb	79.2	79.2	79.2
	Pressure, in. H ₂ O	0.24	0.21	0.23
Blowby Temperature, °F		117	109	113
Blowby Rate, cfm		2.50	2.23	2.34
Crankcase Pressure, in. H ₂ O		3.00	0.08	1.32
Ignition Timing, °BTDC		46	46	46
Intake Manifold Vacuum, in. Hg		9.2	8.8	9.0
Fuel Flow, lbs/hr		---	---	---
Exhaust Back Pressure, in. H ₂ O		11.3	9.0	10.2
Exhaust Gas Analysis	O ₂ , %	1.14	1.00	1.09
	CO, %	0.46	0.14	0.34
	NO _x , ppm	---	---	2200

Southwest Research Institute
Testing Laboratory

DATE: 09-24-87SWRI CODE: I.O-34461

METALS IN PPM

URGENCY DATE:

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-15610-L
SWRI NO. LO-34579
DATE 09-29-87
TEST NO. 31-07-10-85-3
ENGINE NO. 10
TOTAL ENG HRS 197
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION

- (1) Take 2 ounce Oil Sample
- End of candidate flush ("0" hour)
- 8, 16, 20, 24 hours
- "New" Oil
- (2) Note test conditions are "steady state"

OPERATIONAL SUMMARY

Client Oil Code: AL-15610-L

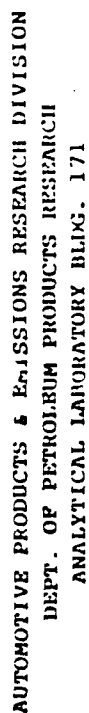
Test Number: 31-07-10-85-3

Laboratory Oil Code: LO-34579

Date Completed: 09-30-87

		Maximum	Minimum	Average
Speed, rpm		2508	2493	2504
Load, bhp		33.8	33.4	33.6
Oil	Cooler into Engine, °F	126	124	125
	Engine ΔT (Out-In), °F	20	10	17
	Pump Gallery, psi	71.6	69.5	70.9
	Engine Gallery, psi	64.0	63.0	63.6
	ΔP (Pump-Engine), psi	8.6	5.5	7.4
	Cylinder Head Gallery, psi	60.4	58.5	59.4
	ΔP (Engine-Head), psi	5.5	3.0	4.2
	Cooling, minutes	////////	////////	////////
Water	Jacket Outlet, °F	117	114	115
	ΔT (Out-In), °F	10	8	9
	Flow, gpm	15.3	15.0	15.2
	Blowby Heat Exchanger, °F	113	110	112
	Marine Manifold, °F	92	86	89
Carburetor Air	Temperature, °F	82	75	80
	Humidity, grains/lb	79.2	79.2	79.2
	Pressure, in. H ₂ O	0.24	0.18	0.21
Blowby Temperature, °F		117	111	113
Blowby Rate, cfm		2.44	2.34	2.38
Crankcase Pressure, in. H ₂ O		2.5	1.2	1.8
Ignition Timing, °BTDC		46	46	46
Intake Manifold Vacuum, in. Hg		9.0	8.7	8.8
Fuel Flow, lbs/hr		---	---	---
Exhaust Back Pressure, in. H ₂ O		11.1	8.0	10.3
Exhaust Gas Analysis	O ₂ , %	1.12	0.94	1.03
	CO, %	0.40	0.17	0.28
	NO _x , ppm	---	---	1060

Southwest Research Institute
Testing Laboratory



TEST: 31-07-10-85-3

DATE: 09-29-87

SWRI CODE: I,O-34579

CHARGE NO. :

METALS IN PPM

[illegible]

URGENCY DATE:

WEAR SCREENER TEST USING METHANOL FUEL

OIL CODE AL-16155-L
SWRI NO. LO-35822
DATE 10-01-87
TEST NO. 31-08-10-85-3
ENGINE NO. 10
TOTAL ENG HRS 224
FUEL M-85 Tank # 105
TEST HOURS 24
FLUSH OIL LO-12119
FLUSH OIL FUEL Phillips "J"
FLUSH TIME 3 Hours

DISCUSSION

(1) Take 2 ounce Oil Sample:

