

AD-A127 239

EVALUATION OF FOUR LUBRICANTS USING A MODIFIED FEDERAL  
TEST METHOD 354 TEST (U) SOUTHWEST RESEARCH INST SAN  
ANTONIO TX ARMY FUELS AND LUBRICA.

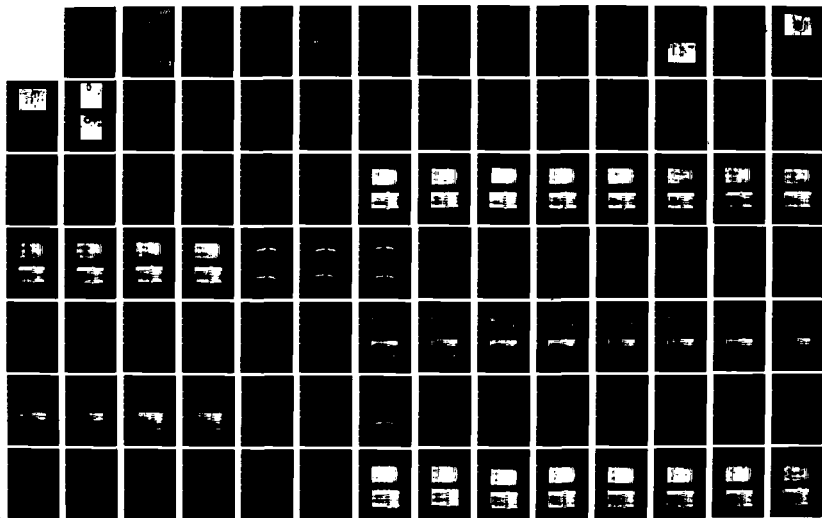
1/2

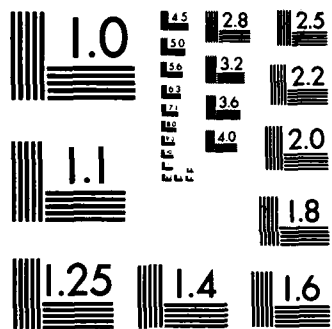
UNCLASSIFIED

R F MONTEYAYOR ET AL. DEC 81 AFLRL-122

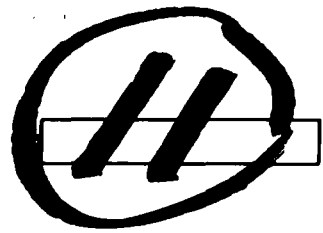
F/G 11/8

NL





MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A



# EVALUATION OF FOUR LUBRICANTS USING A MODIFIED FEDERAL TEST METHOD 354 TEST PROCEDURE

**INTERIM REPORT  
AFLRL No. 122**

By

**A. F. Montemayor  
E. C. Owens  
S. J. Lestz**

**U.S. Army Fuels and Lubricants Research Laboratory  
Southwest Research Institute  
San Antonio, Texas**

Under Contract to

**U.S. Army Mobility Equipment Research  
and Development Command  
Energy and Water Resources Laboratory  
Fort Belvoir, Virginia**

**Contract No. DAAK70-82-C-0001**

Approved for public release; distribution unlimited

December 1981

**DTIC**  
**ELECTE**  
APR 27 1983  
**S** **D**  
**D**

AD A127439

DTIC FILE COPY

### **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 (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM						
1. REPORT NUMBER AFLRL NO. 122	2. GOVT ACCESSION NO. <b>A127239</b>	3. RECIPIENT'S CATALOG NUMBER						
4. TITLE (and Subtitle) EVALUATION OF FOUR LUBRICANTS USING A MODIFIED FEDERAL TEST METHOD 354 TEST PROCEDURE		5. TYPE OF REPORT & PERIOD COVERED Interim Report August 1980 - December 1980						
7. AUTHOR(s) A.F. Montemayor E.C. Owens S.J. Lestz		6. PERFORMING ORG. REPORT NUMBER AFLRL No. 122						
9. PERFORMING ORGANIZATION NAME AND ADDRESSES U.S. Army Fuels and Lubricants Research Lab. Southwest Research Institute P.O. Drawer 28510 San Antonio, TX 78284		8. CONTRACT OR GRANT NUMBER(s) DAAK70-80-C-0001 DAAK70-82-C-0001						
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Mobility Equipment Research and Development Command, Energy and Water Resources Laboratory, Ft. Belvoir, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1L762733AH2OEL; WUB06						
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE December 1981						
		13. NUMBER OF PAGES 133						
		15. SECURITY CLASS. (of this report) Unclassified						
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE						
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited.								
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)								
18. SUPPLEMENTARY NOTES Because of the large number of pages, only a limited number of copies of the appendices have been reproduced. Copies of the appendices may be obtained by requesting this document from the Defense Technical Information Center, Cameron Station, Alexandria VA 22314.								
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)								
<table border="0"> <tr> <td>Detroit Diesel 6V-53T</td> <td>MIL-L-2104</td> </tr> <tr> <td>FTM 354</td> <td>MIL-L-46167</td> </tr> <tr> <td>Cast Iron Block</td> <td>Aluminum Block</td> </tr> </table>			Detroit Diesel 6V-53T	MIL-L-2104	FTM 354	MIL-L-46167	Cast Iron Block	Aluminum Block
Detroit Diesel 6V-53T	MIL-L-2104							
FTM 354	MIL-L-46167							
Cast Iron Block	Aluminum Block							
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Four 100-hour engine tests were conducted using the Detroit Diesel 6V-53T engine. Federal Test Method 354 was utilized for these tests with the cast iron block version of the 6V-53T engine used instead of the aluminum block version. Test lubricants were AL-8925-L, AL-9841-L, AL-10153-L, and AL-8980-L, designated as Oils A, B, C, and D in the report.								

DD FORM 1473  
1 JAN 73

EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED  
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

**UNCLASSIFIED**  
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

**BLANK PAGE**

**UNCLASSIFIED**  
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FOREWORD

The work reported herein was conducted at the U.S. Army Fuels and Lubricants Research Laboratory located at Southwest Research Institute, San Antonio, TX, under Contracts DAAK70-80-C-0001 and DAAK70-82-C-0001, during the period August 1980 through December 1981. The contracting officer's representative was Mr. F.W. Schaekel, Energy and Water Resources Laboratory, USAMERADCOM, DRDME-GL, Ft. Belvoir, VA, and the technical monitor was Mr. Tom Bowen of the same office.

<b>Accession For</b>	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	



ACKNOWLEDGEMENTS

The authors wish to thank Mr. Richard Moon for the supervision and preparation of the tests reported herein.



TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION.....	5
II. OBJECTIVE AND SCOPE.....	5
III. EXPERIMENTAL.....	5
A. Test Engine Set-Up.....	5
B. Test Fuel.....	11
C. Test Lubricants.....	11
IV. DISCUSSION OF RESULTS.....	11
V. CONCLUSIONS.....	15
VI. RECOMMENDATIONS.....	15
VII. REFERENCES.....	16
APPENDICES	
A Performance of AL-8925-L Lubricating Oil in a Two-Cycle Diesel Engine Under Steady-State Turbocharged Conditions.....	17
B Performance of AL-9841-L Lubricating Oil in a Two-Cycle Diesel Engine Under Steady-State Turbocharged Conditions.....	45
C Performance of AL-10153-L Lubricating Oil in a Two-Cycle Diesel Engine Under Steady-State Turbocharged Conditions.....	75
D Performance of AL-8980-L Lubricating Oil in a Two-Cycle Diesel Engine Under Steady-State Turbocharged Conditions.....	105

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	Cooling System and Engine Setup.....	6
2	Engine Oil Coolers.....	8
3	Oil System Schematic.....	8
4	Fuel Filter and Heat Exchanger Setup.....	9
5	Fuel System Schematic.....	9
6	Blowby Surge Tank Setup, Side View.....	10
7	Blowby Surge Tank Setup, Front View.....	10
8	Blowby Surge Tank.....	11
9	Scuffing and Deposits.....	13
10	Measured Wear.....	14
11	Oil Iron Content and Piston WTD.....	14
12	Oil Consumption.....	14

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Analysis of Diesel Fuel .....	12
2	Properties of Test Lubricants.....	12
3	Test Results.....	13

## I. INTRODUCTION

Federal Test Method (FTM) 354 was developed to evaluate the performance of Arctic engine oils in high-output diesel engines.(1)\* This test method(2) used the aluminum block version of the Detroit Diesel 6V-53T engine, and proved to be effective in discriminating lubricant quality under high-output conditions. Because the 6V-53T engine is no longer available in the aluminum block version, the four tests reported herein were conducted using the cast iron version of the 6V-53T engine. The test setup for the four tests differs in several respects from FTM 354. These differences are described in Section III of this report.

## II. OBJECTIVE AND SCOPE

The objective of this work was to determine if the iron block version of the 6V-53T engine could discriminate lubricant quality when run according to FTM 354. Deviations from FTM 354 described in Section III of this report were considered minor when compared to the change from aluminum to cast iron blocks. Due to the limited number of tests run, it was beyond the scope of this report to establish correlations between the aluminum and cast iron tests.

## III. EXPERIMENTAL

### A. Test Engine Setup

The equipment for this program included a 400-hp Midwest absorption dynamometer, an Eaton Dynamic control chassis, and a Hagan pneumatic load transmitting/indicating load system. Combustion air was drawn into the engine through a stack of four dry-type automotive air filters inside a fiberglass-

---

\* Underscored numbers in parentheses refer to references at end of report.

lined 30-gallon barrel, used for noise suppression. Exhaust gas was discharged from the engine into a 4-inch ID flexible line and then into a common exhaust system which operated under 6 to 8 inches water vacuum. Treated water for jacket coolant was then circulated by the engine's centrifugal-type water pump, and the engine coolant thermostat was mechanically locked in the open position to provide normal operating flow restriction. Jacket water was cooled by running it through a tube-in-shell heat exchanger. Fuel was brought to the engine directly from a 4000-gallon underground tank. The fuel system was plumbed in such a way that the return fuel (injector cooling fuel) was diverted to the day tank at a position downstream from the mass flowmeter.

Detailed descriptions of the test setup (Figure 1), engine rebuild, engine calibration, operating procedures, and rating method are given in Federal Test Method 354. Several changes were made in the equipment/procedures specified by FTM 354. These changes are:



FIGURE 1. COOLING SYSTEM AND ENGINE SETUP

---

1. Engine Block - A cast iron version of the 6V-53T engine was used in these tests. The Detroit Diesel model number of the engine is 5063-5395.
2. Engine Coolant - A 50/50 volumetric mixture of a commercial anti-freeze and water was used instead of the coolant prescribed in FTM 354.
3. Oil System - The oil filter assembly was relocated to an off-engine position in order to prevent the filter assembly from vibrating loose. The change from aluminum to cast iron blocks required additional oil-cooling capacity to maintain the correct oil temperature. This was accomplished by using the eight-plate transmission cooler (DD-8539953) in conjunction with the standard sixteen-plate oil cooler (DD-8528885). Figures 2 and 3 depict the layout of the oil system.
4. Fuel System - Two heat exchangers were used to maintain the required fuel temperature as shown in Figures 4 and 5.
5. Blowby System - The change from aluminum to cast iron blocks significantly reduced the amount of blowby emitted by the engine, rendering the blowby meter specified in FTM 354 unusable. To provide an indication of relative blowby, the system shown in Figures 6, 7, and 8 was used. Although this system was not calibrated in standard cubic feet per minute, it served to indicate mechanical engine damage by showing any large increases in blowby. To maintain filter cleanliness, the discharge of the blowby surge tank was not directed into the engine air intake slipstream.
6. Lubricant Inspections - Each sample of engine oil was quantitatively tested for iron content in addition to the tests specified in FTM 354. Each sample was tested in an X-ray fluorescence spectrometer and the results reported in parts per million.

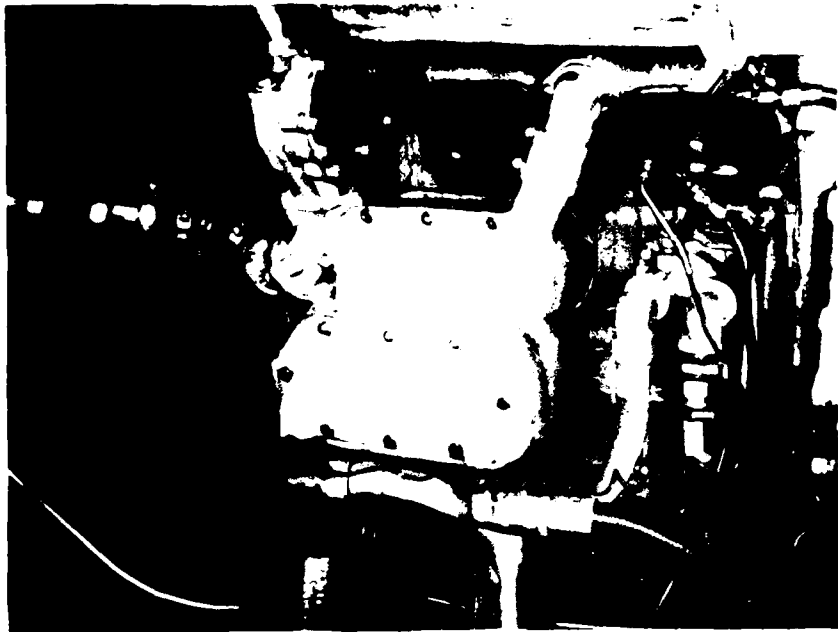


FIGURE 2. ENGINE OIL COOLERS

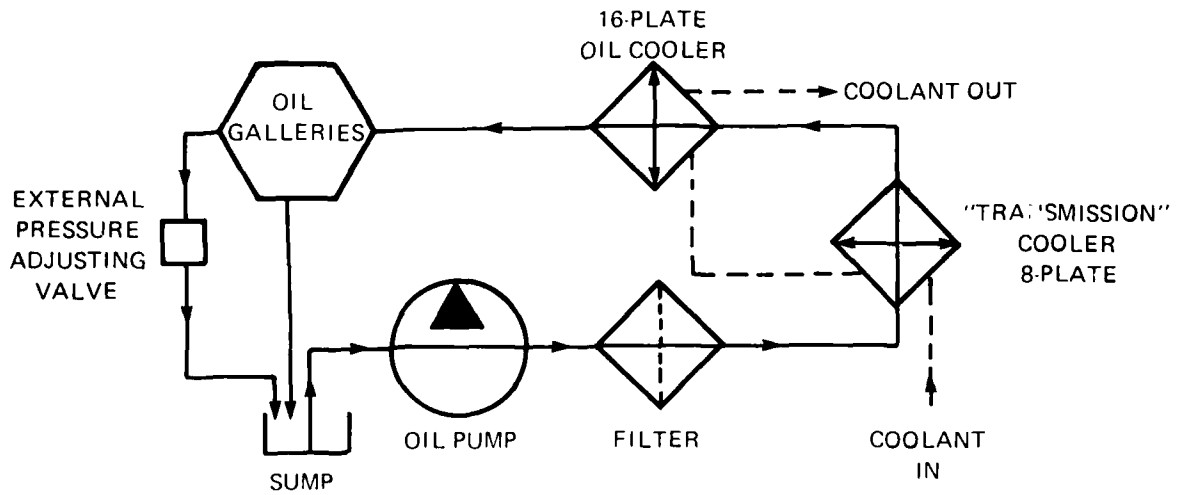


FIGURE 3. OIL SYSTEM SCHEMATIC

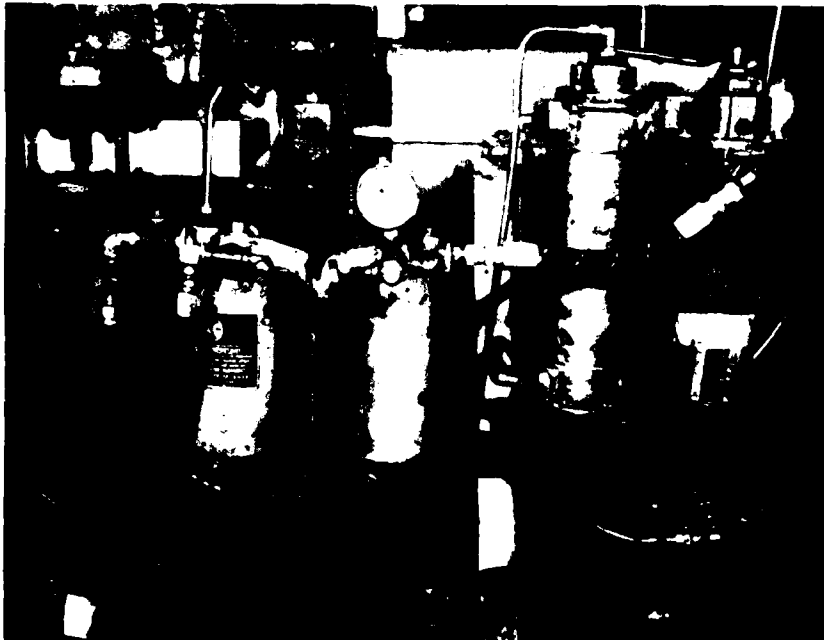


FIGURE 4. FUEL FILTER AND HEAT EXCHANGER SETUP

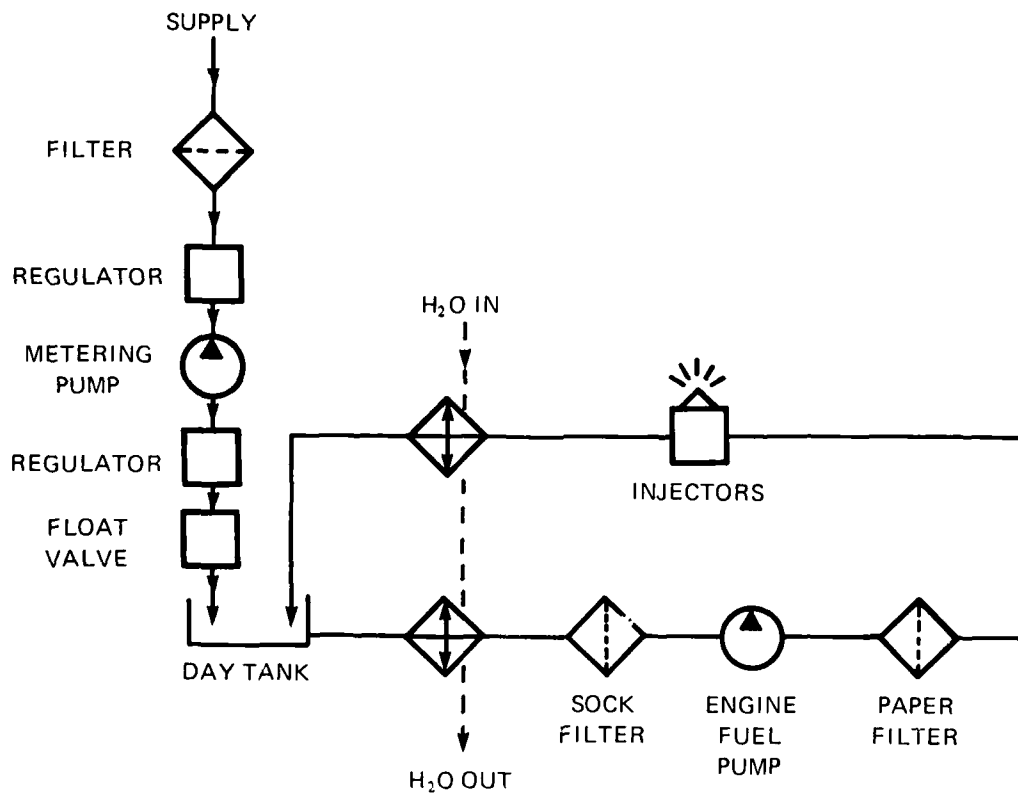


FIGURE 5. FUEL SYSTEM SCHEMATIC

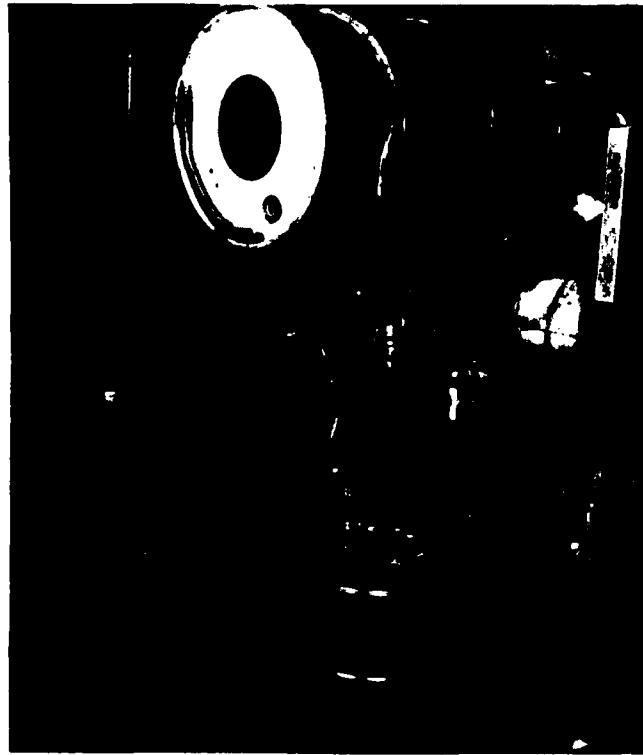


FIGURE 6. BLOWBY SURGE TANK SETUP, SIDE VIEW

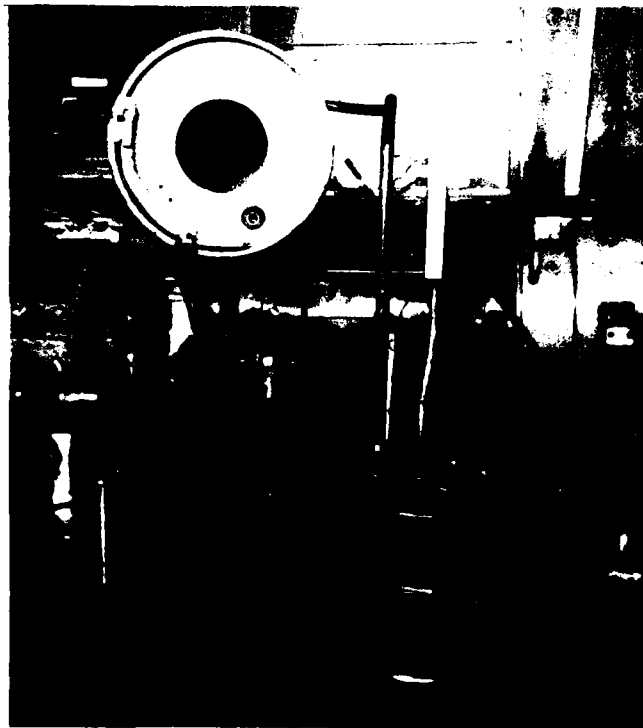


FIGURE 7. BLOWBY SURGE TANK SETUP, FRONT VIEW



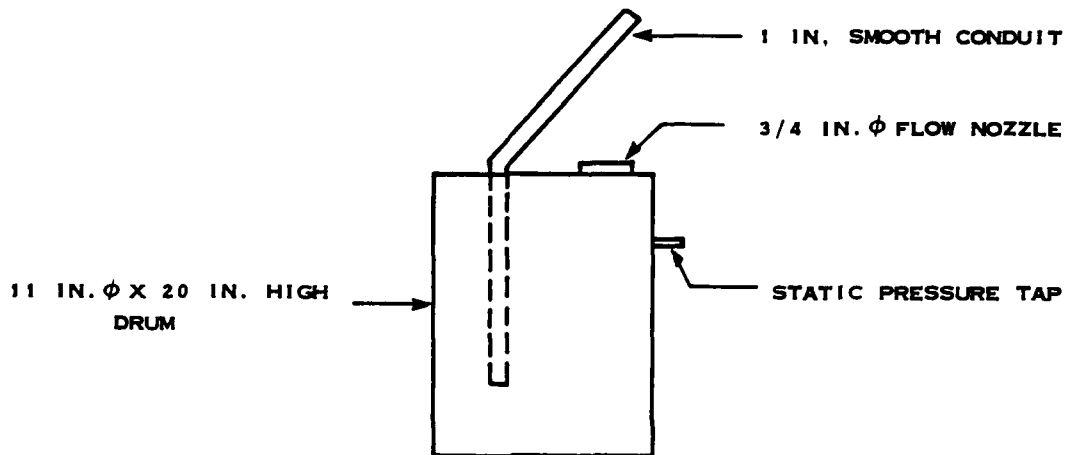


FIGURE 8. BLOWBY SURGE TANK

7. Photographic Data--Black-and-white photographs were taken to document wear parts.

B. Test Fuel

The test fuel used for these tests was CAT 1-H diesel fuel. Typical inspections for this test fuel are given in Table 1 and compared with the requirements of FTM 341.

C. Test Lubricants

The lubricants used in these tests were AL-8925, AL-9841, AL-10153, and AL-8980, designated henceforth as Oils A, B, C, and D, respectively. Properties of the test lubricants are shown in Table 2. Oils A and B were qualified MIL-L-46167 5W-20 lubricants.(3) Oil C was a 10W-30 MIL-L-2104D candidate. Oil D was an SAE 30 grade MIL-L-2104C(4) qualified product which serves as the Army reference oil for MIL-L-2104C.

IV. DISCUSSION OF RESULTS

Test results are presented in Appendices A through D. For purposes of discussion, wear and deposits data have been summarized and are shown in Table 3. These data are represented in graphic form in Figures 9 through 12.

TABLE 1. ANALYSIS OF DIESEL FUEL

Inspection	Test Method	Test Fuel	FTM 341 Requirements
Gravity, °API at 60°F (16°C)	D 287	34.9	Record
Flash Point, °F (°C)	D 93	176 (80)	100 (38) min
Cloud Point, °F (°C)	D 2500	+25 (-4)	Record
Pour Point, °F (°C)	D 97	+5 (-15)	+20 (-7) max
Viscosity 100°F, cSt	D 445	3.21	1.6-4.5
Distillation, °F (°C)	D 86		
IBP		382 (194)	Record
10%		465 (241)	Record
50%		523 (272)	500 (260) min
90%		601 (316)	600-640 (316-338)
EP		671 (355)	650-690 (343-366)
Water and Sediment, vol%	D 1796	0	0.05 max
Ramsbottom Carbon, %	D 524	0.14	Record
Sulfur, wt%	D 1266	0.399	0.35-0.45
Corrosion, 3 hr at 210°F (99°C)	D 130	1a	Pass
Aniline Number, °F (°C)	D 611	153.9 (67.7)	Record
Neutralization No., mg KOH/g	D 974	0.03	Record
Cetane Index	D 976	50	40-45
Lower Heating Value, Btu/lb (MJ/kg)	D 240	18,665 (43.42)	Record

TABLE 2. PROPERTIES OF TEST LUBRICANTS

Test Method	Oils				
	A	B	C	D	
AL Code	8925	9841	10153	8980	
Viscosity grade	5W-20	5W-20	10W-30	30	
Military specification	MIL-L-46167	MIL-L-46167	Candidate MIL-L-2104D	MIL-L-2104C	
°API at 60°F(16°C)	D 287	21.3	36.5	29.2	25.2
K Vis at 40°C, cSt	D 445	26.32	29.56	66.39	109.11
K Vis at 100°C, cSt	D 445	5.90	5.75	10.45	11.65
Viscosity Index	D 2270	179	140	145	93
TAN	D 664	0.3	3.1	2.3	2.3
TBN	D 664	5.5	5.3	8.7	13.3
Flash Point, °C	D 92	234	232	202	223
Sulfated Ash, %	D 874	1.45	1.07	1.09	1.60
Barium, ppm (AA)		9055	2200	<50	<50
Calcium, ppm (AA)		5	146	1400	4750
Magnesium, ppm (AA)		1	955	900	30
Zinc, ppm (AA)		0	1400	1270	670
Sulfur, ppm (XRF)		200	4600	5800	6500
Phosphorous, ppm (XRF)		100	1300	963	700

AA = Atomic Absorption Method.  
XRF = X-ray Fluorescence Method.

TABLE 3. TEST RESULTS

Test Oil	A	B	C	D
Cylinder Scuffing, %Total RTA	10	15	14	7
Intake Port Plugging, %	2	1	1	1
Ring Groove Carbon Filling, %	11	6	10	8
Cylinder Liner Bore Change, in. x 10 <sup>-4</sup>	-4	8	4	0
Ring End Gap Change, (all rings) in. x 10 <sup>-4</sup>	30	13	5	10
Fire Ring End Gap Change, in. x 10 <sup>-4</sup>	20	40	3	0
Final Oil Iron Content, ppm	23	236	119	18
Piston Weighted Deposits (WTD)	314	210	270	202
Fire Ring Face Distress, %	6	1	12	39
2 & 3 Ring Face Distress, %	17	0	19	5
Oil Consumption, Lb/hr	0.51	0.81	0.51	0.59

RTA - Ring travel area

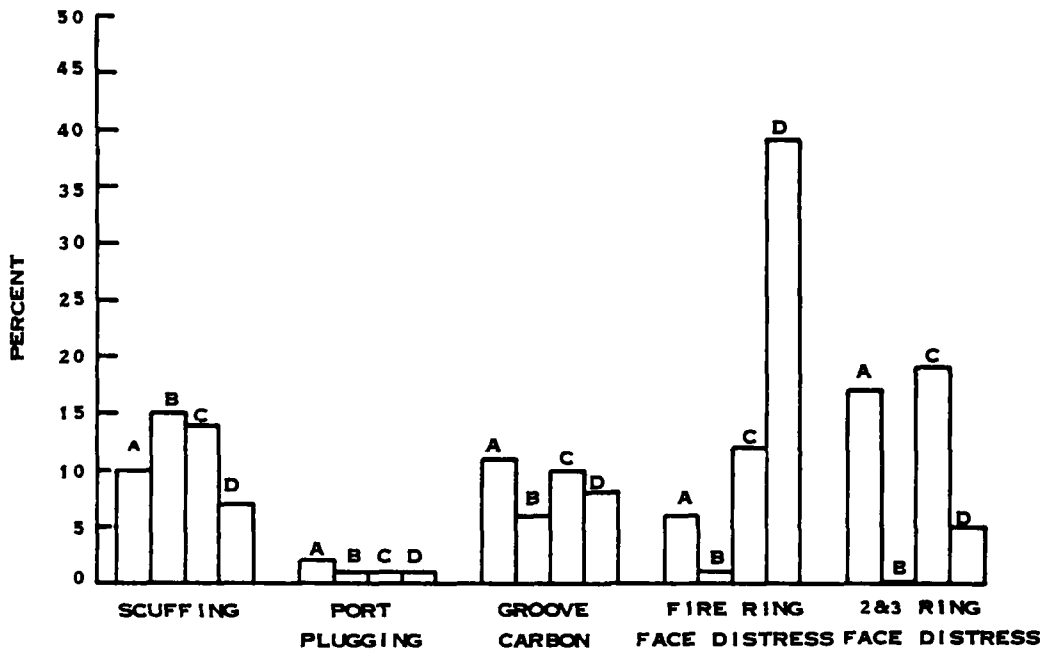


FIGURE 9. SCUFFING AND DEPOSITS

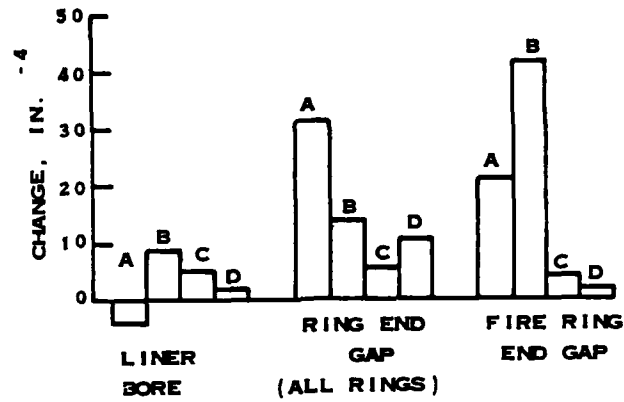


FIGURE 10. MEASURED WEAR

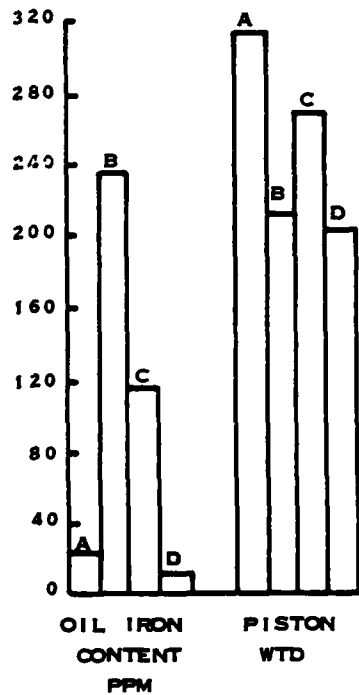


FIGURE 11. OIL IRON CONTENT AND PISTON WTD

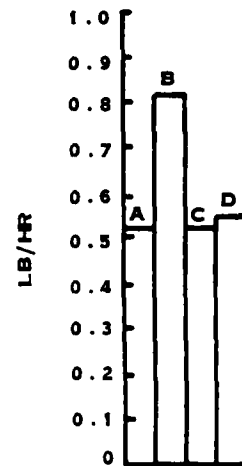


FIGURE 12. OIL CONSUMPTION

From past experience (5,6,7), we would expect oil D to produce better results than oils A, B and C in terms of ring face distress and liner scuffing. We would also expect the performance of oil A to approach that of oil D and to be superior to oil B. Figures 9 through 12 show this expected ranking in terms of liner scuffing but fail to in terms of ring face distress. Fire ring end gap and engine oil content at end of test show the expected ranking, but liner bore wear and ring end gap (all rings) yield ambiguous results. The oil consumption for oil B (0.81 lb/hr) was markedly higher than the other tests and exceeded the FTM 354 validity limit of 0.75 lb/hr. This high oil consumption was probably caused by severe wear of the oil control rings in cylinder 3L. Liner 3L also manifested severe scuffing ratings of 70 percent of the total ring travel area. The severe liner scuffing in 3L should have caused ring face distress in the associated rings. Heavy wear was noted for these rings, but very little ring face distress was seen. The combination of liner scuffing in a heavily oil-bathed area probably produced "mirror-finished" rings. The ambiguous results from this test were heavily influenced by this one liner/piston/ring set. Based on Figures 9 through 12, no clearcut ranking scheme can be established for these lubricants.

