ENGINE-FUEL LUBRICANT COMPATIBILITY TESTS ON MIL-L-2104C OILS USING ENGINE MODEL 6V53T AND HIGH SULFUR FUEL

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Southwest Research Instutite

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by
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Earlier work in this program showed that two MIL-L-2104C lubricants were compatible with the two-cycle diesel engine model 6V53T when subjected to a targeted 210-hour laboratory-dynamometer endurance test cycle, operating with a reference No. 2 diesel fuel having a natural sulfur level of 0.42% wt. In that work, the low-ash (0.93% wt.) lubricant REO 203 demonstrated high-level engine compatibility, and the high-ash (1.75% wt.) lubricant REO 205 was judged borderline compatible with the 6V53T engine. In the current work, the use of high natural sulfur fuel (1.2% wt.) caused increased ringsticking and combustion chamber and ring zone deposits with REO 205 lubricant, and increased cylinder liner wear and intake port plugging

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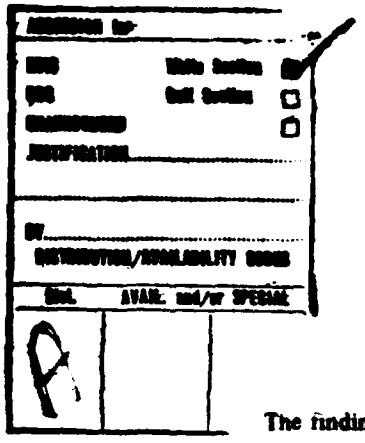
with REO 203 lubricant. Based upon this performance, the 1.2% natural sulfur fuel was judged incompatible with the two-cycle diesel engine, model 6V53T. A recommendation for additional engine testing is made.



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FOREWORD

The work reported herein was conducted at the U.S. Army Fuels and Lubricants Research Laboratory (USAFLRL), located at Southwest Research Institute, San Antonio, Texas, under Contract DAAK02-73-C-0221 during the period June 1973 through September 1973. The contract monitor was Mr. C. F. Schwarz, USA MERDC, Coating and Chemical Laboratory STSFB-GL, Aberdeen Proving Ground, Maryland. Project technical monitors were Messrs. M.E. LePera and T.C. Bowen, also of that office. Current contract monitor is Mr. F.W. Schaekel, USAMERDC, STSFB-GL, Ft. Belvoir, Virginia.

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I. INTRODUCTION

The Department of Defense (DoD) must procure many different types of petroleum fuels to meet the requirements of its military ground, air, and marine equipment. Operation outside the continental United States increases the complexity of fuel logistics because of the wide geographical scatter of the U.S. military installations. Therefore, standardization of fuel requirements between the services and between allied countries has been a continuing subject of discussion and study. The problem of U.S. Army fuel standardization within the NATO complex has been primarily in the area of diesel fuel requirements; namely, the U.S. Army providing diesel fuels meeting VV-F-800a, DF1/DF2, whereas the other NATO countries have interchangeability agreements for using NATO F-54 which is similar to MIL-F-16884F.[1]* Both F-54 and MIL-F-16884F have specification limits that permit higher sulfur and higher distillation values (90%-EP); characteristics that may cause increased wear/deposition in two-cycle diesel engines within the military inventory. Prior to AMC permitting the use of a high-sulfur fuel in lieu of VV-F-800a, additional engine data were desired upon which a sound judgment could be made. To this end, it was decided to undertake the engine tests reported herein.

II. DETAILS OF THE TEST

A. Test Engine

The engine used in this program was the 6V53T, whose characteristics are shown in Table 1. End use for this engine is the M551-Sheridan, Armored Reconnaissance/Airborne Assault Vehicle, Full Tracked, 152mm; a picture of which is shown in Figure 1. The 6V53T engine was selected because it is typical of one family of two-cycle diesel engines found in today's Army, i.e., the 6V53, 3-53, 8V71T, and 12V71T engines that are used throughout the combat vehicle fleet. Specifically, this particular engine model was selected for two reasons: (1) considerable lubricant-engine compatibility data had been accumulated in this engine using MIL-L-2104C oils[2], and (2) this is a highly stressed engine which is sensitive to variations in fuel and lubricant quality and composition.[3]

The laboratory test stand (Figure 2) consisted of a 400 hp Midwest absorption dynamometer, Eaton's Dynamatic control chassis, and a Hagen pneumatic load transmitting/indicating load system. Combustion air is drawn into the engine through a stack of four dry-type automotive air filters inside a fiberglass-lined 30-gallon barrel. Arctic anti-freeze (MIL-A-11755) used for jacket coolant is circulated by the engine centrifugal-type water pump, with the thermostat mechanically blocked open to provide normal operation flow restriction. The throttle (governor-rack control) is operated by an air-powered diaphragm. Blow-by is vented through the rocker cover breather cap to a blow-by meter and then drawn into the air barrel inlet with the combustion air, resulting in 100% blow-by recycle.

B. Test Fuel

The hydrocarbon fuel was blended to generally conform to the specification limits of Military Specification MIL-F-16884F, diesel fuel, marine (DFM). The upper limit of sulfur (1%) and distillation end point (EP 725°F) were selected to assure that the fuel represented the most severe blend that might be found in the logistics system. Table 2 presents a comparison of the specification and procured fuel characteristics for the high-sulfur fuel (DFM) and the reference No. 2 diesel fuel, which is a nominal VV-F-800a[4] No. 2 diesel fuel conforming to the requirements established by Federal Test Method Standard 791B, Method 341.4;[5] and is a straight-run, mid-range natural sulfur fuel which is manufactured under closely controlled refinery operation to minimize compositional deviations. A single batch of this latter fuel was used to generate the engine-lubricant compatibility baseline data that are used for comparison in this program. As noted from Table 2, the sulfur level of the procured diesel marine (DFM) type fuel was higher than the specification limit by 0.2% weight, along with the distillation end point that was above

*Superscript numbers in parentheses indicate references at end of report.

TABLE 1. 6V53T ENGINE CHARACTFRISTICS

Engine type	Turbocharged, two-cycle compression ignition, direct injection uniflow scavenging
Weight, lb (Dry)	1092
Number of cylinders, arrangement	6, V
Displacement, cu. in.	318
Bore and stroke, in.	3-7/8 x 4-1/2
Cylinder block material	Aluminum, with cast iron liners
Rated brake horsepower	300 at 2800 rpm, at 60°F and 29.92 in. Hg
Maximum torque, lb-ft	615 at 2200 rpm
Compression ratio	17 to 1
Fuel system	Unit injectors (N 70, needle valve), primary and secondary engine filters
Governor	Limiting speed, double weight
Oil sump capacity, gal	5
Oil filter	Full-flow single filter
Oil cooling	Integral heat exchanger using 100% jacket-coolant flow
Piston description	
Material design	Cast iron, trunk type
Ring configuration	1–Fire ring (rectangular) 3–Compression rings (rectangular) 2–Oil rings
Oil spray cooled	Yes, from top of connecting rod

FIGURE 1. M551 ARMORED RECONNAISSANCE/ AIRBORNE ASSAULT VEHICLE–"SHERIDAN"

TABLE 2. ANALYSIS OF TEST FUELS

Property	Ref No. 2 DF		MIL-F-16884F (DFM)	
	Test fuel	Specification[a]	Test fuel	Specification[a]
API gravity	33.2	Record	34.1	Record
Viscosity at 100°F, Cs	3.20	1.6–4.5	3.66	52.1–6.0
Flash point, °F	185	100 min	190	140 min
Cloud point, °F	+23	Record	+30	+ 10 max
Pour point, °F	+18	20 max	+10	0 max
Water and sediment	0.0	0.05 max	0	0.01 max
Carbon residue, %	0.10	0.20 max	0.14	0.20 max
Lamp sulfur, %	0.415	0.35 min	1.20	1.00 max
Acid no.	0.108	Record	0.18	0.50 max
Aniline no., °F	145	Record	150	Record
Copper corrosion	1A	No. 2 max	ND	1 max
Distillation, °F				
IBP	410	Record	399	NR
10%	468	Record	447	NR
50%	519	500 min	533	Record
90%	603	600–640	679	675 max
EP	689	650–690	744	725 max
Cetane number	47[b]	40–45	50.5	47 min
Higher heating value, Btu/lb	19,550[c]	Record	18,960	NR
Accelerated stability, total insolubles, mg/100 mℓ	2.1	NR	1.50	2.5 max
Ash, %	0.006	0.01 max	ND	NR

ND = Not determined.
NR = Not required.

[a]Section 4.1, Method 341.7, FTM Std. 791B.
[b]Calculated Cetane Index.
[c]Calculated higher value from gravity, viscosity, and distillation properties.

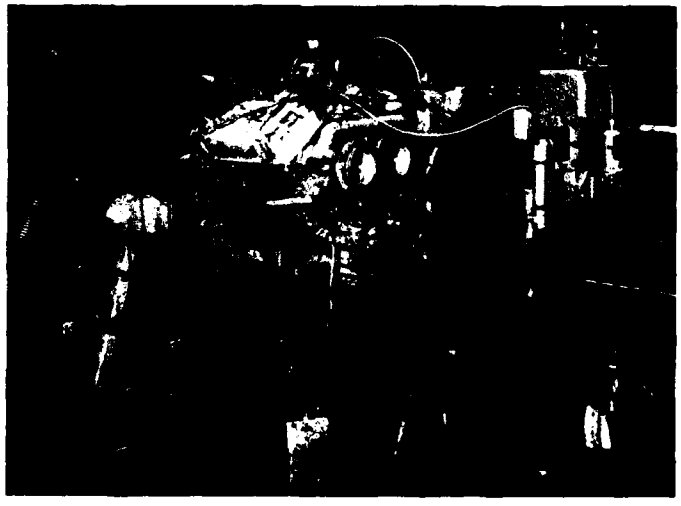

FIGURE 2. DIESEL ENGINE MODEL 6V53T TEST FACILITY

the desired limit by 19°F. Since this fuel procurement was not obtained from a normal refinery run, these deviations from the specification were permitted. The fuel was analyzed when received, between the first and second test and after the final engine run, to define changes in the fuel characteristics which might contribute or detract from the final engine deposit/wear results. These data are reported in the Program Detail Section.

C. Test Lubricants

The two lubricants used in this program were furnished by the U.S. Army Coating and Chemical Laboratory (C&CL), designated REO 205 and REO 203.* Both lubricants meet the requirements established in U.S. Military Specification MIL-L-2104C.[6] Comparison of property data of the oils with MIL-L-2104C requirements is presented in Table 3. These lubricants were selected for this program for three specific reasons: (1) both had been previously evaluated in the 6V53T diesel engine using the reference

TABLE 3. COMPARISON OF TEST LUBRICANT PROPERTY DATA WITH MIL-L-2104C REQUIREMENTS

Property	REO 205	REO 203	MIL-L-2104C
Gravity, °API	27.3	27.4	Report
Flash point, °F	460	465	425 min
Viscosity, CST			
at 210°F	12.93	12.61	9.6–12.9
at 100°F	126.7	121.6	Report
Viscosity index	101	94	75 min
Pour point, °F	−5	−5	0 (max)
Carbon residue, %	1.60	1.19	Report
Sulfated ash, %	1.75	0.93	Report
Total acid no.	3.0	3.6	Report
Total base no.	12.5	5.4	Report
Additive, % wt			
Zn	0.093	0.093	Report
Ca	0.44	0.24	Report
Ba	Nil	Nil	Report

No. 2 diesel fuel, (2) they represent high- and low-ash additive package formulations similar to oils which may be procured by the military under MIL-L-2104C, and (3) the manufacturer of the 6V53T engine recommends use of a low-ash oil (1.00% wt maximum) with fuel having a sulfur content of up to 0.500% weight, and a high-ash oil (up to 1.50% wt) when using a high-sulfur fuel. REO 203 was formulated as a "Universal Oil" to meet the American Petroleum Institute (API) service classification CD/SE[7], while REO 205 was formulated primarily to meet API classification, CD.

D. Test Technique

A laboratory test technique, previously developed by the Army in cooperation with the Coordinating Research Council (CRC)[8], was selected for the DFM program. This technique involves cyclic endurance testing of the vehicle engine on a laboratory dynamometer stand for 210 hr, which is designed to correlate with 20,000 miles field service for a tactical, wheeled vehicle. Compatibility of the engine-fuel-lubricant system is judged on: (1) the ability of the test engine to maintain performance throughout the cycle; (2) wear developed in engine components; (3) accumulation of fuel and lubricant related engine deposits; and (4) the physical and chemical condition of the lubricant as monitored throughout the test.

Even though the M551 is a full-track-laying vehicle, it was decided that the wheeled-vehicle test cycle for the 6V53T engine would be used because of the prior experience[2,9,10] using this test cycle with the Military two-cycle diesel engine. Additionally, the data obtained using this cycle operating on reference No. 2 diesel fuel[2] provided a baseline for the DFM program. The details of the wheeled-vehicle

*These lubricants were originally identified as CCL-L-758 and L-759 respectively.

compatibility test cycle, as applied to the 6V53T engine, are given in Appendix I. The procedure as shown reflects the comments and suggestions provided by the CRC Army Combat Engines Fuels and Lubricants Group. The substance of the CRC guidance is based on a group meeting held 24 August 1972 and is presented in Appendix II. The current procedure is essentially the same as the one used in References 2, 9, and 10, except that glycol coolant (arctic antifreeze, MIL-A-11755) was used in the current series of tests. A summary of the current test procedure is as follows:

- Clean, measure, and rebuild test engine using new cylinder liners, pistons, piston rings, connecting rod, and main bearing inserts, in accordance with standardized buildup procedures specified by appropriate Army Technical Manuals[11,12] or engine manufacturer bulletins.[13]
- Run-in the engine and perform full-load performance calibration using reference No. 2 DF.
- Flush fuel system and conduct full-load performance calibration using test fuel (DFM).
- Conduct compatibility endurance test; operating conditions are summarized in Table 4.
- Perform post-test full-load performance calibration.
- Disassemble, inspect, and rate in accordance with CRC Diesel Manual No. 5,[14] and remeasure engine.

Detailed baseline test data using reference No. 2 diesel fuel (Test Nos. two and three) were appended to the report of reference 2 and are not included in this report. Detailed test data for Test

TABLE 4. 6V53T ENGINE OPERATING CONDITIONS

Parameter	Limits; or settings, for	
	Power mode	Idle mode
Speed, rpm	2800 ± 20	650 ± 10
Fuel flow		
Typical, lb/min, (2 lb wt/time)	2.07 ± 0.07	(use 2 oz)
Fuel/cycle, mm^3	67 – 69	–
Revolutions/2 lb	2680 ± 50	–
Time/2 lb	0.965 ± 0.035	–
Obs BHp output	282 – 300	–
Jacket-out, F	180 ± 2	100 ± 2
Coolant Δ T, F	8 – 12	2 – 3
Oil sump, F	250, max	
Fuel temp & filter, F	90 ± 5	–
Fuel pressure, range, psi	55 – 70	70 max
Compressor suction, clean filter, inches water	6.0 max	–
Compressor suction, dirty filter, inches water	12.0 max	–
Exhaust back pressure (after turbo), inches Hg	2.3	
Crankcase pressure, inches water	6.0 max	
Oil pressure, psi	32 min	5 min
Blowby flow, CFH	1150 max	
Test duration	210 hr	
Oil drains	None	
Oil level checks and additions	Every 14 hr	
Oil samples	Every 14 hr	
Airbox inspection	None	

Nos. 6 and 7, using high-sulfur fuel (DFM), are found in Appendices III and IV. Each appendix includes the following information:

(1) Summary of Buildup Measurements

(2) Summary of Operating Data

a. Power performance before test

b. Tabulated data for power mode, idle mode, and record of unscheduled shutdowns

c. Plotted operating data

(3) Used-Lubricant Analyses

(4) Wear Measurements

(5) Deposit Ratings and Parts Description (in accordance with CRC Rating Manual No. 5)

(6) Photographs of the "average" and "worst" cylinder assemblies from a deposit standpoint (designated by the CRC Army Combat Engines, Fuels, and Lubricants Performance Group)

Only summary and comparative data necessary to establish engine and lubricant performance are presented in the discussion section of the report (Tables 6 through 16 and Figure 3). For detailed test data, the reader is referred to Appendices III and IV.

The CRC Combat Engines, Fuels, and Lubricants Group inspected the pistons, piston rings, cylinder liners, and connecting rod and main bearing inserts at the U.S. Army Fuels and Lubricants Research Laboratory on 14-15 February 1974. Appendix V contains a summary of the inspection results relevant to the fuel sulfur level and its compatibility with the 6V53T engine.

III. DISCUSSION

Four 6V53T engine-fuel-lubricant compatibility tests, using the 210-hr wheeled-vehicle test cycle, form the basis of the current program. A summary of the four tests is shown in Table 5. Note in Table 5

TABLE 5. 6V53T COMPATIBILITY TEST SUMMARY

Test no.	Date completed	Engine no.	Oil codes	Test hours	Reason for stopping test
Reference no. 2 diesel fuel (0.42%-S)					
2	20 Dec 72	6D36804-14	REO 203	210	Completed test
3	16 Jan 73	6D5084-4	REO 205	209.5	OK - (exhaust valve seat breakage in cylinder 2R)
DFM (1.2%-S)					
6	18 Jun 73	6D5084-6	REO 205	194	Power loss; burned exh. valve-2L
7	6 Aug 73	6D5204-1	REO 203	196	Rising crankcase pressure & blow-by flow

that Test Nos. 2 and 3 provide the baseline data for comparison with the current high-sulfur fuel (DFM) test results (Tests 6 and 7).

A. Performance of DFM (High-Sulfur Fuel) and REO 205 Lubricant (High-Ash)—Test No. 6

Engine operation was held within the desired performance envelope through 13 engine cycles, 182 hours (Table 6). During the fourteenth cycle, increasing exhaust temperature and power loss required test termination at 194 hours without obtaining a final power curve. The engine was disassembled and upon inspection of the valve train, a burned exhaust valve in cylinder No. 2 on the left bank was found. No damage to the cylinder, piston, or turbo-charger was noted, and all other cylinders appeared normal. Figure 3 shows the valve compared with a sister valve and valves from adjacent cylinders. Deposit and wear measurements were then completed on all engine parts required by the test plan.