- End of candidate flush ("0" hour)
- 8, 16, 20, 24 hours
- "New" Oil

(2) Note test conditions are "steady state"

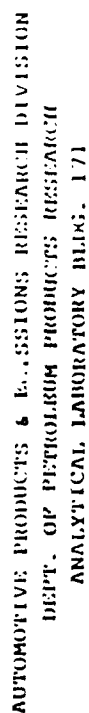
OPERATIONAL SUMMARY

Client Oil Code: AL-16155-L
 Laboratory Oil Code: LO-35822

Test Number: 31-08-10-85-3
 Date Completed: 10-02-87

		Maximum	Minimum	Average
Speed, rpm		2508	2500	2503
Load, bhp		33.8	33.3	33.6
Oil	Cooler into Engine, °F	126	124	125
	Engine ΔT (Out-In), °F	20	17	19
	Pump Gallery, psi	71.7	70.0	70.8
	Engine Gallery, psi	63.6	62.6	63.1
	ΔP (Pump-Engine), psi	9.1	7.0	7.8
	Cylinder Head Gallery, psi	60.6	59.0	59.8
	ΔP (Engine-Head), psi	4.0	3.4	3.2
	Cooling, minutes	////////	////////	////////
Water	Jacket Outlet, °F	116	114	115
	ΔT (Out-In), °F	10	8	10
	Flow, gpm	15.4	15.0	15.1
	Blowby Heat Exchanger, °F	113	108	111
	Marine Manifold, °F	92	87	90
Carburetor Air	Temperature, °F	82	78	80
	Humidity, grains/lb	79.2	79.2	79.2
	Pressure, in. H ₂ O	0.24	0.20	0.21
Blowby Temperature, °F		116	111	113
Blowby Rate, cfm		2.42	2.17	2.32
Crankcase Pressure, in. H ₂ O		2.2	1.4	1.8
Ignition Timing, °BTDC		46	46	46
Intake Manifold Vacuum, in. Hg		8.9	8.6	8.8
Fuel Flow, lbs/hr		---	---	---
Exhaust Back Pressure, in. H ₂ O		11.0	9.4	10.4
Exhaust Gas Analysis	O ₂ , %	1.10	0.80	1.04
	CO, %	0.66	0.21	0.34
	NO _x , ppm	2010	1500	1755

Southwest Research Institute
 Testing Laboratory



SPONSOR CODE: AL-16155-L

SAMPLE:

DATE: 10-01-87

SWRI CODE: 10-35822

CHARGE? NO. :

METALS IN PLM

IRGPN CY DATE:

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

DEFENSE TECHNICAL INFORMATION CTR
CAMERON STATION 12
ALEXANDRIA VA 22314

DEPT OF DEFENSE
OASD/P&L
ATTN: L/EP (MR DYCKMAN) 1
WASHINGTON DC 20301-8000

CDR
DEFENSE GENERAL SUPPLY CTR
ATTN: DGSC-SSM 1
ATTN: DGSC-STC 1
RICHMOND VA 23297-5000

DOD
ATTN: DUSDRE (RAT) (DR DIX) 1
ROOM 3-D-1089, PENTAGON
WASHINGTON DC 20301

DEPARTMENT OF THE ARMY

CDR
US ARMY BELVOIR RESEARCH,
DEVELOPMENT & ENGINEERING CTR
ATTN: STRBE-VF 10
STRBE-BT 2
FORT BELVOIR VA 22060-5606

HQ, DEPT OF ARMY
ATTN: DALO-TSE 1
DALO-TSZ-B (MR KOWALCZYK) 1
DALO-PLA (DR WILTSHIRE) 1
SARD-TR (MS VANNUCCI) 1
WASHINGTON DC 20310-0561