#### V. CONCLUSIONS

Based on this limited number of tests (four), the cast iron 6V-53T engine appears to discriminate lubricant quality when run according to FTM 354 instructions. More cast iron FTM 354 tests will be necessary in order to establish any correlation with standard FTM 354 tests.

#### VI. RECOMMENDATIONS

More cast iron FTM 354 tests should be performed. Candidate oils should be selected to correspond to existing FTM 354 tests. Each test in this report should be repeated in order to determine repeatability and validity of the data.

## VII. REFERENCES

1. Lestz, S.J., "Development of a Diesel Engine Test Technique for Evaluating Arctic Engine Oils," Interim Report No. 24, Government Accession No. AD 768901, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute, September 1973.
2. Method 354, Federal Test Method Standard 791B, "Performance of Arctic Lubricating Oils in a Two-Cycle Diesel Engine Under Steady-State Turbo-supercharged Conditions," January 1973.
3. U.S. Military Specification MIL-L-46167, Lubricating Oil Internal Combustion Engine, Arctic, February 1974; Amendment 1, May 1978.
4. U.S. Military Specification MIL-L-2104C, Lubricating Oil, Internal Combustion Engine, Tactical Service, November 1970.
5. Lestz, S.J., Bowen, T.C., "Development of Army Synthetic Automotive Engine Oils for Arctic Service," Interim Report No. AFLRL 73, AD A019113, Contract Nos. DAAD05-70-C-0250 and DAAK02-73-C-0221, September 1975.
6. Lestz, S.J., Bowen, T.C., "Army Experience With Synthetic Engine Oils in Mixed Fleet Arctic Service," SAE No. 750685, presented at SAE Fuels and Lubricants Meeting, Houston, TX June 1975.
7. Engine Test Report: "Performance of Arctic Lubricating Oils in a Two-Cycle Diesel Engine Under Steady State Turbosupercharged Conditions," Test Lubricant: ME-1 (AL-7022-L), Engine Test Number: 6D8019-8 (Modified Test), Date Completed: 23 November 1977.

APPENDIX A

PERFORMANCE OF AL-8925-L LUBRICATING OIL  
IN A TWO-CYCLE DIESEL ENGINE UNDER  
STEADY-STATE TURBOSUPERCHARGED CONDITIONS

PERFORMANCE OF AL-8925-L LUBRICATING OIL  
IN A TWO-CYCLE DIESEL ENGINE UNDER  
STEADY-STATE TURBOSUPERCHARGED CONDITIONS  
(Method 354 Fed. Test Method Std. 791B)

Engine Test Number: MTC 2 (Modified Test\*)

Date Completed: 26 September 1980

Conducted For

U.S. Army Mobility Equipment Research and Development Command  
Energy and Water Resources Laboratory  
Fort Belvoir, Virginia

by

U.S. Army Fuels and Lubricants Research Laboratory  
Southwest Research Institute  
San Antonio, Texas 78284

\*Modified Test

This test used the cast iron block version of the DD6V-53T engine. Changes include a cast iron engine block, a 16-plate oil cooler and an 8-plate auxiliary oil cooler.



TABLE 1  
6V-53T 6D-151056  
BUILD-UP ENGINE MEASUREMENTS

	Measurements*			
	Min.	Max.	Avg.	Specified Limits**
Connecting rod bearing clearance	0.0036	0.0040	0.0039	0.0010-0.0040
Cylinder liner block bore				
Taper	0.0001	0.0006	0.0002	0.0015 max.
Out-of-round	0.0001	0.0008	0.0003	0.0015 max.
Inside Diameter	4.3566	4.3580	4.3574	4.3565-4.3575 4.3595 max.
Cylinder liners (installed)				
Taper	0.0000	0.0007	0.0003	0.015 max.
Out-of-round	0.0001	0.0007	0.0005	0.015 max.
Inside diameter	3.8753	3.8765	3.8759	3.8752-3.8767
Piston to liner fit <sup>1</sup>	0.0073	0.0089	0.0080	0.0060-0.0095
Piston diameter	3.8673	3.8686	3.8680	3.8669-3.8691
Fire Ring				
End gap	0.029	0.039	0.034	0.020-0.046
Side clearance	0.002	0.004	0.003	0.003-0.006
#1 Compression ring				
End gap	0.026	0.035	0.030	0.020-0.046
Side clearance	0.007	0.008	0.008	0.007-0.010
#2 & #3 Compression ring				
End gap	0.027	0.041	0.033	0.020-0.046
Side clearance	0.005	0.006	0.006	0.005-0.010
Oil rings				
End gap	0.018	0.021	0.019	0.010-0.025
Side clearance	0.0025	0.004	0.0033	0.0015-0.0055

\* All measurements given are in inches.

\*\* Wear limits with new liners in a used block.

<sup>1</sup> Thrust-Anti-thrust direction

TABLE 2

## OPERATING DATA SHEET

Test Run at U.S. Army Fuels &amp; Lubricants Research Laboratory (SwRI)

Test Oil: AL-8925-L

Test Fuel: 1-H CAT

Test No.: MTC-2

Test Stand: 5

Engine No.: 6D-151056

Test Hours: 100 Date Started: 22 September 1980 Completed: 27 September 1980

Total Downtime: 6.42 Hrs Scheduled; 0 Hrs Unscheduled

	<u>Min.</u>	<u>Max.</u>	<u>Avg.</u>
Engine Speed, rpm	2798.0	2802.	2800.
Load, lbs	97.	100.	98.
Output, Bhp	232.	240.	236.
Fuel Rate, lb/min	1.55	1.64	1.60
Oil Consumption, lb/hr			0.5098
<u>Temperature, °F</u>			
Jacket-in	160.	165.	164.
Jacket-out	170.	175.	174.
Oil Sump	231.	239.	234.
Inlet Air (compressor)	84.	108.	97.
Airbox	257.	281.	269.
Exhaust before turbo	790.	840.	816.
Exhaust after turbo	720.	770.	748.
Fuel at filter (secondary)	89.	97.	91.
<u>Pressures</u>			
Compressor suction, in. H <sub>2</sub> O	6.2	6.8	6.50
Compressor discharge, psi <sup>2</sup>	8.5	9.2	8.77
Blower discharge (airbox), psi	14.9	15.5	15.18
Exhaust before turbo, psi	11.0	11.6	11.29
Exhaust after turbo, in. Hg	1.4	2.0	1.83
Oil gallery, psi	33.0	34.5	34.02
Fuel at filter, psi	70.0	72.0	71.12
Blowby, in. H <sub>2</sub> O	0.79	0.91	0.84

TABLE 3

## RATING DATA SHEET

Test Run at U.S. Army Fuels &amp; Lubricants Research Laboratory (SwRI)

Test Oil: AL-8925-L,

Test Fuel: 1-H CAT

Test No.: MTC-2

Test Stand: 5

Engine No.: 6D-151056

Test Hours: 100 Date Started: 22 September 1980 Completed: 26 September 1980

## A. Cylinder Liner Ratings

<u>Cylinder No.</u>	<u>Intake Port Plugging</u>	<u>Restriction, %</u>
1L		1
2L		2
3L		1
1R		1
2R		2
3R		2
Average		1.5

Scuffing, Glazing, and Lacquer\*

<u>Cylinder No.</u>	<u>Scuffing, %</u>			<u>Glazing, %</u>	<u>Lacquer, %</u>
	<u>Thrust</u>	<u>Anti-Thrust</u>	<u>% Total Area</u>		
1L	5	5	5	5	95
2L	5	5	5	5	95
3L	5	5	5	5	95
1R	10	10	10	5	95
2R	5	5	5	2	98
3R	15	50	32.5	10	90
Average	7.5	13.3	10.4	5.3	94.7

\* Total Ring Travel Area

## B. Piston Ratings

Ring Sticking and Condition\*\*

<u>Cylinder No.</u>	<u>Fire</u>	<u>Ring</u>		
		<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>
1L	F- 5	F-N	F-N	F-N
2L	F- 5	F-N	F-N	F-N
3L	F+- 2	F-2	F-2	F-2
1R	F+- 2	F-1	F-10	F-1
2R	F@- 1	F-1	F-1	F-1
3R	F#- 20	F-85	F-100	F-100

\*\* Numbers denote % area ringface burn.

+ What appears to be burning is actually carbon deposit plus 2% burn.

@ What appears to be burning is actually carbon deposit plus 1% burn.

# Partially collapsed.

F = Free N = Normal

TABLE 3 (Cont'd)

Ring Groove Carbon Filling and Oil Groove Lacquer

<u>Cylinder No.</u>	<u>Groove Filling, %</u>			<u>Oil Groove Lacquer (Demerit)</u>		
	<u>Fire</u>	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>	<u>Upper</u>	<u>Lower</u>
1L	10	20	0	0	4	4
2L	10	35	2	0	4	4
3L	5	15	3	0	4	4
1R	10	20	3	0	4	4
2R	10	85	2	0	4	4
3R	15	20	5	0	4	4

Land Description

<u>Cylinder No.</u>	<u>Description</u>
1L	Normal
2L	Normal
3L	Normal
1R	Normal
2R	Normal
3R	Normal

Skirt (Demerit)

<u>Cylinder No.</u>	<u>Thrust</u>	<u>Anti-Thrust</u>
1L	6.0 Lt Scratches	6.2 Lt Scratches, 10% Lt Scuff
2L	6.8 Lt Scratches	6.5 Lt Scratches
3L	5.8 Lt Scratches	5.8 Lt Scratches
1R	6.0 Lt Scratches	5.5 Lt Scratches
2R	6.0 Lt Scratches	5.7 Lt Scratches
3R	5.8 Lt Scratches, 10% P. Melt	6.0 Lt Scratches

C. Other RatingsCombustion Chambers With Exhaust Valves

<u>Cylinder No.</u>	<u>Description</u>
1L	15%B-60%A-20½%½A-5½%A
2L	10%B-80%A-10½%½A
3L	5%B-70%A-10½%½A-15½%½A
1R	90%A-10½%½A
2R	15%B-70%A-10½%½A-5½%½A
3R	5%B-85%A-5½%½A-5½%½A

TABLE 3 (Cont'd)

D. Interim Inspections

<u>Zero Test Hours</u>	<u>Inspection</u>	<u>Zero Test Hours</u>	<u>Inspection</u>
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	Normal
<u>24 Test Hours</u>	<u>Inspection</u>	<u>24 Test Hours</u>	<u>Inspection</u>
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	Normal
<u>48 Test Hours</u>	<u>Inspection</u>	<u>48 Test Hours</u>	<u>Inspection</u>
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	Normal
<u>72 Test Hours</u>	<u>Inspection</u>	<u>72 Test Hours</u>	<u>Inspection</u>
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	Normal

E. Legend

Abbreviations

Definitions

T-Side	Thrust side of cylinder liner or piston skirt. (Inboard left bank and outboard right bank).
AT-Side	Anti-thrust side of cylinder liner or piston skirt (Side opposite thrust side).
Lt	Light
Med	Medium
Hvy	Heavy
P. Melt	Melting of the plating on the piston surface.
Sct	Scratching
Frnt	Front of piston or liner
Rt	Rear of piston or liner
Normal	All components considered normal, unless specified otherwise. This means rings are free, only light scuffing of liner and piston skirts, hard carbon on fire lands and lacquer on other ring lands.

TABLE 4

## OIL ANALYSES DATA SHEET

Test Run at U.S. Army Fuels &amp; Lubricants Research Laboratory (SwRI)

Test Oil - AL-8925-L

Test Fuel 1-H CAT

Test No. MTC-2

Test Stand 5

Engine No. 6D-151056

Test Hours 100 Date: Started 22 September 1980 Completed: 27 September 1980

Determination	Test Hour Sample								
	New Oil	12	24	36	48	60	72	84	100
Viscosity, cSt at 40 °C		28.1	28.4	28.4	28.5	28.7			
		6.22	6.30	6.30	6.34	6.38			
Total Acid Number	.296	0.17	0.14	0.14	0.18	0.17			
Total Base Number	5.54	4.54	3.59	3.59	3.34	2.84			
Sulfated Ash, %		1.58	1.56	1.56	1.69	1.71			
Flash Point, °C		242.	238.	238.	242.	233.			
Iron Content, ppm	16.	15.	18.	18.	18.	15.	21.	19.	23.
Carbon Residue, %		1.70	1.81	1.81	1.89	2.03			

TABLE 5

Lubricant: AL-8925-L

## WEAR MEASUREMENTS

## Cylinder Liner Bore Diameter Change\*

	<u>Cylinder Number</u>					
	1L		2L		3L	
	T-AT**	F-B**	T-AT	F-B	T-AT	F-B
Top	+0.0007	-0.0005	+0.0004	-0.0002	+0.0009	-0.0006
Middle	0.0000	-0.0002	0.0000	-0.0002	+0.0002	-0.0002
Bottom	-0.0003	-0.0001	-0.0001	-0.0004	-0.0003	+0.0001

	<u>Cylinder Number</u>					
	1L		2L		3L	
	T-AT	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0004	-0.0005	-0.0001	-0.0002	+0.0002	-0.0002
Middle	0.0000	-0.0001	0.0000	-0.0002	+0.0001	+0.0001
Bottom	-0.0002	-0.0001	-0.0003	-0.0001	-0.0003	-0.0002

Average Change

	T-AT	F-B
Top	+0.0004	-0.0004
Middle	+0.0001	-0.0001
Bottom	-0.0003	-0.0001

Overall Average Change: -0.0004

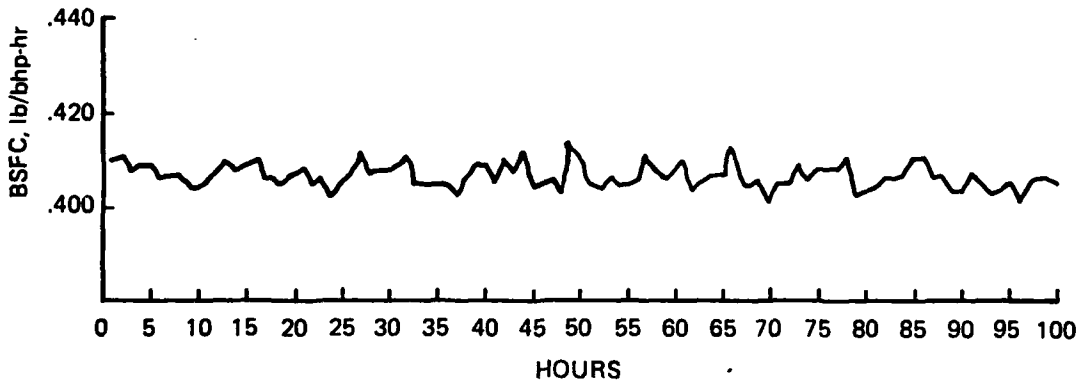
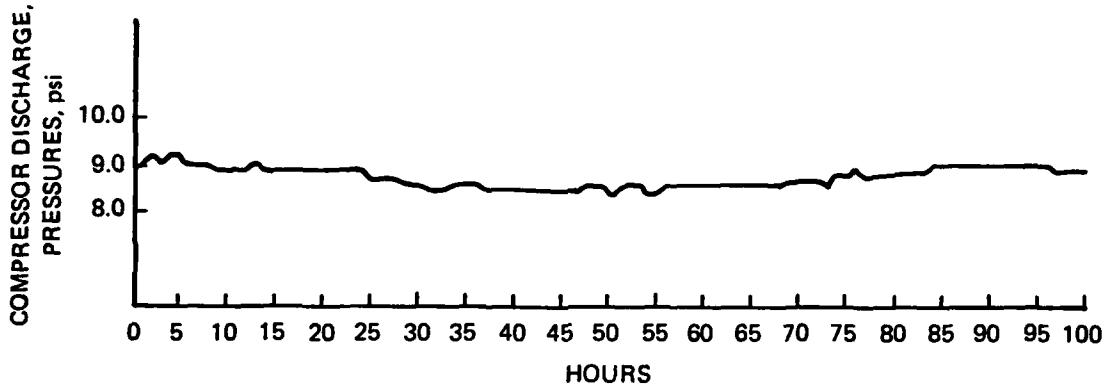
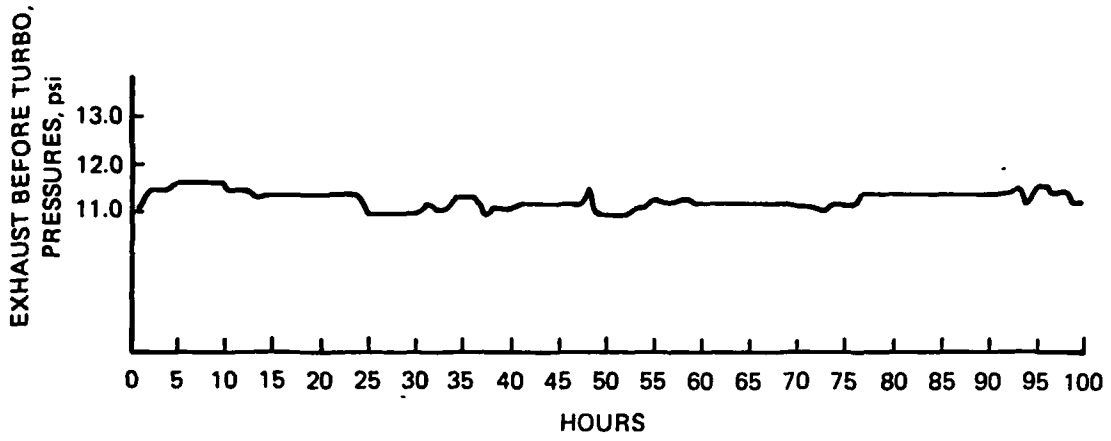
Piston Ring End Gap Change

<u>Ring Number</u>	1L	2L	3L	1R	2R	3R	<u>Average Change</u>
1	+0.001	+0.002	+0.002	+0.003	+0.003	+0.001	+0.002
2	+0.003	+0.001	+0.001	+0.001	+0.003	+0.001	+0.002
3	+0.002	+0.001	+0.002	+0.001	+0.001	+0.001	+0.001
4	+0.001	+0.001	+0.001	+0.004	+0.001	+0.003	+0.002
5	+0.003	+0.005	+0.007	+0.005	+0.002	+0.007	+0.005
6	+0.005	+0.005	+0.003	+0.004	+0.005	+0.005	+0.005
7	+0.005	+0.005	+0.002	+0.004	+0.005	+0.005	+0.004

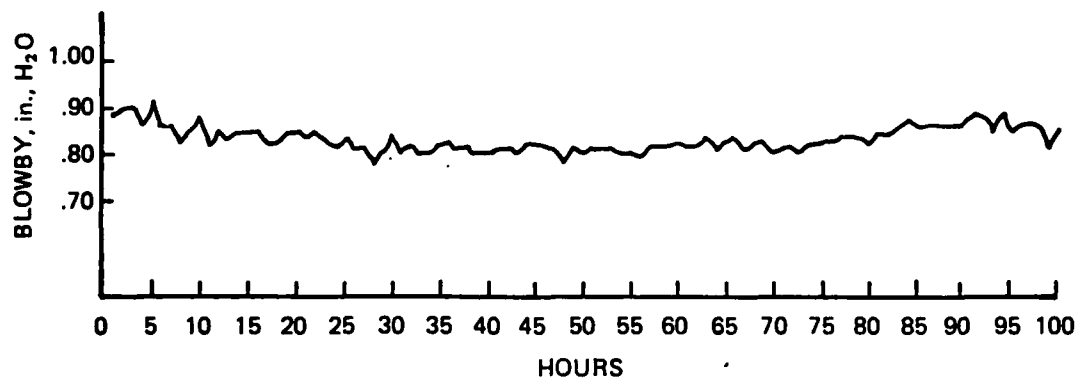
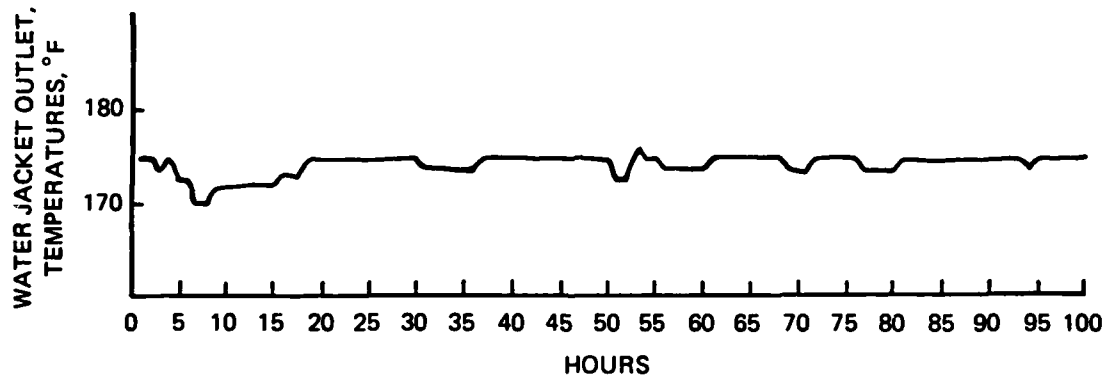
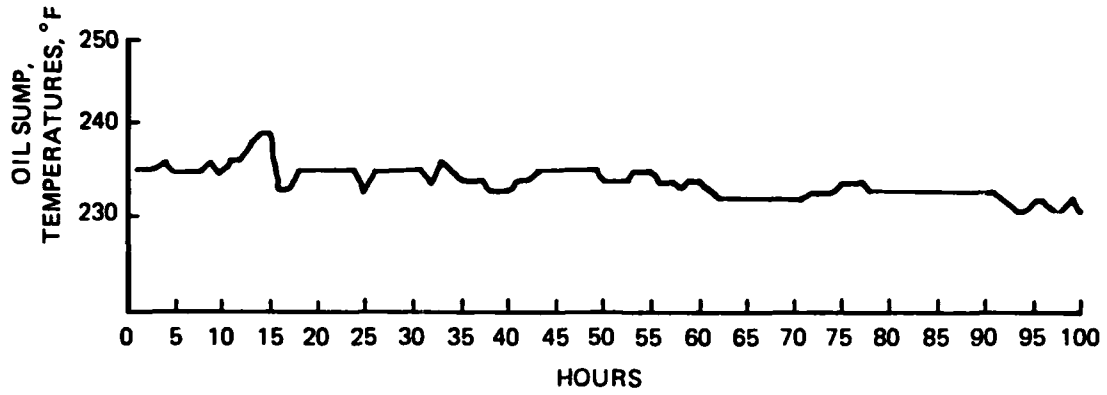
Overall Average Change: +0.003

\* All dimensions given are in inches.

\*\* T-AT = Thrust - Anti-thrust Direction; F-B = Front - Back Direction.







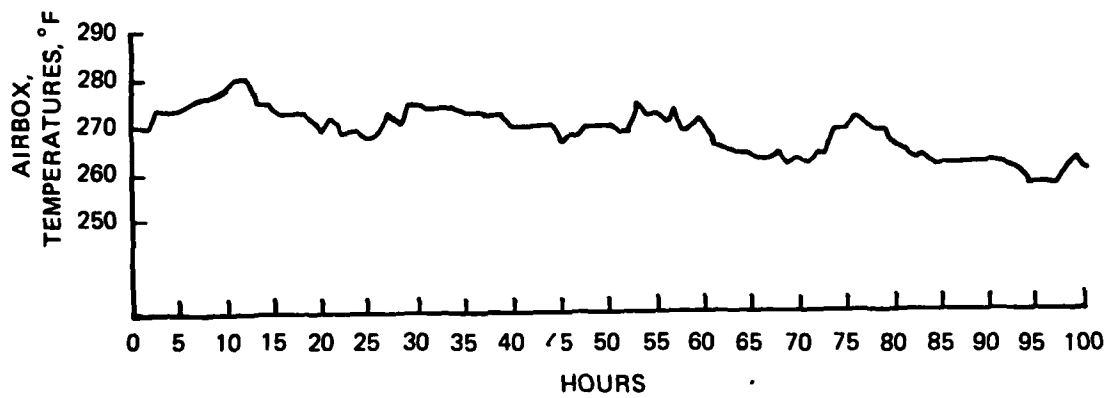
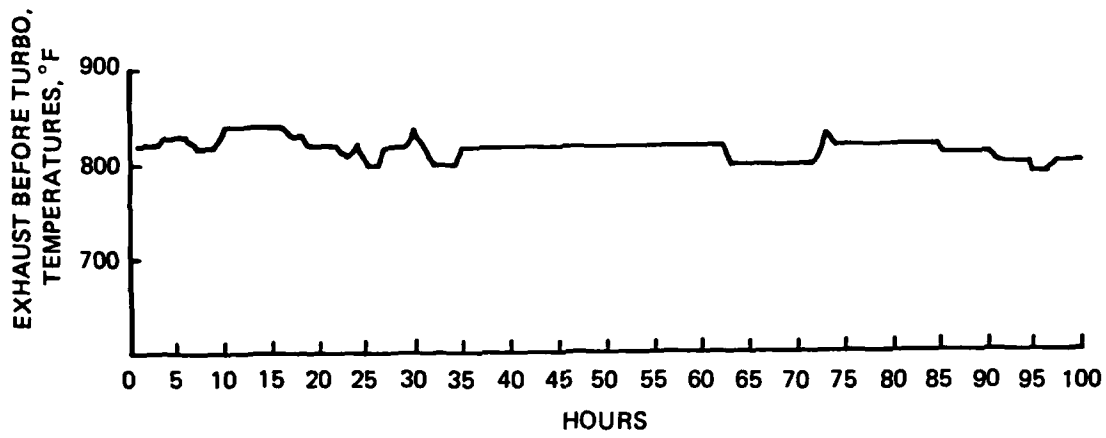
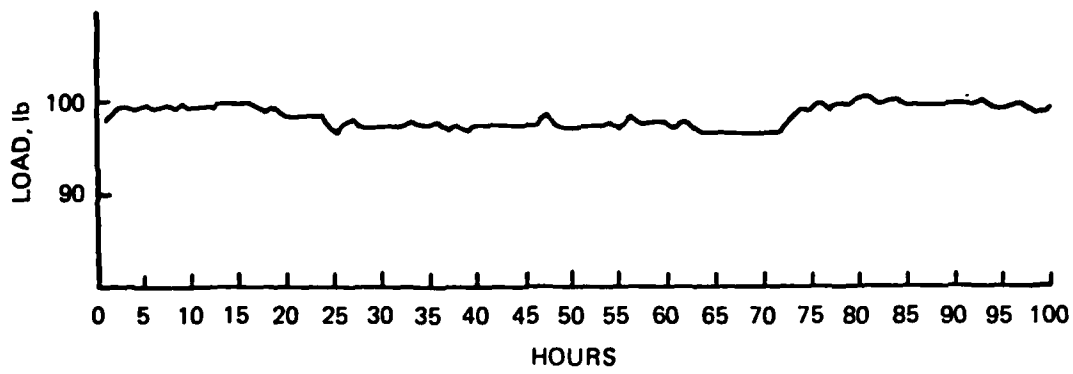


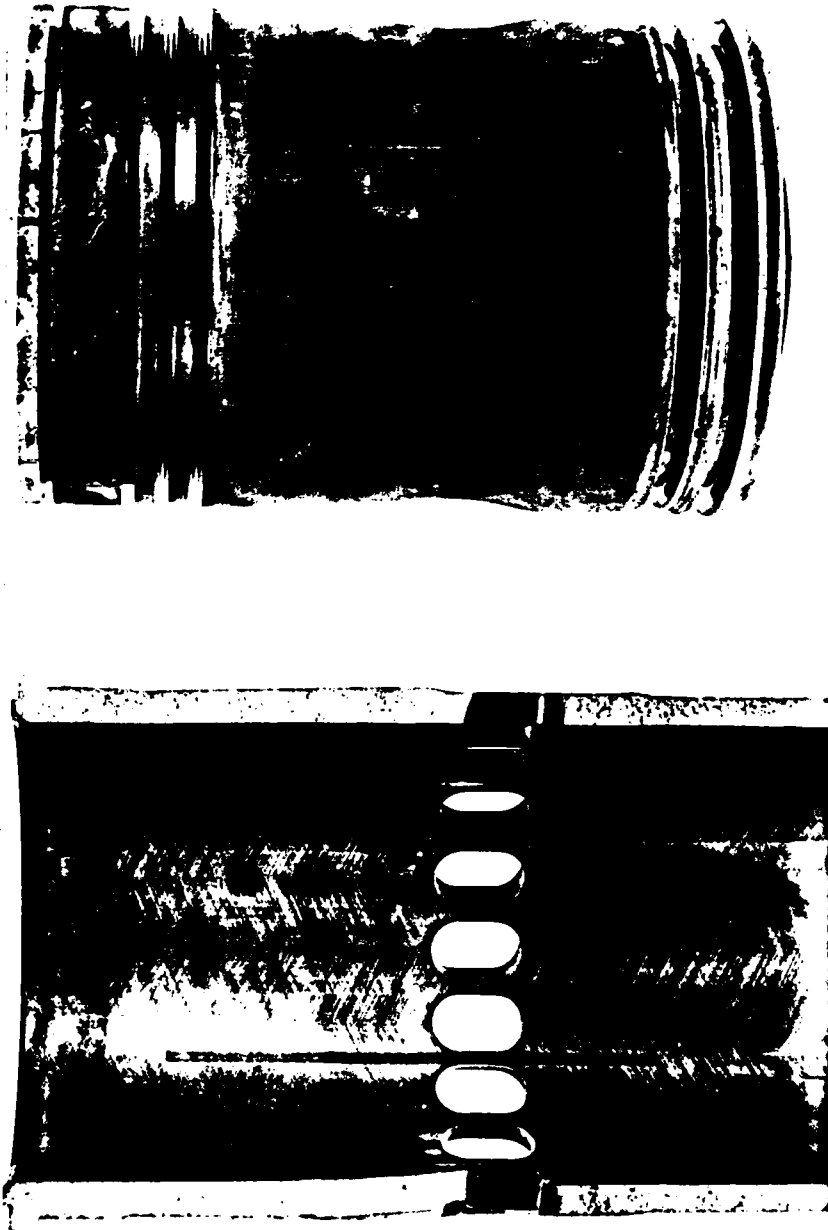
Figure 1. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



1 Right Thrust

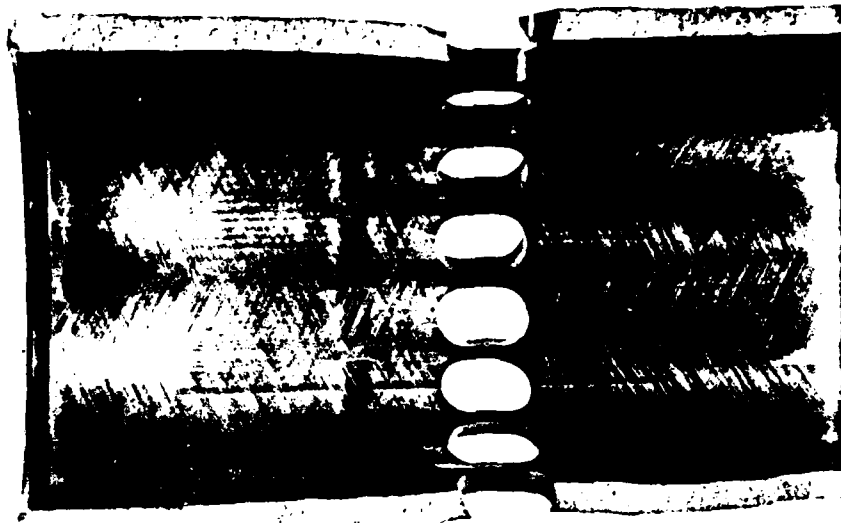
Figure 2. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