Piston ring freedom (Table 7) was less than when using reference No. 2 diesel fuel. This lack of freedom was reflected in both piston ring groove deposits (Table 8) and piston ring groove supporting carbon (Table 9). However, when tests Nos. 3 and 6 are compared (Table 10), using the proposed CRC

TABLE 6. SUMMARY OF OPERATING DATA

Parameters	Power mode							
	REO 205				REO 203			
	DFM		Ref No. 2 DF		DFM		Ref No. 2 DF	
	Test no. 6		Test no. 3		Test no. 7		Test no. 2	
	Max	Avg	Max	Avg	Max	Avg	Max	Avg
Engine speed, rpm, 2800 ± 20	2800	2800	2800	2800	2800	2800	2800	2800
Load, lb	428	421	440	432	428	421	435	431
BHP, obs. (2800/4100) × load	292	288	300	297	292	287	297	294
Fuel/cycle, mm^3	68.1	67.3	67.7	67.1	68.4	67.6	68.2	67.1
Fuel rate, lb/min	2.08	2.06	2.09	2.07	2.09	2.06	2.10	2.07
Oil consumption, lb/hr avg for test duration	–	0.52	–	0.49	–	0.52	–	0.66
	194 hr		209.5 hr		196 hr		210 hr	
Temperatures, °F								
Jacket-in	171	170	174	172	174	170	176	172
Jacket-out, 180+5	182	181	184	181	186	181	184	181
Oil sump	238	237	236	234	240	236	246	238
Inlet air (compressor)	101	95	94	79	114	99	96	83
Airbox	287	282	281	270	300	290	304	291
Exhaust before turbo	1060	1050	1060	1035	1100	1070	1090	1060
Exhaust after turbo	900	880	900	860	930	900	920	885
Fuel at filter (secondary)	91	89	82	78	100	90	83	80
Pressures								
Compressor suction, in. H_2O	10.8	6.9	11.2	7.1	12.9	8.0	11.2	7.2
Compressor discharge, in. Hg	24.7	23.8	24.2	23.4	24.3	23.0	24.0	23.2
Blower discharge (airbox), in. Hg	36.7	35.7	38.7	37.0	37.7	35.8	38.5	37.0
Crankcase, dipstick tube, in. H_2O	4.7	4.2	5.0	4.5	6.0	5.4	4.2	3.5
Exhaust before turbo, in. Hg	26.3	25.7	26.7	25.9	26.9	25.0	26.7	25.9
Exhaust after turbo, in. Hg	2.2	2.1	2.2	2.2	2.9	1.9	2.2	2.1
Oil gallery, psi	43	41.7	42.7	41.8	41.5	40.8	36.2	35.4
Fuel at filter, psi	72	69.8	74.5	73.6	71.0	69.6	72	72
Blow-by flow, cfh at 29.92 in. Hg and 115°F	900	850	1100	1020	1030	910	900	790
Record of unscheduled shutdowns	None		None		None		a	

a Repair oil leak at filter housing & flush main heat exchanger—24 hours total

TABLE 7. PISTON RING FREEDOM

Ring No.	DFM			Ref No. 2 DF		
	Free	Cold stuck & pinched	Hot stuck	Free	Cold stuck & pinched	Hot stuck
REO 205						
1	3	1	2	5	0	1[a]
2	5	0	1	6	0	0
3	5	1	0	6	0	0
4	6	0	0	6	0	0
Total	19	2	3	23	0	1[a]
REO 203						
1	6	0	0	6	0	0
2	6	0	0	6	0	0
3	6	0	0	6	0	0
4	6	0	0	6	0	0
Total	24	0	0	24	0	0

[a]Valve Failure

TABLE 8. PISTON RING GROOVE DEPOSITS BACK OF GROOVE: PERCENT CARBON FILLING

Ring No.	DFM			Ref No. 2 DF		
	Max	Avg	Avg (w/o Max)	Max	Avg	Avg (w/o max)
REO 205						
1	100[a](3)[b]	5.8	15	100[a]	21	6
2	100[a](1)	77	72	90	72	68
3	100[a](1)	27	12	40	19	15
4	10	2	1	3	1	<1
REO 203						
1	3	1	1	15	7	5
2	85	63	59	75	70	69
3	20	12	11	5	4	3
4	0	0	0	0	0	0

[a]Stuck = 100% volume fill.
[b]Numbers in parentheses indicate number stuck.

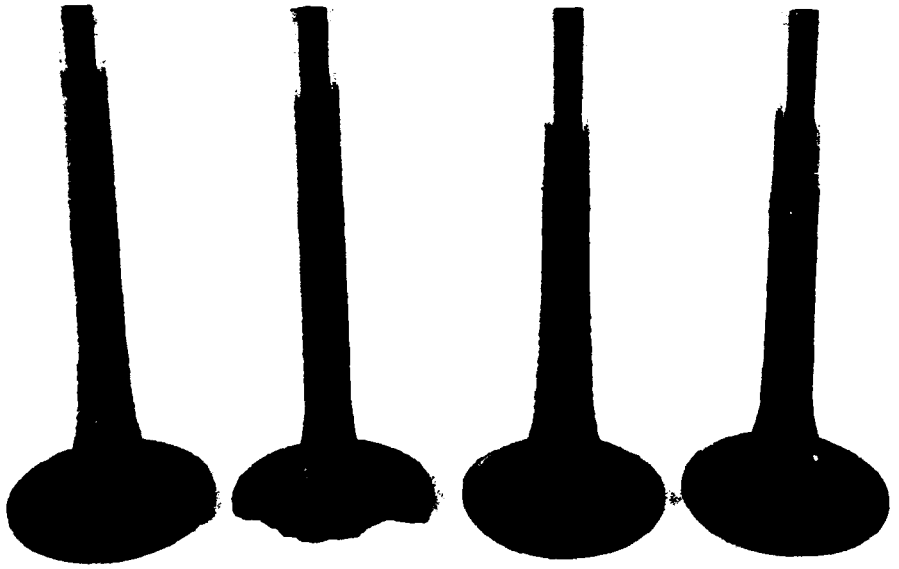

FIGURE 3. DAMAGED AND ADJACENT EXHAUST VALVES (Test No. 6)

"F"-rating method[15], the total 6-cylinder demerit deposit rating was slightly less (cleaner) when DFM fuel was used. This is because the "F"-rating method does not include cylinders with stuck rings in calculating the deposit ratings. Thus, test No. 6, with several stuck rings, gave a cleaner rating using this method. In all cases, ring No. 1 is the top ring, also referred to as the fire ring. Piston skirt deposits (Table 11) were essentially the same as those formed when using the reference fuel. Intake port deposits were found to be twice the level (3% vs 1.5%) of that observed in the test using reference fuel.

Wear was generally the opposite of the deposit trend; i.e., cylinder liner scuffing (Table 12), piston ring gap change (Table 13), and cylinder liner diameter change (Table 14) decreased when using the DFM instead of the reference No. 2 diesel fuel.

TABLE 9. PISTON GROOVE–INSIDE DIAMETER PERCENT RING SUPPORTING CARBON

Position	DFM			Ref No. 2 DF		
	Max	Avg	Avg (w/o max)	Max	Avg	Avg (w/o max)
REO 205						
Ring no. 1						
Thrust	100[a](3)[b]	50	0	100[a](1)	17	0
Rear	100[a](3)	57	13	100[a](1)	17	0
Antithrust	100[a](3)	57	13	100[a](1)	17	0
Front	100[a](3)	53	7	100[a](1)	17	0
Ring no. 2						
Thrust	100[a](1)	49	39	100	49	24
Rear	100[a](1)	68	51	90	42	32
Antithrust	100[a](1)	76	52	100	64	56
Front	100[a](1)	67	43	100	57	48
REO 203						
Ring no. 1						
Thrust	0	0	0	0	0	0
Rear	0	0	0	0	0	0
Antithrust	0	0	0	0	0	0
Front	0	0	0	0	0	0
Ring no. 2						
Thrust	90	63	50	80	36	27
Rear	85	52	45	60	18	9
Antithrust	100	58	49	100	49	39
Front	90	37	26	70	38	31

[a]Stuck = 100% volume fill.
[b]Number in parentheses indicate number stuck.

TABLE 10. PISTON "F" RATING[a] DEMERITS

"F" Demerit	REO 205		REO 203	
	DFM	Ref no. 2 DF	DFM	Ref no. 2 DF
	Test no./Test hr			
	6/194	3/209.5	7/196	2/210
Minimum cylinder	80[b]	160[c]	133	131
Maximum cylinder	280	210	189	168
Average cylinder	175	197	148	150
Total cylinder	1048	1183	890	899

[a]Proposed CRC F-Rating Method for Total Demerits (0 = Clean)–Location Factor not used; Piston Skirt Demerit not included.
[b]Fire rings not removed from cyls 1R, 1L, 3L, & 3L Top C/R, otherwise min was 187.
[c]Fire ring not removed from cyl 2R, otherwise min was 198.

TABLE 11. PISTON SKIRT DEPOSIT DEMERITS

Position	DFM			Ref no. 2 DF		
	Max	Avg	Avg (w/o max)	Max	Avg	Avg (w/o max)
REO 205						
Thrust	4.2	3.5	3.3	4.8	4.4	4.3
Antithrust	4.2	3.7	3.6	5.0	4.4	4.3
Avg T & AT		3.6	3.5		4.4	4.3
REO 203						
Thrust	4.1	4.0	3.9	4.5	4.2	4.1
Antithrust	4.1	3.9	3.8	3.8	3.6	3.6
Avg T & AT		4.0	3.9	-	3.9	3.9

TABLE 12. CYLINDER LINER SCUFFING PERCENT COMPRESSION RING-TRAVEL AREA SCUFFED

Area scuffed	DFM			Ref no. 2 DF		
	Max	Avg	Avg (w/o max)	Max	Avg	Avg (w/o max)
REO 205						
Thrust	35	13	9	40	15	10
Antithrust	25	13	10	40	12	7
Total area	25	13	10	40	14	8
Glazed deposits	60	44	41	55	31	29
Lacquered deposits	35	28	23	15	9	8
REO 203						
Thrust	30	13	10	15	5	3
Antithrust	30	14	11	5	2	2
Total area	25	14	11	8.5	4	3
Glazed deposits	70	54	51	25	19	13
Lacquer deposits	35	23	21	12	9	9

Fuel analyses following completion of the test (Table 15 dated 18 June 1973) provide no indication of major fuel degradation, even though the fuel injection system recycles approximately 50% of the fuel back to the storage tank. This causes the fuel to undergo a cyclic heating to approximately 160°F with cooling to 80°F.

Final oil analyses (Table 16) were comparable to the results obtained on the oil when using reference No. 2 diesel fuel. Origin of the tin (33 ppm) is not known and reexamination of the engine did not clarify this point.

Overall, the use of the DFM appeared to increase ring zone and combustion chamber deposits, an expected result due to the fuel's high distillation end-point. The piston ring surfaces had undergone severe attack, due most likely to the high-sulfur content of the fuel, and apparently the oil could not inhibit this action. However, cylinder liner wear, oil degradation, scuffing, etc., were well controlled by the high-ash oil additive package, especially when considering that the fuel was on the extreme side of the specification.

TABLE 13. PISTON RING GAP CHANGE

Ring No.	DFM			Ref no. 2 DI		
	Max	Avg	Avg (w/o max)	Max	Avg	Avg (w/o max)
REO 205						
1[a]	0.008	0.007	0.007	0.010	0.005	0.003
2[b]	0.004	0.003	0.003	0.007	0.005	0.005
3[b]	0.004	0.003	0.002	0.010	0.006	0.005
4	0.003	0.002	0.002	0.012	0.005	0.004
5–7	0.014	0.010	0.009	0.036	0.015	0.011
REO 203						
1	0.021	0.013	0.012	0.003	0.002	0.002
2	0.005	0.004	0.004	0.003	0.002	0.002
3	0.006	0.004	0.003	0.004	0.002	0.002
4	0.006	0.004	0.004	0.004	0.002	0.002
5–7	0.016	0.013	0.012	0.010	0.007	0.006

[a]3 struck rings not included.
[b]1 struck ring not included.

TABLE 14. CYLINDER LINER DIAMETER CHANGE

Location	DFM			Ref no. 2 DI		
	Max	Avg	Avg (w/o max)	Max	Avg	Avg (w/o max)
REO 205						
Perpendicular to Crank						
Top	0.0016	0.0012	0.0011	0.0053	0.0025	0.0020
Middle	0.0007	0.0004	0.0004	0.0011	0.0010	0.0010
Bottom	0.0003	0.0002	0.0001	0.0007	0.0004	0.0003
Parallel to Crank						
Top	0.0010	0.0005	0.0004	0.0010	0.0006	0.0005
Middle	0.0008	0.0002	0.0001	0.0011	0.0006	0.0005
Bottom	0.0003	0.0001	0.0001	0.0006	0.0003	0.0002
REO 203						
Perpendicular to Crank						
Top	0.0036	0.0026	0.0020	0.0011	0.0008	0.0007
Middle	0.0013	0.0011	0.0010	0.0009	0.0007	0.0007
Bottom	0.0009	0.0007	0.0007	0.0003	0.0002	0.0002
Parallel to Crank						
Top	0.0015	0.0007	0.0006	0.0007	0.0004	0.0004
Middle	0.0011	0.0006	0.0005	0.0004	0.0003	0.0002
Bottom	0.0005	0.0003	0.0003	0.0010	0.0003	0.0002

TABLE 15.

Property	DFM		
	5/24/73	6/18/73	8/6/73
API gravity, deg	34.1	33.6	33.7
Viscosity at 100°F, cs	3.66	3.78	3.78
Flash point, °F	190	–	180
Cloud point, °F	+30	–	+33
Pour point, °F	+10	–	+28
Water + sediment	Water=0 Sed=Trace	Water=0 Sed=Trace	– –
Carbon residue %	0.14	0.12	0.21
Sulfur %	1.21	1.205	1.21
Acid no.	0.18	0.21	0.19
Aniline point, °F	150	150	148.6
Distillation, °F			
IBP	399	402	382
10%	447	448	454
50%	533	532	538
90%	679	686	677
EP	744	736	753
Accelerated gum mg/100 mℓ	1.5	0.6	1.2
Gross heating value Btu/lb	18,960	–	–

B. Performance of DFM (High-Sulfur Fuel) and REO 203 Lubricant (Low-Ash)–Test No. 7

Engine operation remained within the desired performance envelope through 13 engine cycles (Table 6) as in Test No. 6; then, crankcase pressure began increasing. At the completion of the fourteenth cycle (196 hours), crankcase pressure and blow-by flow rate approached the maximum allowable limits. Experience[2,3] had shown that rising crankcase pressure and blow-by flow rate are generally indicative of pending severe piston scuffing and piston/liner seizure. Therefore, to assure engine integrity, the test was terminated, and no attempt was made to run the final power curve.

The engine was disassembled, and deposit/wear measurements were made. Generally ring freedom and deposition (Tables 7, 8, 9 and 11) showed little or no change from the rating levels recorded when using the reference fuel. The piston deposit ratings obtained using the "F" rating method (Table 10) confirmed the similar deposition severity of test No. 2 and No. 7. However, intake port deposits increased significantly from one percent restriction in the test using reference fuel to 9% restriction in the test using DFM.

In the cases of cylinder liner scuffing, piston ring gap change, and cylinder liner wear (Tables 12, 13 and 14), all areas showed major increases over the test using reference fuel, and in most cases the wear rates reached levels comparable to those using REO 205 lubricant and reference fuel. Of major significance, the fire-ring gap increased to a level over twice that experienced with REO 205 and the reference fuel (Table 13, ring No. 1). This wear was the reason for increased crankcase pressure.

Fuel analyses (Table 15, dated 6 August 1973) accomplished after the completion of Test No. 7 showed no significant changes from the as-received condition. Lubricant analyses compared favorably with the test results using reference fuel (Table 16).

Overall, the use of DFM with REO 203 showed increased wear, but no increased deposit formation except for intake port plugging. Again, as in Test No. 6, piston ring surface deterioration was extreme, and the oil formulation appeared to be unable to inhibit the deterioration. Based on close examination of the engine, the remaining 14-hour cycle of the test might have been completed without major engine component failure.

TABLE 16. LUBRICANT ANALYSES

Properties	REO 205		REO 203	
	DFM 194 hrs	Ref no. 2 DF 209.5 hrs	DFM 196 hrs	Ref no. 2 DF 210 hrs
Viscosity, cs, 100°F				
Start	126.7	126.7	121.6	121.6
End	136.5	147.1	137.8	130.1
Δ	9.8	20.4	16.2	8.5
Viscosity, cs, 210°F				
Start	12.93	12.93	12.61	12.61
End	13.74	14.42	13.73	13.33
Δ	0.81	1.49	1.12	0.72
Total acid no.				
Start	3.0	3.0	3.6	3.6
End	4.0	4.9	4.5	4.4
Δ	1.0	1.9	0.9	0.8
Total base no.				
Start	12.5	12.5	5.4	5.4
End	10.9	12.2	3.8	5.6
Δ	−1.6	−0.3	−1.6	0.2
Carbon residue, %				
Start	1.69	1.69	1.19	1.19
End	2.55	2.56	1.85	1.66
Δ	0.86	0.87	0.66	0.47
Sulfated ash, %				
Start	1.75	1.75	0.93	0.93
End	2.17	2.27	1.03	1.08
Δ	0.42	0.52	0.10	0.15
Metals, ppm, end of test				
Iron	136	151	183	54
Tin	33	0	0	0
Lead	20	24	29	10
Chromium	0	0	10	2

IV. CONCLUSIONS

- Marine Diesel Fuel (DFM, 1.2% sulfur) is judged incompatible for use with the current family of military two-cycle diesel engines.
- Use of DFM produces engine deterioration resulting in reduced performance, and possible increased maintenance, and reduction in engine life.
- The combination of high-ash lubricant (REO 205) and reference No. 2 diesel fuel produces borderline acceptable engine compatibility. Use of DFM with REO 205 produces major increases in ring sticking and ring face distress over an otherwise borderline acceptable performance.