CDR
US ARMY MATERIEL COMMAND
ATTN: AMCDE-SS 1
AMCSM-SP 1
AMCDE-WH 1
5001 EISENHOWER AVE
ALEXANDRIA VA 22333-0001

PROJ MGR, MOBILE ELECTRIC POWER
ATTN: AMCPM-MEP-TM 1
(COL BRAMLETTE)
7500 BACKLICK ROAD
SPRINGFIELD VA 22150

CDR
US ARMY TANK-AUTOMOTIVE COMMAND
ATTN: AMSTA-RG 1
AMSTA-TSL (MR BURG) 1
AMSTA-MTC (MR GAGLIO) 1
AMSTA-RGP (MR RAGGIO) 1
AMSTA-MLF (MR KELLER) 1
AMSTA-MC 1
AMSTA-MV 1
AMSTA-Z (MR FARKUS) 1
WARREN MI 48397-5000

CDR
US ARMY GENERAL MATERIAL &
PETROLEUM ACTIVITY
ATTN: STRGP-F (MR ASHBROOK) 1
STRGP-FE, BLDG 85-3 1
STRGP-FT (MR ROBERTS) 1
NEW CUMBERLAND PA 17070-5008

CDR, US ARMY TROOP SUPPORT
COMMAND
ATTN: AMSTR-E (MR CHRISTENSEN) 1
4300 GOODFELLOW BLVD
ST LOUIS MO 63120-1798

CDR
US ARMY LABORATORY COMMAND
ATTN: AMSLC-TP-PB (MR GAUL) 1
ADELPHI MD 20783-1145

CDR
US ARMY YUMA PROVING GROUND
ATTN: STEYP-MT-TL-M 1
(MR DOEBBLER)
YUMA AZ 85364-9130

CDR
US ARMY RESEARCH OFFICE
ATTN: SLCRO-EG (DR MANN) 1
P O BOX 12211
RSCH TRIANGLE PARK NC 27709-2211

CDR
US ARMY GENERAL MATERIAL &
PETROLEUM ACTIVITY
ATTN: STRGP-PW 1
BLDG 247, DEFENSE DEPOT TRACY
TRACY CA 95376-5051

CDR
AMC MATERIEL READINESS SUPPORT
ACTIVITY (MRSA)
ATTN: AMXMD-MO (MR BROWN) 1
LEXINGTON KY 40511-5101

CDR
US ARMY ORDNANCE CENTER &
SCHOOL
ATTN: ATSL-CD-CS
ABERDEEN PROVING GROUND MD
21005-5006

CDR
US ARMY ENGINEER SCHOOL
ATTN: ATSE-CD
FORT LEONARD WOOD MO 65473-5000

CDR
US ARMY QUARTERMASTER SCHOOL
ATTN: ATSM-CDM
ATSM-LL FSD
FORT LEE VA 23801

PROJECT MANAGER
PETROLEUM & WATER LOGISTICS
ATTN: AMCPM-PWL
4300 GOODFELLOW BLVD
ST LOUIS MO 63120-1798

CDR
US ARMY LOGISTICS CTR
ATTN: ATCL-CD
ATCL-MS
FORT LEE VA 23801-6000

HQ
US ARMY TRAINING & DOCTRINE CMD
ATTN: ATCD-SL
FORT MONROE VA 23651-5000

CDR
US ARMY TRANSPORTATION SCHOOL
ATTN: ATSP-CD-MS
FORT EUSTIS VA 23604-5000

DEPARTMENT OF THE NAVY

OFFICE OF THE CHIEF OF NAVAL
RESEARCH
ATTN: OCNR-126 (DR ROBERTS)
ARLINGTON VA 22217-5000

DEPARTMENT OF THE AIR FORCE

HQ AIR FORCE SYSTEMS COMMAND
ATTN: AFSC/DLF (DR DUES)
ANDREWS AFB MD 20334

CDR
US AIR FORCE WRIGHT AERO LAB
ATTN: AFWAL/POSL (MR JONES)
WRIGHT-PATTERSON AFB OH
45433-6563

CDR
SAN ANTONIO AIR LOGISTICS CTR
ATTN: SAALC/SFT (MR MAKRIS)
KELLY AIR FORCE BASE TX 78241

OTHER GOVERNMENT AGENCIES

NATIONAL AERONAUTICS AND SPACE
ADMINISTRATION
LEWIS RESEARCH CENTER
CLEVELAND OH 44135

US DEPARTMENT OF ENERGY
MAIL CODE CE-151
FORRESTAL BLDG.
1000 INDEPENDENCE AVE, SW
WASHINGTON DC 20585