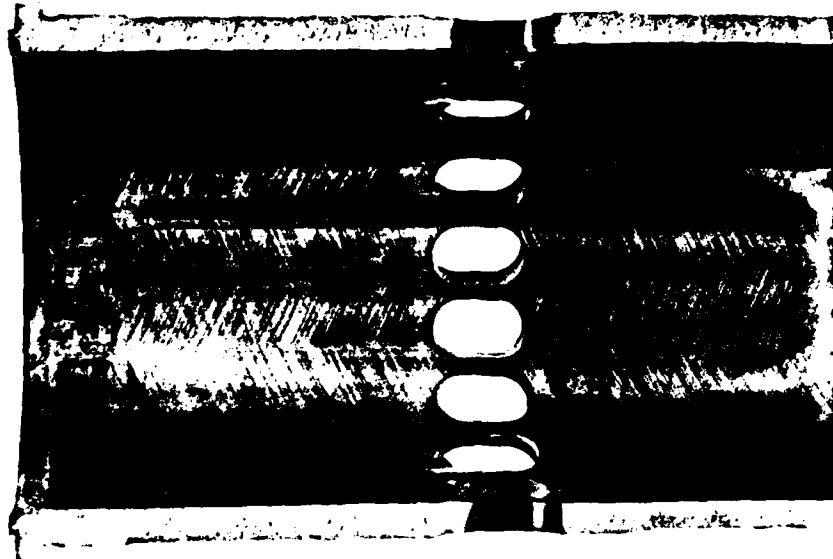
1 Right Anti-Thrust

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



2 Right Thrust

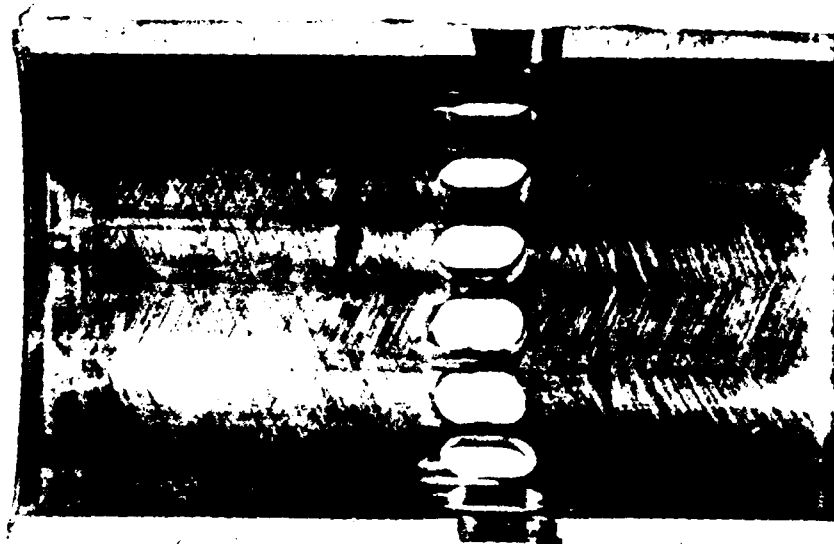
Figure 4. METHOD 504

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



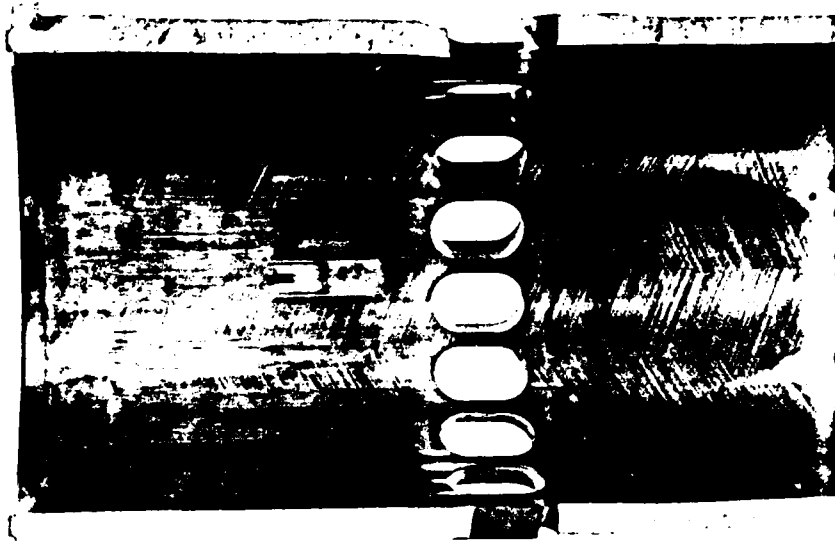
2 Right Anti-Thrust

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



3 Right Thrust

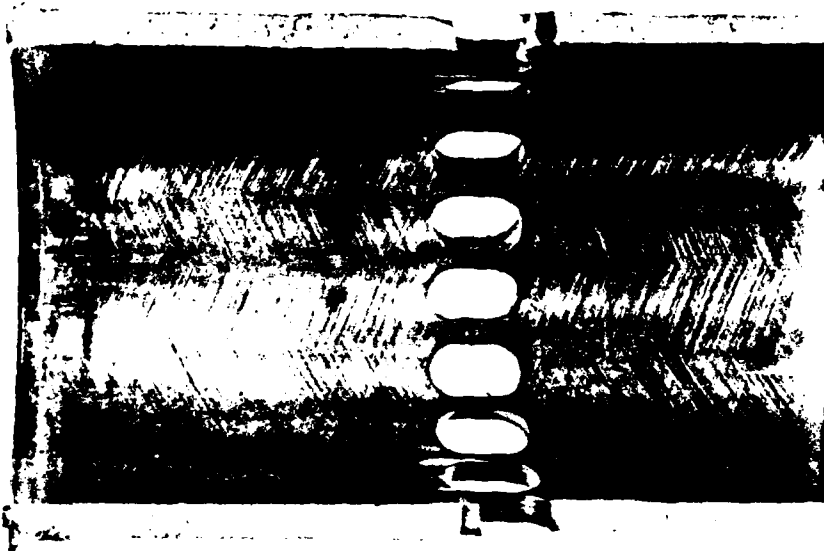
Figure 6. MITH-D 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



3 Right Anti-Thrust

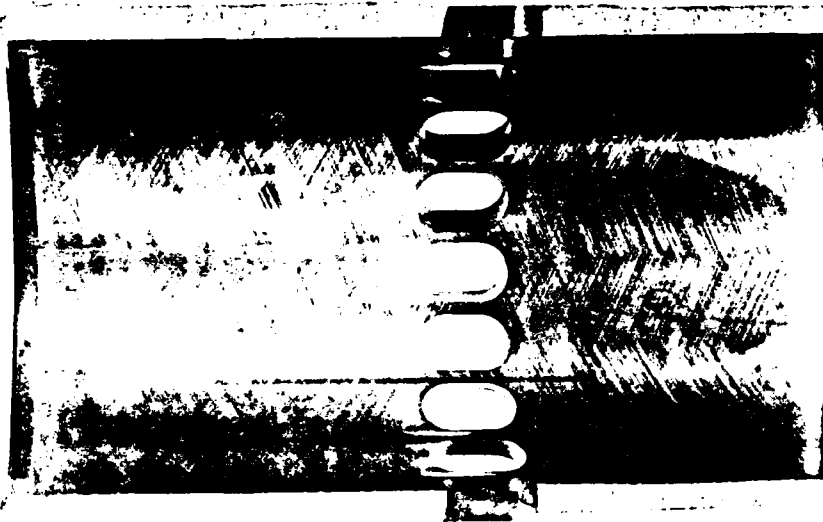


Figure 7. METHOD 354  
Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



1 - Left Thrust

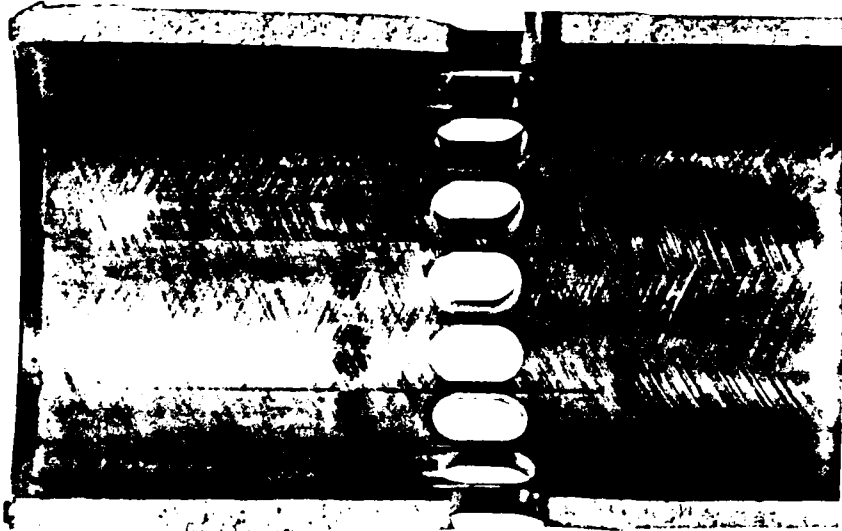
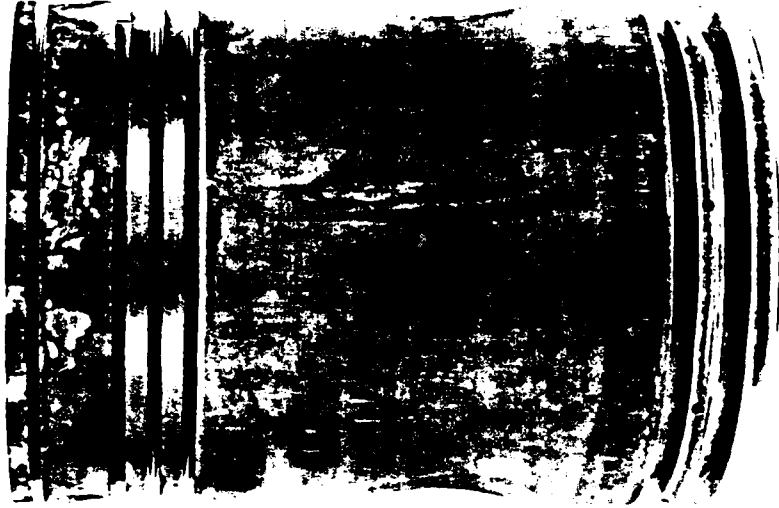
Figure 8. M.I.800 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



1 Left Anti-Thrust

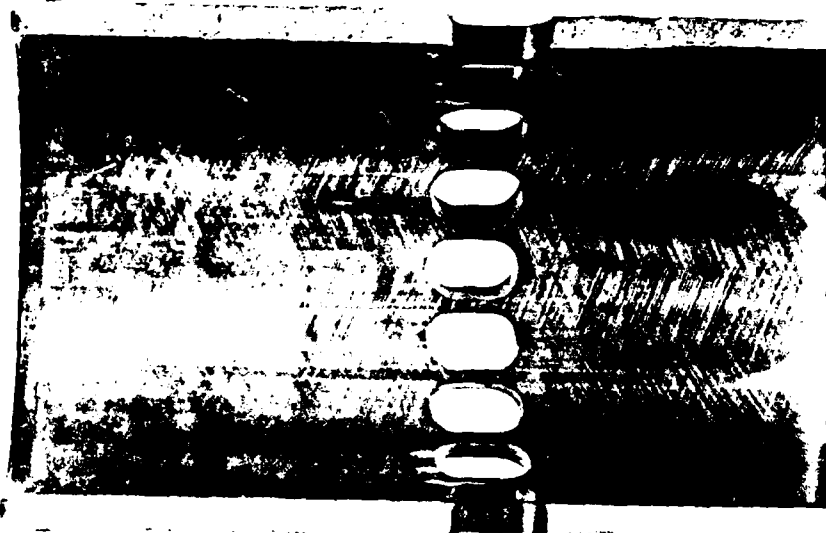
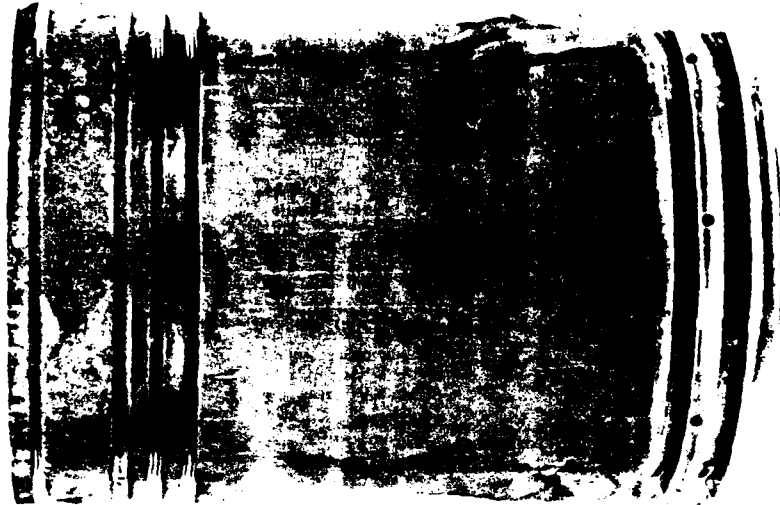
Figure 9. MTRND 384

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



2 Left Thrust

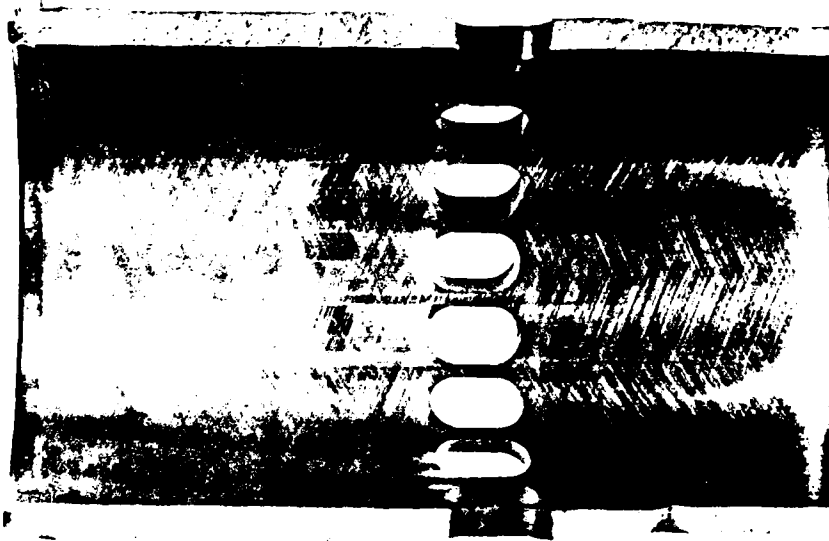
Figure 10. Method 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



2 Left Anti-Thrust

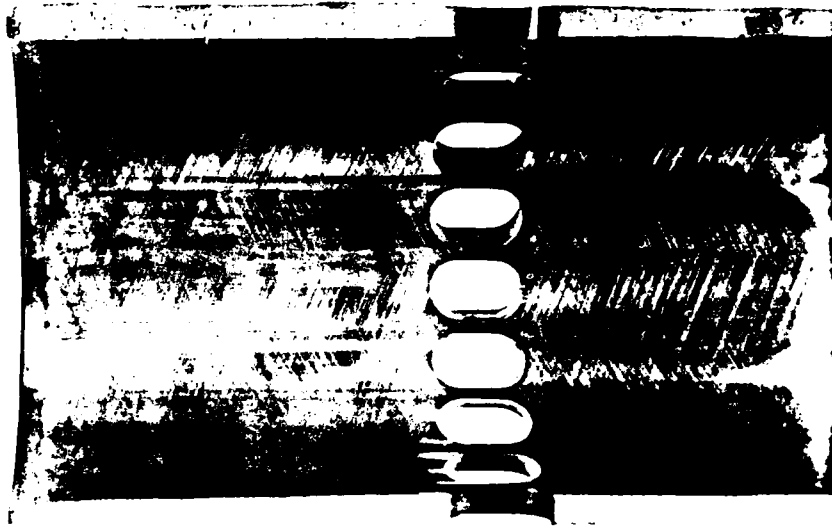
Figure 11. M108D-4

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



3 Left Thrust

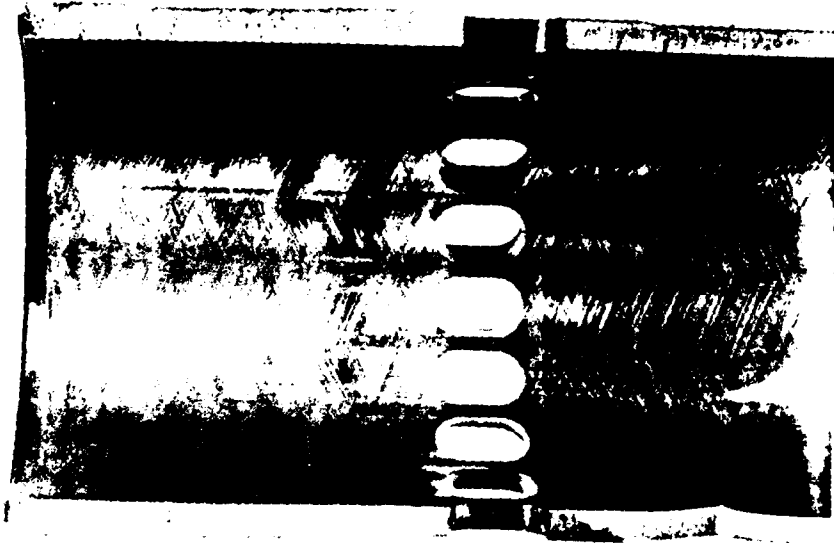
Figure 12. Method 554

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



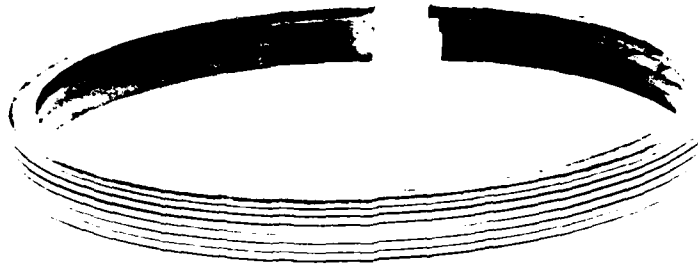
3 Left Anti-Thrust

Condition of Compression Ring Face

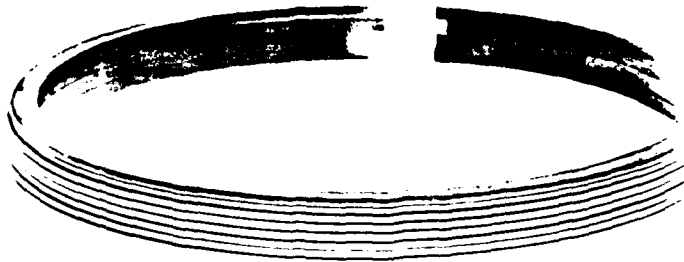
Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



1 Right



2 Right

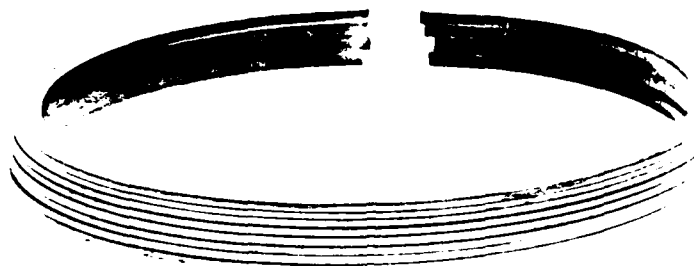
Figure 14. METHOD 154

Condition of Compression Ring Face

Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



3 Right



1 Left



Figure 15. Method 384

Condition of Compression Ring Face

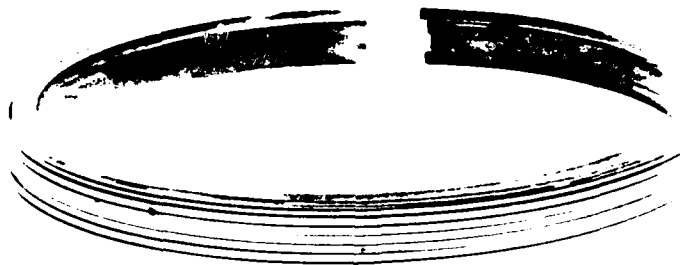
Test Time 100 Hours

Test No. MTC-2

Lubricant AL-8925-L



2 Left



3 Left

APPENDIX B

PERFORMANCE OF AL-9841-L LUBRICATING OIL  
IN A TWO-CYCLE DIESEL ENGINE UNDER  
STEADY-STATE TURBOSUPERCHARGED CONDITIONS

PERFORMANCE OF AL-9841-L LUBRICATING OIL  
IN A TWO-CYCLE DIESEL ENGINE UNDER  
STEADY STATE TURBOSUPERCHARGED CONDITIONS  
(Method 354 Fed. Test Method Std. 791B)

Engine Test Number: MTC-3 (Modified Test\*)

Date Completed: 10 October 1980

Conducted For

U.S. Army Mobility Equipment Research and Development Command  
Energy and Water Resources Laboratory  
Fort Belvoir, Virginia

By

U.S. Army Fuels & Lubricants Research Laboratory  
Southwest Research Institute  
San Antonio, Texas 78284

\*Modified Test

This test used the cast iron block version of the DD6V-53T engine. Changes include a cast iron engine block, a 16 plate oil cooler and an 8 plate auxiliary oil cooler.

TABLE I

6V-53T 6D-151056  
BUILD-UP ENGINE MEASUREMENTS

	Measurements*			
	Min.	Max.	Avg.	Specified Limits**
Connecting rod Bearing clearance	0.0038	0.0041	0.0040	0.0010 to 0.0040
Cylinder liner block bore				
Taper	0.0001	0.0004	0.0002	0.0015 max.
Out-of-round	0.0001	0.0008	0.0003	0.0015 max.
Inside diameter	4.3567	4.3579	4.3573	4.3565-4.3575 4.3595 max.
Cylinder liners (installed)				
Taper	0.0000	0.0003	0.0002	0.0015 max.
Out-of-round	0.0000	0.0006	0.0002	0.0015 max.
Inside diameter	3.8753	3.8767	3.8759	3.8752-3.8767
Piston to liner fit <sup>1</sup>	0.0078	0.0092	0.0085	0.0060-0.0095
Piston diameter	3.8670	3.8681	3.8675	3.8669-3.8691
Fire ring				
End gap	0.031	0.041	0.036	0.020-0.046
Side clearance	0.003	0.004	0.004	0.003-0.006
#1 Compression ring				
End gap	0.028	0.037	0.033	0.020-0.046
Side clearance	0.008	0.009	0.008	0.007-0.010
#2 & #3 Compression ring				
End gap	0.023	0.038	0.032	0.020-0.046
Side clearance	0.006	0.007	0.007	0.005-0.010
Oil rings				
End gap	0.017	0.023	0.020	0.010-0.025
Side clearance	0.003	0.0035	0.003	0.0015-0.0055

\* All measurements given are in inches.

\*\* Wear limits with new liners in a used block.

<sup>1</sup> Thrust-Antithrust direction

TABLE 2

## OPERATING DATA SHEET

Test Run at U.S. Army Fuels &amp; Lubricants Research Laboratory (SwRI)

Test Oil: AL-9841-L

Test Fuel: 1-H CAT

Test No.: MTC-3

Test Stand: 5

Engine No: 6D-151056

Test Hours: 100

Date Started: 6 October 1980

Completed: 10 October 1980

Total Downtime: 5.42 Hrs Scheduled; 0 Hrs Unscheduled

	<u>Min.</u>	<u>Max.</u>	<u>Avg.</u>
Engine Speed, rpm	2799.	2802.	2800.
Load, lbs	97.	100.	99.
Output, BHp	233.	240.	237.
Fuel Rate, lb/min	1.58	1.63	1.60
Oil Consumption, lb/hr			.8105
<u>Temperature, °F</u>			
Jacket-in	160.	166.	163.
Jacket-out	170.	177.	174.
Oil Sump	230.	237.	233.
Inlet Air (compressor)	75.	96.	87.
Air Box	268.	280.	275.
Exhaust before turbo	820.	870.	851.
Exhaust after turbo	720.	760.	730.
Fuel at filter (secondary)	85.	90.	89.
<u>Pressures</u>			
Compressor suction, in., H <sub>2</sub> O	6.60	6.90	6.73
Compressor discharge, psi	9.60	10.30	9.79
Blower discharge, psi	16.50	17.50	17.03
Exhaust before turbo, psi	12.50	13.40	12.96
Exhaust after turbo, in., Hg	1.80	2.40	2.33
Oil gallery, psi	24.00	29.00	28.00
Fuel at filter, psi	56.00	58.00	56.89
Blowby, in., H <sub>2</sub> O	1.12	1.71	1.50

TABLE 3  
RATING DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil: AL-9841-L

Test Fuel: 1-H CAT

Test No.: MTC-3

Test Stand: 5

Engine No: 6D-151056

Test Hours: 100

Date Started: 6 October 1980

Completed: 10 October 1980

A. Cylinder Liner Ratings

Intake Port Plugging

<u>Cylinder No.</u>	<u>Restriction, %</u>
1 L	< 1
2 L	< 1
3 L	< 1
1 R	< 1
2 R	< 1
3 R	< 1
Average	< 1

Scuffing, Glazing, and Lacquer\*

<u>Cylinder No.</u>	<u>Scuffing, %</u>			<u>Glazing, %</u>	<u>Lacquer, %</u>
	<u>Thrust</u>	<u>Anti-Thrust</u>	<u>% Total Area</u>		
1 L	2	2	2	0	100
2 L	1	1	1	0	100
3 L	75	65	70	0	100
1 R	5 <sup>+</sup>	5	5	0	100
2 R	5 <sup>+</sup>	10	7.5	0	100
3 R	5	5	5	0	100
Average	15.5	14.7	15.1	0	100

\* Total Ring Travel Area

+ Mostly Light Vertical Lines

TABLE 3 - Continued

B. Piston Ratings

Cylinder No.	Ring Sticking and Condition**			
	Fire	Ring		
		No. 1	No. 2	No. 3
1 L	25% c.s. <sup>@</sup> 2	F-0	F-0	F-0
2 L	F-0	F-0	F-0	F-0
3 L	F <sup>#a</sup> -1	F <sup>a</sup> -0	F <sup>a</sup> -5	F <sup>a</sup> -1
1 R	F-1	F-0	F-0	F-0
2 R	F-1	F-0	F-0	F-0
3 R	F-0	F-0	F-0	F-0

\*\* Numbers denote % area ringface burn

@ Removed

# Partially collapsed

a Heavy wear

F Free

Ring Groove Carbon Filling and Oil Groove Lacquer

Cylinder No.	Fire	Groove Filling, %			Oil Groove Lacquer (Demerit)	
		No. 1	No. 2	No. 3	Upper	Lower
1 L	5	0	0	0	3.0	3.0
2 L	5	15	0	0	3.0	3.0
3 L	10	55	5	1	3.0	3.0
1 R	5	5	0	0	3.0	3.0
2 R	5	20	0	0	3.0	3.0
3 R	5	3	0	0	3.0	3.0

Land Description

Cylinder No.	Description
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

Skirt (Demerit)

Cylinder No.	Thrust	Anti-Thrust
1 L	5.5 Lt. Sct	5.9 Lt. Sct
2 L	6.0 Lt. Sct	5.9 Lt. Sct
3 L	5.6 Lt. Sct, 15% P. Melt	6.0 Lt. Sct, Scuffing, 25% P. Melt
1 R	5.0 Lt. Sct	4.5 Lt. Sct
2 R	5.9 Lt. Sct	5.5 Lt. Sct
3 R	5.5 Lt. Sct	5.3 Lt. Sct

C. Other Ratings

Combustion Chambers with Exhaust Valves, %

<u>Cylinder No.</u>	<u>Description</u>
1 L	20B-70A-10½A
2 L	25B-70A-5½A
3 L	15B-70A-15½A
1 R	15B-65A-20½A
2 R	5B-75A-20½A
3 R	5C-5B-85A-5½A

D. Interim Inspections

<u>Zero Test Hours</u>	<u>Inspection</u>	<u>Zero Test Hours</u>	<u>Inspection</u>
1 L	Normal	1 R	Normal
2 L	Normal	2 R	Normal
3 L	Normal	3 R	Normal
<u>24 Test Hours</u>	<u>Inspection</u>	<u>24 Test Hours</u>	<u>Inspection</u>
1 L	Normal	1 R	Normal
2 L	Normal	2 R	Normal
3 L	Cylinder Liner- Med. to Hvy. Scuffing	3 R	Normal
<u>48 Test Hours</u>	<u>Inspection</u>	<u>48 Test Hours</u>	<u>Inspection</u>
1 L	Normal	1 R	Normal
2 L	Cylinder Liner, Med. to Hvy. Glazing	2 R	Normal
3 L	Cylinder liner, Hvy Scuffing & Glazing	3 R	Normal
<u>72 Test Hours</u>	<u>Inspection</u>	<u>72 Test Hours</u>	<u>Inspection</u>
1 L	Normal	1 R	Cylinder Liner, Med. to Hvy Glazing
2 L	Cylinder Liner, Med. to Hvy. Glazing	2 R	Normal
3 L	Piston Skirt, Lt. P. Melt on AT-side; Cylinder liner, AT-side, Hvy. Scuffing	3 R	Normal



TABLE 3 - Continued

E. Legend

<u>Abbreviations</u>	<u>Definitions</u>
T-Side	Thrust side of cylinder liner or piston skirt. (Inboard left bank and outboard right bank)
AT-Side	Anti-thrust side of cylinder liner or piston skirt. (Side opposite thrust side).
Lt	Light
Med.	Medium
Hvy.	Heavy
P. Melt	Melting of the plating on the piston's surface
Sct	Scratching
Frnt	Front of piston or liner
Rt	Rear of piston or liner
Normal	All components considered normal, unless specified otherwise. This means rings are free, only light scuffing of liner and piston skirts, hard carbon on fire lands and lacquer on other ring lands.
c.s.	Cold Stuck

TABLE 4

## OIL ANALYSES DATA SHEET

Test Run at U.S. Army Fuels &amp; Lubricants Research Laboratory (SwRI)

Test Oil - AL-9841-L

Test Fuel 1-H CAT

Test No. MTC-3

Test Stand 5

Engine No. 6D-151056

Test Hours 100

Date: Started 6 October 1980

Completed: 10 October 1980

Determination	New Oil		Test Hour Sample					
	12	24	36	48	60	72	84	100
Viscosity, cSt at 40°C	32.92			33.96		34.17		34.89
	6.28			6.41		6.62		6.57
Total Acid Number	3.11	3.36		4.35		4.35		4.60
Total Base Number	5.30	3.83		3.71		3.86		3.90
Sulfated Ash, %		1.14		1.23				1.33
Flash Point, °C		222.		220.				224.
Iron Content, ppm		165.	527.	455.	341.	299.	182.	236.
Carbon Residue, %		1.35		1.54		1.55		1.62

TABLE 5

Lubricant: AL-9841-L

## WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change\*

	<u>Cylinder Number</u>					
	1L		2L		3L	
	T-AT**	F-B**	T-AT	F-B	T-AT	F-B
Top	+0.0009	-0.0003	+0.0004	+0.0001	+0.0069	+0.0034
Middle	+0.0008	-0.0001	+0.0004	-0.0001	+0.0043	+0.0046
Bottom	0.0000	+0.0001	+0.0001	+0.0003	+0.0001	+0.0004

	<u>Cylinder Number</u>					
	1R		2R		3R	
	T-AT	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0006	+0.0002	+0.0007	0.0000	+0.0009	-0.0001
Middle	+0.0003	+0.0001	+0.0005	+0.0001	+0.0005	+0.0002
Bottom	+0.0002	+0.0002	+0.0002	+0.0002	+0.0002	+0.0001

	<u>Average Change</u>	
	T-AT	F-B
Top	+0.0173	+0.0006
Middle	+0.0011	+0.0008
Bottom	+0.0001	+0.0002

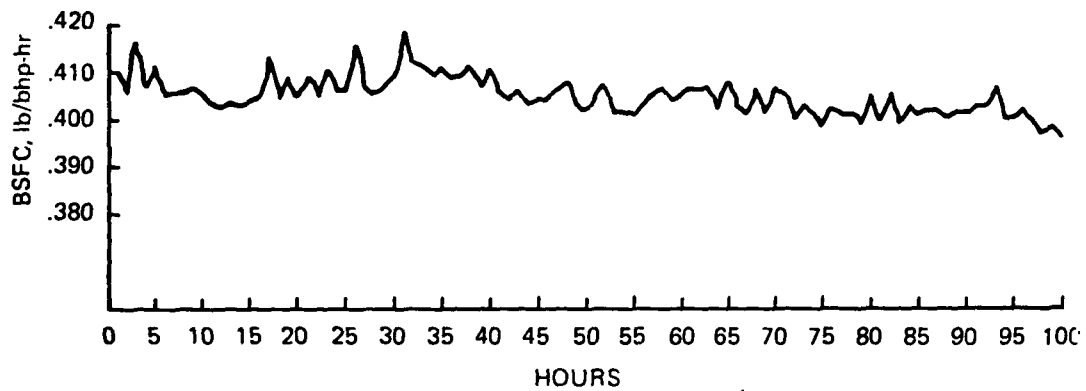
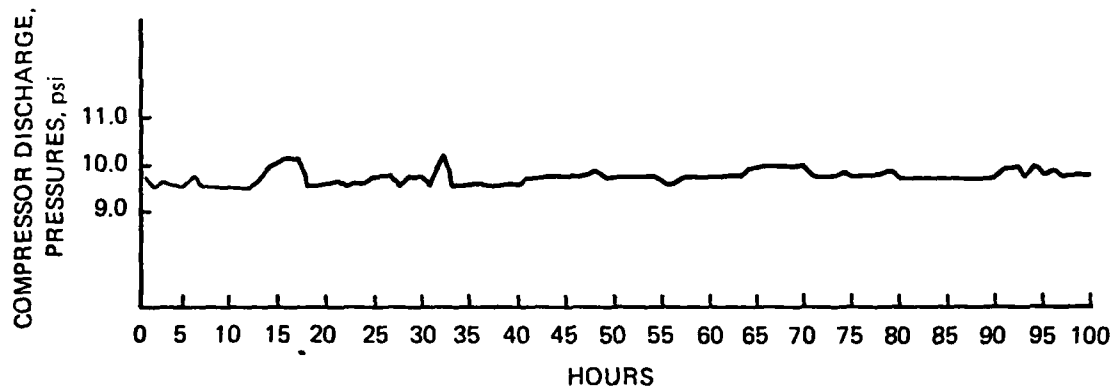
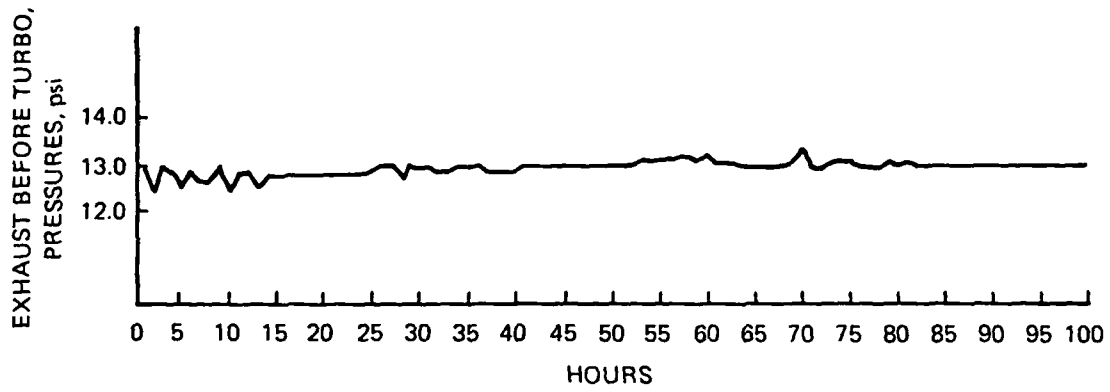
Overall Average Change: +0.0008