- The combination of low-ash lubricant (REO 203) and reference No. 2 diesel fuel produces the desired high-level fuel-lubricant-engine compatibility; however, use of DFM with REO 203 produces significant increases in engine wear, ring face distress, and intake port plugging.

V. RECOMMENDATIONS

As a result of recent meetings on interchangeability of diesel fuels, USAMC and allied nations have established a maximum allowable sulfur content of 0.7% for diesel fuel. Such a fuel (designated NATO F-54) should be evaluated in a similar manner as the tests reported herein. These tests would provide a set of data for fuels of intermediate sulfur content, which should help in defining the overall effects of fuel sulfur content on two-cycle diesel engine performance.

VI. STATUS OF PROGRAM

During the period from September, 1972, through July, 1974, 13 6V53T engine/lubricant/fuel compatibility tests were conducted at USAFLRL. In tests 1 through 5, MIL-L-2104C lubricants REO 203 and REO 205 were run once each and REO 204 three times, using the 210-hr wheeled-vehicle test cycle with the reference No. 2 diesel fuel (0.42% natural sulfur). This work was reported in an interim report (AFLRL No. 29).

Tests 6 (REO 205) and 7 (REO 203), run on the 210-hr wheeled-vehicle cycle using DFM fuel (1.2% natural sulfur), are covered in this report.

Another interim report (AFLRL No. 37) covering tests 8, 9, and 10 is under preparation and will be published as soon as possible. Tests 8 (REO 203) and 9 (REO 205) were run on the 240-hr tracked-vehicle cycle using reference No. 2 diesel fuel. In test 10 another MIL-L-2104C lubricant (CCL-L-734) was run on the 210-hr wheeled-vehiclee cycle using reference No. 2 diesel fuel (0.42% natural sulfur).

Test 11 (REO 203) and tests 12 and 13 (both REO 205) were run on the 210-hr wheeled-vehicle cycle using a fuel with 0.70% natural sulfur which nominally met NATO F-54 requirements. The report of these tests is in preparation.

A final report will be issued covering all 13 6V53T engine compatibility tests in which the fuels, lubricants, and test cycle effects will be discussed. Also, this final report will tie in the results of the recent AVDS-1790-2A engine compatibility tests using the same MIL-L-2104C lubricants and reference No. 2 diesel fuel.

VII. ACKNOWLEDGEMENT

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APPENDIX I

COMPATIBILITY TEST PROCEDURE
WHEELED--VEHICLE TEST CYCLE 6V53T ENGINE

COMPATIBILITY TEST PROCEDURE
WHEELED-VEHICLE TEST CYCLE
6V53T ENGINE

I. Pretest Inspection

A pretest inspection will be made to ascertain the condition of the engine prior to test. During the inspection, initial measurement of engine components listed in Table I will be made. Components found to be out of new or service limits will be replaced. The engine will be fitted with new connecting rod and main bearings, new cylinder liners, and new piston and piston ring sets. Parts such as the oil pan, cylinder heads, valves, cylinder block passages, and heat exchangers will be cleaned. Standardized build-up procedures specified by the appropriate Army Technical Manual/Engine Manufacturer[9, 10] will be used. During rebuild, the engine will be fitted with appropriate temperature and pressure sensing devices to measure the following:

Temperatures:

Exhaust (before and after turbocharger)
Intake Air (before turbocharger)
Oil
  Main gallery
  Sump
Coolant (to and from engine)
Fuel (to engine)

Pressures:

Exhaust (before and after turbocharger)
Intake Air (before and after turbocharger)
Airbox
Fuel (to injector pump)
Oil (Main gallery)
  Crankcase

Flows:

Fuel
Blowby

Table 1

Wear Data Evaluation

The following engine components are gauged before and after the test. Data are evaluated on change during test.

Crankshaft end play.
Cylinder Bores--Parallel and perpendicular to crankshaft at the top, middle and bottom.

Piston--Parallel and perpendicular to wrist pin at the top and bottom.
Piston Rings--Gap and side clearance.
Piston Pins and Bushings.
Connecting Rod Bearings--Position A, B and C.
Connecting Rod Journals.
Main Bearings--Position A, B and C.
Main Bearing Journals.
Valve Clearance.

Engine Ratings (Deposits/Condition)

CRC Diesel Rating Manual used to rate following components.

Pistons
Rings
Ring Grooves
Lands
Skirt
Undercrown

Valves
Tappets, Cams and Rocker Arms
Cylinders
Bearings
Main
Connecting Rod
General engine--rust and sludge

II. Engine Break-In

An engine break-in will be conducted using the provided test lubricant and the following cycle:

Engine Speed, rpm	Load, Obs BHp	Time, min.
1800	30	15
2200	130	30
2500	200	30
2800	225	30

III. Full Load Performance Determination--

Immediately following the break-in conduct a full load performance determination consisting of measuring engine torque, brake horsepower and brake specific fuel consumption at 200 rpm intervals between engine speeds of 1800 and 2800 rpm at full throttle. Change oil and filter after power curve.

IV. Compatibility Endurance Test*

The compatibility endurance test consists of repeating the endurance cycle for * days without interruption for * hours of engine operation. During test, the engine is to be operated using arctic anti-freeze as the coolant. Coolant temperatures must be maintained within ±5°F of the listed value; and, the idle temperature must be obtained within 10 minutes after starting each idle portion of the cycle. Coolant will be used to control the oil temperature which shall not exceed 250°F. The fuel is to be held within 5°F of the intake air (to turbocharger) temperature by use of an external water to fuel heat exchanger.

Wheeled Vehicle-Endurance Cycle

Period	Time, hrs.	Load, %	Speed, rpm	Coolant Temp., °F
1	2	100	2800 ± 20	180
2	1	0	650 ± 25	100
3	2	100	2800	180
4	1	0	650	100
5	2	100	2800	180
6	1	0	650	100
7	2	100	2800	180
8	1	0	650	100
9	2	100	2800	180
10	10	----------Shutdown----------		

* Wheeled Vehicle Cycle = 15 days for 210 hours operation

Notes:

1. Coolant temperature refers to jacket outlet. The thermostat is blocked open.

2. Anti-Freeze used as coolant; MIL-A-11755C, A-1, 15 October 1971.

3. Temperature reduced to 100°F within 10 minutes after idle runs start.

4. Temperature limits, ± 5°F.

5. Maximum allowable oil sump temperature, 250°F.

6. No oil drains during wheeled-vehicle test cycle.

7. Oil Samples:
   Wheeled-Vehicle Cycle
   a. One-half pint sample every 14 hours -- 12 total
   b. 1 pint sample every 70 hours -- 3 total

8. Makeup oil; add to full mark on sight glass; weight oil in.

9. At the start of each day's operation during the wheeled vehicle cycle, run at idle for 5 minutes and then proceed directly to full rack power at 2800 RPM.

10. At end of day's operation, idle the engine for 5 minutes (without resetting jacket coolant controller), and take oil sample prior to shutdown.

11. Take complete log sheet readings at the end of the 2 hour power phases, and at the end of the idle phases.

Fresh test oil will be placed in the engine at the start of the endurance test; and there will be no forced oil additions. Make-up oil shall be added, as required only in one-quart increments during the shutdown periods. Records of all oil additions must be maintained. Oil samples are to be taken after each day of engine operation as shown in Table II. The sampling method consists of installing a tap in the oil cooler inlet or oil gallery and taking the sample just prior to shutdown. The sample line must be flushed before taking each sample (return all flush oil to the crankcase). Specific operating limits for the 6V53T are given in Table III for the wheeled-vehicle cycle.

TABLE II. New and Used Oil Sampling and Analysis Schedule - Wheeled Vehicle Cycle

Type Sample and Analysis	New Oil	Hours of Engine Operation														
		14	28	42	56	70	84	98	112	126	140	154	168	182	196	210
Type Sample	1	2	2	2	2	1	2	2	2	2	1	2	2	2	2	1
Viscosity																
100°F D445	X					X					X					X
210°F D445	X					X					X					X
Total Acid D664	X					X					X					X
Total Base D2896	X					X					X					X
Insolubles D893																
Pentane (A&B)	X					X					X					X
Benzene (A&B)	X					X					X					X
Gravity D287	X															X
Pour Point D97	X															X
Carbon Residue D524	X															X
Sulfated Ash D872	X					X					X					X
Flash Point D92	X					X					X					X
I. R.	X					X					X					X
A. A., ppm																
Na**	X					X					X					X
Cu	X					X					X					X
Cr	X					X					X					X
Mo*	X					X					X					X
Pb	X					X					X					X
Sn	X					X					X					X
Fe	X					X					X					X
Al	X					X					X					X

1 Large volume sample (16 oz.)
2 Small volume sample (8 oz.)
X Indicates analysis to be performed.
* Substitute for Cr for AVDS-1790 engine.
** Analyze for 6V53T only.

Table III. Wheeled Vehicle Test Cycle

Operating Condition	Limits; or settings, for	
	Power Phase	Idle Phase
Speed, rpm	2800 ± 20	650 ± 10
Fuel Flow		
Typical, lb/min, (2 lb wt/time)	2.07 ± .07	(use 2 oz)
Fuel/cycle, mm^3	67 - 69	-
Revolutions/2 lb	2680 ± 50	-
Time/2 lb	0.965 ± .035	-
Obs BHp output	282 - 300	-
Jacket-out, °F	180 ± 2	100 ± 2
Coolant Δ T, °F	8 - 12	2 - 3
Oil Sump, °F	250, max	-
Fuel Temp & Filter	90 ± 5	-
Fuel Pressure, range	55 - 70	70 max
Compressor Suction, clean filter, inches water	6.0 max	-
Compressor Suction, dirty filter, inches water	12.0 max	-
Exhaust Back Pressure (after turbo), inches Hg	2.3 max	-
Crankcase Pressure	6.0 max	-
Oil Pressure, minimum	32 psi	5 psi
Blowby Flow, CFH	1150 max	-
Test Duration	210 Hrs	
Oil Drains	None	
Oil Level Checks and Additions	Every 14 Hrs	
Oil Samples	Every 14 Hrs	
Airbox Inspection	None	

V. Full Load Performance Determination--

Immediately following the final endurance cycle a full load performance determination will be made. The determination is the same as in Sec. III.

VI. Engine Inspection and Lubricant Deposit Ratings

After completion of the final performance determination, the engine will be disassembled for inspection, measurements and deposit ratings. Measurement of the components listed in Table I will be made; and, other loaded components will be inspected reporting their condition. Engine parts will be rated for lubricant deposits and displayed for inspection by members of the Coordinating Research Council's, Motor Army Combat Engine Fuels and Lubricants Performance Group.

VII. Test Oils

Lubricants to be tested are being furnished by U. S. Army Mobility Equipment Research and Development Cent r, Coating and Chemical Laboratory (C&CL).

VIII. Test Fuel

Diesel fuel to be used is designated reference no. 2 diesel fuel, and it is approved by C&CL according to the requirements set forth in Section 4. 1, Method 341, FTM Standard 791B.

APPENDIX II

CRC GUIDANCE

CRC GUIDANCE

During a meeting held 24 August 1972, the following test modifications were proposed by the CRC Army Combat Engine Fuels and Lubricants Group:

1. Engine Buildup - Standardized buildup procedures specified by the appropriate Army Technical Manual/Engine Manufacturer should be used. It was the group's opinion that specialized buildup, such as would be used in strickly lubricant evaluation programs, could possibly cloud the original intent of the compatibility tests by imposing unrealistic engine environments for the oils. Review of the standardized procedures indicate that sufficient data for evaluating wear performance will be generated using these procedures. Only one exception to standard measurements will be made in that ring proudness will be measured using a simple V-block fixture.

2. Engine Rebuild Parts - Engine components such as ring sets and bearings used for rebuilding a specific engine should be from a single supplier. Use of a single manufacturers parts will assist in limiting variation in results.

3. Used Oil Analyses - The following analyses will be performed on 60,120,180, and 240 hour AVDS-1790 samples and 70, 140, and 210 hour 6V53T samples:

Analysis	Method
Viscosity (100°F & 210°F)	D445
TAN	D664
TBN	D2876
Insolubles (Pentane & Benzene)	D893 (Procedure A & B)
Gravity	D287
Flash Point	D92
Sulfated Ash	D872
IR	(to be determined)
Additive Content (Zn,Ca,Ba)	Atomic Absorption
Elemental Analysis	
AVDS-1790 (Sn,Fe,Cu,Pb,Al & Mo)	Atomic Absorption
6V53T (Na,Fe,Cu,Pb,Al,Cr & Sn)	Atomic Absorption

In the event abnormal results are obtained, additional analyses of the remaining samples will be performed.

4. Endurance Cycle AVDS - 1790 Tests - The 2 hours shutdown period is to be lengthened to 4-hours. It is felt that this would assist in control by allowing repetitive operation on a daily basis rather than the scheduled 22-hours cycle.

5. 6V53T Endurance Cycle - Immediately following the last 2-hours of full load operation, the engine will be idled for 5-minutes prior to shutdown. This is to avoid a hot-shutdown which could over stress the engine.

6. 6V53T Coolant - Arctic antifreeze meeting Specification MIL-A-11755C will be used as coolant. This will standardize the coolant and provide additional stressing of the lubricant.

APPENDIX III

Test Number 6

Fuel: MIL-F-16884 (DFM)
Oil: REO 205, CCL-L-758
Engine No.: 6D5084-6
Test Hours: 194
Date Completed: 18 June 1973

TABLE 1
6V53T 6D5084-6
BUILD-UP ENGINE MEASUREMENTS

Measurements	Inches Min.	Max.	Avg.	Specified Limits (1)
Crankshaft main bearing clearance	.0043	.0057	.0050	.0070 max.
Camshaft bearing clearance				
Left cam	.0060	.0068	.0064	.0080 max.
Right cam	.0055	.0069	.0061	.0080 max.
Connecting rod bearing clearance	.0017	.0030	.0025	.0016-.0046
Crankshaft end-play	.006	.006	.006	.004-.011
Oil pump				
Between rotors	.003	.003	.003	.004-.011
Outer rotor/housing	.0015	.0015	.0015	.001-.0035
Cylinder liner block bore				
Taper	.0000	.0005	.0003	.0015 max.
Out-of-round	.0000	.0012	.0007	.0015 max.
Inside diameter	4.3575	4.3591	4.3582	4.3595 max.
Cylinder liners (installed)				
Taper	.0000	.0012	.0006	.002 max. (2)
Out-of-round	.0000	.0012	.0005	.003 max. (2)
Inside diameter	3.8756	3.8776	3.8766	3.8752-3.8767
Piston to liner fit	.0066	.0086	.0078	.0060-.0095
Piston Diameter	3.8683	3.8692	3.8688	3.8669-3.8691
Fire ring				
End gap	.30	.35	.33	.020-.046
Side clearance	.004	.004	.004	.003-.006
#1 Compression ring				
End gap	.024	.042	.035	.020-.046
Side clearance	.007	.009	.008	.007-.010
#2 & #3 Compression rings				
End gap	.028	.044	.034	.020-.046
Side clearance	.006	.007	.007	.005-.008
Oil rings				
End gap	.018	.024	.020	.010-.025
Side clearance	.003	.010	.004	.0015-.0055

(1) Limits on new parts unless maximum wear limit specified.
(2) Wear limits with new liners in a used block.

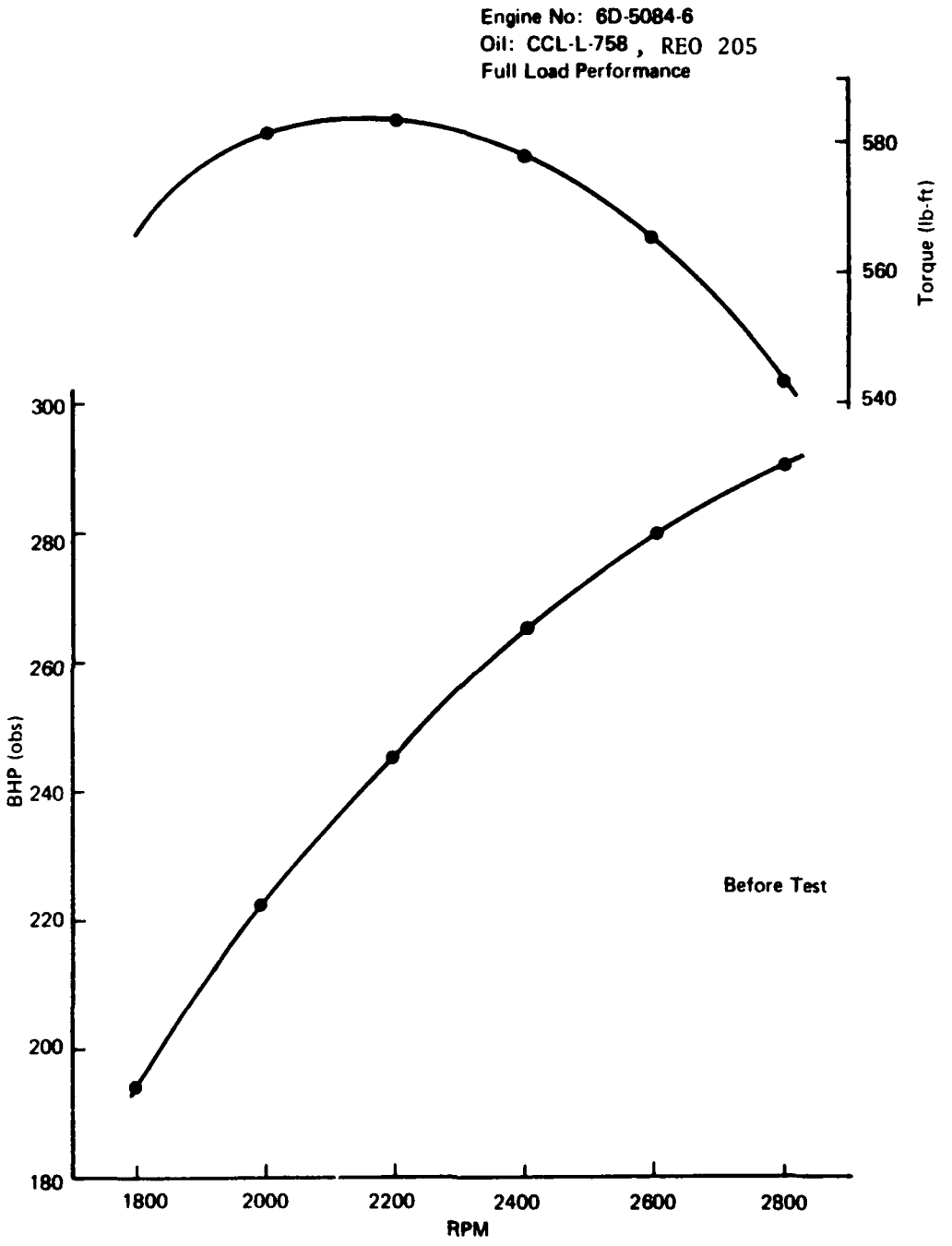

Engine No: 6D-5084-6
Oil: CCL-L-758 , REO 205
Full Load Performance
580
560
540
Torque (lb-ft)
300
280
260
240
220
200
180
BHP (obs)
Before Test
1800
2000
2200
2400
2600
2800
RPM

FIGURE 1

TABLE 2
SUMMARY OF OPERATING DATA

Engine Test No. 6D5084-6 Oil Code CCL-L-758 (REO 205)

	Power Mode			Idle Mode
	Min.	Max.	Avg.	Avg.
Engine speed, rpm, 2800±20/ 650±10	2800	2800	2800	650
Load, lbs	354	428	421	-
BHp, obs. (2800/4100) x load	242	292	288	-
Fuel/cycle, mm^3	66.2	68.1	67.3	-
Fuel rate, lb/min	1.96	2.08	2.06	
Oil consumption, (lb/hr Avg for 194 Hrs)	-	-	0.52	
Temperatures, ^oF				
Jacket-in	168	171	170	
Jacket-out 180±5/100±2	179	182	181	101
Oil sump	235	238	237	121
Inlet air (compressor)	90	101	95	
Airbox	276	287	282	
Exhaust before turbo	1020	1060	1050	
Exhaust after turbo	500	900	880	
Fuel at filter (secondary)	84	91	89	
Pressures				
Compressor suction, in. H_2O	6.4	10.8	6.9	
Compressor discharge in. Hg	22.8	24.7	23.8	-
Blower discharge (airbox), in. Hg	34.6	36.7	35.7	-
Crankcase, dipstick tube in. H_2O	3.9	4.7	4.2	-
Exhaust before turbo, in. Hg	24.5	26.3	25.7	
Exhaust after turbo, in. Hg	1.9	2.2	2.1	-
Oil gallery, psi	40.5	43	41.7	26.8
Fuel at filter, psi	66	72	69.8	
Blowby flow, cfh at 29.92 in. Hg and 115^oF	780	900	850	-

Unscheduled Shutdowns

At 30 hours: Repaired flexible exhaust pipe, lost 20 minutes
At 194 hours: Stopped due to power loss. Test terminated.

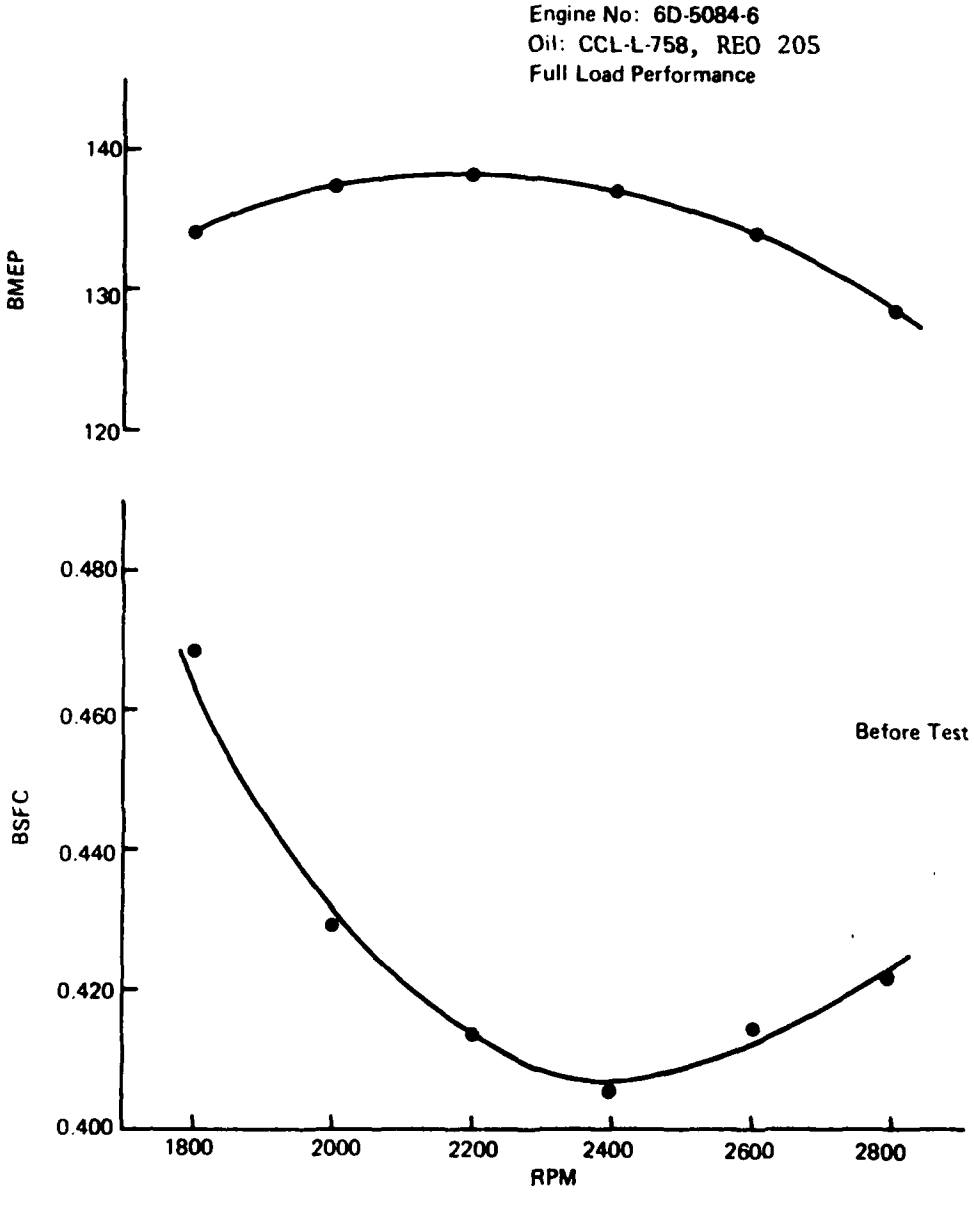

Engine No: 6D-5084-6
Oil: CCL-L-758, REO 205
Full Load Performance
BMEP
140
130
120
BSFC
0.480
0.460
0.440
0.420
0.400
Before Test
1800
2000
2200
2400
2600
2800
RPM

FIGURE 2

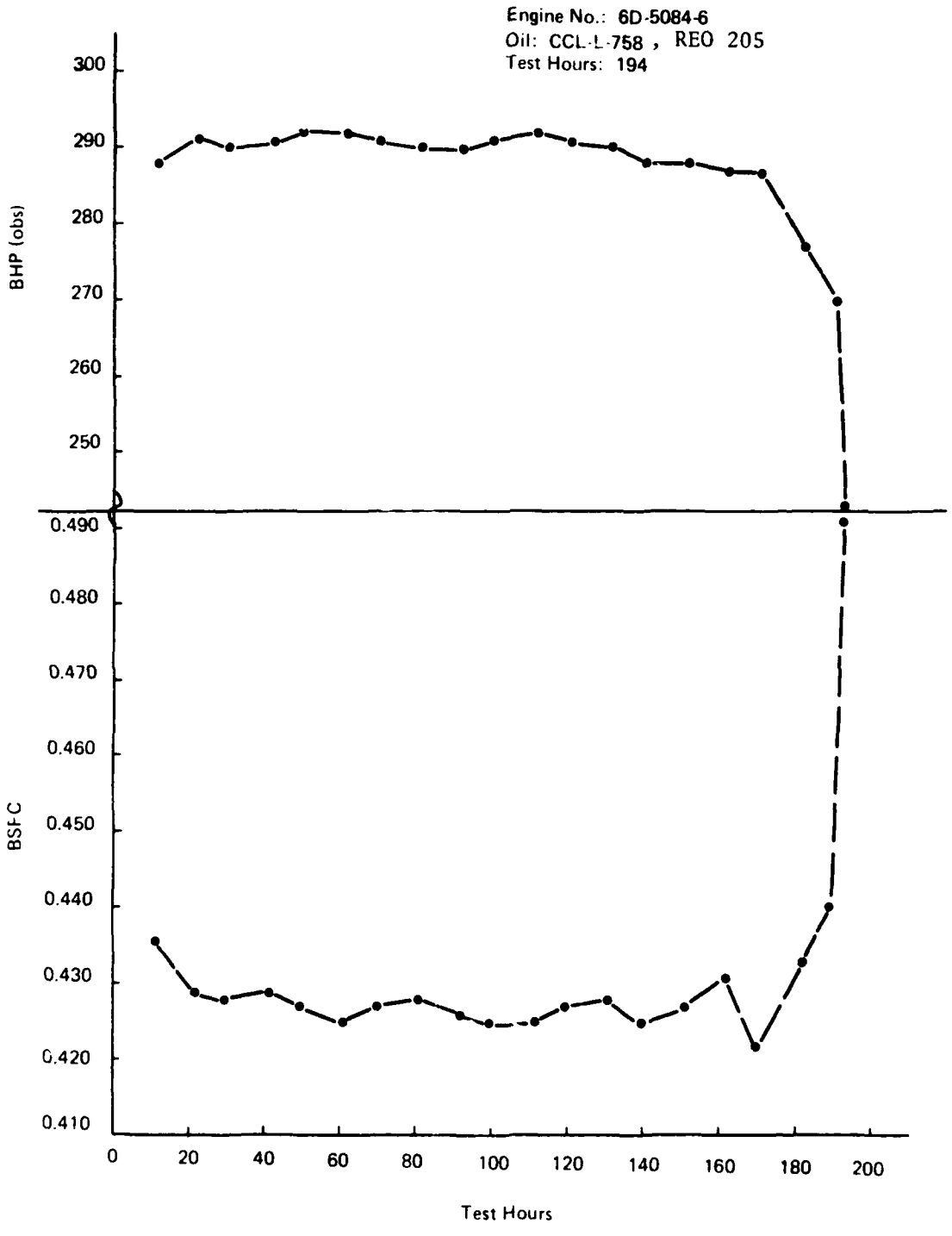

Engine No.: 6D-5084-6
Oil: CCL-L-758 , REO 205
Test Hours: 194
BHP (obs)
300
290
280
270
260
250
BSFC
0.490
0.480
0.470
0.460
0.450
0.440
0.430
0.420
0.410
0
20
40
60
80
100
120
140
160
180
200
Test Hours

FIGURE 3

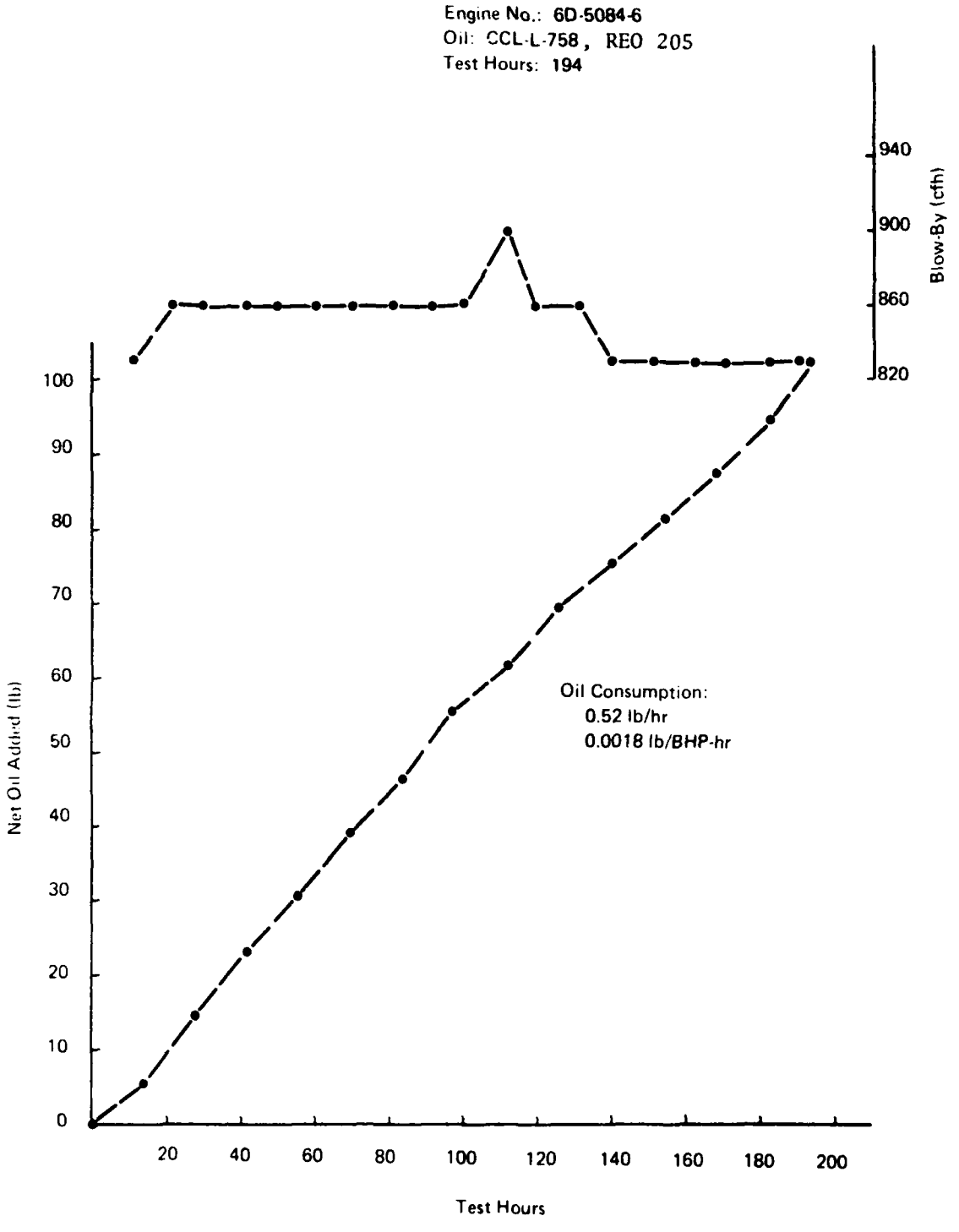
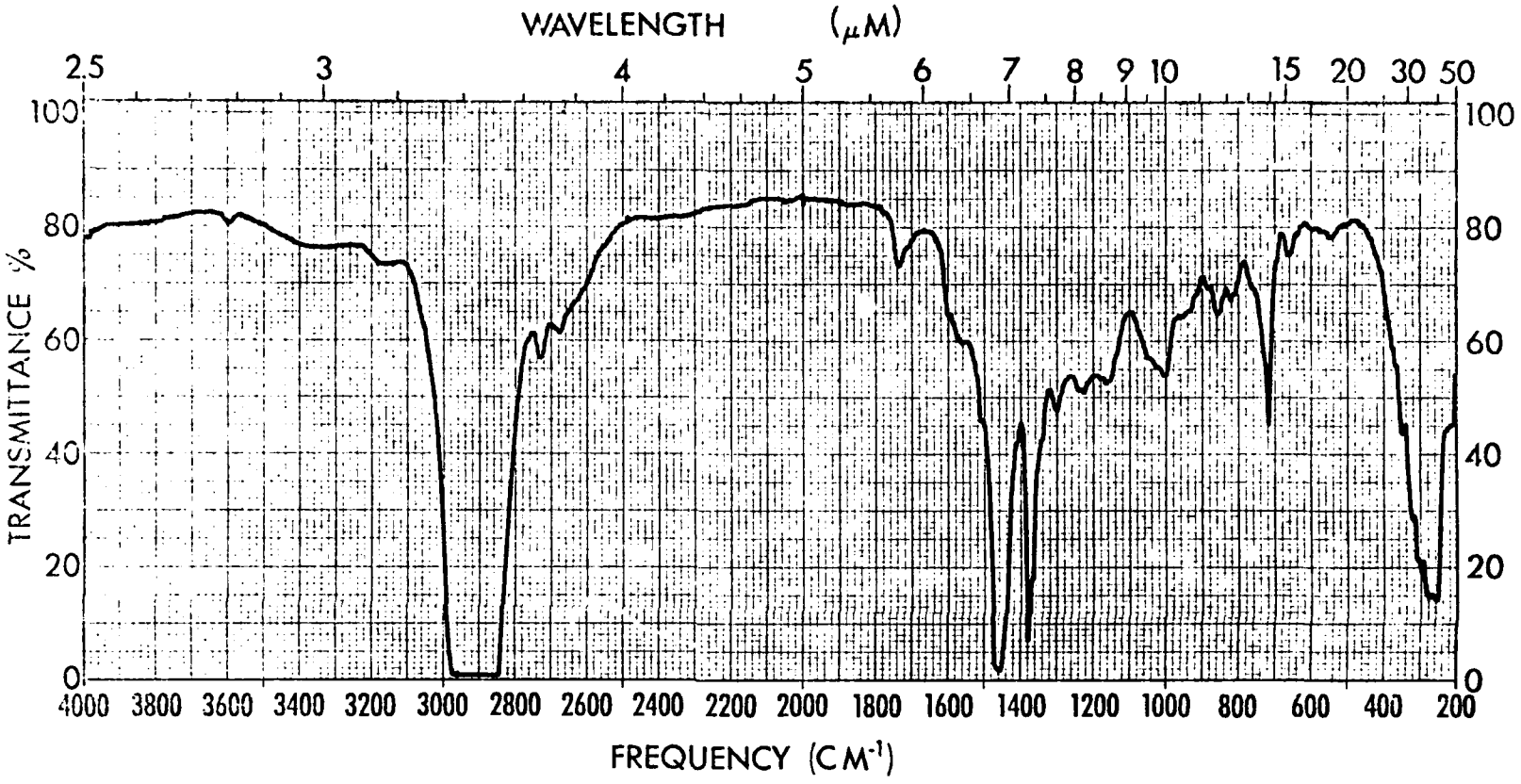