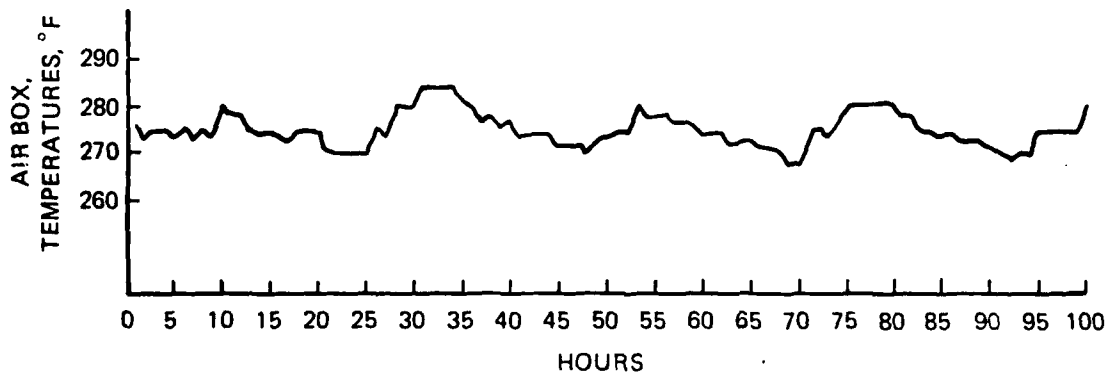
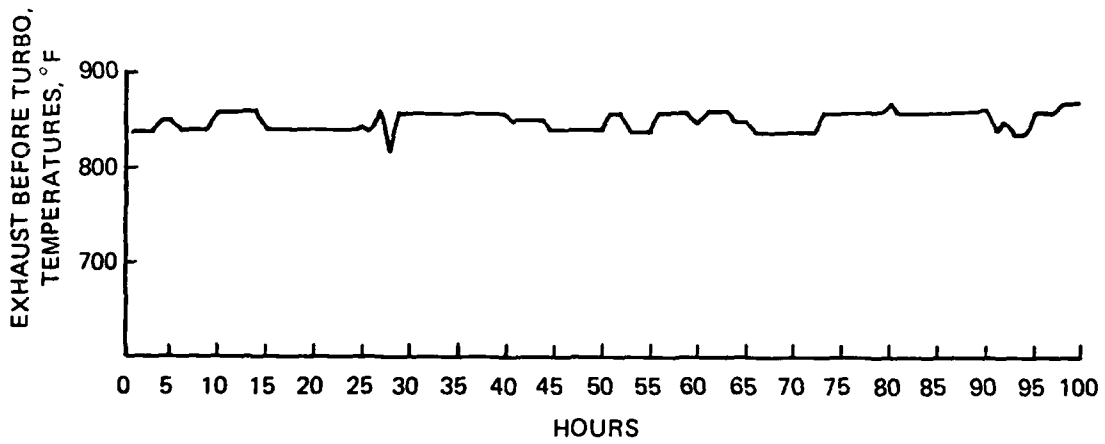
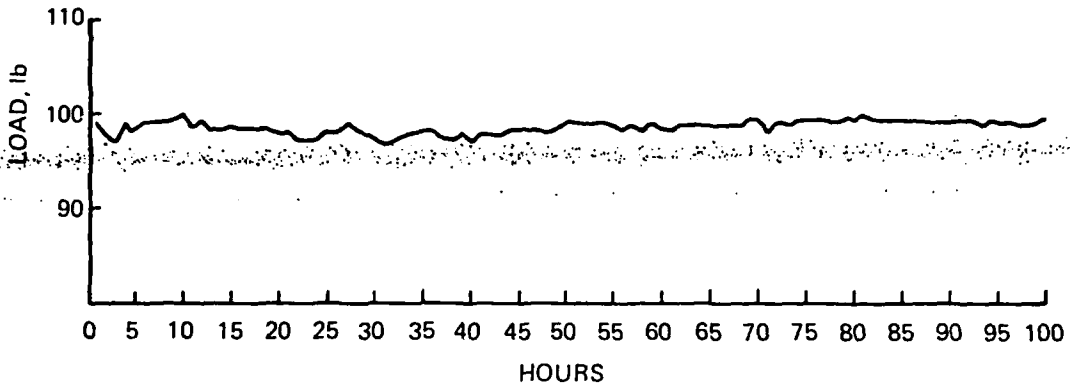
Ring Number	<u>Piston Ring End Gap Change</u>						
	1L	2L	3L	1R	2R	3R	Average Change
1	+0.002	+0.002	+0.011	+0.002	+0.004	+0.004	+0.004
2	+0.001	+0.001	+0.009	+0.002	+0.003	+0.002	+0.003
3	+0.002	+0.002	+0.004	+0.002	+0.001	+0.002	+0.002
4	+0.001	+0.001	+0.006	+0.002	+0.002	+0.003	+0.003
5	+0.007	+0.010	+0.147	+0.007	+0.007	+0.009	+0.031
6	+0.006	+0.006	+0.099	+0.006	+0.007	+0.008	+0.022
7	+0.006	+0.007	+0.113	+0.006	+0.006	+0.004	+0.024

Overall Average Change: +0.013

\* All measurements given are in inches

\*\* T-AT = Thrust - Anti-thrust Direction; F-B = Front - Back Direction





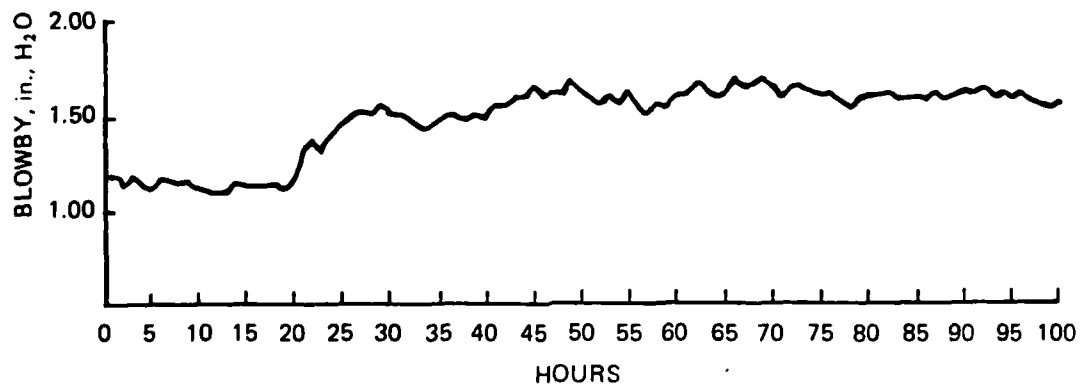
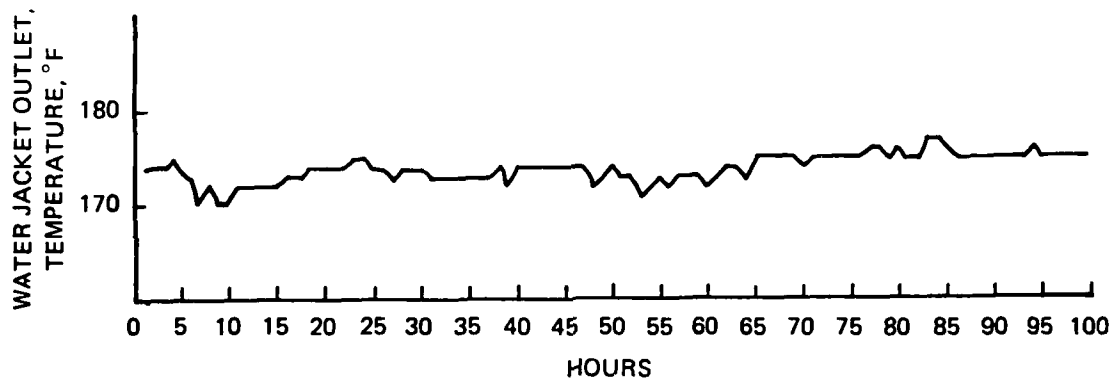
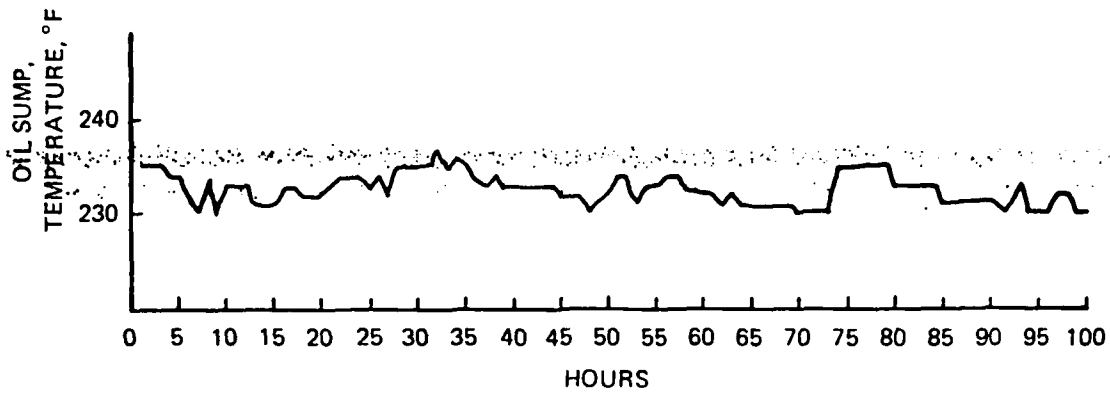


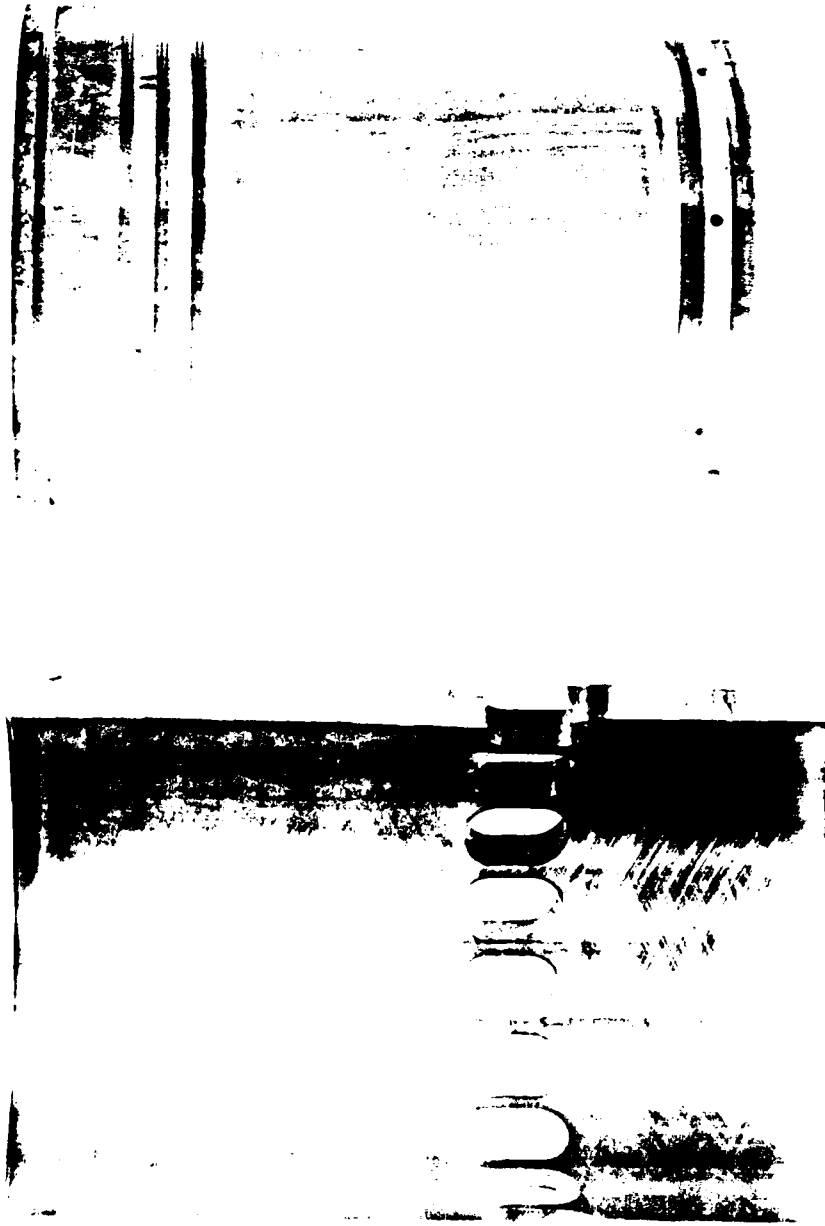
Figure 1. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



1 Right Thrust

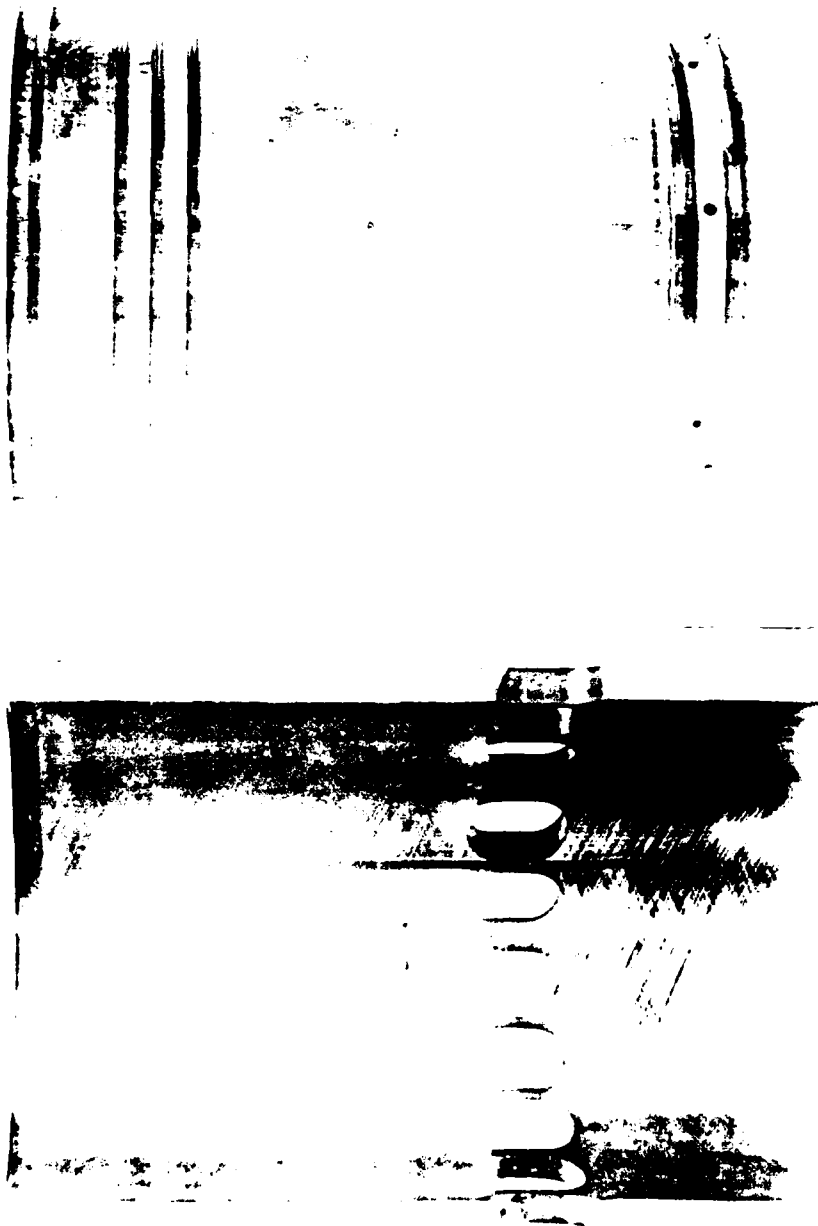
Figure 2. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



1 Right Antithrust



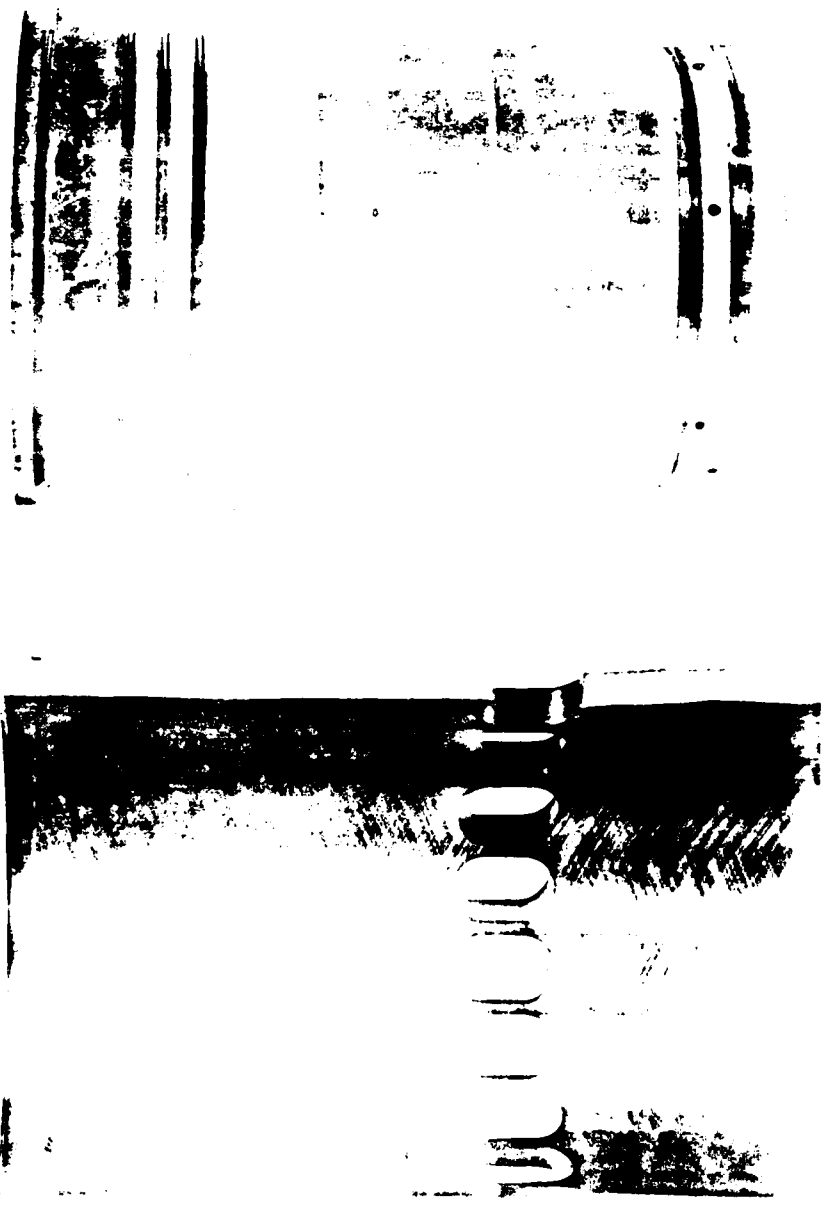
Figure 3. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. A1-9841-L



2 Right Antithrust

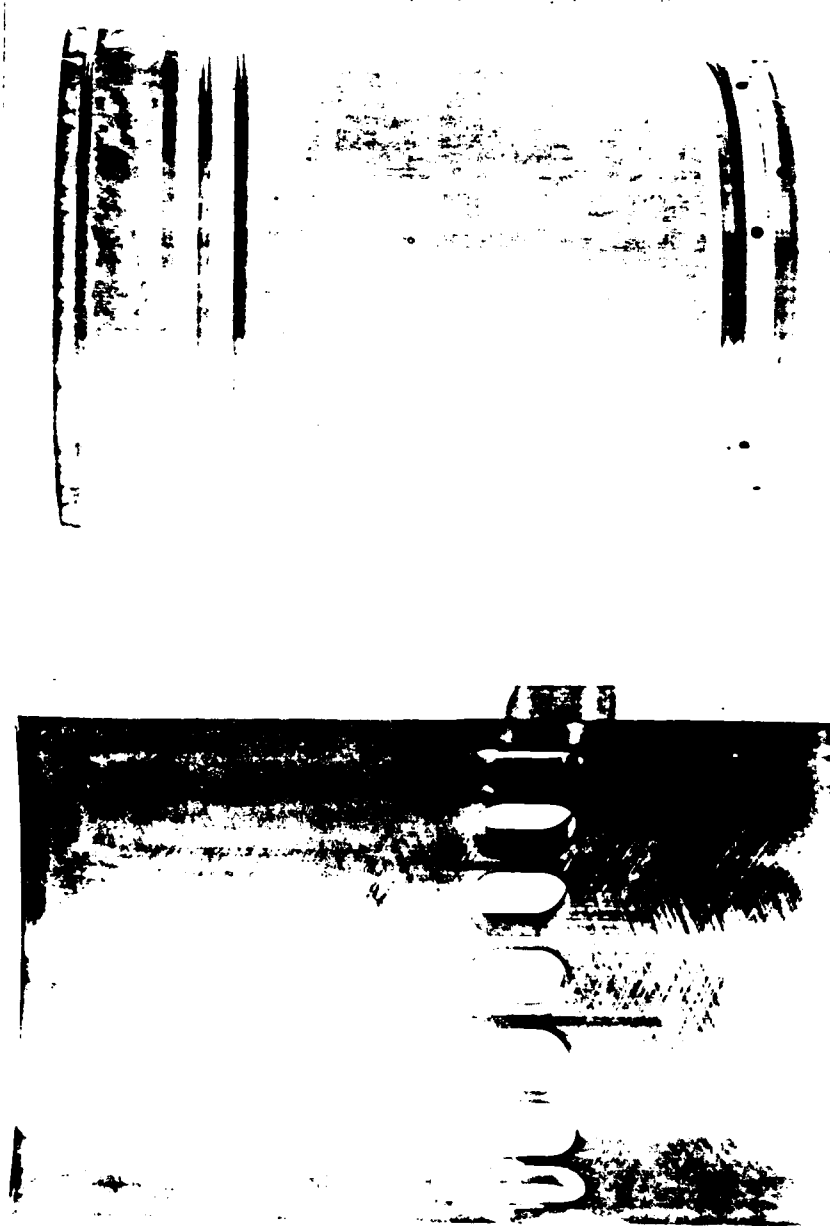
Figure 4. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



2 Right Antithrust

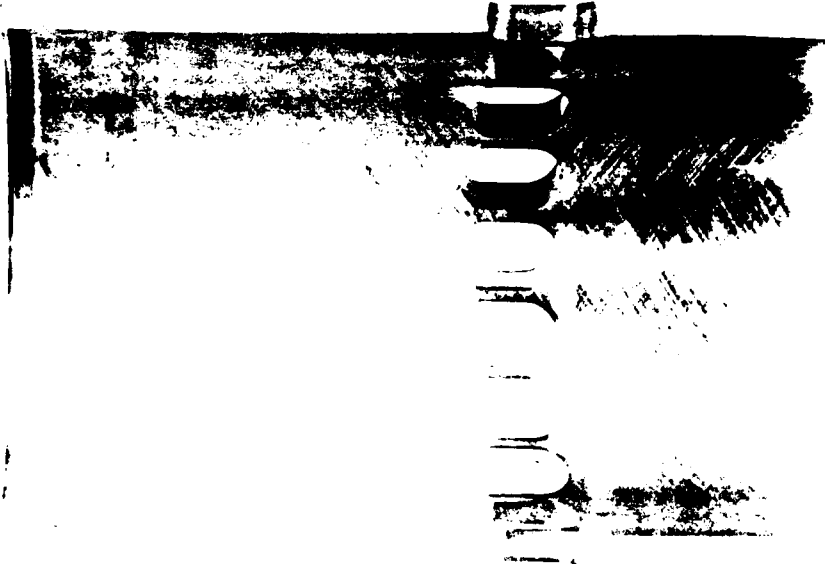
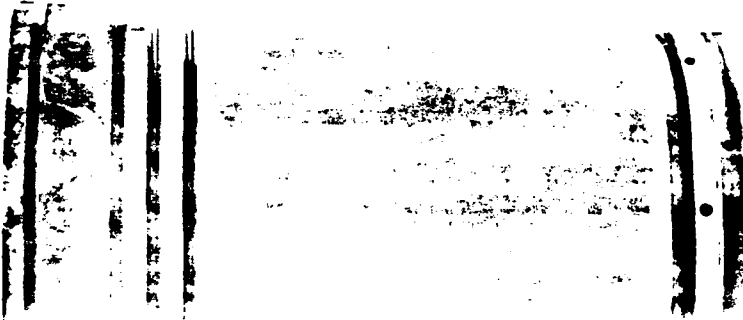
Figure 5. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



3 Right Thrust

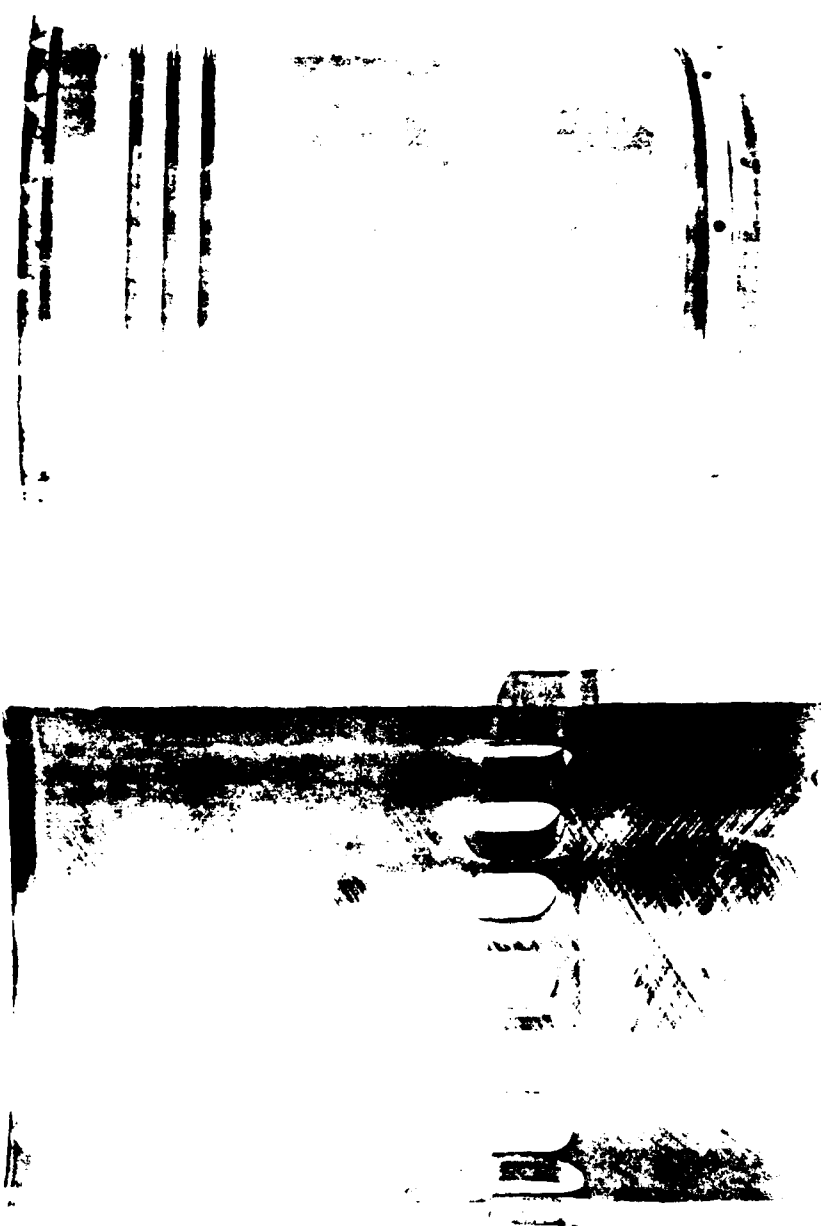
Figure 6. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



3 Right Antithrust

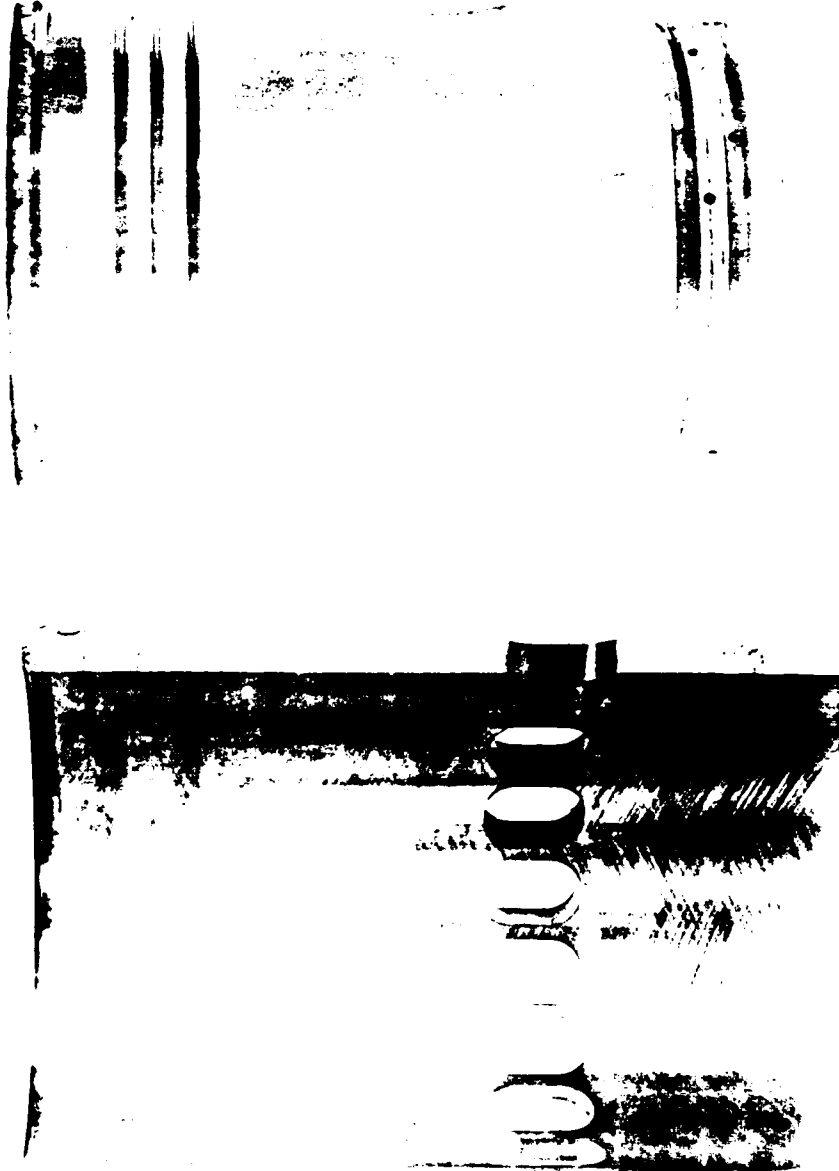
Figure 7. METHOD 354

Condition of Piston and Cylinder liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



1 Left Thrust

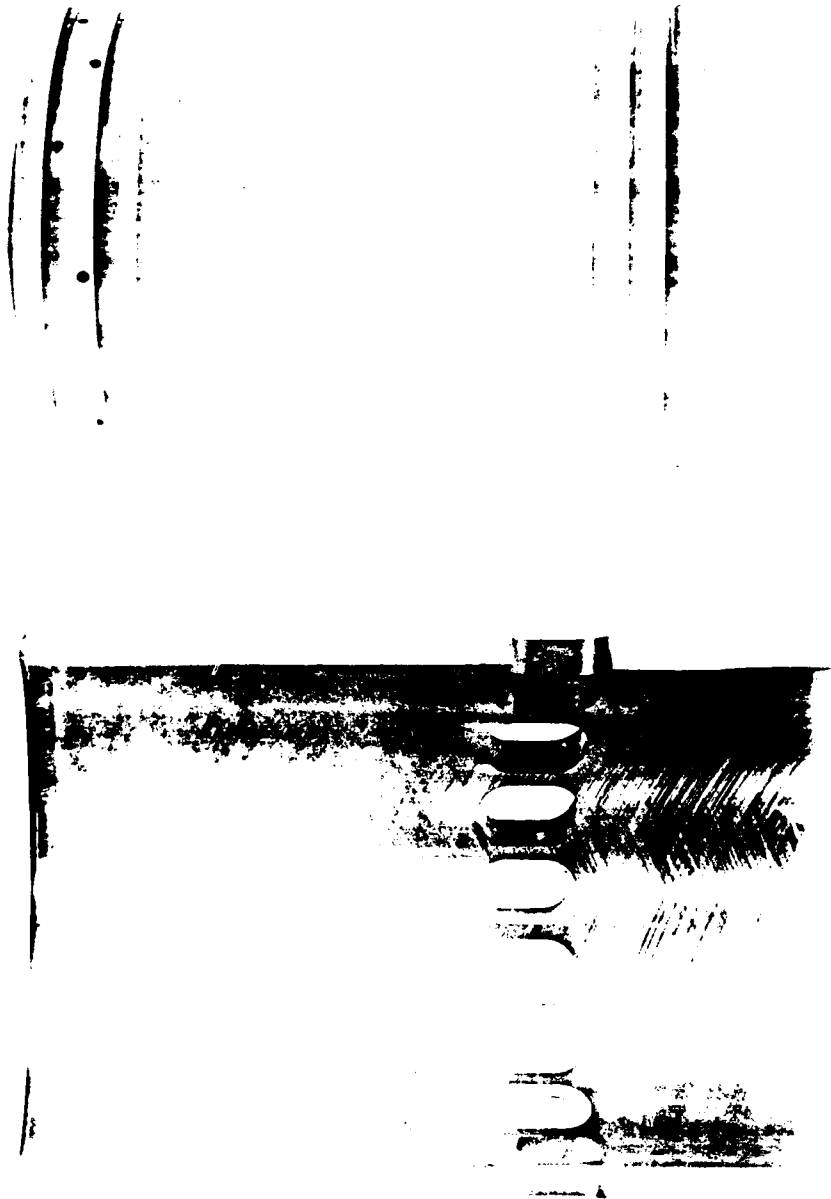
Figure 8. METHOD 354

Condition of Piston and Cylinder liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