Engine No.: 6D-5084-6
Oil: CCL-L-758, REO 205
Test Hours: 194
940
900
860
820
Blow-By (cfh)
100
90
80
70
60
50
40
30
20
10
0
Net Oil Added (lb)
Oil Consumption:
0.52 lb/hr
0.0018 lb/BHP-hr
20
40
60
80
100
120
140
160
180
200
Test Hours

FIGURE 4

TABLE 3
LUBRICANT ANALYSES
6V53T - 6D5084-6
Oil: CCL-L-758 REC 205

Property	New Oil	42	70	98	140	168	194
K. Vis, Cs, 100	126.70	136.34	140.76	138.72	145.07	146.19	136.53
K. Vis, Cs, 210	12.93	13.70	14.02	13.77	14.44	14.32	13.74
V-I	101	106	105	103	106	106	105
TAN (D664)	2.98	3.59	3.85	3.85	4.32	4.22	4.01
TBN (D2896)	12.54	11.98	11.39	10.80	10.80	11.10	10.86
Insolubles (D893),%							
Pentane A	0.04	0.07	0.08	0.10	0.09	0.14	0.10
Benzene A	0.04	0.05	0.06	0.06	0.06	0.07	0.09
Pentane B	0.04	0.12	0.24	0.20	0.29	0.30	0.33
Benzene B	0.04	0.10	0.18	0.15	0.21	0.21	0.24
Gravity ^{o}API (D287)	27.3	N.D.	N.D.	N.D.	N.D.	N.D.	26.0
Pour (D97),^{o}F	-5	N.D.	N.D.	N.D.	N.D.	N.D.	-5
Carbon Residue (D524),%	1.69	N.D.	N.D.	N.D.	N.D.	N.D.	2.55
Flash Pt.(D92),^{o}F	460	450	460	460	455	460	455
S. Ash, % (D872)	1.75	1.98	2.08	1.98	2.17	2.19	2.17
Metals PPM, A.A.							
Na	212	188	200	175	213	218	218
Cu	0	5.5	5.5	6.5	6.0	5.8	5.8
Cr	0	0	0	0	0	0	0
Pb	6.5	10	15	16	18	18	20
Sn	0	31.5	41.5	37.5	38.5	34.5	33
Fe	7	65	78	76	101	108	136
Al	0	0	2.5	3.5	3.5	4.0	3.5
I.R. Trace No.	155	246	247	248	249	250	251

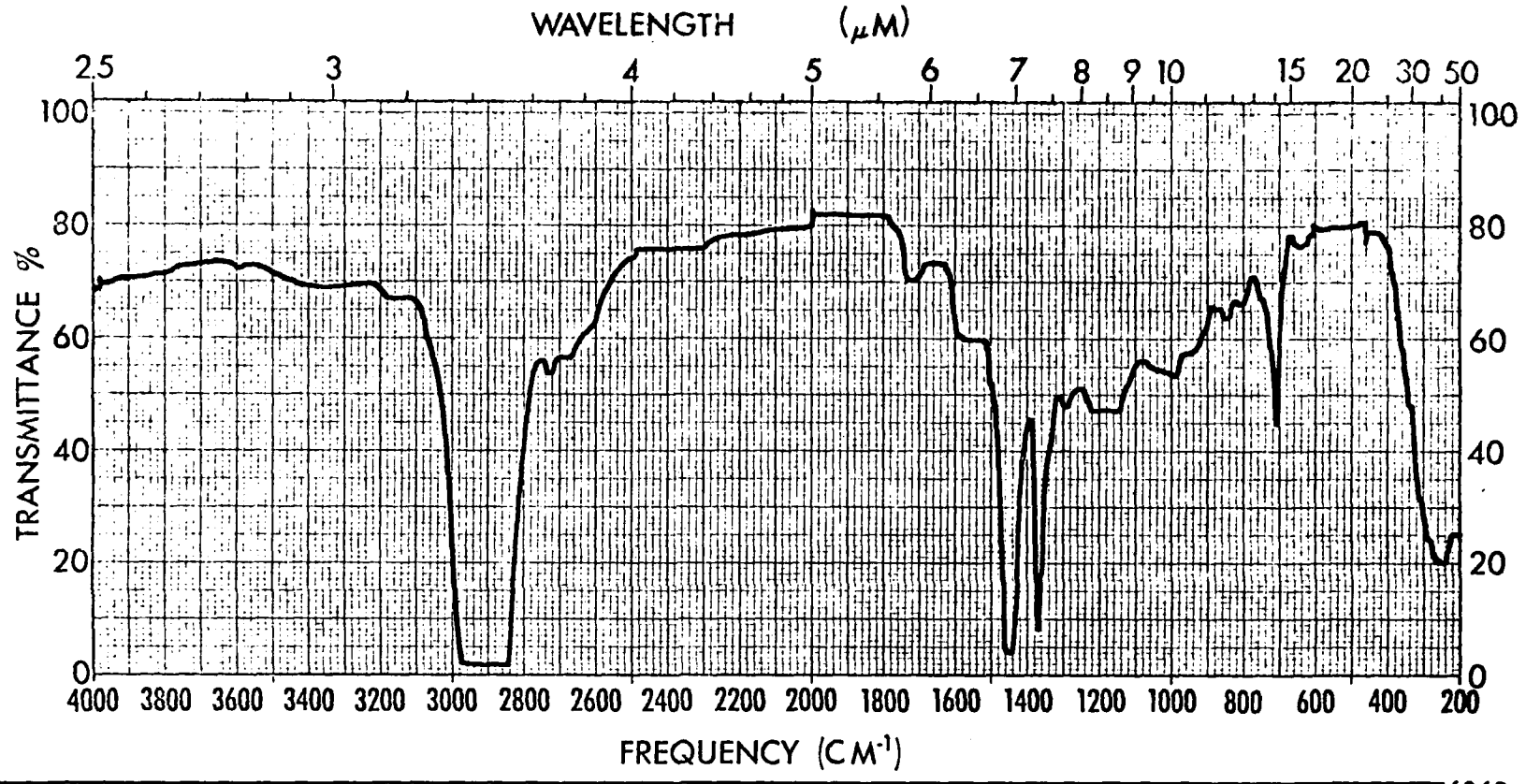
N.D. - Not Determined



SPECTRUM NO. 155b-	ORIGIN	LEGEND	REMARKS
SAMPLE AL-4489-L		1.	
REO 205	PURITY	2.	
	PHASE	DATE 12-18-72	
New Oil	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE

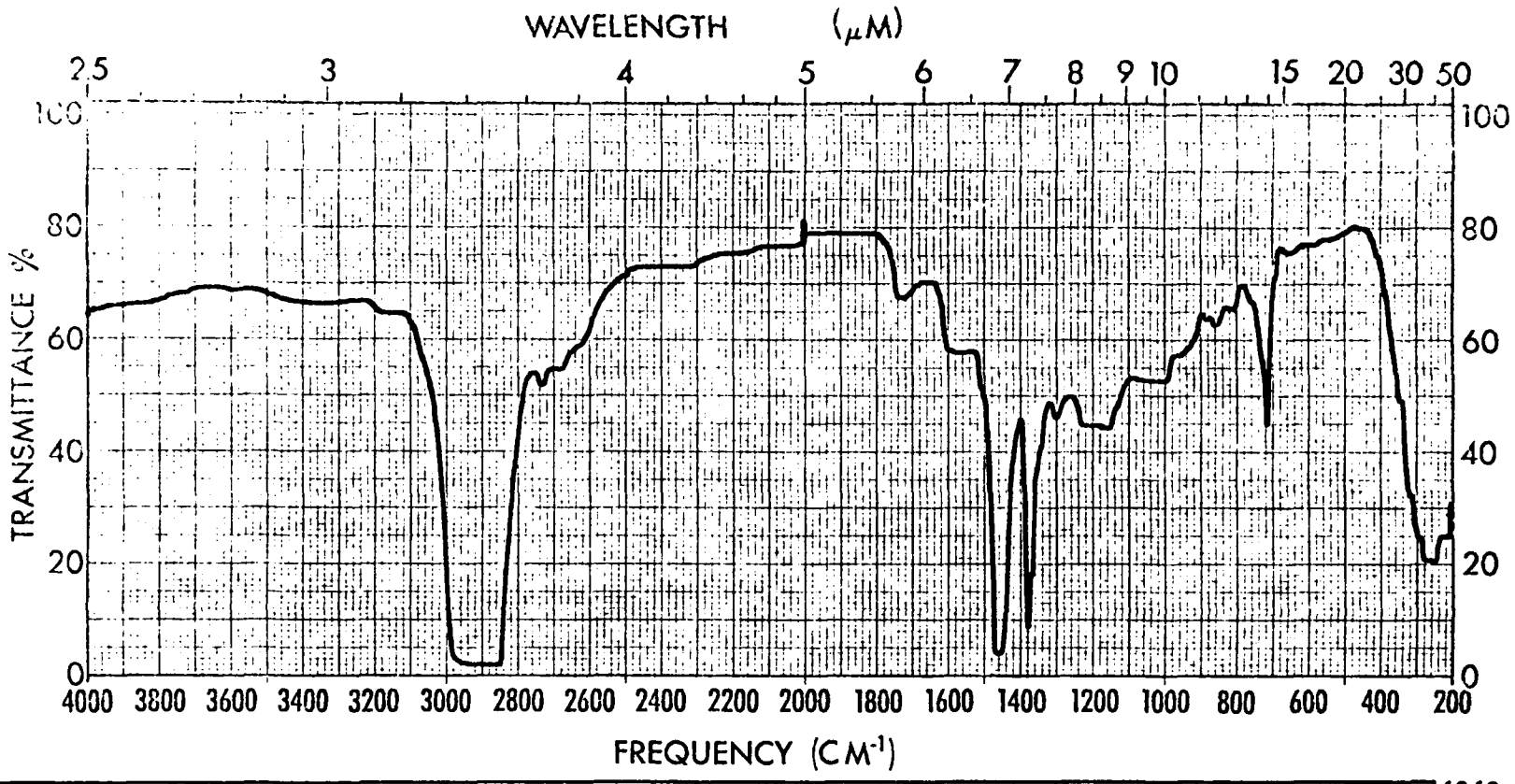
FIGURE 5-1



SPECTRUM NO. 246	ORIGIN	LEGEND	REMARKS
SAMPLE AL-4489-L		1.	
42 Hr	PURITY	2.	
REO 205	PHASE	DATE 6-27-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO.____ SAMPLE____

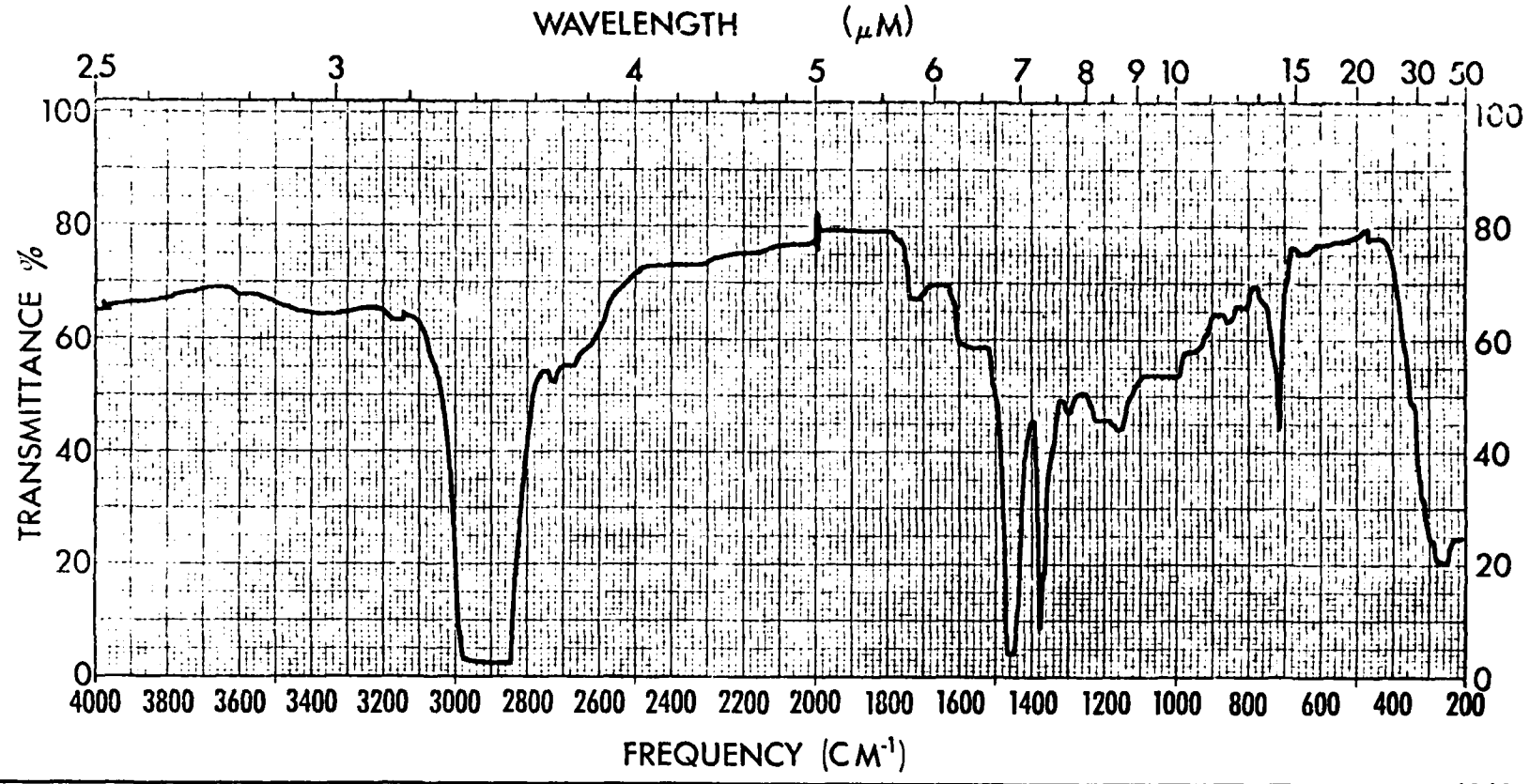
FIGURE 5-2



SPECTRUM NO. 247	ORIGIN	LEGEND	REMARKS
SAMPLE AL-4489-L		1.	
70 Hr	PURITY	2.	
REO 205	PHASE	DATE 6-27-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE

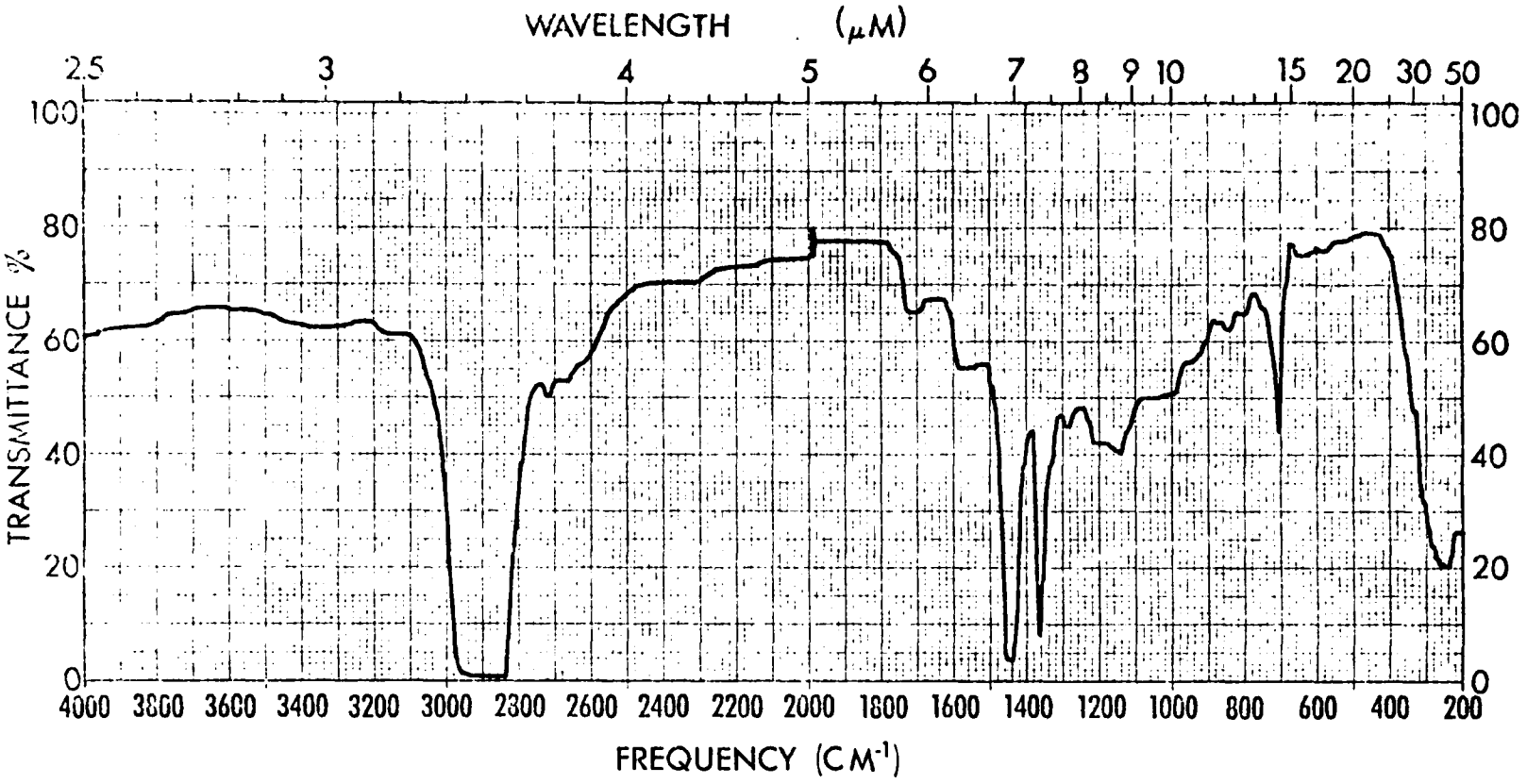
FIGURE 5-3



SPECTRUM NO. 248	ORIGIN	LEGEND	REMARKS
SAMPLE AL-4489-L		1.	
98 Hr	PURITY	2.	
REO 205	PHASE	DATE 6-27-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE

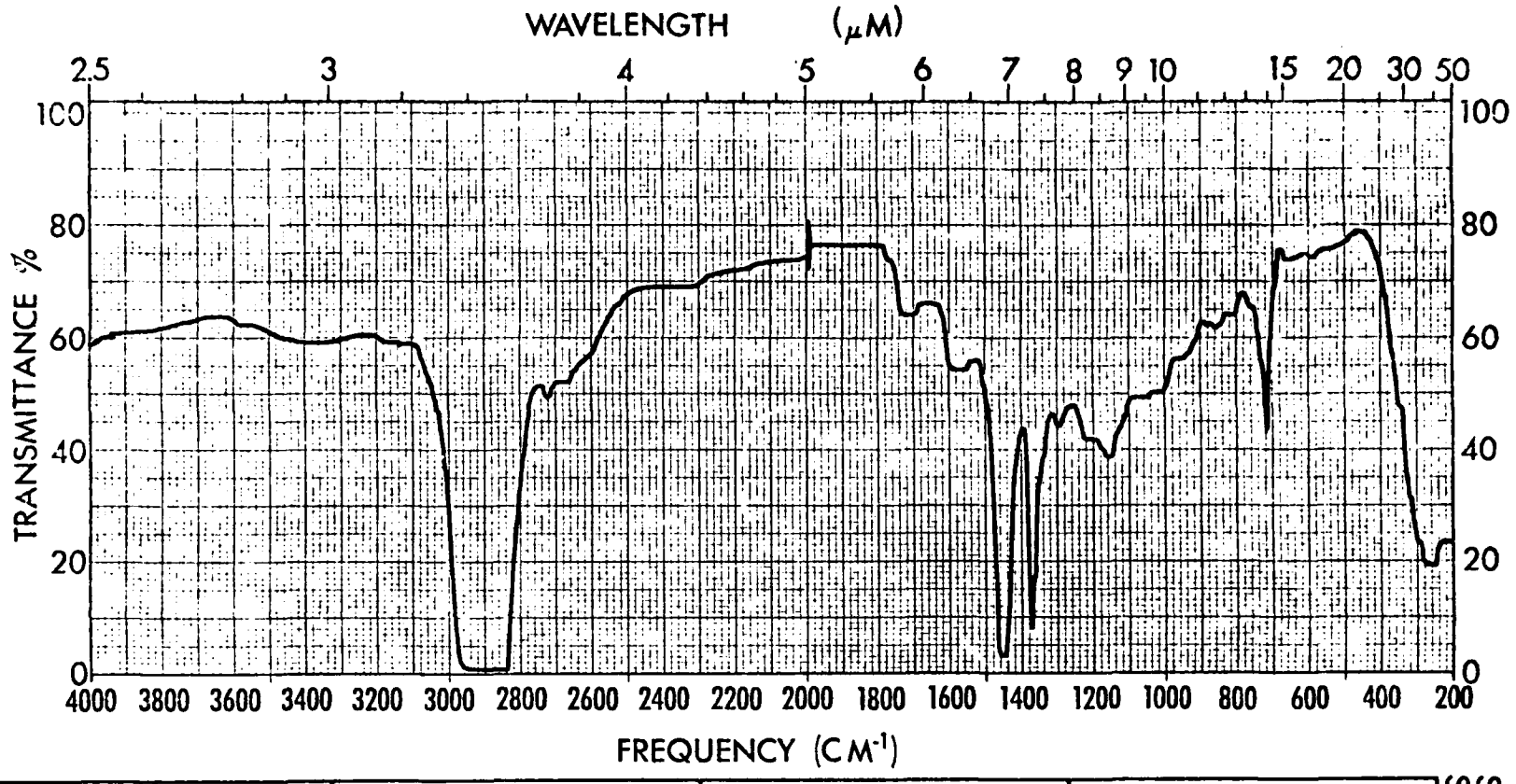
FIGURE 5-4



SPECTRUM NO. 249	ORIGIN	LEGEND	REMARKS
SAMPLE AL-4489-L		1.	
140 Hr	PURITY	2.	
REO 205	PHASE	DATE 6-27-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO. ____
SAMPLE ____

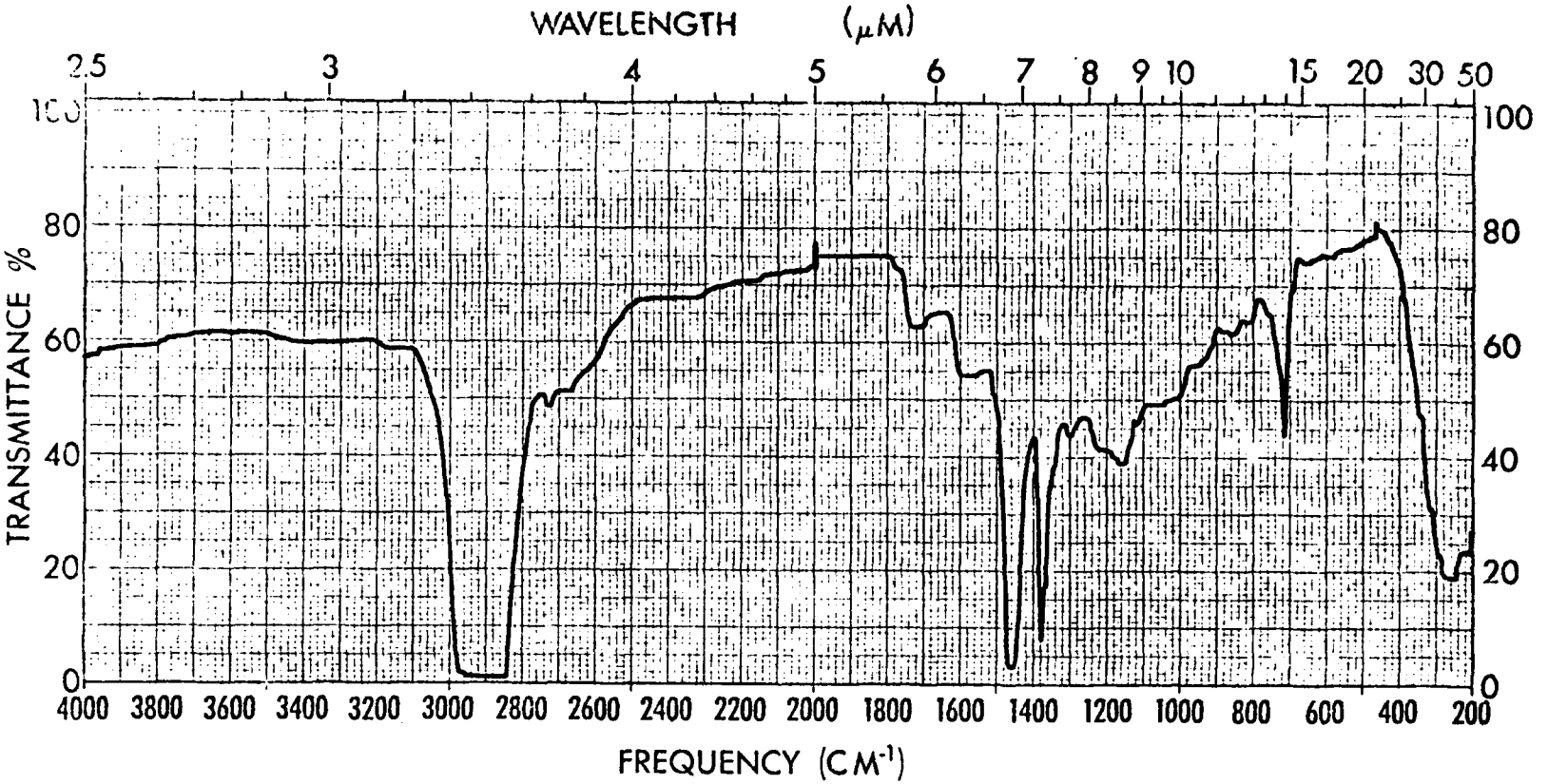
FIGURE 5-5



SPECTRUM NO. 250	ORIGIN	LEGEND	REMARKS
SAMPLE AL-4489-L		1.	
168 Hr	PURITY	2.	
REQ 205	PHASE	DATE 6-28-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO.
SAMPLE

FIGURE 5-6



SPECTRUM NO. 251	ORIGIN	LEGEND	REMARKS
SAMPLE AL-4489-L		1.	
194 Hr	PURITY	2.	
REO 205	PHASE	DATE 6-28-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO.
SAMPLE

FIGURE 5-7

WEAR MEASUREMENTS
(INCHES)
TABLE 4-1
ENGINE NO. 6D5084-6
OIL: CCL-L-758 , REO 205
Hrs. 194

Piston No.	Piston Ring Gap 1	2	3	4	5	6	7
1L Before	0.033	0.035	0.037	0.044	0.024	0.020	0.020
After	Stuck	.038	.038	.046	.038	.028	.028
Change	-	.003	.001	.002	.014	.008	.008
2L Before	0.030	0.030	0.028	0.028	0.022	0.018	0.018
After	.038	.033	.030	.029	-	.028	.028
Change	.008	.003	.002	.001	-	.010	.010
3L Before	0.035	0.042	0.029	0.029	0.022	0.020	0.022
After	Stuck	Stuck	Sluggish	.032	.035	.030	.032
Change	-	-	-	.003	.013	.010	.010
1R Before	0.035	0.024	0.040	0.043	0.022	0.018	0.018
After	Stuck	.028	.044	.045	.033	.025	.025
Change	-	.004	.004	.002	.011	.007	.007
2R Before	0.032	0.041	0.044	0.028	0.022	0.018	0.018
After	.038	.043	.048	.030	.034	.025	.025
Change	.006	.002	.004	.002	.012	.007	.007
3R Before	0.035	0.040	0.028	0.029	0.020	0.018	0.018
After	.042	.043	.030	.032	.033	.025	.025
Change	.007	.003	.002	.003	.013	.007	.007

TABLE 4-2
ENGINE NO. 6D5084-6
OIL: CCL-L-758, REO 205
Hrs. 194

Cylinder No.	Cylinder Liner Perpendicular to Crankshaft Top	Middle	Bottom	Parallel to Crankshaft Top	Middle	Bottom
1L Before	3.8777	3.8776	3.8776	3.8767	3.8777	3.8767
After	3.8786	3.8783	3.8775	3.8766	3.8775	3.8768
Change	.0009	.0007	-.0001	-.0001	-.0002	.0001
2L Before	3.8761	3.8772	3.8764	3.8758	3.8768	3.8770
After	3.8768	3.8777	3.8763	3.8764	3.8767	3.8768
Change	.0007	.0005	-.0001	.0006	-.0001	-.0002
3L Before	3.8764	3.8771	3.8761	3.8776	3.8775	3.8771
After	3.8780	3.8771	3.8764	3.8773	3.8775	3.8774
Change	.0016	.0000	.0003	-.0003	.0000	.0003
1R Before	3.8758	3.8765	3.8766	3.8759	3.8771	3.8765
After	3.8772	3.8768	3.8767	3.8769	3.8772	3.8765
Change	.0014	.0003	.0001	.0010	.0001	.0000
2R Before	3.8760	3.8770	3.8758	3.8756	3.8764	3.8766
After	3.8771	3.8774	3.8759	3.8758	3.8772	3.8767
Change	.0011	.0004	.0001	.0002	.0008	.0001
3R Before	3.8761	3.8773	3.8768	3.8762	3.8771	3.8768
After	3.8776	3.8779	3.8770	3.8770	3.8770	3.8768
Change	.0015	.0006	.0002	.0008	-.0001	.0000

TABLE 4-3
ENGINE NO. 6D-5084-6
OIL: CCL-L-758, REO 205
Hrs. 194

Cylinder No.	Piston O.D.
1L Before	3.8692
After	3.8682
Change	.0010
2L Before	3.8692
After	3.8677
Change	.0015
3L Before	3.8690
After	3.8680
Change	.0010
1R Before	3.8685
After	3.8668
Change	.0017
2R Before	3.8683
After	3.8668
Change	.0015
3R Before	3.8685
After	3.8670
Change	.0015

TABLE 4-4
ENGINE NO. 6D5084-6
OIL: CCL-L-758 , REO 205
Hrs. 194

Number		Main Bearing Journal AA	Main Bearing Journal BB	Main Bearing F	Main Bearing R
1	Before	3.4992	3.4994	3.5048	3.5049
	After	3.4992	3.4994	3.5052	3.5052
	Change	.0000	.0000	.0004	.0003
2	Before	3.4995	3.4990	3.5038	3.5039
	After	3.4991	3.4989	3.5046	3.5045
	Change	.0004	.0001	.0008	.0006
3	Before	3.4992	3.4993	3.5047	3.5048
	After	3.4991	3.4992	3.5050	3.5048
	Change	.0001	.0001	.0003	.0000
4	Before	3.4993	3.4992	3.5038	3.5037
	After	3.4990	3.4990	3.5038	3.5038
	Change	.0003	.0002	.0000	.0001

Number		Crankshaft Thrust Washers 1	2	3	4
A	Before	.1204	.1199	.1207	.1198
	After	.1204	.1199	.1207	.1198
	Change	.0000	.0000	.0000	.0000
B	Before	.1208	.1205	.1202	.1203
	After	.1208	.1204	.1200	.1203
	Change	.0000	.0001	.0002	.0000

Exhaust Valve Clearances

Before Test	All .024" to .026"
After Test (a)	All .024" to .026" (Except 2L = approx. .010")

(a) - at 193 hours when fuel injectors changed.

TABLE 4-5

ENGINE NO. 6D5084-6
OIL: CCL-L-758, REO 205
Hrs. 194

Cylinder No.	Rod Bearing Journal AA	Rod Bearing Journal BB	Rod Bearing F	Rod Bearing R
1L Before	2.7492	2.7495	2.7512	2.7515
After	2.7490	2.7490	2.7516	2.7516
Change	.0002	.0005	.0004	.0001
2L Before	2.7490	2.7490	2.7516	2.7518
After	2.7489	2.7489	2.7521	2.7520
Change	.0001	.0001	.0005	.0002
3L Before	2.7490	2.7492	2.7518	2.7520
After	2.7486	2.7489	2.7520	2.7523
Change	.0004	.0003	.0002	.0003
1R Before	2.7496	2.7493	2.7520	2.7515
After	2.7492	2.7492	2.7522	2.7520
Change	.0004	.0001	.0002	.0005
2R Before	2.7491	2.7490	2.7518	2.7518
After	2.7489	2.7487	2.7521	2.7520
Change	.0002	.0003	.0003	.0002
3R Before	2.7490	2.7490	2.7515	2.7515
After	2.7488	2.7486	2.7520	2.7515
Change	.0002	.0004	.0005	.0000

TABLE 5-1

RING STICKING

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973
Fuel MIL-F-16884(DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

Piston Number

Ring No.	1L	2L	3L (W)	1R	2R	3R (A)
1	Cold Pinched	Free	100% Hot Stuck	100% Hot Stuck	Free	Free
2	Free	Free	270° Hot Stuck	Free	Free	Free
3	Free	Free	Cold Pinched	Free	Free	Free
4	Free	Free	Free	Free	Free	Free

Indicate by letter—Free or Sluggish, or by number and letter—percent Pinched (cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

(A) and (W) indicate average and worst from deposit standpoint.

TABLE 5-2

RING DEPOSITS

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973
Fuel MIL-F-16884(DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

Cylinder Number			1L		2L		3L		1R		2R		3R	
			CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Piston Ring	Top	1	*		80AH	20-5	*		*		100AH	-	100AH	-
		2	30AH	70-6	90AH	10-4	*		100AH	-	70AH	30-7	80AH	20-6
		3	-	-	-	10-3	*		10AH	50-3 25-2	-	60-4	5AH	65-5
		4	-	30-3	-	40-3	-	70-3	-	70-7 30-3	-	60-3	-	25-3
	ID	1	*		(1)	-	*		*		100AH	-	100AH	-
		2	80CH 20AH	-	70BH 30AH	-	*		(2)	-	35BH 65AH	-	90CH 10AH	-
		3	100AH	-	100AH	-	*		5BH 95AH	-	100AH	-	100AH	-
		4	70AH	30-7	100AH	-			100AH	-	100AH	-	100AH	-
	Bottom	1	*		-	5-9 60-3	*		*		10AH	40-5 30-3	10AH	20-6 50-3
		2	-	60-3	-	40-2	*		-	80-3	5AH	60-3	-	40-3
		3	-	70-3	-	60-3	*		-	20-7 60-2	-	60-3	-	60-4
		4	-	60-3	-	40-3	5AS	35-3	-	65-7 35-3	-	40-3	-	60-3

See pages 4, 36 and 37 of Manual. Areas previously rated for carbon, rate 0 for lacquer

* Ring not removed from piston (see page 1).
(1) 20CH, 40BH, 40AH
(2) 30CH, 30BH, 40AH

TABLE 5-3

RING FACE CONDITION

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973
Fuel MIL-F-16884(DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

	Cylinder Number					
	1L	2L	3L	1R	2R	3R
First Ring (1)	Normal Wear	Heavy Wear	Excessive Wear	Excessive Wear	Excessive Wear	Excessive Wear
Second Ring (1)						
Third Ring (1)						
Fourth Ring (1)						
Oil Ring Slots–% Open	100	100	100	100	100	100

Pages 1 and 2 and 59 through 65 of Manual.