1 Left Antithrust

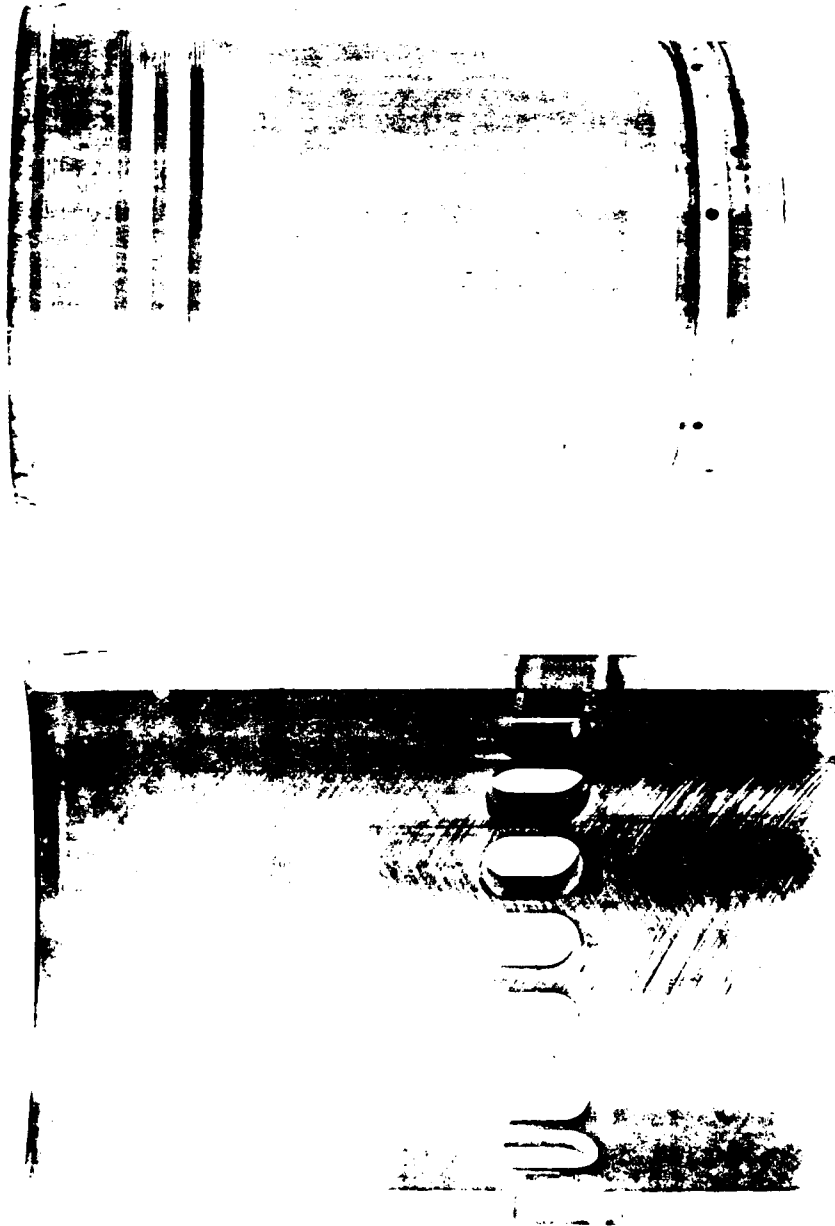
Figure 9. METHOD 354

Condition of Piston and Cylinder liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



2 Left Thrust

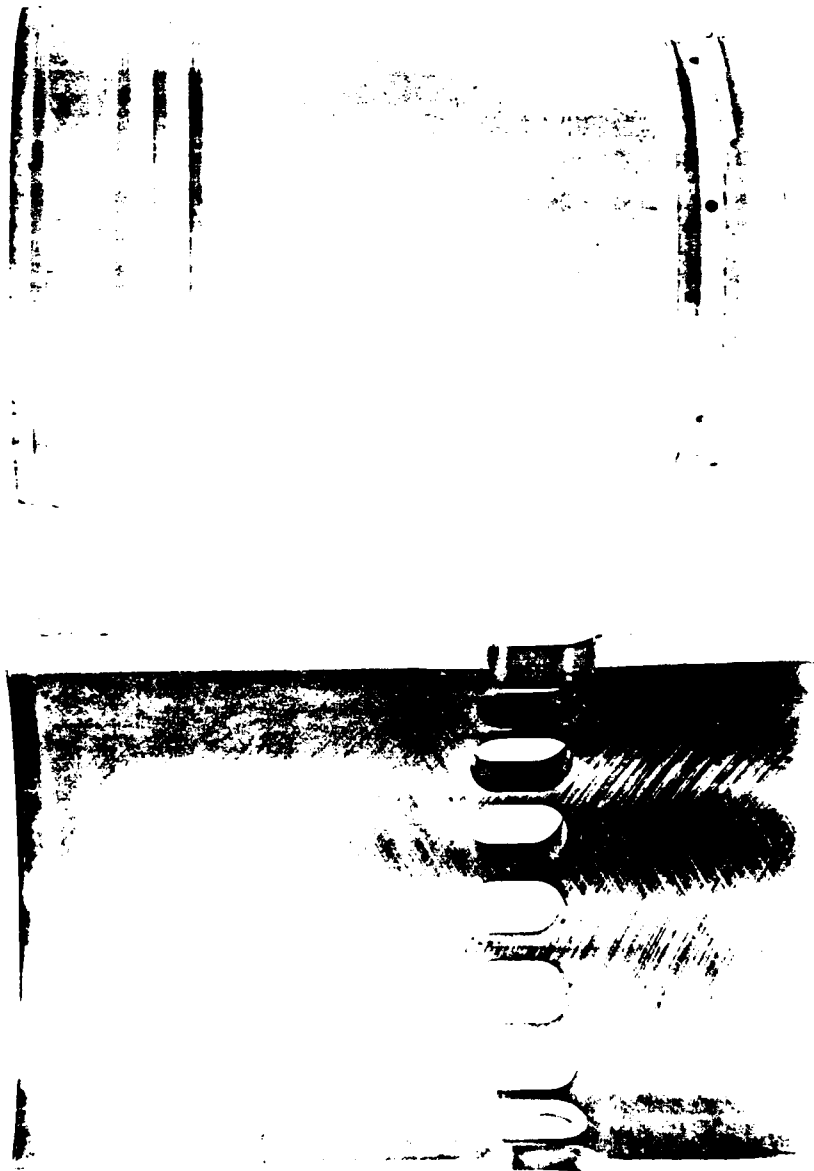
Figure 10. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



2 Left Antithrust



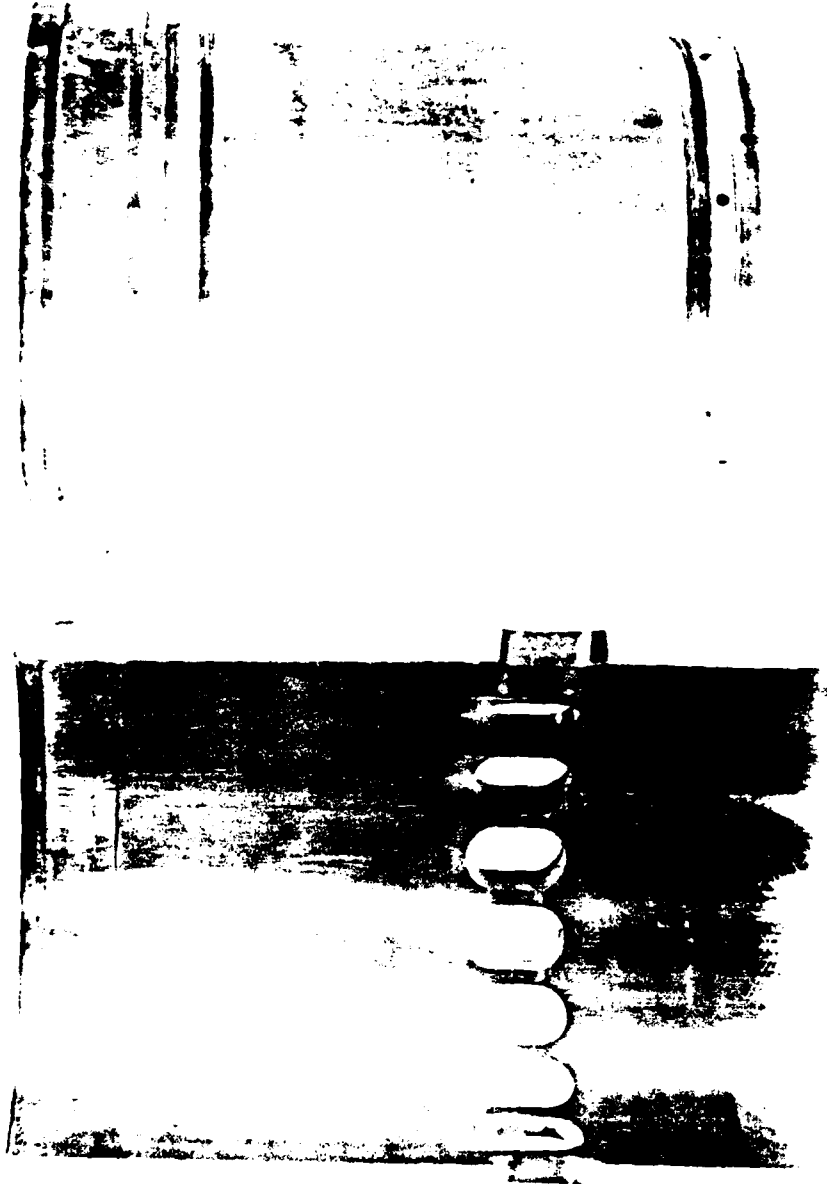
Figure 11. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



3 Left Thrust

Figure 12. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



3 Left Antithrust

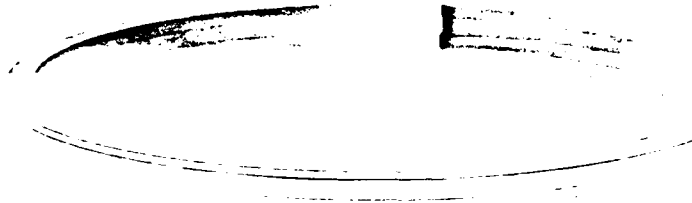
Figure 13. METHOD 354

Condition of Compression Ring Face

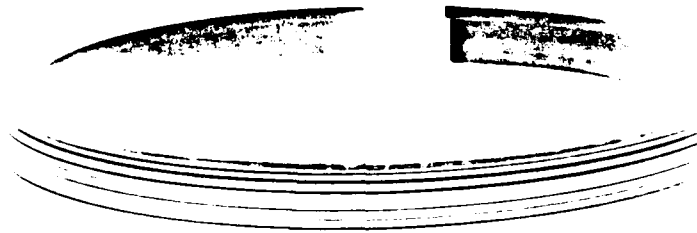
Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



1 Right



2 Right

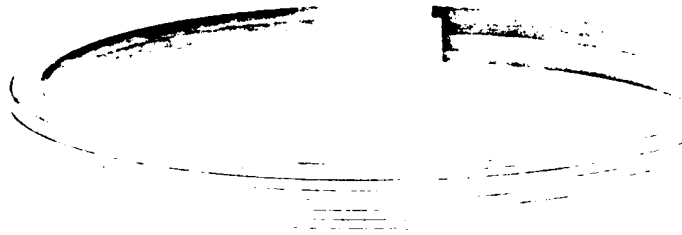
Figure 14. METHOD 354

Condition of Compression Ring Face

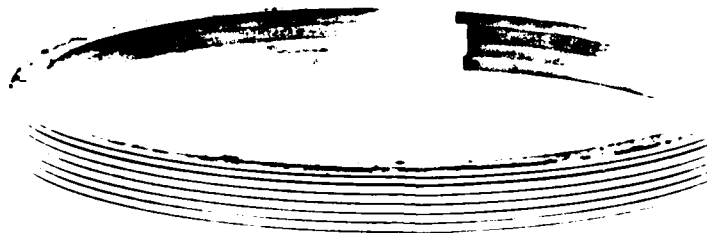
Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



3 Right



1 Left

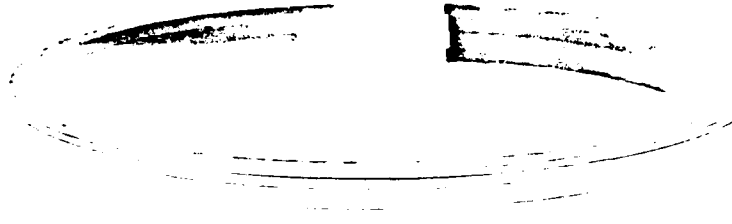
Figure 15. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours

Test No. MTC-3

Lubricant No. AL-9841-L



2 Left



3 Left

APPENDIX C

PERFORMANCE OF AL-8980-L LUBRICATING OIL IN  
A TWO-CYCLE DIESEL ENGINE UNDER  
STEADY-STATE TURBOSUPERCHARGED CONDITIONS

PERFORMANCE OF AL-8980-L LUBRICATING OIL IN  
A TWO-CYCLE DIESEL ENGINE UNDER  
STEADY-STATE TURBOSUPERCHARGED CONDITIONS  
(Method 354 Fed. Test Method Std. 791B)

Engine Test Number: MTC-1 (Modified Test\*)

Date Completed: 12 September 1980

Conducted For

U.S. Army Mobility Equipment Research and Development Command  
Energy and Water Resources Laboratory  
Fort Belvoir, Virginia

by

U.S. Army Fuels and Lubricants Research Laboratory  
Southwest Research Institute  
San Antonio, Texas 78284

\* Modified Test

This test used the cast iron block version of the DD6V-53T engine. Changes include a cast iron engine block, a 16-plate oil cooler and 8-plate auxiliary oil cooler.

TABLE 1

6V-53T 6D-151056  
BUILD-UP ENGINE MEASUREMENTS

<u>Measurements*</u>	<u>Min.</u>	<u>Max.</u>	<u>Avg.</u>	<u>Specified Limits**</u>
Connecting rod bearing clearance	0.0035	0.0040	0.0038	0.0010-0.0040
Cylinder liner block bore				
Taper	0.0000	0.0005	0.0002	0.0015 max.
Out-of-round	0.0000	0.0009	0.0004	0.0015 max.
Inside Diameter	4.3568	4.3581	4.3574	4.3565-4.3575 New 4.3595 max.
Cylinder liners (installed)				
Taper	0.0000	0.0007	0.0003	0.0015 max.
Out-of-round	0.0000	0.0009	0.0003	0.0015 max.
Inside diameter	3.8751	3.8762	3.8756	3.8752-3.8767
Piston to liner fit	0.0072	0.0087	0.0079	0.0060-0.0095
Piston diameter	3.8673	3.8684	3.8678	3.8669-3.8691
Fire Ring				
End gap	0.028	0.039	0.034	0.020-0.046
Side clearance	0.003	0.004	0.003	0.003-0.006
#1 Compression ring				
End gap	0.024	0.036	0.031	0.020-0.046
Side clearance	0.007	0.009	0.008	0.007-0.010
#2 & #3 Compression ring				
End gap	0.025	0.039	0.032	0.020-0.046
Side clearance	0.005	0.006	0.006	0.005-0.010
Oil rings				
End gap	0.018	0.020	0.019	0.010-0.025
Side clearance	0.002	0.004	0.003	0.0015-0.0055

\* All dimensions given are in inches.

\*\* Limits on new parts unless maximum wear limit specified.



TABLE 2

## OPERATING DATA SHEET

Test Run at U.S. Army Fuels &amp; Lubricants Research Laboratory (SwRI)

Test Oil: AL-8980-L, MC-520, Imperial OE/HDO-30

Test Fuel: 1-H CAT

Test No.: MTC-1

Test Stand: 5

Engine No.: 6D-151056

Test Hours: 100 Date Started: 8 September 1980 Completed: 12 September 1980

Total Downtime: 5.9 Hrs Scheduled; 0 Hrs Unscheduled

	<u>Min.</u>	<u>Max.</u>	<u>Avg.</u>
Engine Speed, rpm	2800	2802	2800.48
Load, lb	97.1	104	99.32
Output, Bhp	234	249.5	238.33
Fuel Rate, lb/min	1.61	1.72	1.64
Oil Consumption, lb/hr			.5933
<u>Temperature, °F</u>			
Jacket-in	160	165	163.06
Jacket-out	173	176	174.75
Oil Sump	242	250	246.16
Inlet Air (compressor)	85	100	92.95
Airbox	273	285	280.34
Exhaust before turbo	820	880	854.55
Exhaust after turbo	720	770	751.80
Fuel at filter (secondary)	89	97	90.78
<u>Pressures</u>			
Compressor suction, in. H <sub>2</sub> O	6.1	6.5	6.26
Compressor discharge, psi	10.0	11.1	10.48
Blower discharge (airbox), psi	16.0	17.5	16.77
Exhaust before turbo, psi	12.0	13.5	12.79
Exhaust after turbo, in. Hg	2.0	2.4	2.18
Oil gallery, psi	40.0	44.0	41.88
Fuel at filter, psi	58.0	60.0	59.36
Blowby, in. H <sub>2</sub> O	0.95	1.13	1.03

Date \_\_\_\_\_

Signed \_\_\_\_\_

Approved Laboratory \_\_\_\_\_

USAFRLR

TABLE 3

## RATING DATA SHEET

Test Run at U.S. Army Fuels &amp; Lubricants Research Laboratory (SWI)

Test Oil: AL-8980-L, MC-520, Imperial OE/HDO-30 Test Fuel: 1-H CAT

Test No.: MTC-1 Test Stand: 5 Engine No.: 6D-151056

Test Hours: 100 Date Started: 8 September 1980 Completed: 12 September 1980

## A. Cylinder Liner Ratings

<u>Cylinder No.</u>	<u>Intake Port Plugging</u>	<u>Restriction, %</u>
1L		< 1
2L		< 1
3L		< 1
1R		< 1
2R		< 1
3R		< 1
Average		< 1

Scuffing, Glazing, and Lacquer\*

<u>Cylinder No.</u>	<u>Thrust</u>	<u>Scuffing, %</u>			<u>Glazing, %</u>	<u>Lacquer, %</u>
		<u>Anti-Thrust</u>	<u>Total</u>			
1L	5	10	7.5	0	100	
2L	10	5	7.5	5	95	
3L	5	5	5	5	95	
1R	0	0	0	5	95	
2R	20	10	1.5	5	95	
3R	5	5	5	5	95	
Average	7.5	5.83	6.7	4.16	95.83	

\* Total Ring Travel Area

## B. Piston Ratings

Ring Sticking and Condition\*

<u>Cylinder No.</u>	<u>Fire</u>	<u>Ring</u>		
		<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>
1L	F 55	F-0	F-0	F-0
2L	S 50	F-0	F-0	F-0
3L	S 20	F-5	F-10	F-5
1R	S 35	F-0	F-0	F-0
2R	F 15	F-10	F-25	F-10
3R	5%P 60	F-0	F-5	F-5

\* Numbers denote % area ring face burn F = free P = pinched  
S = sluggish HS = hot stuck

TABLE 3 (Cont'd)

Ring Groove Carbon Filling and Oil Groove Lacquer

<u>Cylinder No.</u>	<u>Groove Filling, %</u>				<u>Oil Groove Lacquer (Demerit)</u>	
	<u>Fire</u>	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>	<u>Upper</u>	<u>Lower</u>
1L	10	15	0	0	3	3
2L	10	10	0	0	3	3
3L	15	65	2	0	3	3
1R	10	15	0	0	3	3
2R	5	10	0	0	3	3
3R	10	15	2	0	3	3

Land Description

<u>Cylinder No.</u>	<u>Description</u>
1L	Normal
2L	Normal
3L	Normal
1R	Normal
2R	Normal
3R	Normal

Skirt (Demerit)

<u>Cylinder No.</u>	<u>Thrust</u>	<u>Anti-Thrust</u>
1L	5.0 Lt. Scratches	4.5 Lt. Scratches
2L	5.4 Lt. Scratches	5.0 5% Scuff & Lt. Scratches
3L	5.5 10% Scuff & Scratches	5.5 Lt. Scratches
1R	5.5 Lt. Scratches	5.2 Lt. Scratches
2R	5.5 Lt. Scratches	5.2 Lt. Scratches
3R	5.0 30% Scuff & Scratches	5.5 Lt. Scratches

C. Other Ratings

Combustion Chambers With Exhaust Valves\*

<u>Cylinder No.</u>	<u>Description</u>
1L	10%C-15%B-15%A-60% <sup>1</sup> / <sub>A</sub>
2L	5%D-20%C-20%B-20%A-35% <sup>1</sup> / <sub>A</sub>
3L	5%D-50%C-10%B-20%A-25% <sup>1</sup> / <sub>A</sub>
1R	50%D-20%C-15%B-10%A-5% <sup>1</sup> / <sub>A</sub>
2R	10%D-50%C-20%B-10%A-10% <sup>1</sup> / <sub>A</sub>
3R	10%D-50%C-10%B-20%A-10% <sup>1</sup> / <sub>A</sub>

\* All Hard Carbon; Depths A-B-C-D

TABLE 3 (Cont'd)

D. Interim Inspections

<u>Zero Test Hours</u>	<u>Inspection</u>	<u>Zero Test Hours</u>	<u>Inspection</u>
1L	Normal	1R	Normal
2L	Normal	2R	Normal
3L	Normal	3R	Normal
<u>24 Test Hours</u>	<u>Inspection</u>	<u>24 Test Hours</u>	<u>Inspection</u>
1L	Lt Scuffing F*&B*	1R	Normal
2L	Normal	2R	Lt Glazing B
3L	Lt Scuffing B	3R	Lt Scuffing B
<u>48 Test Hours</u>	<u>Inspection</u>	<u>48 Test Hours</u>	<u>Inspection</u>
1L	Lt to med glazing of liner	1R	Normal
2L	Normal	2R	Lt to med glazing of liner
3L	Lt Scuffing & glazing B	3R	Med to hvy glazing of liner
<u>72 Test Hours</u>	<u>Inspection</u>	<u>72 Test Hours</u>	<u>Inspection</u>
1L	Lt to med glazing of liner	1R	Lt to med glazing of liner
2L	Lt glazing of liner	2R	Med to hvy glazing of liner
3L	Lt scuffing & glazing B	3R	Med to hvy glazing of liner

\*F = Front side of cylinder liner

\*R = Back side of cylinder liner

E. Legend

Abbreviations

Definitions

T-Side	Thrust side of cylinder liner or piston skirt. (Inboard left bank and outboard right bank).
AT-Side	Anti-thrust side of cylinder liner or piston skirt (Side opposite thrust side).
Lt	Light

TABLE 3 (Cont'd)

Abbreviations	Definitions
Med	Medium
Hvy	Heavy
P. Melt	Melting of the plating on the piston surface.
Sct	Scratching
Frt	Front of piston or liner
Rr	Rear of piston or liner
Normal	All components considered normal, unless specified otherwise. This means rings are free, only light scuffing of liner and piston skirts, hard carbon on fire lands and lacquer on other ring lands.

Date \_\_\_\_\_ Signed \_\_\_\_\_

Approved Laboratory \_\_\_\_\_ USAFLRL \_\_\_\_\_

TABLE 4.  
OIL ANALYSIS DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (WARI)      Test Fuel: 1-H CAT  
 Test Oil - AL-8980-1, MC 520, Imperial OE/HDO-30  
 Test No. MTC-1      Test Stand 5      Engine No. 6D-151056  
 Test Hours 100      Date: Started 8 September 1980      Completed 12 September 1980

Determination	New Oil	Test Hour Sample										
		12	24	36	48	60	72	84	100			
Viscosity, cSt												
at 40°C	109.11	-	136.71	-	154.63	-	165.45	-	167.05			
at 100°C	11.65	-	13.47	-	14.57	-	15.16	-	15.86			
Total Acid Number	2.30	-	2.88	-	3.13	-	3.31	-	3.38			
Total Base Number	13.3	-	8.24	-	6.67	-	7.27	-	7.20			
Sulfated Ash, %	1.6	-	1.98	-	2.05	-	2.06	-	2.13			
Flash Point, °C	223	-	227	-	234	-	218	-	218			
Iron Content, ppm	-	18	23	23	20	25	27	30	18			

- Not determined

Date \_\_\_\_\_ Signed \_\_\_\_\_

Approved Laboratory \_\_\_\_\_

USAF/FL 1

TABLE 5

6V-53T

Test MTC-1

Lubricant: AL-8980-L

## WEAR MEASUREMENTS

Cylinder Liner Bore Diameter Change\*

	Cylinder Number					
	1L		2L		3L	
	T-AT**	F-B**	T-AT	F-B	T-AT	F-B
Top	+0.0005	-0.0004	+0.0002	-0.0002	+0.0006	-0.0005
Middle	+0.0001	-0.0002	-0.0001	-0.0002	+0.0001	-0.0001
Bottom	-0.0002	-0.0005	-0.0002	-0.0001	-0.0001	0.0000

	Cylinder Number					
	1R		2R		3R	
	T-AT	F-B	T-AT	F-B	T-AT	F-B
Top	+0.0003	-0.0003	+0.0002	-0.0001	+0.0004	0.0000
Middle	+0.0002	+0.0003	+0.0001	+0.0005	0.0000	+0.0003
Bottom	+0.0001	0.0000	-0.0001	-0.0001	-0.0005	+0.0005

Average Change

	T-AT	F-B
Top	+0.0004	-0.0003
Middle	+0.0001	+0.0001
Bottom	-0.0002	0.0000

Overall Average Change: +0.0000

Piston Ring End Gap Change

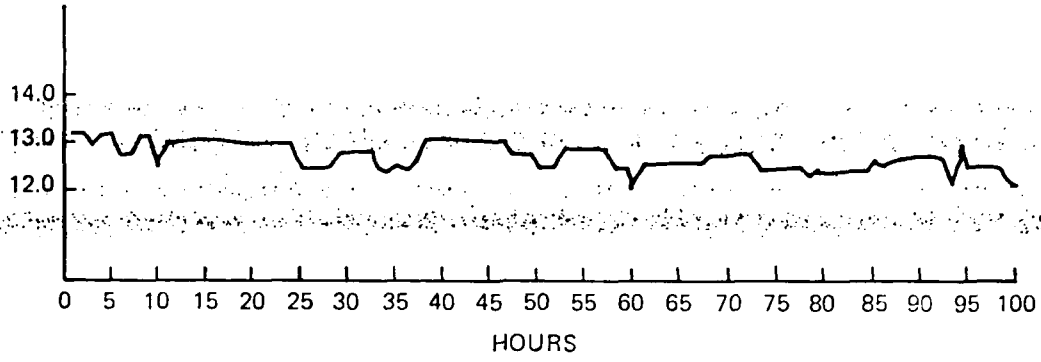
Ring Number	1L	2L	3L	1R	2R	3R	Average Change
1	-0.001	+0.001	+0.001	-0.002	0.000	+0.001	0.0000
2	-0.002	-0.001	-0.001	0.000	-0.002	-0.001	-0.0012
3	0.000	0.000	0.000	0.000	+0.003	0.000	+0.0005
4	0.000	0.000	0.000	-0.001	-0.004	0.000	-0.0008
5	+0.004	+0.004	+0.004	+0.004	+0.004	+0.005	+0.0042
6	+0.001	+0.003	+0.003	Broken	+0.003	+0.003	+0.0026
7	0.000	+0.003	+0.002	Broken	+0.002	+0.003	+0.0020

Overall Average Change: +0.0009

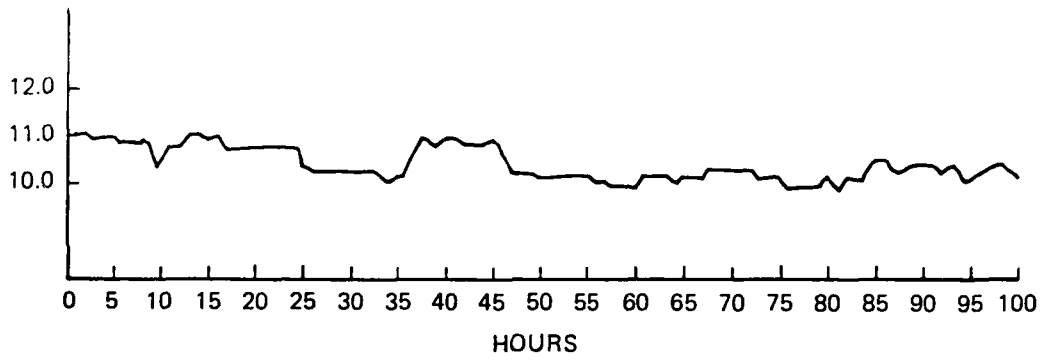
\* All dimensions given are in inches.

\*\* T-A = Thrust-Antithrust Direction; F-B = Front-Back Direction

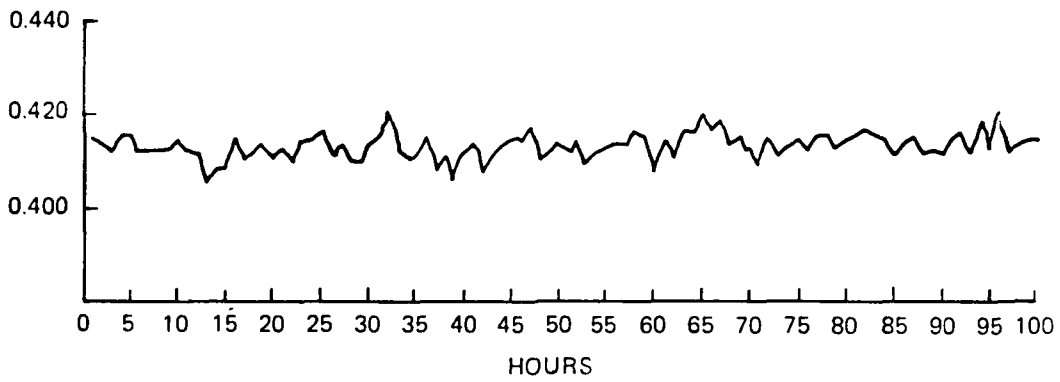
EXHAUST BEFORE TURBO,  
PRESSURES, psi



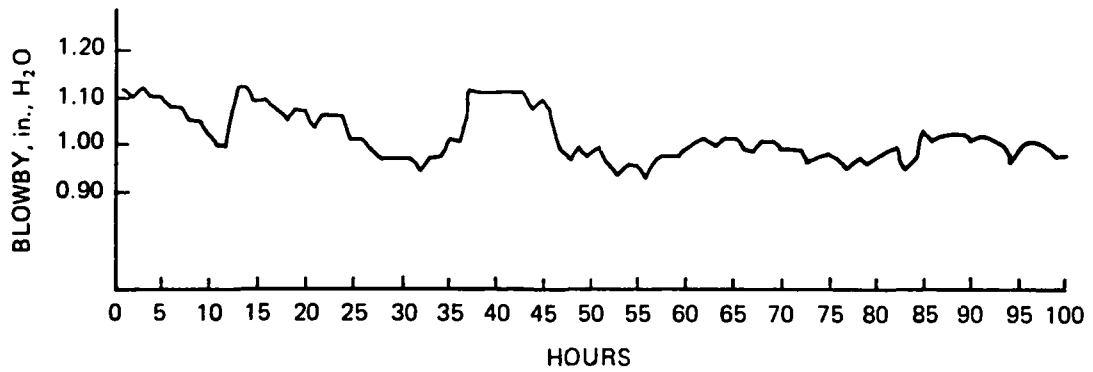
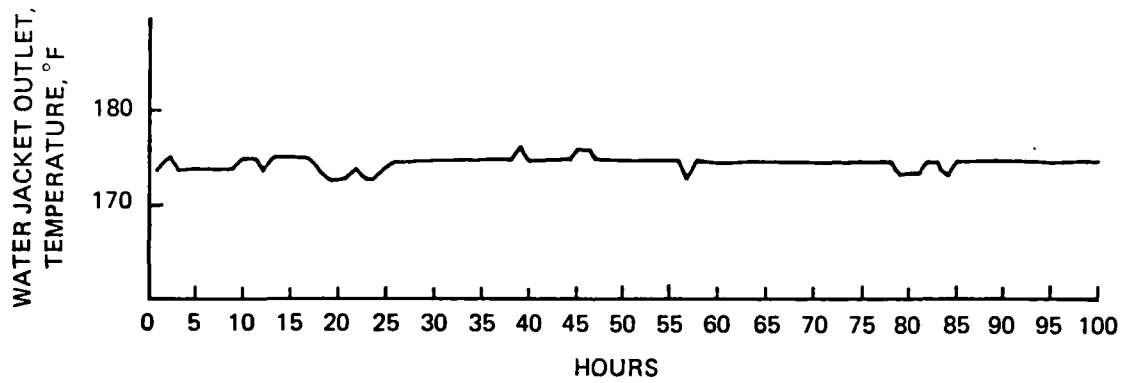
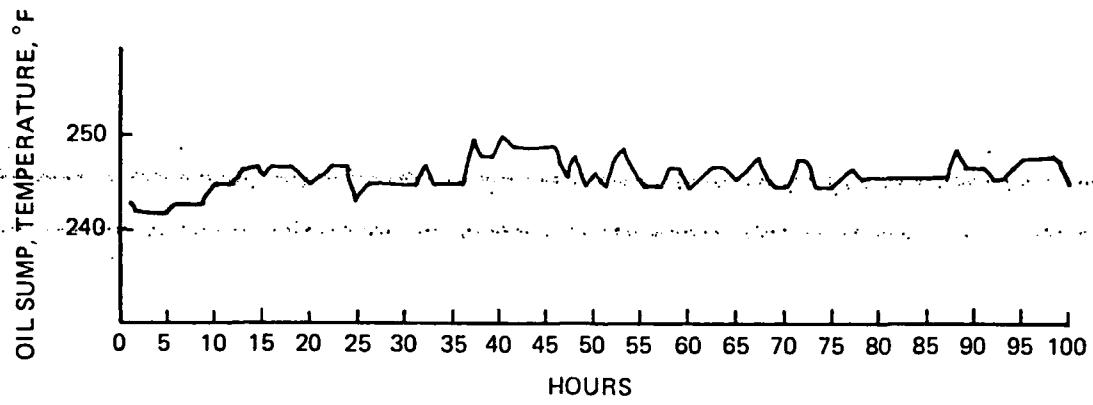
COMPRESSOR DISCHARGE  
PRESSURES, psi



BSFC, lb/bhp-hr







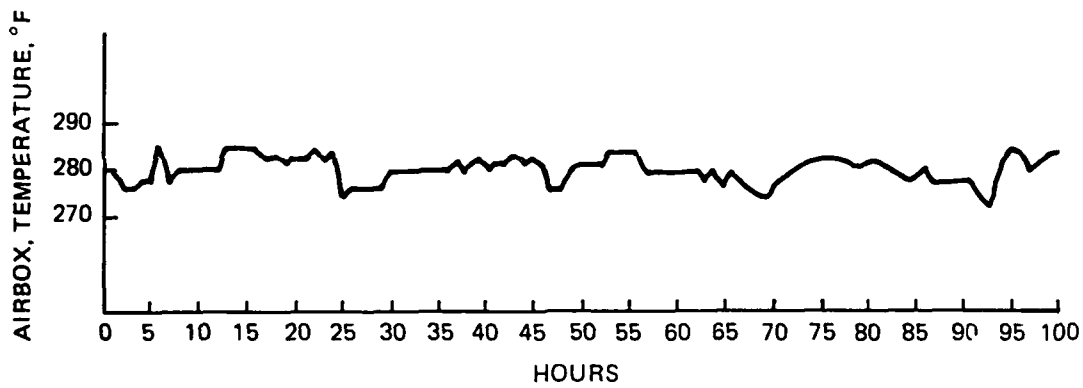
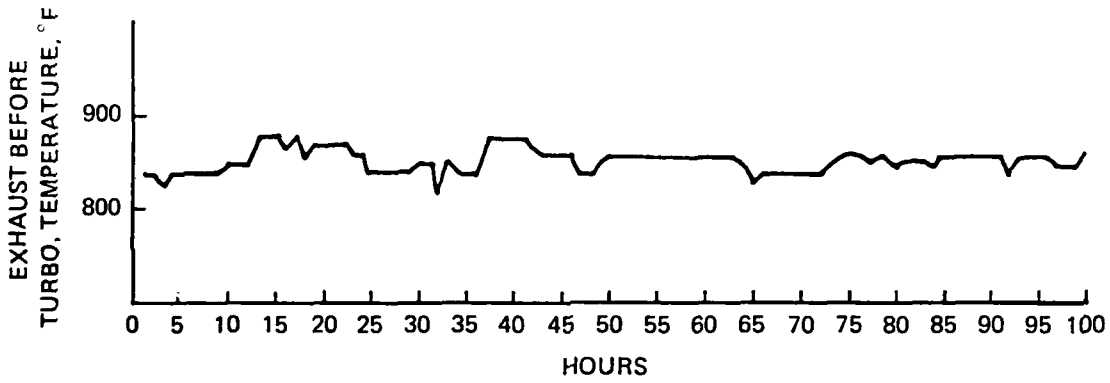
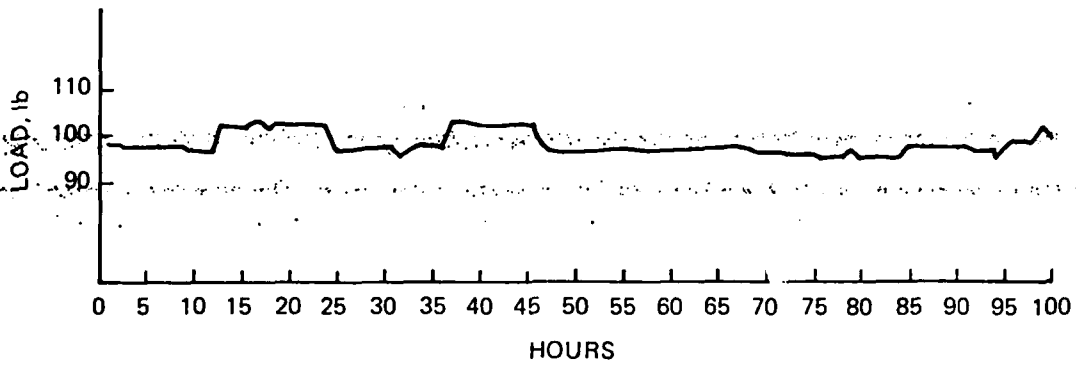
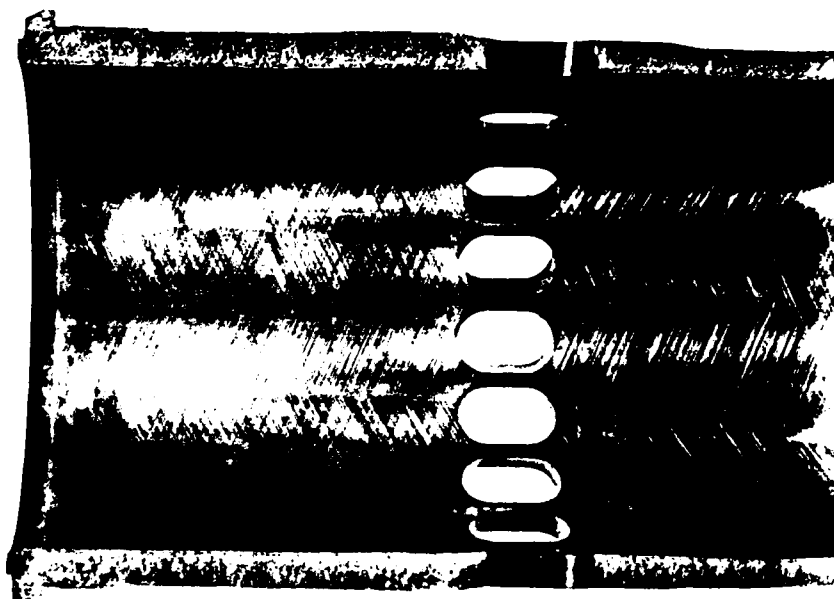
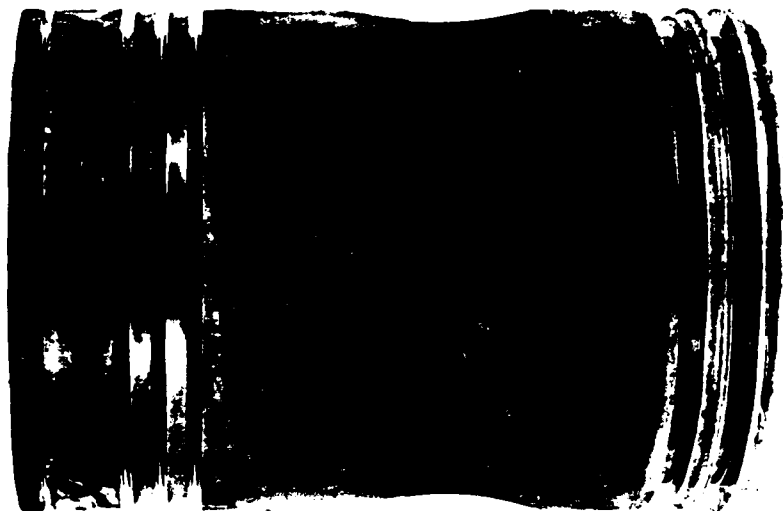


Figure 1. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

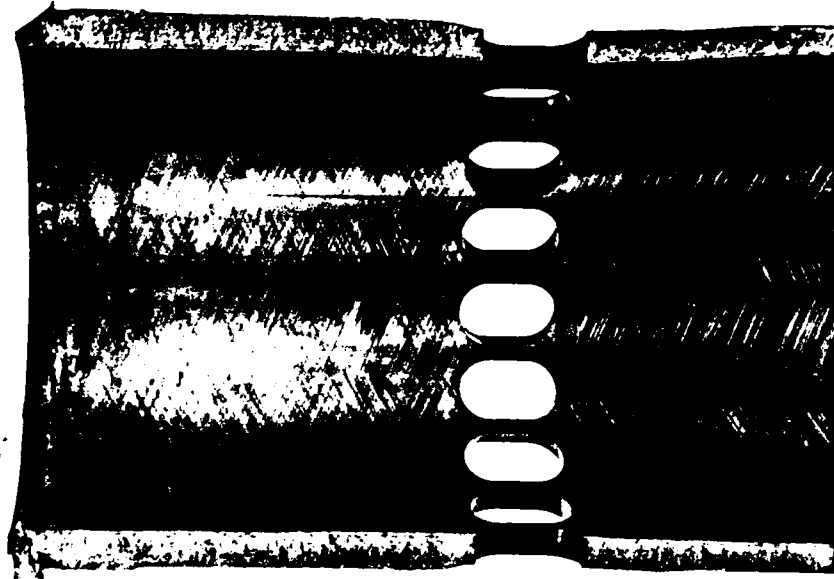


1 Right Thrust

Figure 2. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

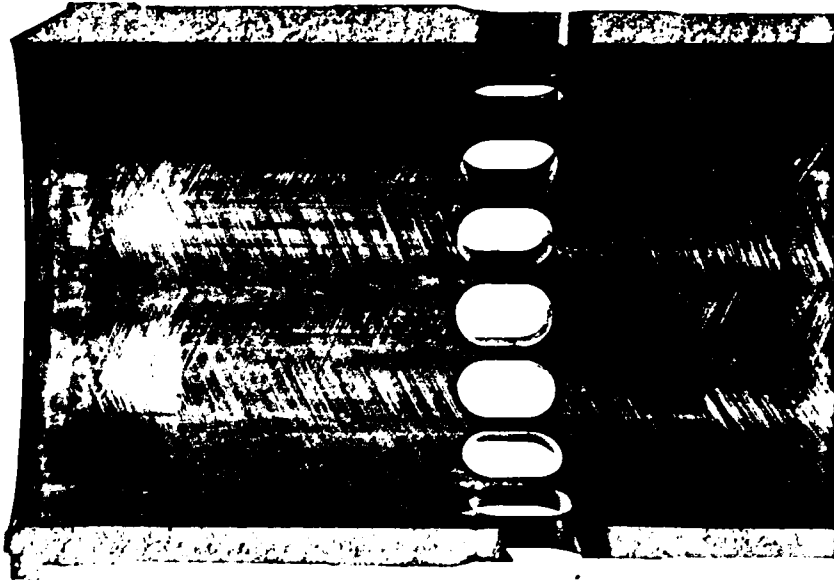
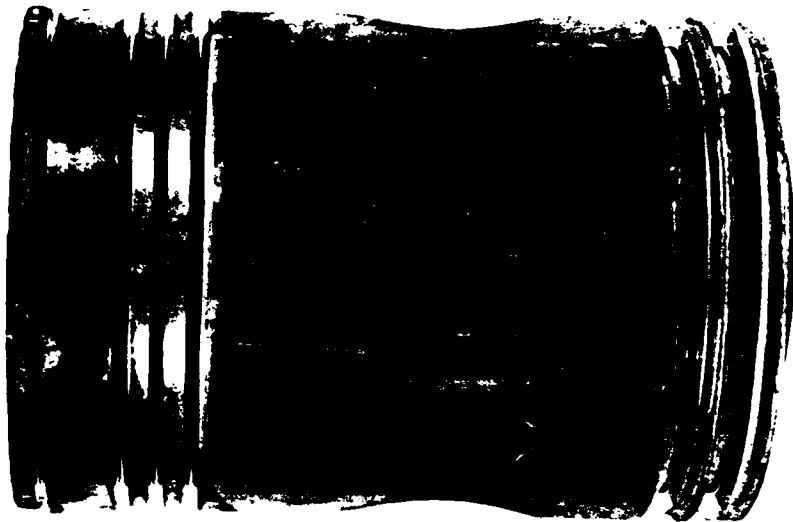


1 Right Anti-Thrust

Figure 3. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

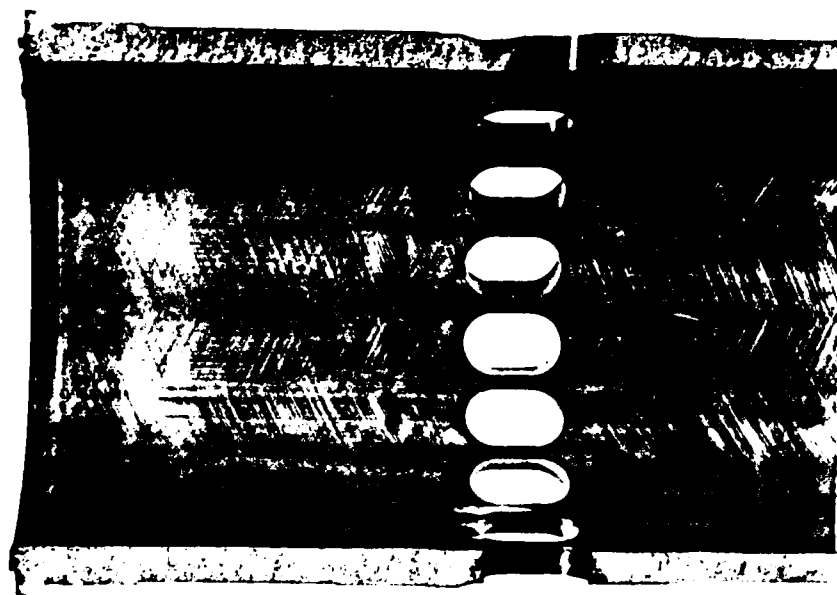
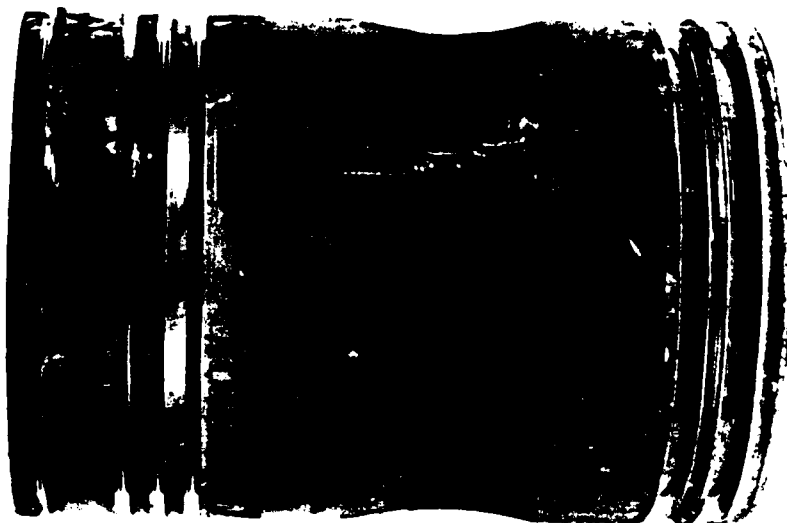


2 Right Thrust

Figure 4. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

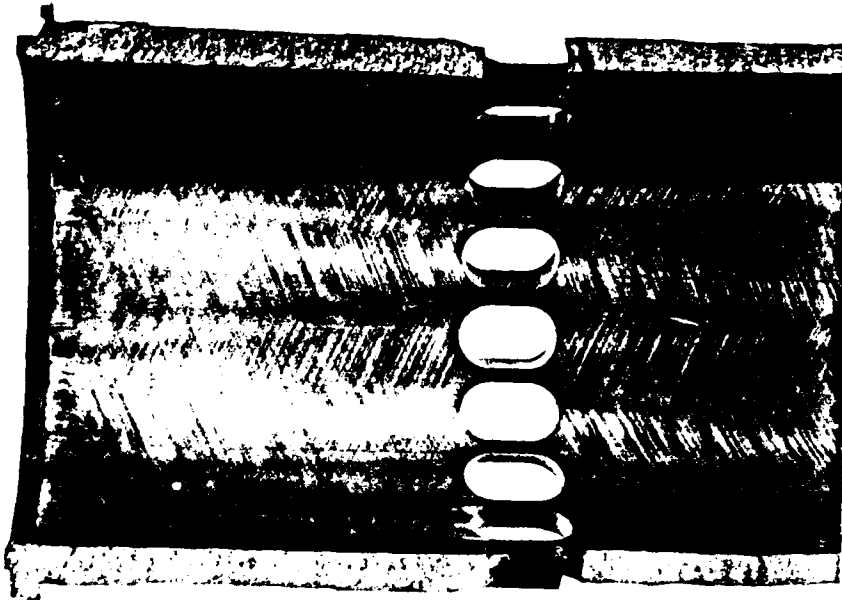


2 Right Anti-Thrust

Figure 5. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

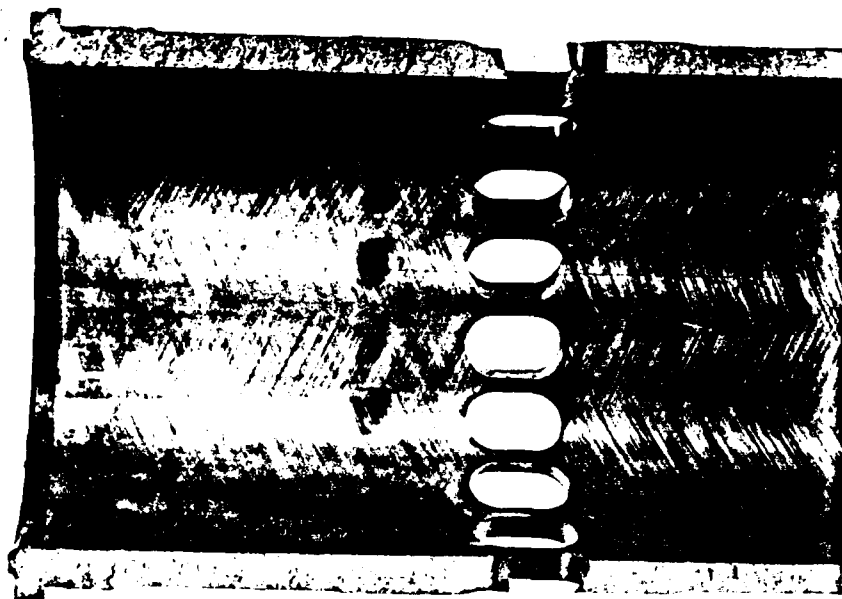


3 Right Thrust

Figure 6. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



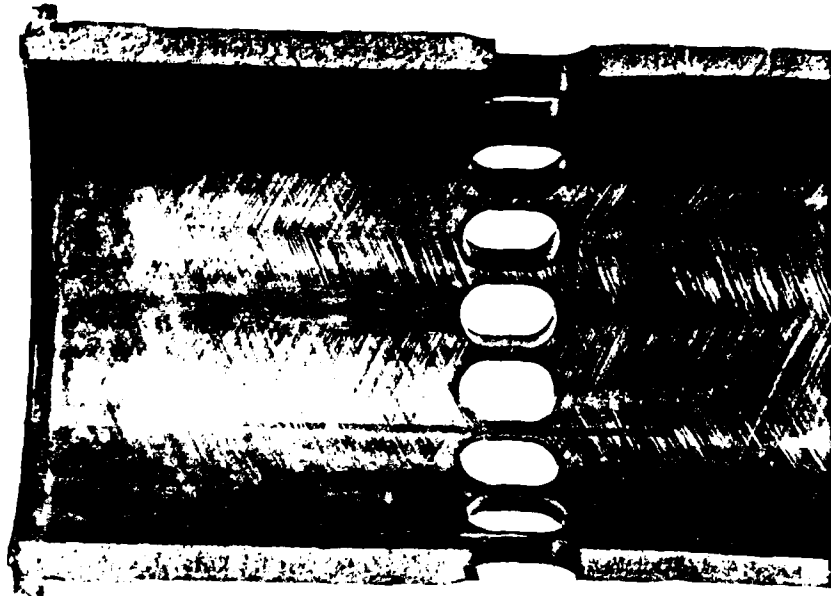
3 Right Anti-Thrust



Figure 7. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OC/HDO-30

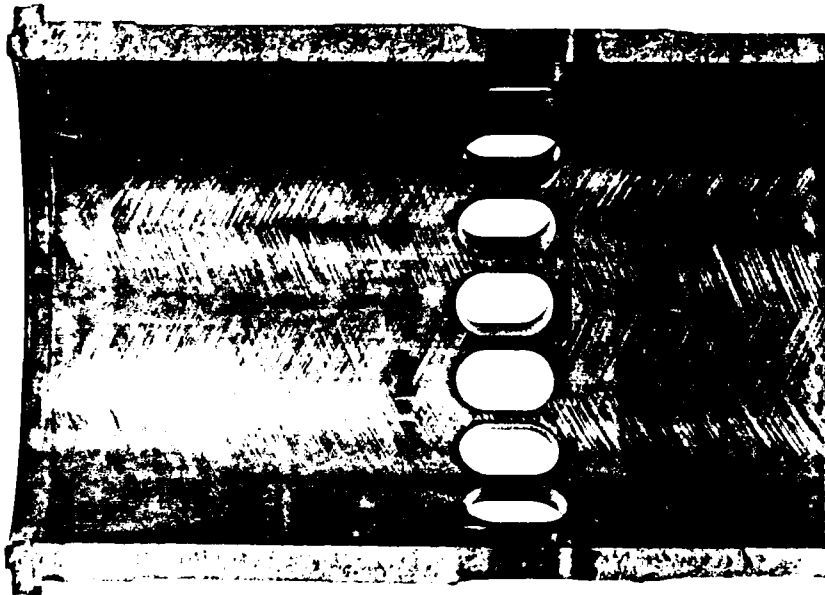


1 Left Thrust

Figure 8. METHOD 354

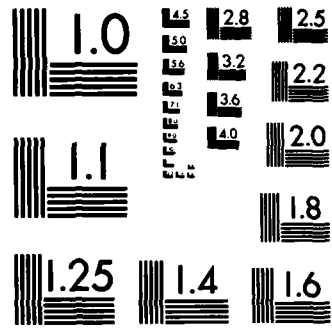
Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



1 Left Anti-Thrust



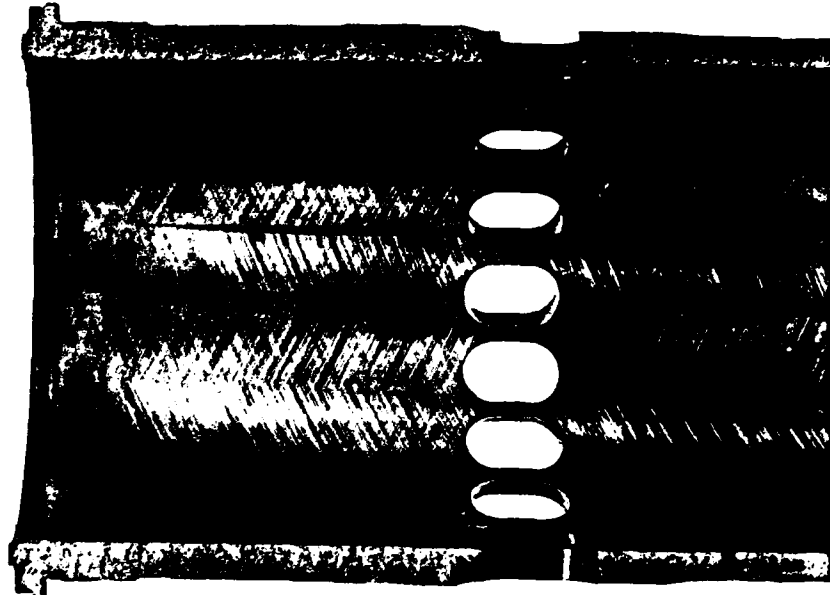


MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS-1963-A

Figure 9. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

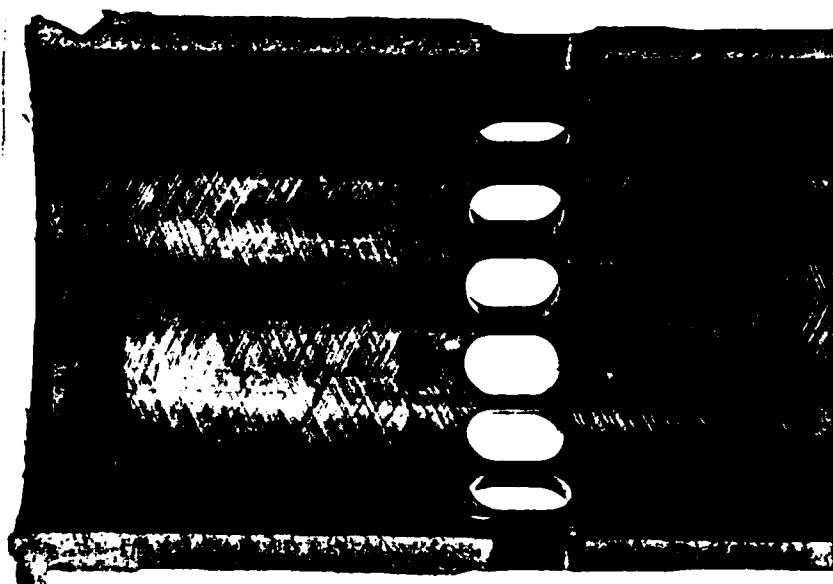
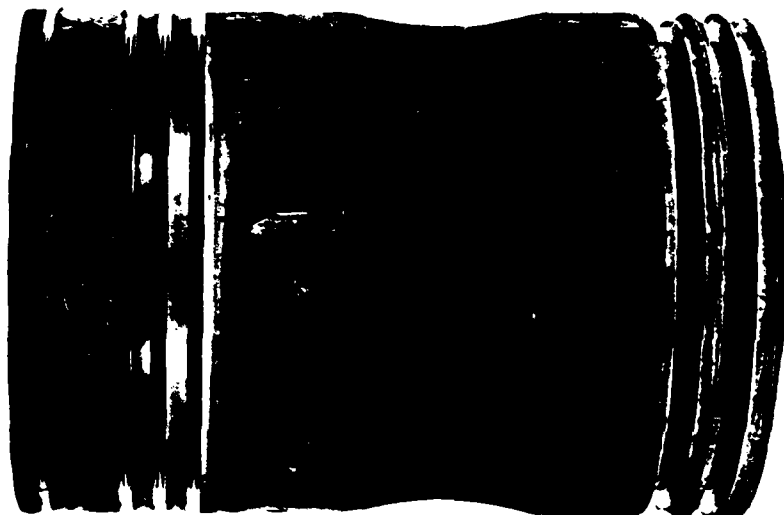


2 Left Thrust

Figure 10. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

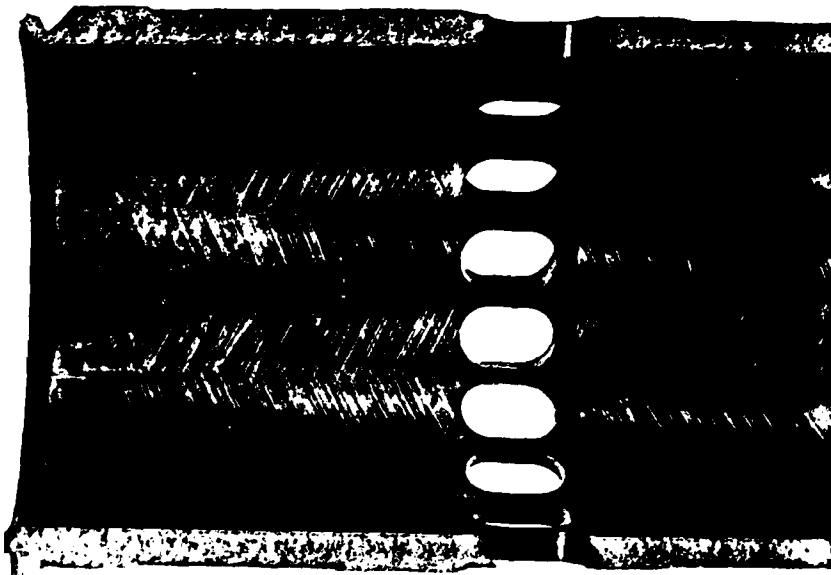
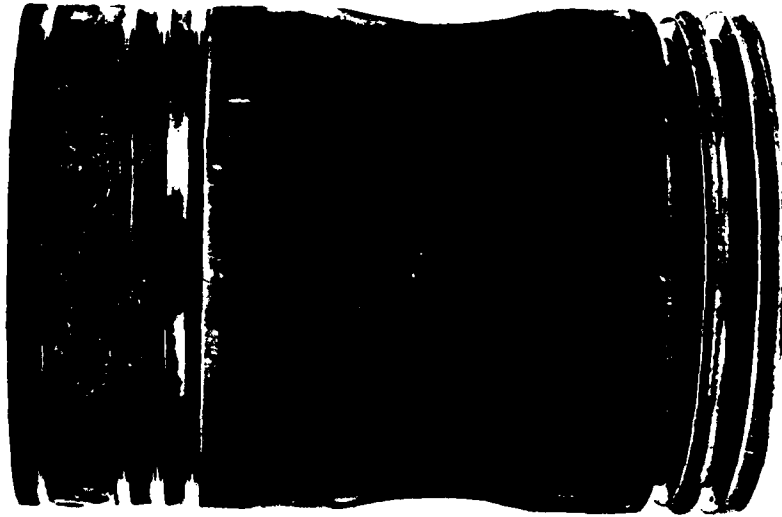


2 Left Anti-Thrust

Figure 11. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30

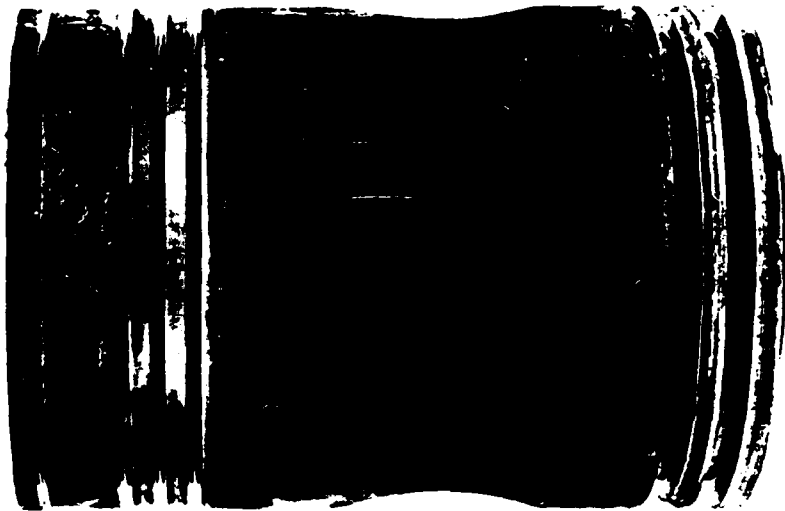


3 Left Thrust

Figure 12. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



3 Left Anti-Thrust



Figure 13. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



1 Right

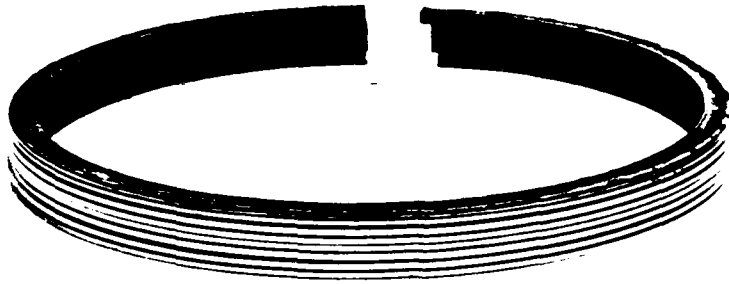


2 Right

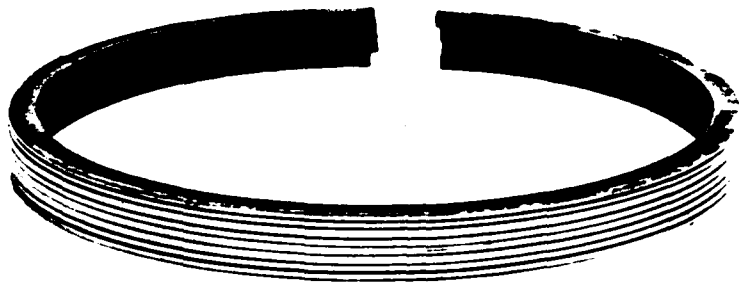
Figure 14. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



3 Right



1 Left

Figure 15. METHOD 354

Condition of Compression Ring Face

Test Time 100 Hours Test No. MTC-1 Lubricant AL-8980-L MC-520 Imperial OE/HDO-30



2 Left



3 Left

APPENDIX D

PERFORMANCE OF AL-01053-L LUBRICATING OIL  
IN A TWO-CYCLE DIESEL ENGINE UNDER  
STEADY-STATE TURBOSUPERCHARGED CONDITIONS

PERFORMANCE OF AL-10153-L LUBRICATING OIL  
IN A TWO-CYCLE DIESEL ENGINE UNDER  
STEADY STATE TURBOSUPERCHARGED CONDITIONS  
(Method 354 Fed. Test Method Std. 791B)

Engine Test No: MTC-4 (Modified Test\*)

Date Completed: 7 November 1980

Conducted For

U.S. Army Mobility Equipment Research and Development Command  
Energy and Water Resources Laboratory  
Fort Belvoir, Virginia

By

U.S. Army Fuels & Lubricant Research Laboratory  
Southwest Research Institute  
San Antonio, Texas 78284

Modified Test\*

This test used the cast iron block version of the DD6V-53T engine. Changes include a cast iron engine block, a 16 plate oil cooler and an 8 plate auxiliary oil cooler.