(1) Chrome on ring faces is severely stressed. Individual rings displayed some or all of the following:

Storing, scuffing, ridging, cracking, checking, and pitting.

TABLE 5-4

PISTON SURFACE DEPOSITS

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973

Fuel MIL-F-16884(DFM)(AL-4669-F) Lubricant CCL-L-758 Observer J. Simpson

(REO 205)

		Piston Number					
		1L	2L	3L	1R	2R	3R
Top* A		30CA 30BA 40AHC	5CA 15BA 80AHC	30CA 20CSH 30BA 20AHC	10CA 25BA 65AHC	35DA 65ASC	25DA 10CSC 65 ASC
Combustion Chamber* A		20BA 80AA	25BA 75AM	30DS 60CA 10AA	5DA 80CA 15ASC	10DA 55CA 35BSC	20CA 60BA
Under Head* A		100-3	100-3	100-3	100-3	100-3	100-3
Skirts* A	Thrust	3.6	4.2	3.2	3.4	3.5	3.0
	Anti-Thrust	3.3	3.5	3.6	4.2	3.8	3.7
Relief Areas* A		C L	C L	C L	N/A C L	C L	C L
Lands	1	60BH - 40AH -	70BH - 30AH -	20BH - 80AH -	60BH - 40AH -	70BH - 30AH -	40BH - 60AH -
	2	70BH - 30AH -	50BH - 50AH -	60BH 35AH 5-6	80BH 20AH	75BH - 25AH -	60BH - 40AH -
	3	40BH - 60AH -	25BH 65AH 10-6	85BH - 15AH -	40BH - 60AH -	45BH 50AH 5-6	40BH 55AH 5-6
	4	20AH 45-9 35-5	35AH 45-6 20-4	10BH 60AH 30-8	45BH 40AH 15-5	15AH 10-9 15-6 40-4 20-3	35AH 45-9 15-7 5-4

Lacquer—Pages 4, 36, 37 of Manual.

*Carbon and Ash: Use Volume Factor (Pages 5 and 40 through 47)
Indicate H, M, or S (Page 5)

* The letter A in last position designates an ash deposit.

TABLE 5-5

PISTON RING GROOVE DEPOSITS

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973
Fuel MIL-F-16884 (DFM) (AL-4669-F Lubricant CCL-L-758 Observer J. Simpson

(REO 205)

		Cylinder Number											
		1L		2L		3L		1R		2R		3R	
		CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Top of Groove	1	*		100AH	-	*	-	*		10AH	90-7	15AH	85-7
	2	40AH	60-3	20AH	80-4	*	-	-	100-7	25AH	75-5	65AH	35-5
	3	-	100-3	-	100-3	*	-	-	30-7 70-4	-	100-4	5AH	95-5
	4	-	100-3	-	100-3	40AH	60-5	-	100-4	-	100-4	-	100-5
Back of Groove	1	*	-	25	-	*	-	*	-	15	-	5	-
	2	80	-	75	-	*	-	45	-	75	-	85	-
	3	1	-	10	-	*	-	10	-	15	-	25	-
	4	1	-	2	-	10		1	-	1	-	2	-
Bottom of Groove	1	*		-	100-5	*	-	*	-	10AH	90-5	-	100-4
	2	20AH	80-4	-	100-3	*	-	25AH	75-5	-	100-3	-	100-4
	3	-	100-3	-	100-3	*	-	-	100-4	-	100-3	-	100-4
	4	-	100-3	-	100-3	-	100-4	-	100-4	-	100-3	-	100-4
Drain Holes—% Blocked			0		0		0		0		0		0

Lacquer: Pages 4, 36, and 37
*Carbon and Ash: Use Volume Factor (Pages 5 and 40 through 47)
Indicate H, M, or S (Page 5)
†Carbon and Ash: Indicate Percent Filled and H, M, or S (Page 5)

* Ring not removed from piston (see page 1)
+ % volume fill

Table 5-5a

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 194
TEST LABORATORY AFLRL
LUBRICANT REO 205

RATER J, Simpson DATE 9 July 1973
LABORATORY TEST NUMBER 6D5084-6 (Test No. 6)
STAND NO. 5 ENGINE NO. 6D5084
FUEL MIL-F-16884 (DFM)

PISTON NO. 1L

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	165.25

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	**		80	80.00	1	1.00	1	1.00										
CARBON	MHC	0.75																		
CARBON	MC	0.50																		
CARBON	LC	0.25									60	15.00	70	17.50	40	10.00				
CARBON	VLC	0 15									40	6.00	30	4.50	60	9.00	20	3.00		
CARBON	CARBON RATING				80.00		1.00		1.00		21.00		22.00		19.00		3.00			
LACQUER	BL	0.100					60	6.00									45	4.50		
LACQUER	DBrL	0.075							80	6.00										
LACQUER	AL	0.050															35	1.75		
LACQUER	LAL	0.025																	100	2.50
LACQUER	VLAL	0.010																		
LACQUER	RL	0.001																		
LACQUER	LACQUER RATING		---		---		6.00		6.00		---		---		---		6.25		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING					80.00		7.00		7.00		21.00		22.00		19.00		9.25		2.50	

*WEIGHTED TOTAL DEPOSITS

**Pinched ring not removed

Table 5-5b

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 194
TEST LABORATORY AFLRL
LUBRICANT REO 205

RATER J. Simpson DATE 9 July 1973
LABORATORY TEST NUMBER 6D5084-6 (Test No. 6)
STAND NO. 5 ENGINE NO. 6D5084
FUEL MIL-F-16884 (DFM)

PISTON NO. 2L

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	187.13

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1		GROOVES NO. 2		GROOVES NO. 3		GROOVES NO. 4		LANDS NO. 1		LANDS NO. 2		LANDS NO. 3		LANDS NO. 4		UNDER-CROWN	
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00	25	25.00	75	75.00	10	10.00	2	2.00										
	MHC	0.75																		
	MC	0.50																		
	LC	0.25									70	17.50	50	12.50	25	6.25				
	VLC	0.15									30	4.50	50	7.50	65	9.75	35	5.25		
	CARBON RATING		25.00		75.00		10.00		2.00		22.00		20.00		16.00		5.25			
LACQUER	BL	0.100																		
	DBrL	0.075							60	4.5							45	3.38		
	AL	0.050													10	0.50	20	1.00		
	LAL	0.025																	100	2.50
	VLAL	0.010																		
	RL	0.001																		
	LACQUER RATING		---		---		---				---		---		0.50		4.38		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			25.00		75.00		10.00		6.50		22.00		20.00		16.50		9.63		2.50	

*WEIGHTED TOTAL DEPOSITS

Table 5-5c

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 194
TEST LABORATORY AFLRL
LUBRICANT REO 205

RATER J. Simpson DATE 9 July 1973
LABORATORY TEST NUMBER 6D5084-6 (Test No. 6)
STAND NO. 5 ENGINE NO. 6D5084
FUEL MIL-F-16884 (DFM)

PISTON NO. 3L

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	80.71

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
			NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4			
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00	**		**		**		10	10.00										
	MHC	0.75																		
	MC	0.50																		
	LC	0.25									20	5.00	60	15.00	85	21.25	10	2.50		
	VLC	0.15									80	1.20	35	5.25	15	2.25	60	9.00		
	CARBON RATING								10.00		6.20		20.25		23.50		11.50			
LACQUER	BL	0.100															30	3.00		
	DBrL	0.075							45	3.38			5	0.38						
	AL	0.050																		
	LAL	0.025																	100	2.50
	VLAL	0.010																		
	RL	0.001																		
	LACQUER RATING		---		---		---		3.38		---		0.38		---		3.00		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING									13.38		6.20		20.63		23.50		14.50		2.50	

*WEIGHTED TOTAL DEPOSITS

**Stuck rings - not removed

Table 5-5d

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 194
TEST LABORATORY AFLRL
LUBRICANT REO 205

RATER J. Simpson DATE 9 July 1973
LABORATORY TEST NUMBER 6D5084-6 (Test No. 6)
STAND NO. 5 ENGINE NO. 6D5084
FUEL MIL-F-16884 (DFM)

PISTON NO. 1R

NO. 1 GROOVE, VOLUME %	
PISTON WTD* RATING	142.50

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	**		45	45.00	10	10.00	1	1.00										
	MHC	0.75																		
	MC	0.50																		
	LC	0.25									60	15.00	80	20.00	40	10.00	45	11.25		
	VLC	0.15									40	6.00	20	3.00	60	9.00	40	6.00		
	CARBON RATING				45.00		10.00		1.00		21.00		23.00		19.00		17.25			
LACQUER	BL	0.100					10	1.00	20	2.00										
	DBrL	0.075																		
	AL	0.050															15	0.75		
	LAL	0.025																	100	2.50
	VLAL	0.010																		
	RL	0.001																		
	LACQUER RATING										---		---		---		0.75		2.50	
CLEAN		0																		
ZONAL RATING			---		---		1.00		2.00											
LOCATION FACTOR																				
WEIGHTED RATING					45.00		11.00		3.00		21.00		23.00		19.00		18.00		2.50	

*WEIGHTED TOTAL DEPOSITS

**Stuck ring not removed

Table 5-5e

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 194
TEST LABORATORY AFLRL
LUBRICANT REO 205

RATER J. Simpson DATE 9 July 1973
LABORATORY TEST NUMBER 6D5084-6 (Test No. 6)
STAND NO. 5 ENGINE NO. 6D5084
FUEL MIL-F-16884 (DFM)

PISTON NO. 2R

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	280.51

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
			NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4			
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00	15	15.00	75	75.00	15	15.00	1	1.00										
	MHC	0.75																		
	MC	0.50																		
	LC	0.25									70	17.50	75	18.75	45	11.25				
	VLC	0.15									30	4.50	25	3.75	50	7.50	15	2.25		
	CARBON RATING		15.00		75.00		15.00		1.00		22.00		22.50		18.75		2.25			
LACQUER	BL	0.100															10	1.00		
	DBrL	0.075							20	1.50					5	0.38	15	1.13		
	AL	0.050															40	2.00		
	LAL	0.025															20	0.50	100	2.50
	VLAL	0.010																		
	RL	0.001																		
	LACQUER RATING		---		---		---		1.50		---		---		0.38		4.63		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			15.00		75.00		15.00		2.50		22.00		22.50		19.13		6.88		2.50	

*WEIGHTED TOTAL DEPOSITS

Table 5-5f

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 194
TEST LABORATORY AFLRL
LUBRICANT REO 205

RATER J. Simpson DATE 9 July 1973
LABORATORY TEST NUMBER 6D5084-6 (Test No. 6)
STAND NO. 5 ENGINE NO. 6D5084
FUEL MIL-F-16884 (DFM)

PISTON NO. 3R

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	193.26

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	NO. 1 DEMERIT	NO. 2 AREA-%	NO. 2 DEMERIT	NO. 3 AREA-%	NO. 3 DEMERIT	NO. 4 AREA-%	NO. 4 DEMERIT	LANDS NO. 1 AREA-%	NO. 1 DEMERIT	NO. 2 AREA-%	NO. 2 DEMERIT	NO. 3 AREA-%	NO. 3 DEMERIT	NO. 4 AREA-%	NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	5	5.00	85	85.00	25	25.00	2	2.00										
CARBON	MHC	0.75																		
CARBON	MC	0.50																		
CARBON	LC	0.25									40	10.00	60	15.00	40	10.00				
CARBON	VLC	0.15									60	9.00	40	6.00	55	8.25	35	5.25		
CARBON RATING			5.00		85.00		25.00		2.00		19.00		21.00		18.25		5.25			
LACQUER	BL	0.100	5	0.50			20	2.00									45	4.50		
LACQUER	DBrL	0.075							20	1.50					5	0.38	15	1.13		
LACQUER	AL	0.050															5	0.25		
LACQUER	LAL	0.025																	100	2.50
LACQUER	VLAL	0.010																		
LACQUER	RL	0.001																		
LACQUER RATING			0.50		---		2.00		1.50		---		---		0.38		5.88		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			5.50		85.00		27.00		3.50		19.00		21.00		18.63		11.13		2.50	

*WEIGHTED TOTAL DEPOSITS

TABLE 5-6

PISTON GROOVE INSIDE DIAMETER–% RING SUPPORTING CARBON

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973
Fuel MIL-F-16884 (DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

Piston Ring	Quadrant	Piston Number					
		1L	2L	3L	1R	2R	3R
1	1	a +	0	b +	b +	0	0
	2	a +	40	b +	b +	0	0
	3	a +	40	b +	b +	0	0
	4	a +	20	b +	b +	0	0
2	1	15	60	b +	0	60	60
	2	20	70	b +	25	90	100
	3	75	70	b +	10	100	100
	4	100	70	b +	80	10	10

+ Ring not removed from piston (see page 1)
a - cold pinch
b - hot stuck

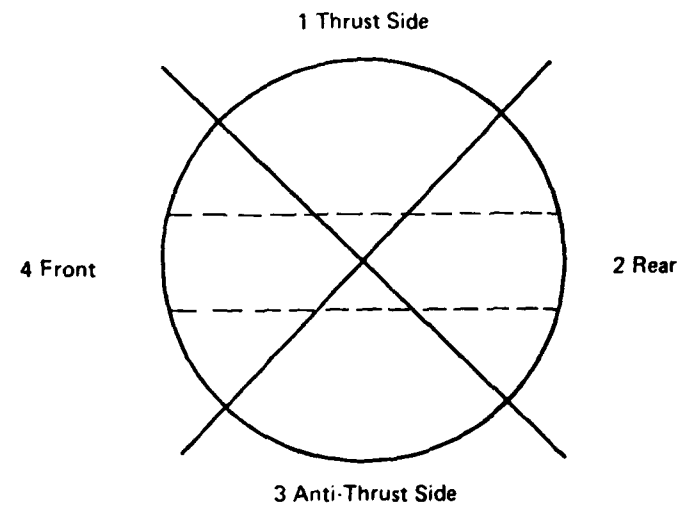


TABLE 5-7

PISTON SURFACE CONDITION

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973

Fuel MIL-F-16884(DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

	Piston Number					
	1L	2L	3L	1R	2R	3R
Top Land	----------	----------	-----Normal	----------	----------	----------
Skirt	20% Scuffing	1% Scored 5% Light Scuffing	10% Scuffing	20% Scuffing	5% Scuffing	20% Scuffing
Piston Pin	----------	----------	-----Normal	----------	----------	----------

Pages 1 through 2 and 59 through 65 of Manual.

TABLE 5-8

VALVE DEPOSITS

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973

Fuel MIL-F-16884 (DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

		Cylinder Number											
		1L		2L (1)		3L		1R		2R		3R	
		CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LARQ
Head	INT												
	EXH	100ASC		A to B depth soft carbon		C depth soft carbon		100ASC	100ASC	100ASC	100ASC	100ASC	100ASC
Face	INT												
	EXH	Normal		Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Tulip†	INT												
demerits	EXH	0.5		0.5		0.5		0.5		0.5		0.5	
Stem	INT												
	EXH	0		0		0		0		0		0	

*Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of Manual).

†Use Chart, Page 21—Indicate H, M, or S (Page 5).

Lacquer: Pages 4, 36 and 37.

(1) The head of one exhaust valve was broken (burned ?)

TABLE 5-9

EXHAUST VALVE SURFACE CONDITIONS

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973

Fuel MIL-F-16884 (DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

	1L	2L	3L	1R	2R	3R
Freeness in Guide	Free	Free	Free	Free	Free	Free
Head		(1)	Normal			
Face	(2)	(1)	(2)	(2)	(2)	(2)
Seat			Normal			
Stem			Normal			
Tip			Normal			

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

(1) Broken or burned - one valve only
(2) Evidence of leakage

TABLE 5-10

TAPPETS, CAMS, AND ROCKER ARMS

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973
Fuel MIL-F-16884 (DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

			Cylinder Number					
			1L	2L	3L	1R	2R	3R
Tappet Deposit		INT						
		EXH	----------	----------	Not Rated	----------	----------	----------
Tappet Surface Condition		INJ	----------	----------	Not Rated	----------	----------	----------
		INT						
		EXH	----------	----------	Not Rated	----------	----------	----------
Cam Lobes			----------	----------	Normal	----------	----------	----------
Rocker Arms	Tip	INT						
		EXH	----------	----------	Not Rated	----------	----------	----------
	Bushing	INT						
		EXH	----------	----------	Not Rated	----------	----------	----------
	Shaft	INT						
		EXH	----------	----------	Not Rated	----------	----------	----------

Lacquer: Pages 4, 36 and 37 of Manual
See Pages 1, 2, 16 through 23, and 54 through 65.

TABLE 5-11

CYLINDER LINERS AND CYLINDER HEADS

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973
Fuel MIL-F-16884 (DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

Cylinder Liner Scuffing
Percent of Total Ring Travel Area (1)

Cylinder Number	Percent Port Restriction	Percent Scuffed		% Total Area Scuffed	% Glazed	% Lacquer
		Thrust	Anti-Thrust			
1L		3	12	7.5	55	25
2L		6	3	4.5	45	10
3L		35	15	25	40	25
1R		10	25	17.5	35	30
2R		5	5	5	30	35
3R		20	15	17.5	60	35
Average		13	13	13	44	28

(1) Percent scuffed in compression ring travel area.

Cylinder Head Deposits*

%	1L	2L	3L	1R	2R	3R
HC						
MC						
SC						

* Not rated, too much carbon had fallen off due to temperature and humidity changes.