TABLE 1  
6V53T 6D-151056  
BUILD-UP ENGINE MEASUREMENTS

	Measurements *			
	Min.	Max.	Avg.	Specified Limits**
Connecting rod bearing clearance	0.0024	0.0031	0.0029	0.0010 to 0.0040
Cylinder liner block bore				
Taper	0.0000	0.0004	0.0002	0.0015 max
Out-of-round	0.0000	0.0007	0.0003	0.0015 max
Inside diameter	4.3568	4.3579	4.3574	4.3565 - 4.3575 4.3595 max
Cylinder liners (installed)				
Taper	0.0000	0.0006	0.0003	0.0015 max
Out-of-round	0.0000	0.0008	0.0003	0.0015 max
Inside diameter	3.8754	3.8763	3.8758	3.8752 to 3.8767
Piston to liner fit <sup>1</sup>	0.0072	0.0088	0.0081	0.0060 to 0.0095
Piston diameter	3.8675	3.8682	3.8678	3.8669 to 3.8691
Fire ring				
End gap	0.034	0.041	0.036	0.020 to 0.046
Side clearance	0.003	0.004	0.0035	0.003 to 0.006
#1 Compression ring				
End gap	0.032	0.037	0.034	0.020 to 0.046
Side clearance	0.008	0.008	0.008	0.007 to 0.010
#2 & #3 Compression ring				
End gap	0.028	0.036	0.034	0.020 to 0.046
Side clearance	0.005	0.007	0.0058	0.005 to 0.010
Oil rings				
End gap	0.018	0.021	0.019	0.010 to 0.025
Side clearance	0.002	0.004	0.002	0.0015 to 0.0055

\* All measurements are in inches

\*\* Wear limits with new liners in a used block

<sup>1</sup> Thrust-Antithrust direction

TABLE 2

## OPERATING DATA SHEET

Test Run at U.S. Army Fuels &amp; Lubricants Research Laboratory (SwRI)

Test Oil: AL-10153-L

Test Fuel: 1-H Cat

Test No. MTC-4

Test Stand 5

Engine No. 6D-151056

Test Hours 100

Date: Started 3 November 1980

Completed 7 November 1980

Total Downtime 6.75 Hrs Scheduled; 0 Hrs Unscheduled

	<u>Min.</u>	<u>Max.</u>	<u>Avg.</u>
Engine speed, rpm	2799	2802	2800
Load, lbs	98	100	99
Output, BHp	235	240	238
Fuel rate, lb/min	1.60	1.67	1.62
Oil Consumption, lb/hr			.5059

Temperatures, °F

Jacket-in	158	160	160
Jacket-out	160	172	170
Oil sump	235	245	240
Inlet air (compressor)	72	90	81
Airbox	243	274	259
Exhaust before turbo	720	880	809
Exhaust after turbo	700	870	730
Fuel at filter (secondary)	85	91	88

Pressures

Compressor suction, in., H <sub>2</sub> O	5.2	6.5	6.2
Compressor discharge, psi	6.1	10.8	9.7
Blower discharge, psi	12.1	18.0	17.1
Exhaust before turbo, psi	8.9	13.5	12.8
Exhaust after turbo, in., Hg	1.2	2.5	2.3
Oil gallery, psi	41.5	46.0	43.8
Fuel at filter, psi	71.0	72.2	71.7
Blowby, in., H <sub>2</sub> O	.78	2.1	1.7

TABLE 3

## RATING DATA SHEET

Test Run at U.S. Army Fuels &amp; Lubricants Research Laboratory (SwRI)

Test Oil: AL-10153-L

Test Fuel: 1-H CAT

Test No. MTC-4

Test Stand 5

Engine No. 6D-151056

Test Hours: 100 Date: Started 3 November 1980 Completed 7 November 1980

A. Cylinder Liner RatingsIntake Port Plugging

<u>Cylinder No.</u>	<u>Restriction, %</u>
1 L	< 1
2 L	< 1
3 L	< 1
1 R	< 1
2 R	< 1
3 R	< 1
Average	< 1

Scuffing, Glazing, and Lacquer\*

<u>Cylinder No.</u>	<u>Scuffing, %</u>			<u>Glazing, %</u>	<u>Lacquer, %</u>
	<u>Thrust</u>	<u>Anti-Thrust</u>	<u>% Total Area Scuffed</u>		
1 L#	10	10	10	0	60
2 L#	5	5	5	0	60
3 L#	15	10	12.5	0	60
1 R#	25	20	22.5	0	60
2 R#	30	10	20	5	55
3 R#	15	15	15	0	60
Average	16.7	11.7	14.2	1	59.2

\*Total Ring Travel Area

#Some Light Vertical Lines



TABLE 3 - Continued

B. Piston Ratings

<u>Cylinder No.</u>	<u>Ring Sticking and Condition*</u>			
	<u>Fire</u>	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>
1 L	F#-1	F-<1	F-0	F-<1
2 L	F -1	F-0	F-0	F-0
3 L	5% P -1	F-0	F-0	F-<1
1 R	F-15	F-10	F-0	F#-5
2 R	5% P-50	F-100	F-100	F-90
3 R	F -2	F-0	F-<1	F-0

\* Numbers denote % area ring face burn

F-Free

# Ring Face Chipped

P-Pinched

Ring Groove Carbon Filling and Oil Groove Lacquer

<u>Cylinder No.</u>	<u>Groove Filling, %</u>				<u>Oil Groove Lacquer (Demerit)</u>	
	<u>Fire</u>	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>	<u>Upper</u>	<u>Lower</u>
1 L	20	5	0	0	5	5
2 L	20	5	0	0	5	5
3 L	5	15	0	0	5	5
1 R	15	35	0	0	5	5
2 R	10	20	0	0	5	5
3 R	15	70	0	0	5	5

Land Description

<u>Cylinder No.</u>	<u>Description</u>
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

Skirt (Demerit)

<u>Cylinder No.</u>	<u>Thrust</u>	<u>Anti-Thrust</u>
1 L	5.5-5% scuffing; Lt. Scr.	6.0-Very Lt. Scr.
2 L	6.2 - Lt. Scr.	5.5-5% Scuffing; Lt. Scr.
3 L	6.6-Lt. Scr.	5.5-Lt. Scr.
1 R	5.8-5% Scuffing; Lt. Scr.	5.5-Lt. Scr.
2 R	6.6-Lt. Scr.	5.8-Lt. Scr.
3 R	6.5-Lt. Scr.	6.0-Lt. Scr.

C. Other Ratings

Combustion Chambers

<u>Cylinder No.</u>	<u>Description</u>	<u>Cylinder No.</u>	<u>Description</u>
1 L	70%A, 30% $\frac{1}{2}$ A, HC	1 R	75%A, 25% $\frac{1}{2}$ A, HC
2 L	65%A, 35% $\frac{1}{2}$ A, HC	2 R	50%A, 50% $\frac{1}{2}$ A, HC
3 L	60%A, 40% $\frac{1}{2}$ A, HC	3 R	30%A, 70% $\frac{1}{2}$ A, HC

D. Interim Inspections

Zero Test Hours

	<u>Inspection</u>
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal
3 R	Normal

24 Test Hours

	<u>Inspection</u>
1 L	Normal
2 L	Normal
3 L	Normal
1 R	Normal
2 R	Normal; med to hvy scuffing Rr of liner
3 R	Normal

48 Test Hours

	<u>Inspection</u>
1 L	Normal; med to hvy glazing Frt & Rr of liner
2 L	Normal; hvy glazing Frt & Rr of liner
3 L	Normal; top compression ring stuck, med to hvy glazing Frt & Rr of liner

TABLE 3 - Continued

<u>48 Test Hours</u>	<u>Inspection</u>
1 R	Normal; Med glazing; Med to Hvy scuffing to Rr & AT-side of liner
2 R	Normal; Hvy scuffing to Rr & AT-side of liner
3 R	Normal; Hvy glazing to Frt & Rr of liner
<u>72 Test Hours</u>	<u>Inspection</u>
1 L	Normal; Hvy glazing to Frt & Rr of liner
2 L	Normal; Fire & top compression rings stuck; Hvy glazing Frt & Rr of liner
3 L	Normal; Lt to Med scuffing, Med. glazing of liner
1 R	Normal; Top compression ring stuck; Hvy scuffing to Frt, Med to Hvy glazing of liner
2 R	Normal; Top compression ring stuck; Hvy scuffing and glazing to Rr of liner
3 R	Normal; Hvy glazing to Frt & Rr of liner

E. Legend

Abbreviations

Definitions

T-side	Thrust side of cylinder liner or piston skirt. (Inboard left bank & outboard right bank).
AT-side	Anti-thrust side of cylinder liner or piston skirt. (Side opposite the thrust side).
Lt.	Light
Med.	Medium
Hvy.	Heavy
P. Melt	Melting of the plating on the piston surface.
Scr.	Scratching
Frt.	Front of piston or liner
Rr.	Rear of piston or liner
Normal	All components considered normal, unless specified otherwise. This means rings are free, only light scuffing of liner and piston skirts, hard carbon on fire lands, and lacquer on other ring lands.

TABLE 4

OIL ANALYSES DATA SHEET

Test Run at U.S. Army Fuels & Lubricants Research Laboratory (SwRI)

Test Oil - AI-10153-L

Test Fuel - 1-H Cat

Test No. MTC-4

Test Stand 5

Engine No. 6D-151056

Test Hours 100

Date: Started 3 November 1980

Completed 7 November 1980

TEST HOUR SAMPLE

Determination	New Oil	12	24	36	48	60	72	84	100
Viscosity, cSt									
at 40°C			69.06		72.07		75.19		79.14
at 100°C			10.37		10.66		10.96		11.35
Total Acid Number	2.34		2.75		3.31		3.42		4.05
Total Base Number	8.74		7.22		6.59		6.59		5.5
Sulfated Ash, %			1.07				1.21		1.1
Flash Point, °C			212				216		218
Iron Content, ppm		84	110	133	118	116	111	109	119

TABLE 5

Lubricant: AL-10153-L

## WEAR MEASUREMENTS

## Cylinder Liner Bore Diameter Change\*

	<u>Cylinder Number</u>					
	<u>1L</u>		<u>2L</u>		<u>3L</u>	
	<u>T-AT**</u>	<u>F-B**</u>	<u>T-AT</u>	<u>F-B</u>	<u>T-AT</u>	<u>F-B</u>
Top	+ .0007	+ .0001	+ .0008	+ .0002	+ .0005	+ .0002
Middle	+ .0003	+ .0001	+ .0002	+ .0004	+ .0002	+ .0008
Bottom	- .0002	+ .0001	+ .0002	+ .0002	+ .0003	+ .0004

	<u>Cylinder Number</u>					
	<u>1R</u>		<u>2R</u>		<u>3R</u>	
	<u>T-AT</u>	<u>F-B</u>	<u>T-AT</u>	<u>F-B</u>	<u>T-AT</u>	<u>F-B</u>
Top	+ .0010	+ .0006	+ .0011	+ .0012	+ .0004	+ .0004
Middle	+ .0004	+ .0004	+ .0007	+ .0001	+ .0005	+ .0004
Bottom	+ .0003	+ .0003	+ .0003	+ .0011	+ .0003	+ .0002

	<u>Average Change</u>	
	<u>T-AT</u>	<u>F-B</u>
Top	+0.0008	+0.0005
Middle	+0.0004	+0.0004
Bottom	+0.0002	+0.0004

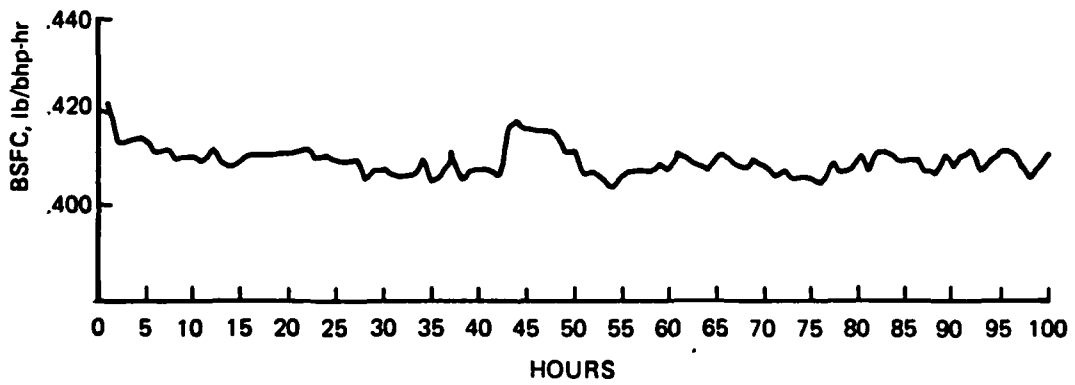
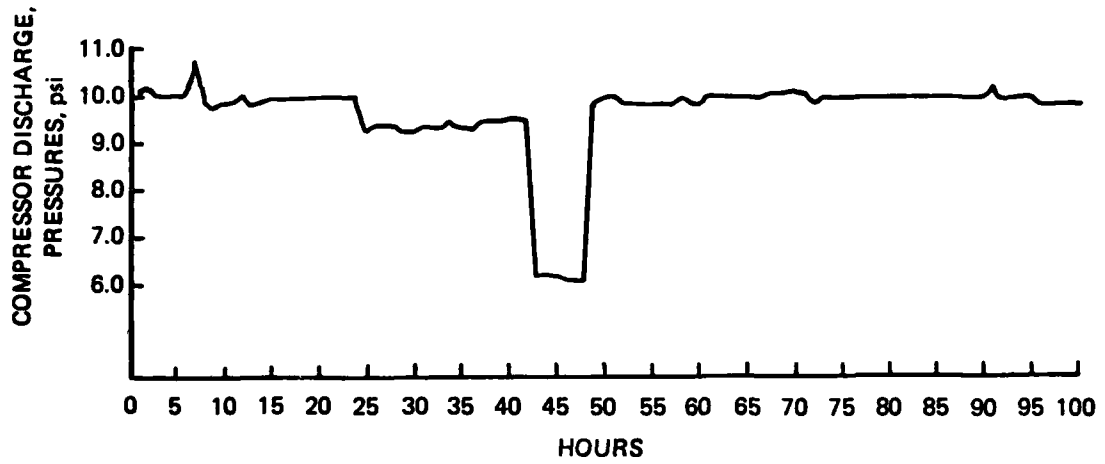
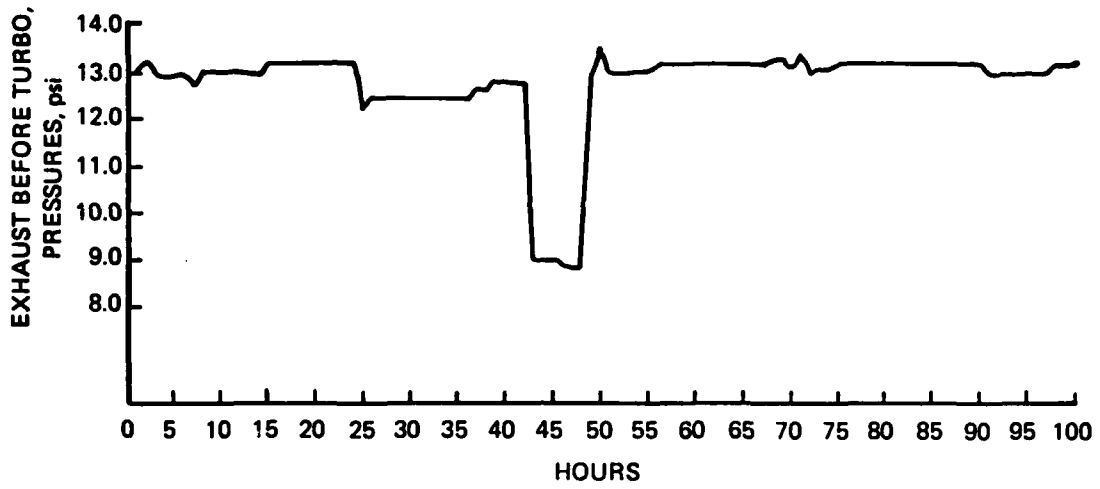
Overall Average Change: +0.0004

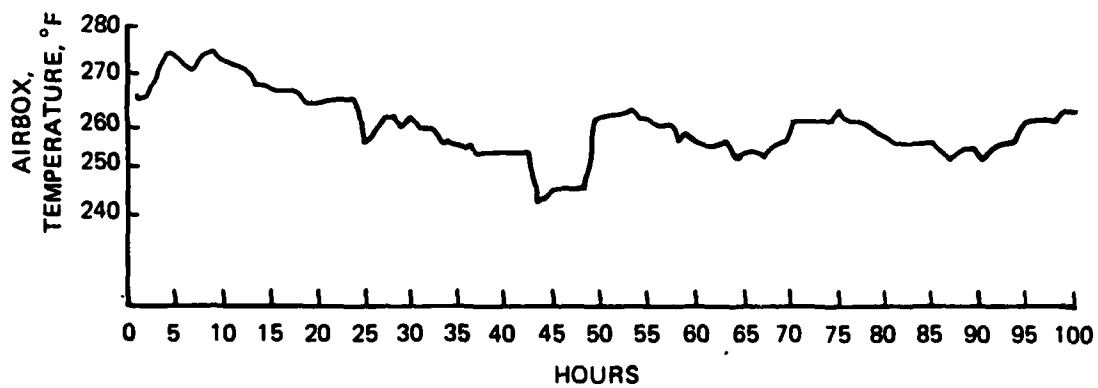
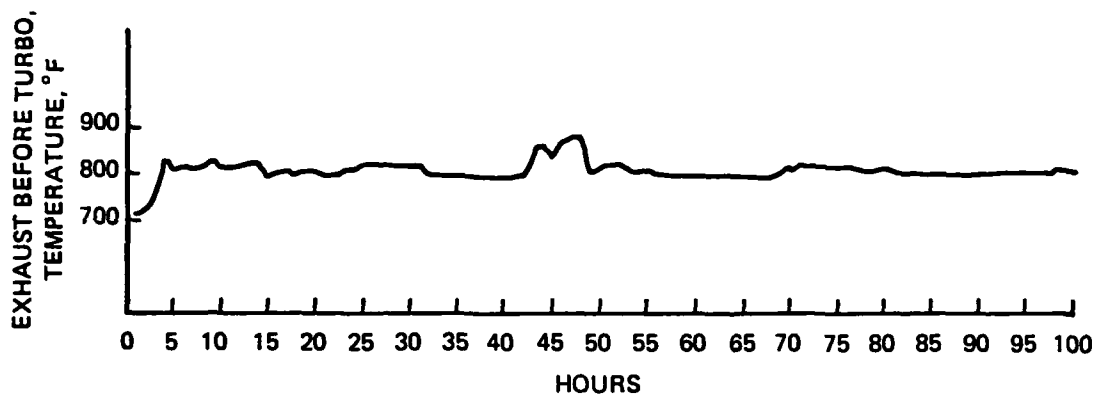
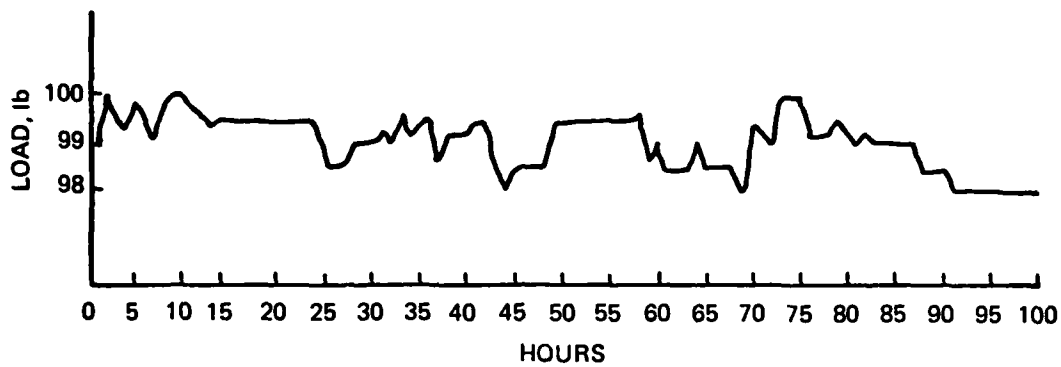
<u>Ring Number</u>	<u>Piston Ring End Gap Change</u>						
	<u>1L</u>	<u>2L</u>	<u>3L</u>	<u>1R</u>	<u>2R</u>	<u>3R</u>	<u>Average Change</u>
1	+0.001	-0.001	+0.001	+0.001	-0.001	+0.001	+0.0003
2	-0.002	-0.001	0.000	-0.001	+0.001	-0.002	-0.0008
3	-0.001	-0.002	0.000	-0.001	0.000	+0.001	-0.0005
4	-0.001	0.000	-0.001	0.000	-0.002	-0.002	-0.0010
5	+0.002	+0.003	+0.003	+0.003	+0.006	+0.004	+0.0035
6	+0.001	0.000	+0.002	+0.001	+0.002	+0.002	+0.0013
7	0.000	+0.001	0.000	+0.001	+0.002	+0.002	+0.0010

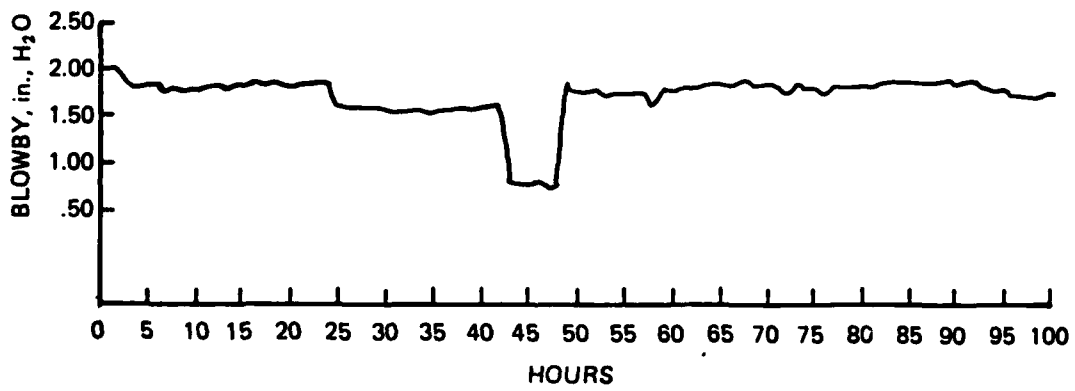
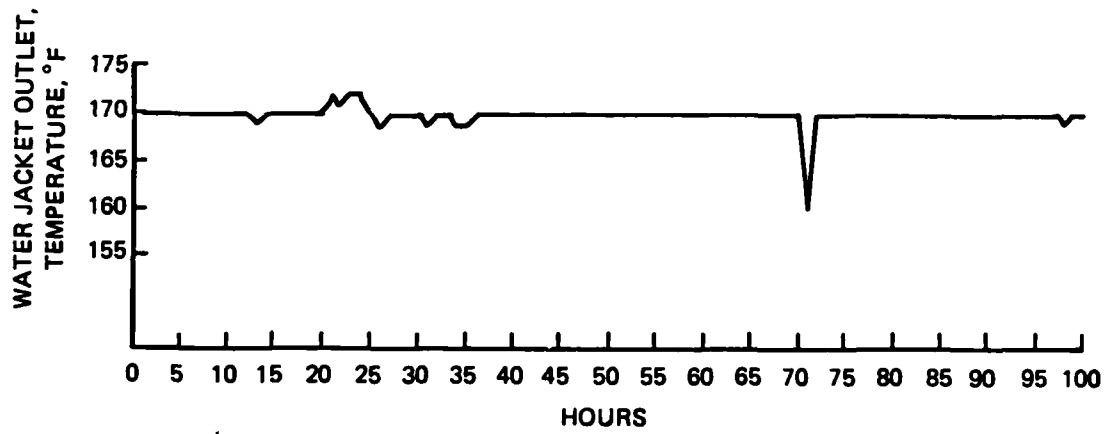
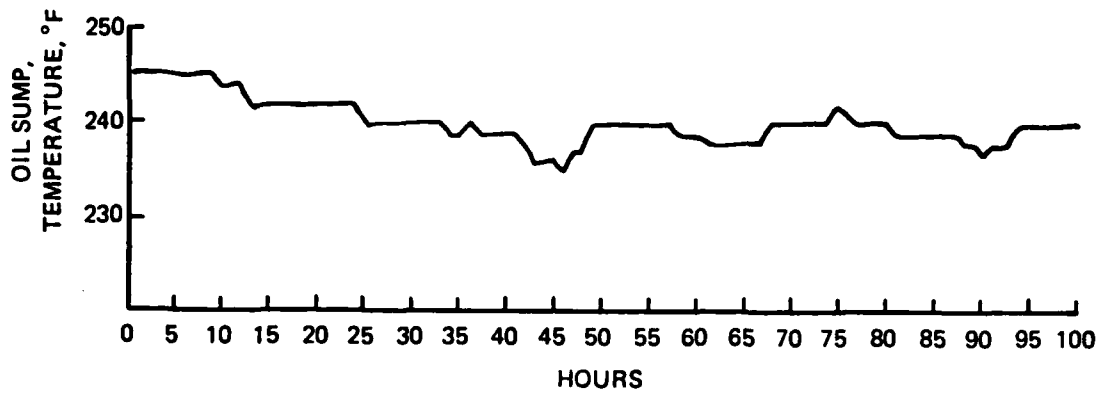
Overall Average Change : +0.0005

\* All dimensions given are in inches.

\*\* T-AT= Thrust-Anti-thrust direction; F-B= Front-Back direction









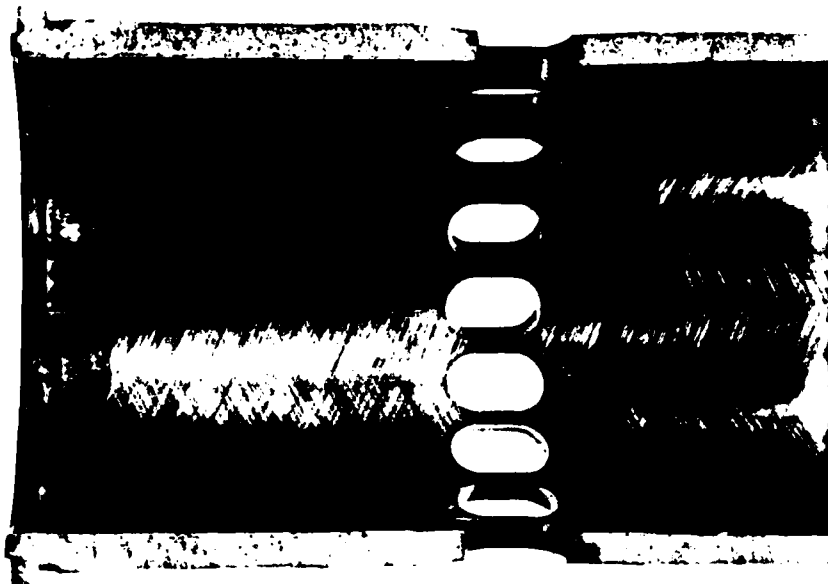
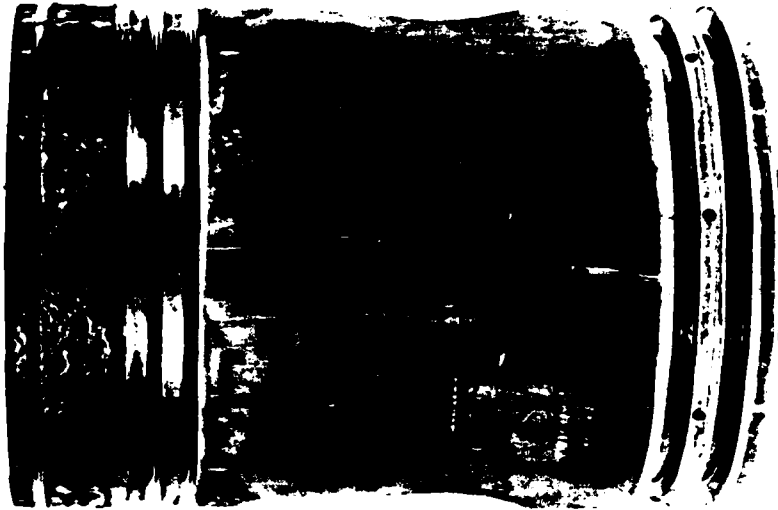
FLIGHT 1. METHOD 3M

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



1 Right Thrust

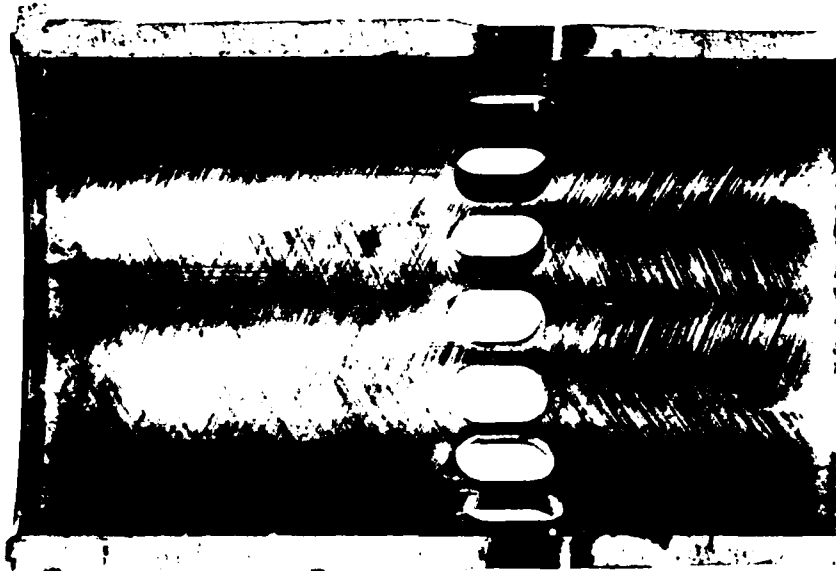
Figure 2. METHOD 554

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



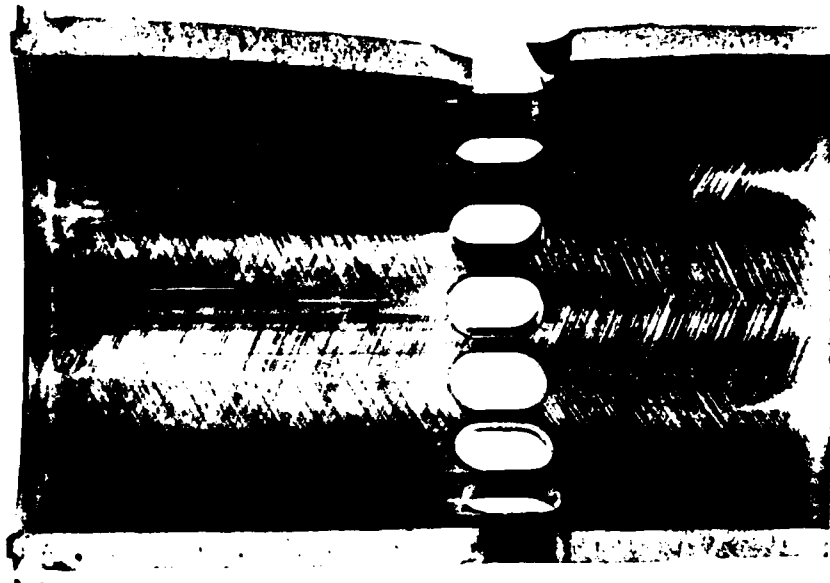
1 Right Antithrust

Figure 3. METHOD 354  
Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



2 Right Thrust

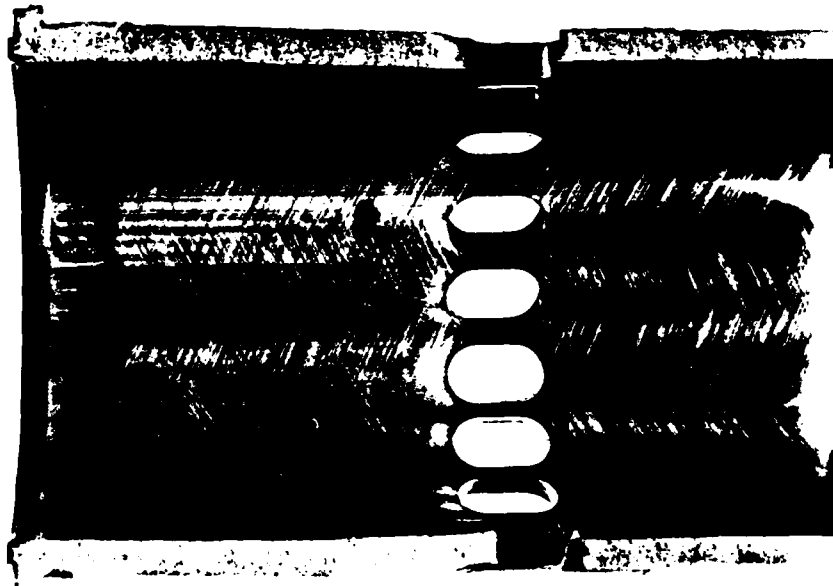
Figure 4. METHOD 354

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



2 Right Antithrust

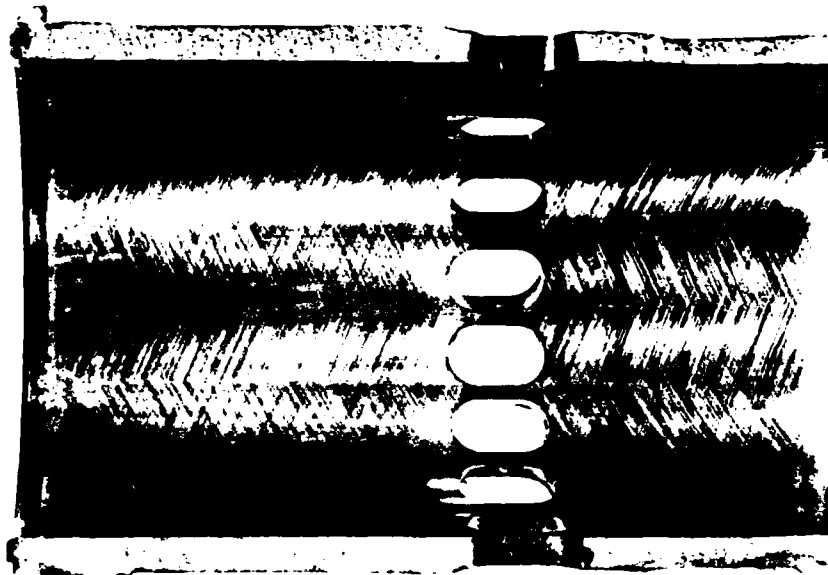
Figure 5. METHOD MTC

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



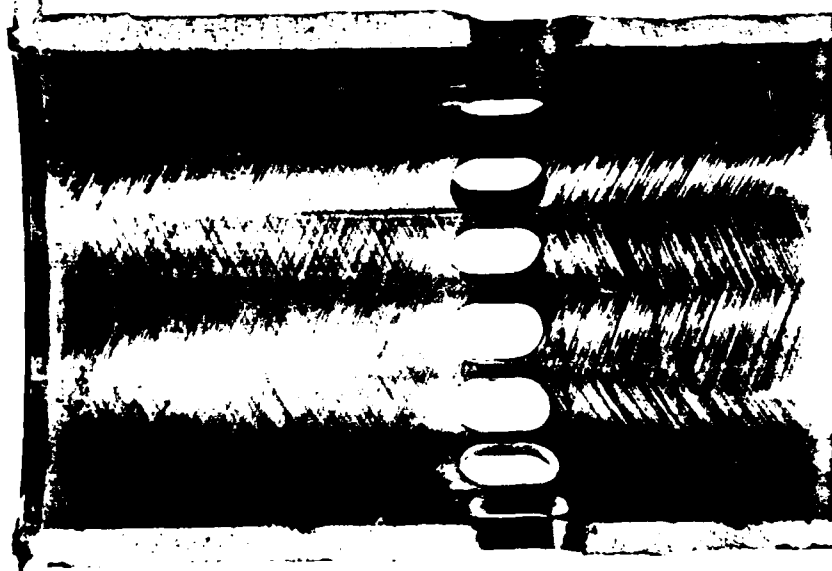
3 Right Thrust

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



3 Right Antithrust

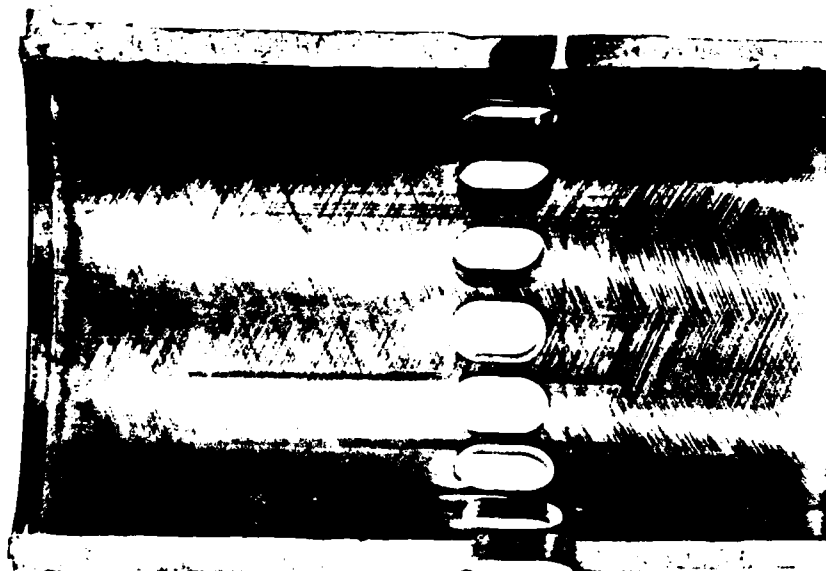
Figure 7. METHOD 30.

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-01053-L



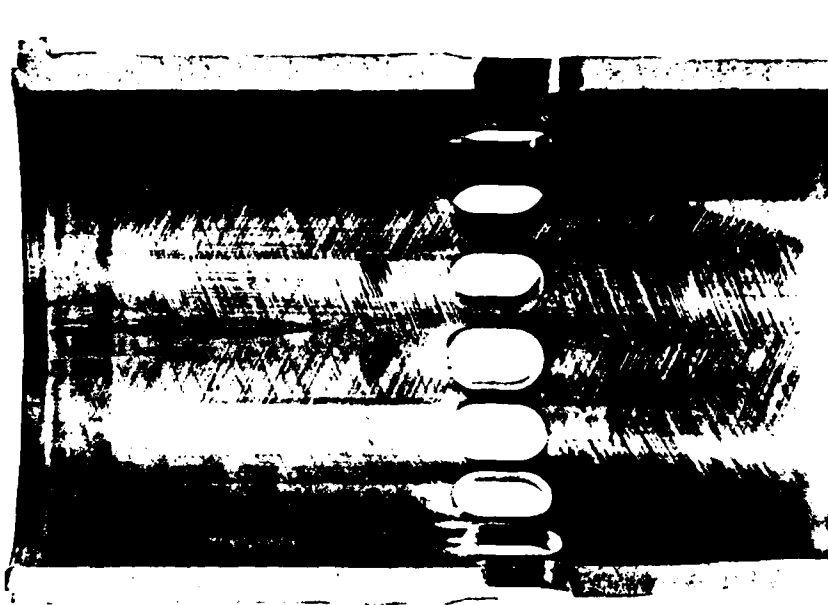
1 Left Thrust

Figure 3. METHOD 33.  
Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



1 Left Antithrust



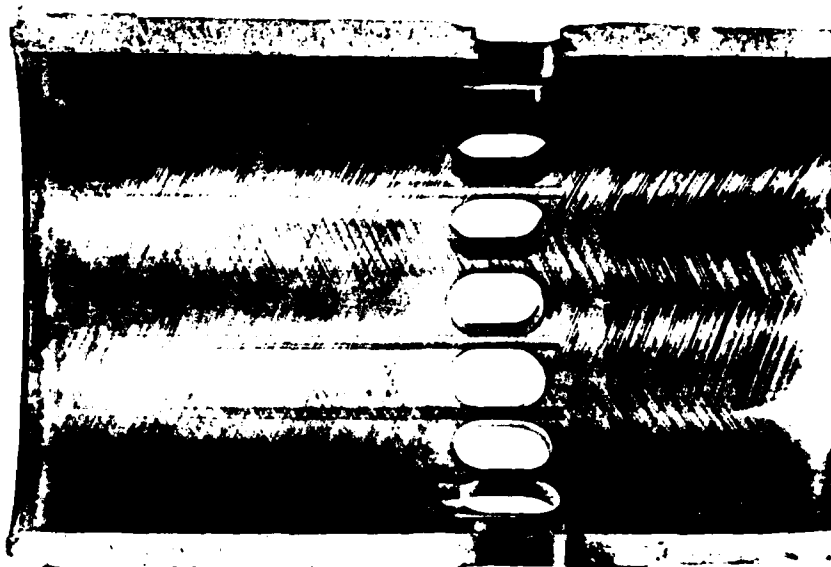
Figure 8. METHOD 300

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



2 Left Thrust

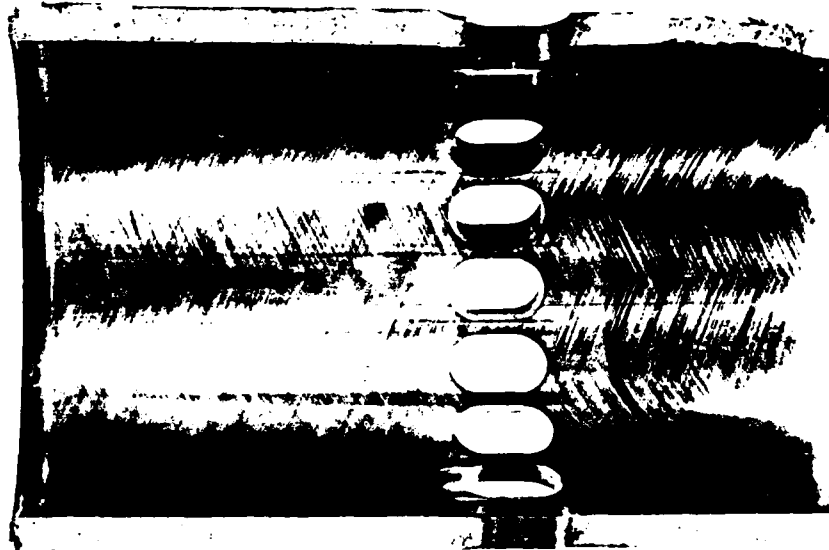
Figure 10. METHOD 104

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



2 Left Antithrust

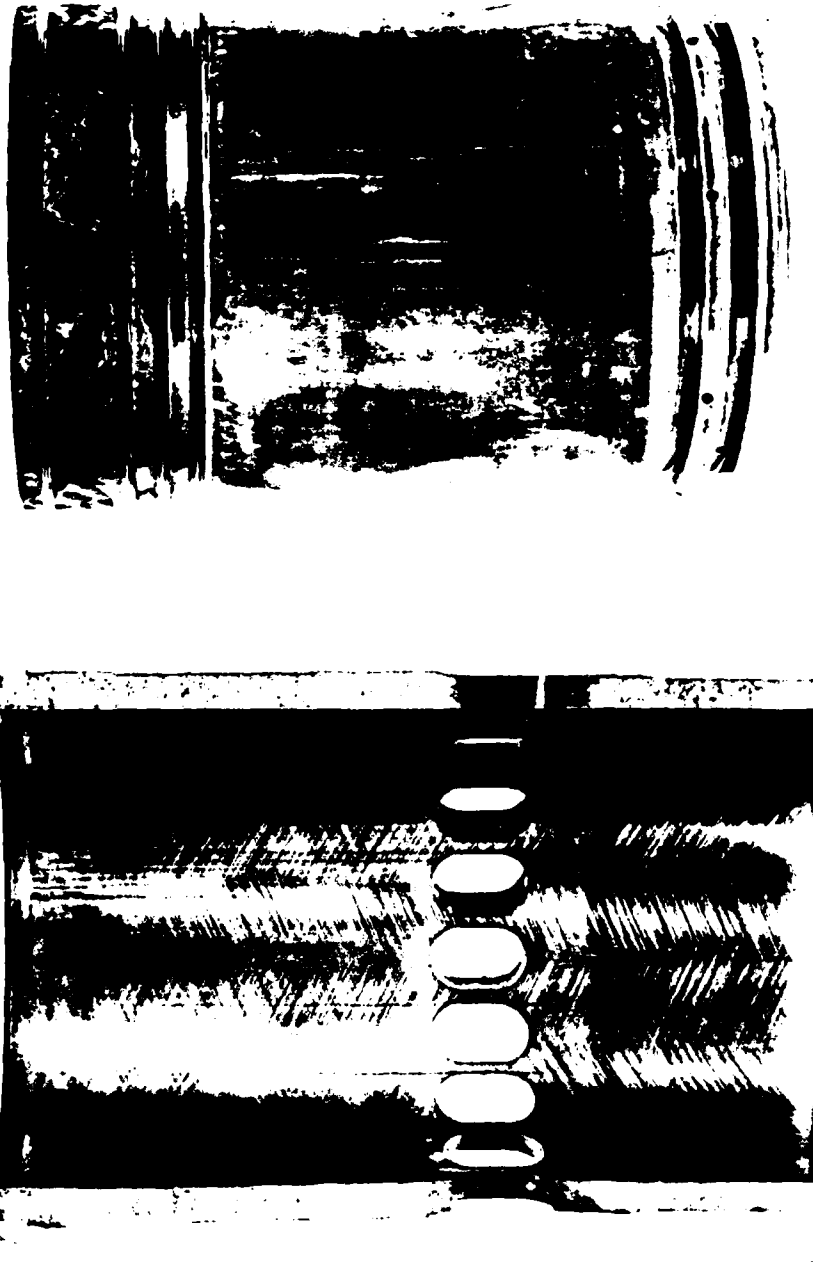
Figure 1. MTC-4

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



3 Left Thrust

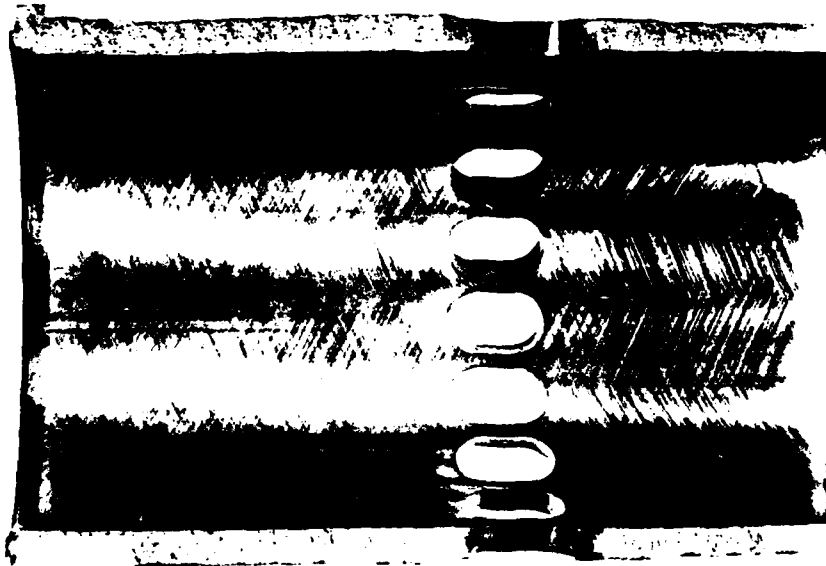
Figure 12. METHOD B.1

Condition of Piston and Cylinder Liner

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



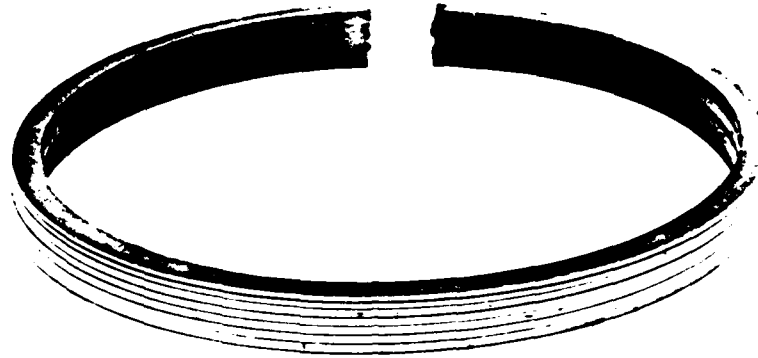
3 Left Antithrust

Figure 13. METHOD 354  
Condition of Compression Ring Face

Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



1 Right



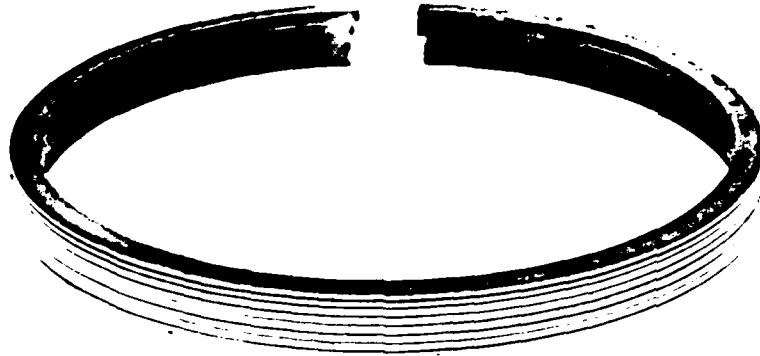
2 Right

Figure 14. METHOD 304  
Condition of Compression Ring Face

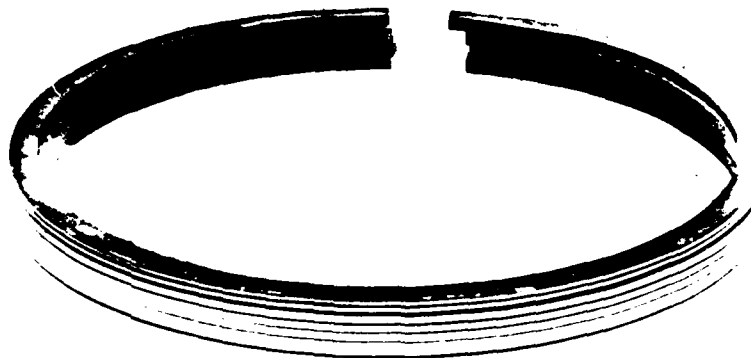
Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



3 Right



1 Left

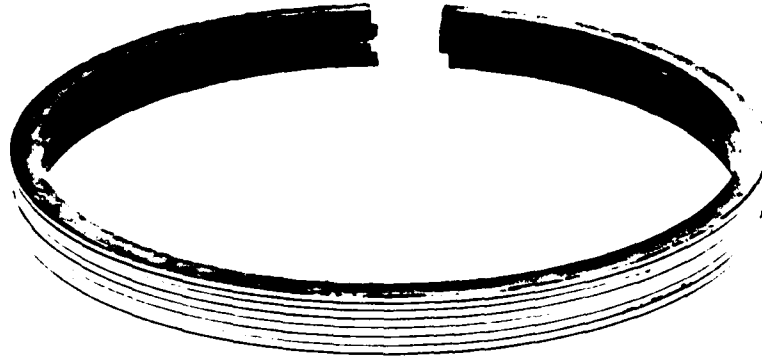
Figure 1. METHOD 35.

Condition of Compression Ring Face

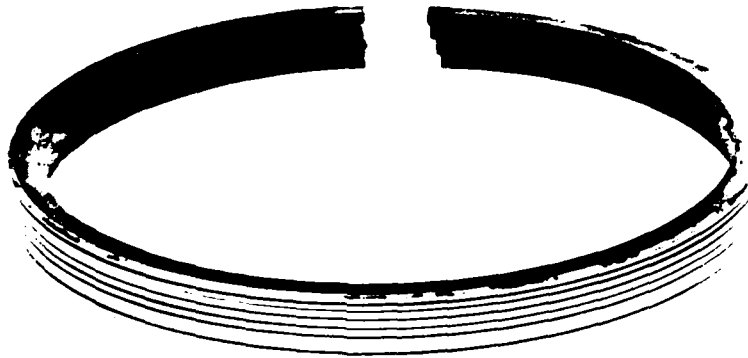
Test Time 100 Hours

Test No. MTC-4

Lubricant: AL-10153-L



2 Left



3 Left

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

DEFENSE DOCUMENTATION CTR  
CAMERON STATION 12  
ALEXANDRIA VA 22314

DEPT OF DEFENSE  
ATTN: DASD-LM(MR DYCKMAN) 1  
WASHINGTON DC 20301

COMMANDER  
DEFENSE LOGISTICS AGY  
ATTN DLA-SME (MRS P MCLAIN) 1  
CAMERON STATION  
ALEXANDRIA VA 22314

COMMANDER  
DEFENSE FUEL SUPPLY CTR  
ATTN: DFSC-T (MR. MARTIN) 1  
CAMERON STA  
ALEXANDRIA VA 22314

COMMANDER  
DEFENSE GENERAL SUPPLY CTR  
ATTN: DGSC-SSA 1  
RICHMOND VA 23297

DOD  
ATTN: DUSD (RAT) (Dr. Dix) 1  
ATTN: DUSD (RTI) (Dr. Young) 1  
WASHINGTON, DC 20301

DEFENSE ADVANCED RES PROJ AGENCY  
DEFENSE SCIENCES OFC 1  
1400 WILSON BLVD  
ARLINGTON VA 22209

DEPARTMENT OF THE ARMY

HQ, DEPT OF ARMY  
ATTN: DALO-TSE (COL ST. ARNAUD) 1  
DALO-AV 1  
DALO-SMZ-E 1  
DAMA-CSS-P (DR BRYANT) 1  
DAMA-ARZ-E (DR VERDERAME) 1  
WASHINGTON DC 20310

CDR  
U.S. ARMY MOBILITY EQUIPMENT  
R&D COMMAND  
Attn: DRDME-GL 10  
DRDME-WC 2  
FORT BELVOIR VA 22060

CDR  
US ARMY MATERIEL DEVEL &  
READINESS COMMAND  
ATTN: DRCLD (MR BENDER) 1  
DRCDMR (MR GREINER) 1  
DRCDMD-ST (DR HALEY) 1  
DRCQA-E 1  
DRCDE-SG 1  
DRCIS-C (LTC CROW) 1  
DRCSM-WRS (MR. SCHEUBLE) 1  
5001 EISENHOWER AVE  
ALEXANDRIA VA 22333

CDR  
US ARMY TANK-AUTOMOTIVE CMD  
ATTN DRSTA-GSPE 1  
DRSTA-RG 1  
DRSTA-NS (DR CHURCH) 1  
DRSTA-G 1  
DRSTA-M 1  
DRSTA-GBP (MR MCCARTNEY) 1  
WARREN MI 48090

DIRECTOR  
US ARMY MATERIEL SYSTEMS  
ANALYSIS AGENCY  
ATTN DRXSY-CM 1  
DRXSY-S 1  
DRXSY-L 1  
ABERDEEN PROVING GROUND MD 21005

DIRECTOR  
APPLIED TECHNOLOGY LAB  
U.S. ARMY R&T LAB (AVRADCOM)  
ATTN DAVDL-ATL-ATP (MR MORROW) 1  
DAVDL-ATL-ASV (MR CARPER) 1  
FORT EUSTIS VA 23604

HQ, 172D INFANTRY BRIGADE (ALASKA)  
ATTN AFZT-DI-L 1  
AFZT-DI-M 1  
DIRECTORATE OF INDUSTRIAL  
OPERATIONS  
FT RICHARDSON AK 99505

CDR  
US ARMY GENERAL MATERIAL &  
PETROLEUM ACTIVITY  
ATTN STSGP-F (MR SPRIGGS) 1  
STSGP-PE (MR MCKNIGHT),  
BLDG 85-3 1  
STSGP (COL CLIFTON) 1  
NEW CUMBERLAND ARMY DEPOT  
NEW CUMBERLAND PA 17070



CDR  
US ARMY MATERIEL ARMAMENT  
READINESS CMD  
ATTN DRSAR-LEM 1  
ROCK ISLAND ARSENAL IL 61299

CDR  
US ARMY COLD REGION TEST CENTER  
ATTN STECR-TA 1  
APO SEATTLE 98733

HQ, DEPT. OF ARMY  
ATTN: DAEN-RDM 1  
WASHINGTON, DC 20310

CDR  
US ARMY RES & STDZN GROUP  
(EUROPE)  
ATTN DRXSN-UK-RA 1  
BOX 65  
PO NEW YORK 09510

HQ, US ARMY AVIATION R&D CMD  
ATTN DRDAV-GT (MR R LEWIS) 1  
DRDAV-D (MR CRAWFORD) 1  
DRDAV-N (MR BORGMAN) 1  
DRDAV-E 1  
4300 GOODFELLOW BLVD  
ST LOUIS MO 63120

CDR  
US ARMY FORCES COMMAND  
ATTN AFLG-REG 1  
AFLG-POP 1  
FORT MCPHERSON GA 30330

CDR  
US ARMY ABERDEEN PROVING GROUND  
ATTN: STEAP-MT 1  
STEAP-MT-U (MR DEAVER) 1  
ABERDEEN PROVING GROUND MD 21005

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

PROJ MGR, ABRAMS TANK SYS  
ATTN DRCPM-GCM-S 1  
ATTN DRCPM-GCM-LF (MAJ SIKES) 1  
WARREN MI 48090

PROJ MGR, FIGHTING VEHICLE SYS  
ATTN DRCPM-FVS-SE 1  
WARREN MI 48090

PROJ MGR, M60 TANK DEVELOPMENT  
USMC-LNO, MAJ. VARELLA 1  
US ARMY TANK-AUTOMOTIVE CMD (TACOM)  
WARREN MI 48090

PROJ MGR, M113/M113A1 FAMILY  
VEHICLES  
ATTN DRCPM-M113 1  
WARREN MI 48090

PROJ MGR, MOBILE ELECTRIC POWER  
ATTN DRCPM-MEP-TM 1  
7500 BACKLICK ROAD  
SPRINGFIELD VA 22150

PROJ MGR, IMPROVED TOW  
VEHICLE  
US ARMY TANK-AUTOMOTIVE CMD  
ATTN DRCPM-ITV-T 1  
WARREN MI 48090

CDR  
US ARMY EUROPE & SEVENTH ARMY  
ATTN AEAGC-FMD 1  
ATTN: AEAGC-TE 1  
APO NY 09403

PROJ MGR, PATRIOT PROJ OFC  
ATTN DRCPM-MD-T-G 1  
US ARMY DARCOM  
REDSTONE ARSENAL AL 35809

CDR  
THEATER ARMY MATERIAL MGMT  
CENTER (200TH)  
DIRECTORATE FOR PETROL MGMT  
ATTN AEAGD-MM-PT-Q 1  
ZWEIBRUCKEN  
APO NY 09052

CDR  
US ARMY RESEARCH OFC  
ATTN DRXRO-ZC 1  
DRXRO-EG (DR SINGLETON) 1  
DRXRO-CB (DR GHIRARDELLI) 1  
P O BOX 12211  
RSCH TRIANGLE PARK NC 27709

DIR  
US ARMY AVIATION R&T LAB (AVRADCOM)  
ATTN DAVDL-AS (MR D WILSTEAD) 1  
NASA/AMES RSCH CTR  
MAIL STP 207-5  
MOFFIT FIELD CA 94035

CDR  
TOBYHANNA ARMY DEPOT  
ATTN SDSTO-TP-S 1  
TOBYHANNA PA 18466

DIR  
US ARMY MATERIALS & MECHANICS  
RSCH CTR  
ATTN DRXMR-E 1  
DRXMR-R 1  
DRXMR-T 1  
WATERTOWN MA 02172

CDR  
US ARMY DEPOT SYSTEMS CMD  
ATTN DRSDS 1  
CHAMBERSBURG PA 17201

CDR  
US ARMY WATERVLIET ARSENAL  
ATTN SARWY-RDD 1  
WATERVLIET NY 12189

CDR  
US ARMY LEA  
ATTN DALO-LEP 1  
NEW CUMBERLAND ARMY DEPOT  
NEW CUMBERLAND PA 17070

CDR  
US ARMY GENERAL MATERIAL &  
PETROLEUM ACTIVITY  
ATTN STSGP-PW (MR PRICE) 1  
BLDG 247, DEFENSE DEPOT TRACY  
TRACY CA 95376

CDR  
US ARMY FOREIGN SCIENCE & TECH  
CENTER  
ATTN DRXST-MT1 1  
FEDERAL BLDG  
CHARLOTTESVILLE VA 22901

CDR  
DARCOM MATERIEL READINESS  
SUPPORT ACTIVITY (MRSA)  
ATTN DRXMD-MD 1  
LEXINGTON KY 40511

HQ, US ARMY T&E COMMAND  
ATTN DRSTE-TO-O 1  
ABERDEEN PROVING GROUND, MD 21005

HQ, US ARMY ARMAMENT R&D CMD  
ATTN DRDAR-LC 1  
DRDAR-SC 1  
DRDAR-AC 1  
DRDAR-QA 1  
DOVER NJ 07801

HQ, US ARMY TROOP SUPPORT &  
AVIATION MATERIAL READINESS  
COMMAND  
ATTN DRSTS-MEG (2) 1  
DRCPO-PDE (LTC FOSTER) 1  
4300 GOODFELLOW BLVD  
ST LOUIS MO 63120

DEPARTMENT OF THE ARMY  
CONSTRUCTION ENG RSCH LAB  
ATTN CERL-EM 1  
CERL-ZT 1  
CERL-EH 1  
P O BOX 4005  
CHAMPAIGN IL 61820

DIR  
US ARMY ARMAMENT R&D CMD  
BALLISTIC RESEARCH LAB  
ATTN DRDAR-BLV 1  
DRDAR-BLP 1  
ABERDEEN PROVING GROUND, MD 21005

HQ  
US ARMY TRAINING & DOCTRINE CMD  
ATTN ATCD-S (LTC LESKO) 1  
FORT MONROE VA 23651

DIRECTOR  
US ARMY RSCH & TECH LAB (AVRADCOM)  
PROPULSION LABORATORY  
ATTN DAVDL-PL-D (MR ACURIO) 1  
21000 BROOKPARK ROAD  
CLEVELAND OH 44135

CDR  
US ARMY NATICK RES & DEV LAB  
ATTN DRDNA-YE (DR KAPLAN) 1  
NATICK MA 01760

CDR  
US ARMY TRANSPORTATION SCHOOL  
ATTN ATSP-CD-MS 1  
FORT EUSTIS VA 23604

CDR  
 US ARMY QUARTERMASTER SCHOOL  
 ATTN ATSM-CD (COL VOLPE) 1  
     ATSM-CDM 1  
     ATSM-TNG-PT 1  
 FORT LEE VA 23801  
  
 HQ, US ARMY ARMOR CENTER  
 ATTN ATZK-CD-SB 1  
 FORT KNOX KY 40121  
  
 CDR  
 101ST AIRBORNE DIV (AASLT)  
 ATTN: AFZB-KE-J 1  
     AFZB-KE-DMMC (CPT MORRIS) 1  
 FORT CAMPBELL, KY 42223  
  
 CDR  
 US ARMY LOGISTICS CTR  
 ATTN ATCL-MS (MR A MARSHALL) 1  
 FORT LEE VA 23801  
  
 CDR  
 US ARMY FIELD ARTILLERY SCHOOL  
 ATTN ATSF-CD 1  
 FORT SILL OK 73503  
  
 CDR  
 US ARMY ORDNANCE CTR & SCHOOL  
 ATTN ATSL-CTD-MS 1  
 ABERDEEN PROVING GROUND MD 21005  
  
 CDR  
 US ARMY ENGINEER SCHOOL  
 ATTN ATSE-CDM 1  
 FORT BELVOIR VA 22060  
  
 CDR  
 US ARMY INFANTRY SCHOOL  
 ATTN ATSH-CD-MS-M 1  
 FORT BENNING GA 31905  
  
 CDR  
 US ARMY AVIATION BOARD  
 ATTN ATZQ-OT-C 1  
     ATZQ-OT-A 1  
 FORT RUCKER AL 36362  
  
 CDR  
 US ARMY MISSILE CMD  
 ATTN DRSMI-O 1  
     DRSMI-RK 1  
     DRSMI-D 1  
 REDSTONE ARSENAL, AL 35809

CRD  
 US ARMY AVIATION CTR & FT RUCKER  
 ATTN ATZQ-D 1  
 FORT RUCKER AL 36362  
  
 PROJ MGR M60 TANK DEVELOP.  
 ATTN DRCPM-M60-E 1  
 WARREN MI 48090  
  
 CDR  
 US ARMY INFANTRY BOARD  
 ATTN ATZB-IB-PR-T 1  
 FORT BENNING, GA 31905  
  
 CDR  
 US ARMY FIELD ARTILLERY BOARD  
 ATTN ATZR-BDPR 1  
 FORT SILL OK 73503  
  
 CDR  
 US ARMY ARMOR & ENGINEER BOARD  
 ATTN ATZK-AE-PD 1  
     ATZK-AE-CV 1  
 FORT KNOX, KY 40121  
  
 CDR  
 US ARMY CHEMICAL SCHOOL  
 ATTN ATZN-CM-CS 1  
 FORT MCCLELLAN, AL 36205  
  
 CHIEF, U.S. ARMY LOGISTICS  
 ASSISTANCE OFFICE, FORSCOM  
 ATTN DRXLA-FO (MR PITTMAN) 1  
 FT MCPHERSON, GA 30330

DEPARTMENT OF THE NAVY

CDR  
 NAVAL AIR PROPULSION CENTER  
 ATTN PE-71 (MR WAGNER) 1  
     PE-72 (MR D'ORAZIO) 1  
 P O BOX 7176  
 TRENTON NJ 06828  
  
 CDR  
 NAVAL SEA SYSTEMS CMD  
 CODE 05D4 (MR K LAYNE) 1  
 WASHINGTON DC 20362  
  
 CDR  
 DAVID TAYLOR NAVAL SHIP R&D CTR  
 CODE 2830 (MR G BOSMAJIAN) 1  
 CODE 2831 1  
 CODE 2832  
 ANNAPOLIS MD 21402

JOINT OIL ANALYSIS PROGRAM - TECHNICAL SUPPORT CTR BLDG 780 NAVAL AIR STATION PENSACOLA FL 32508	1	CDR, NAVAL MATERIEL COMMAND ATTN MAT-08E (DR A ROBERTS) MAT-08E (MR ZIEM) CP6, RM 606 WASHINGTON DC 20360	1 1
DEPARTMENT OF THE NAVY HQ, US MARINE CORPS ATTN LPP (MAJ SANDBERG) LMM/3 (MAJ STROCK) WASHINGTON DC 20380	1 1	CDR NAVY PETROLEUM OFC ATTN CODE 40 CAMERON STATION ALEXANDRIA VA 22314	1
CDR NAVAL AIR SYSTEMS CMD ATTN CODE 5304C1 (MR WEINBURG) CODE 53645 (MR MEARNES) WASHINGTON DC 20361	1 1	CDR MARINE CORPS LOGISTICS SUPPORT BASE ATLANTIC ATTN CODE P841 ALBANY GA 31704	1
CDR NAVAL AIR DEVELOPMENT CTR ATTN CODE 60612 (MR L STALLINGS) WARMINSTER PA 18974	1	DEPARTMENT OF THE AIR FORCE HQ, USAF ATTN LEYSF (MAJ LENZ) WASHINGTON DC 20330	1
CDR NAVAL RESEARCH LABORATORY ATTN CODE 6170 (MR H RAVNER) CODE 6180 CODE 6110 (DR HARVEY) WASHINGTON DC 20375	1 1 1	HQ AIR FORCE SYSTEMS CMD ATTN AFSC/DLF (LTC RADLOFF) ANDREWS AFB MD 20334	1
CDR NAVAL FACILITIES ENGR CTR ATTN CODE 120 (MR R BURRIS) CODE 120B (MR BUSCHELMAN) 200 STOWWALL ST ALEXANDRIA VA 22322	1 1	CDR US AIR FORCE WRIGHT AERONAUTICAL LAB ATTN AFWAL/POSF (MR CHURCHILL) AFWAL/POSL (MR JONES) AFWAL/MLSE (MR MORRIS) AFWAL-MLBT WRIGHT-PATTERSON AFB OH 45433	1 1 1 1
CHIEF OF NAVAL RESEARCH ATTN CODE 473 ARLINGTON VA 22217	1	CDR SAN ANTONIO AIR LOGISTICS CTR ATTN SAALC/SFQ (MR MAKRIS) SAALC/MMPRR KELLY AIR FORCE BASE, TX 78241	1 1
CDR NAVAL AIR ENGR CENTER ATTN CODE 92727 LAKEHURST NJ 08733	1	CDR WARNER ROBINS AIR LOGISTIC CTR ATTN WR-ALC/MMIRAB-1 (MR GRAHAM) ROBINS AFB GA 31098	1
COMMANDING GENERAL US MARINE CORPS DEVELOPMENT & EDUCATION COMMAND ATTN: DO75 (LTC KERR) QUANTICO, VA 22134	1		

OTHER GOVERNMENT AGENCIES

US DEPARTMENT OF TRANSPORTATION  
ATTN AIRCRAFT DESIGN CRITERIA  
BRANCH 2  
FEDERAL AVIATION ADMIN  
2100 2ND ST SW  
WASHINGTON DC 20590

DIRECTOR  
NATL MAINTENANCE TECH SUPPORT  
CTR 2  
US POSTAL SERVICE  
NORMAN OK 73069

NATIONAL AERONAUTICS AND  
SPACE ADMINISTRATION  
LEWIS RESEARCH CENTER  
MAIL STOP 5420  
(ATTN: MR. GROBMAN) 1  
CLEVELAND, OH 44135

NATIONAL AERONAUTICS AND  
SPACE ADMINISTRATION  
VEHICLE SYSTEMS AND ALTERNATE  
FUELS PROJECT OFFICE  
ATTN: MR. CLARK 1  
LEWIS RESEARCH CENTER  
CLEVELAND, OH 44135

US DEPARTMENT OF ENERGY  
SYSTEMS EEF, ATTN: MR. ALPAUGH 1  
FORRESTAL BLDG.  
1000 INDEPENDENCE AVE., SW  
WASHINGTON, DC 20585

DEPARTMENT OF TRANSPORTATION  
FEDERAL AVIATION ADMINISTRATION  
AWS-110, ATTN: MR. NUGENT 1  
800 INDEPENDENCE AVE, SW  
WASHINGTON, DC 20590

US DEPARTMENT OF ENERGY  
CE-131.2, GB-096  
ATTN: MR ECKLUND 1  
FORRESTAL BLDG.  
1000 INDEPENDENCE AVE, SW  
WASHINGTON, DC 20585

US DEPARTMENT OF ENERGY  
BARTLESVILLE ENERGY RSCH CTR  
DIV OF PROCESSING & THERMO RES 1  
DIV OF UTILIZATION RES 1  
BOX 1398  
BARTLESVILLE OK 74003

SCI & TECH INFO FACILITY  
ATTN NASA REP (SAK/DL) 1  
P O BOX 8757  
BALTIMORE/WASH INT AIRPORT MD 21240

ENVIRONMENTAL PROTECTION AGCY  
OFFICE OF MOBILE SOURCES  
MAIL CODE ANR-455  
(MR. G. KITTREDGE) 1  
401 M ST., SW  
WASHINGTON DC 20460

**END**

**FILMED**

**5-83**

**DTIC**