Carbon and Ash: Use Volume Factor Pages 5 and 40 through 47
Indicate H, M, or S
Lacquer: Use Pages 4, 36, and 37
For Surface Condition—See Pages 1, 2, 16 through 23 and 54 through 65

TABLE 5-12

SURFACE CONDITION

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973
Fuel MIL-F-16884 (DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

Bearing No.	1	2	3	4			
Main—Bearing	NORMAL WITH LIGHT PITTING						
—Journal	NORMAL						
Rod—Bearing	1L	2L	3L	1R	2R	3R	
	NORMAL WEAR						
—Journal	NORMAL						
Piston Pin	NORMAL						
Bushing	NORMAL						

Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

TABLE 5-13

SLUDGE DEPOSITS

Engine Model 6V53T Serial No. 6D5084-6 Date 9 July 1973
Fuel MIL-F-16884 (DFM) (AL-4669-F) Lubricant CCL-L-758 (REO 205) Observer J. Simpson

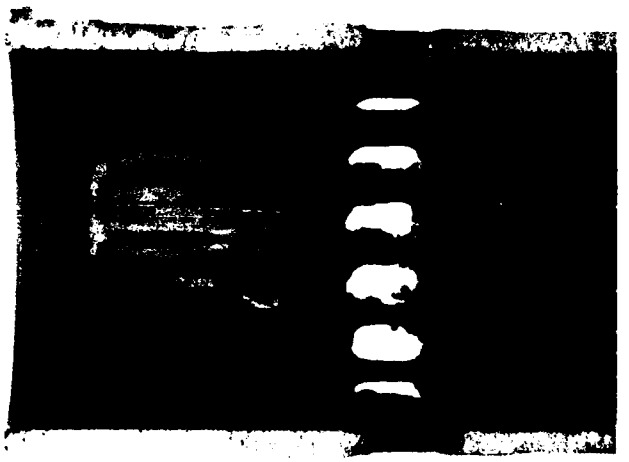
	Rating
Connecting Rods	Clean
Rocker Arm Covers	0.5
Top Deck	0.5
Push Rod Covers	-
Push Rod Chamber	-
Timing Gear Cover	-
Oil Pan	0.5
Oil Screen	Clean

See pages 5 and 40 to 47 of Manual.

Use CRC Volume Factor Technique.

Figure 6-1

TEST 6 194 HRS OIL CODE
CCL-L-758 (REO 205)



3 Right Thrust
A

3 Right Thrust
A

Figure 6-2

TEST 6 194 HRS OIL CODE
CCL-L-758 (REO 205)

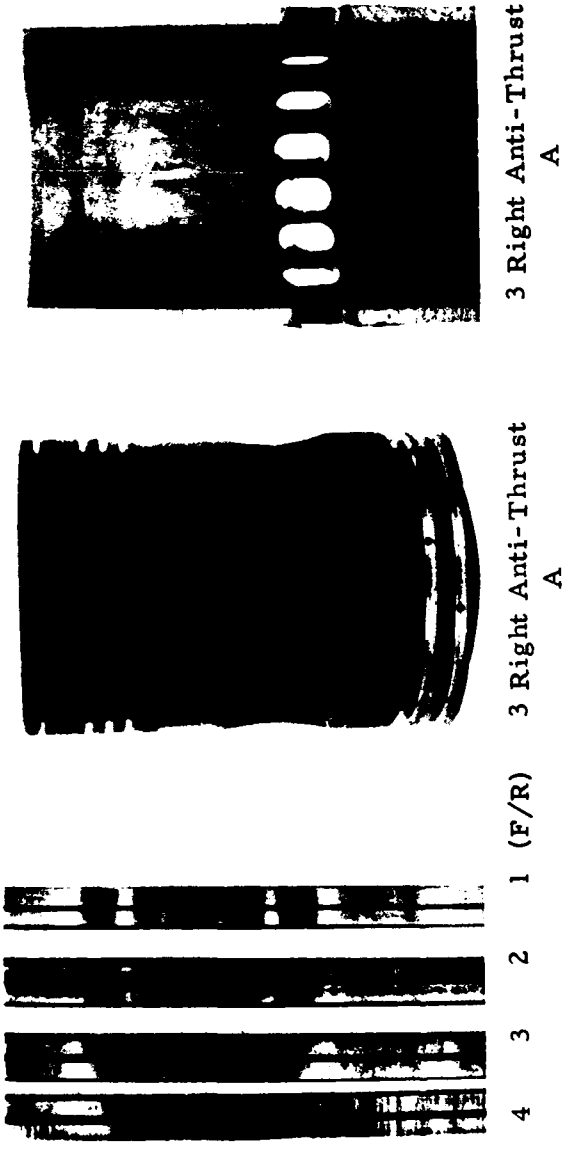
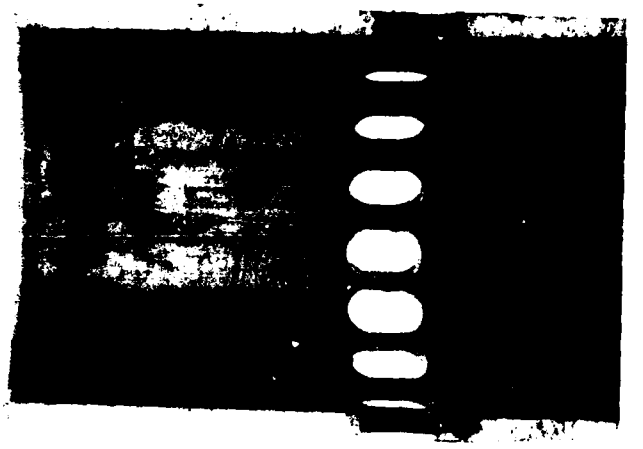


Figure 6-3

TEST 6

194 HRS

OIL CODE
CCL-L-758 (REO 205)

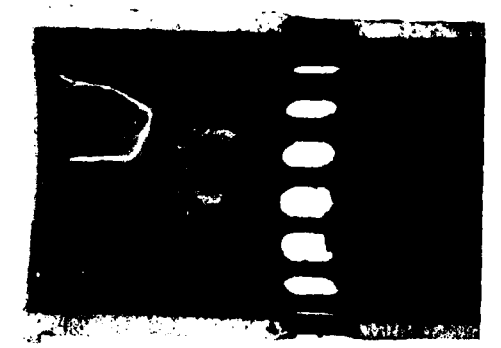


3 Left Thrust
W

3 Left Thrust
W

Figure 6-4

TEST 6 194 HRS OIL CODE CCL-L-758 (REO 205)



3 Left Anti-Thrust W

3 Left Anti-Thrust W

4

APPENDIX IV

Test Number 7

Fuel: MIL-F-16884 (DFM)
Oil: REO 203, CCL-L-759
Engine No.: 6D5204-1
Test Hours: 196
Date Completed: 6 August 1973

TABLE 1
6V53T 6D5204-1
BUILD-UP ENGINE MEASUREMENTS

Measurements	Inches Min.	Max.	Avg.	Specified Limits (1)
Crankshaft main bearing clearance	.0035	.0050	.0043	.0070 max.
Camshaft bearing clearance				
Left cam	.0051	.0064	.0057	.0080 max.
Right cam	.0055	.0065	.0062	.0080 max.
Connecting rod bearing clearance	.0018	.0037	.0025	.0016-.0046
Crankshaft end-play	.007	.007	.007	.004-.011
Oil pump				
Between rotors	.005	.005	.005	.004-.011
Outer rotor/housing	.0025	.0025	.0025	.001-.0035
Cylinder liner block bore				
Taper	.0000	.0004	.0002	.0015 max.
Out-of-round	.0000	.0005	.0002	.0015 max.
Inside diameter	4.3564	4.3578	4.3571	4.3595 max.
Cylinder liners (installed)				
Taper	.0000	.0016	.0005	.002 max. (2)
Out-of-round	.0000	.0014	.0004	.003 max. (2)
Inside diameter	3.8755	3.8776	3.8764	3.8752-3.8767
Piston to liner fit	.0072	.0088	.0079	.0060-.0095
Piston Diameter	3.8679	3.8690	3.8686	3.8669-3.8691
Fire ring				
End gap	.024	.038	.031	.020-.046
Side clearance	.003	.004	.004	.003-.006
#1 Compression ring				
End gap	.024	.032	.028	.020-.046
Side clearance	.007	.008	.008	.007-.010
#2 & #3 Compression rings				
End gap	.025	.040	.031	.020-.046
Side clearance	.006	.007	.006	.005-.008
Oil rings				
End gap	.018	.026	.022	.010-.025
Side clearance	.002	.004	.003	.0015-.0055

(1) Limits on new parts unless maximum wear limit specified.
(2) Wear limits with new liners in a used block.

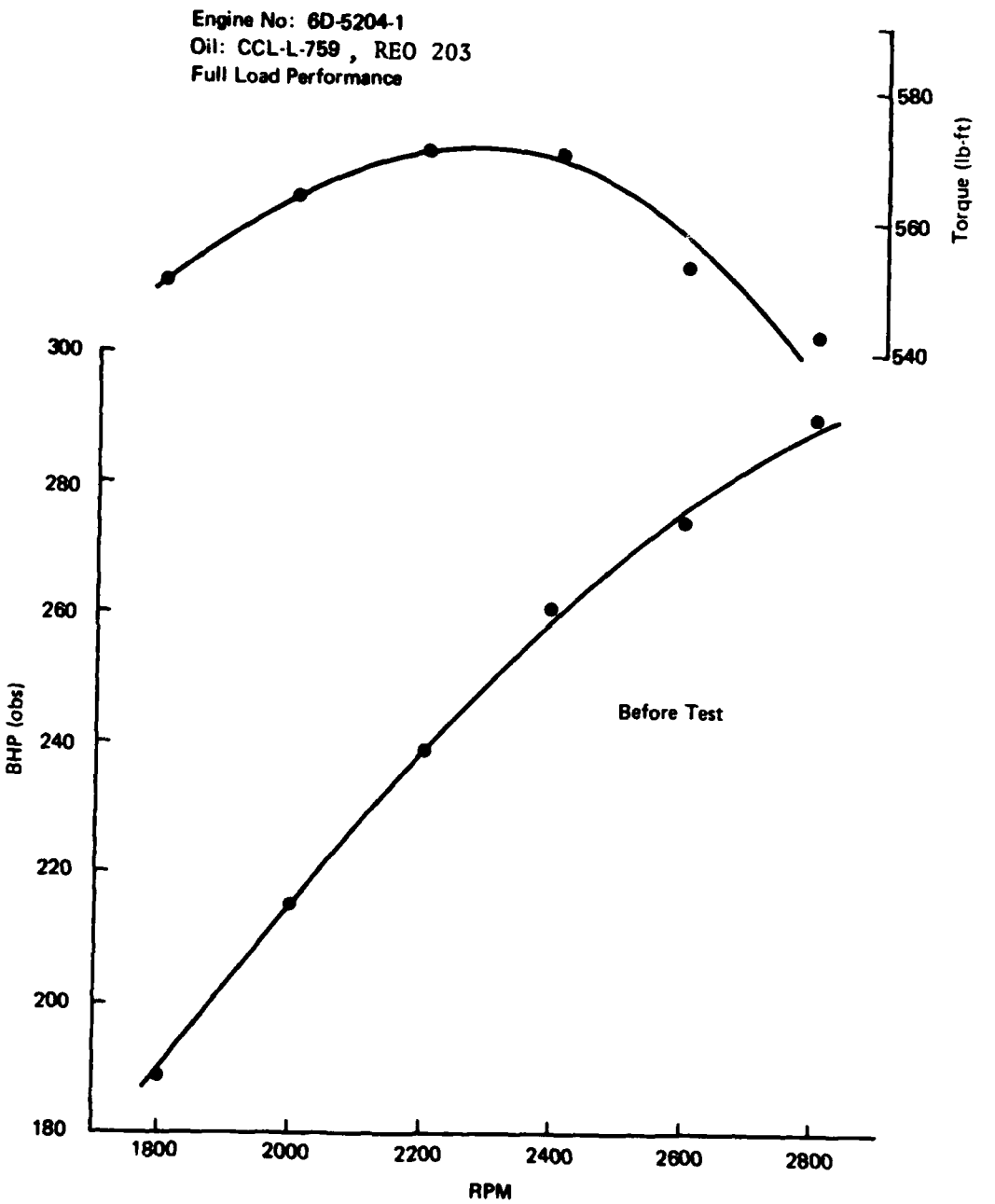

Engine No: 6D-5204-1
Oil: CCL-L-759 , REO 203
Full Load Performance
580
560
540
Torque (lb-ft)
300
280
260
240
220
200
180
BHP (obs)
Before Test
1800
2000
2200
2400
2600
2800
RPM

FIGURE 1

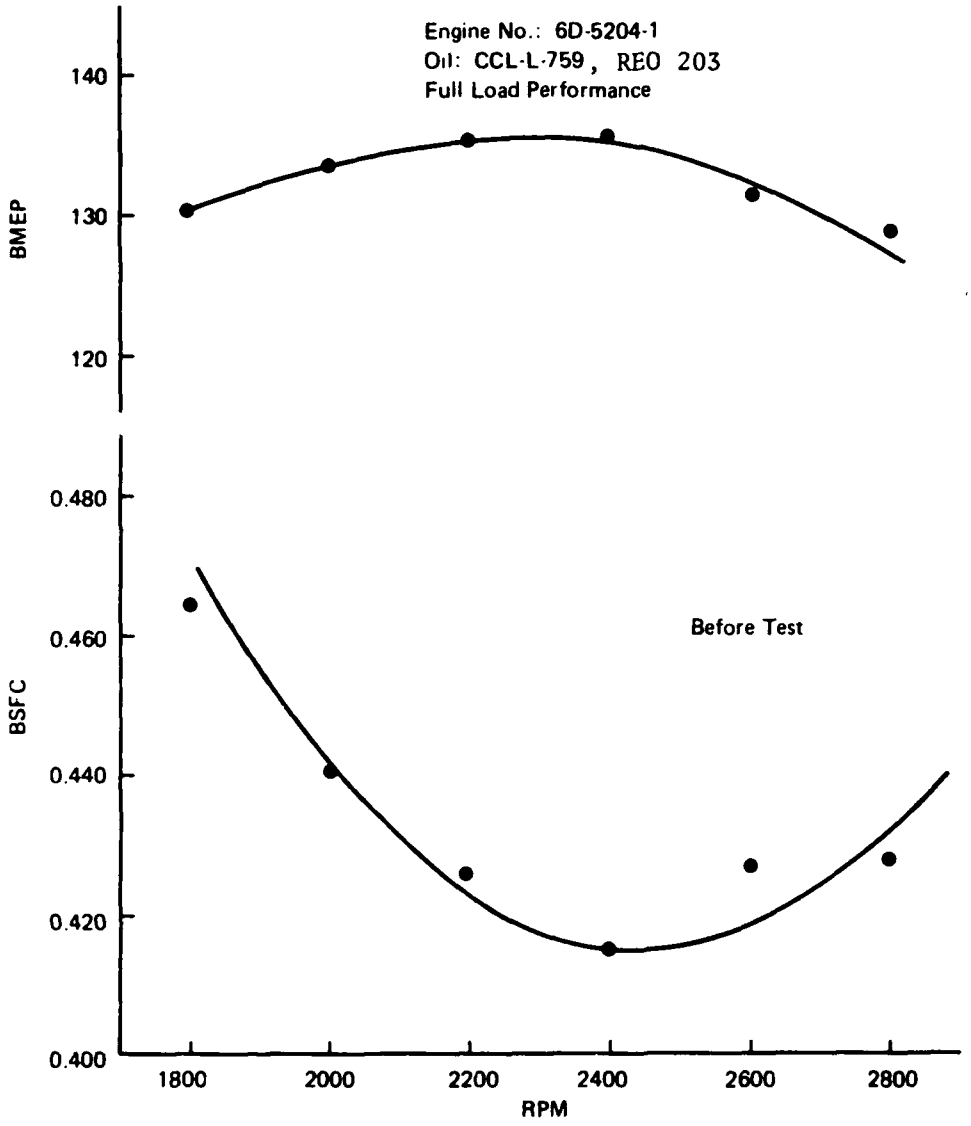

Engine No.: 6D-5204-1
Oil: CCL-L-759, REO 203
Full Load Performance
BMEP
140
130
120
BSFC
0.480
0.460
0.440
0.420
0.400
Before Test
1800
2000
2200
2400
2600
2800
RPM

FIGURE 2

TABLE 2

SUMMARY OF OPERATING DATA

Engine Test No. 6D5204-1 Oil Code CCL-L-759 REO 203

	Power Mode			Idle Mode
	Min.	Max.	Avg.	Avg.
Engine speed, rpm, 2800±20/ 650±10	2800	2800	2800	640
Load, lbs.	412	428	421	
BHp, obs. (2800.4100) x load	281	292	287	
Fuel/cycle, mm^3,	65.9	68.4	67.6	
Fuel rate, lb/min	2.01	2.09	2.06	
Oil consumption, (lb/hr Avg for 196 Hrs)			0.52	
Temperatures, ^oF				
Jacket-in	168	174	170	
Jacket-out 180±5/100±2	170	186	181	98
Oil sump	232	240	236	121
Inlet air (compressor)	78	114	99	
Airbox	272	300	290	
Exhaust before turbo	1020	1100	1070	
Exhaust after turbo	860	930	900	
Fuel at filter (secondary)	85	100	90	
Pressures				
Compressor suction, in. H_2O	6.6	12.9	8.0	
Compressor discharge in. Hg	21.0	24.3	23.0	
Blower discharge (airbox), in.Hg	34.0	37.7	35.8	
Crankcase, dipstick tube in. H_2O	4.9	6.0	5.4	
Exhaust before turbo, in. Hg	23.8	26.9	25.0	
Exhaust after turbo, in. Hg	1.6	2.9	1.9	
Oil gallery, psi	40.0	41.5	40.8	26
Fuel at filter, psi	67.5	71.0	69.6	
Blowby flow, cfh at 29.92 in. Hg and 115^oF	830	1030	910	

Unscheduled Shutdowns

At 137 Hrs: Repair auxiliary oil cooler water line - Lost 30 minutes.

At 196 Hrs: Test terminated due to high crankcase pressure.

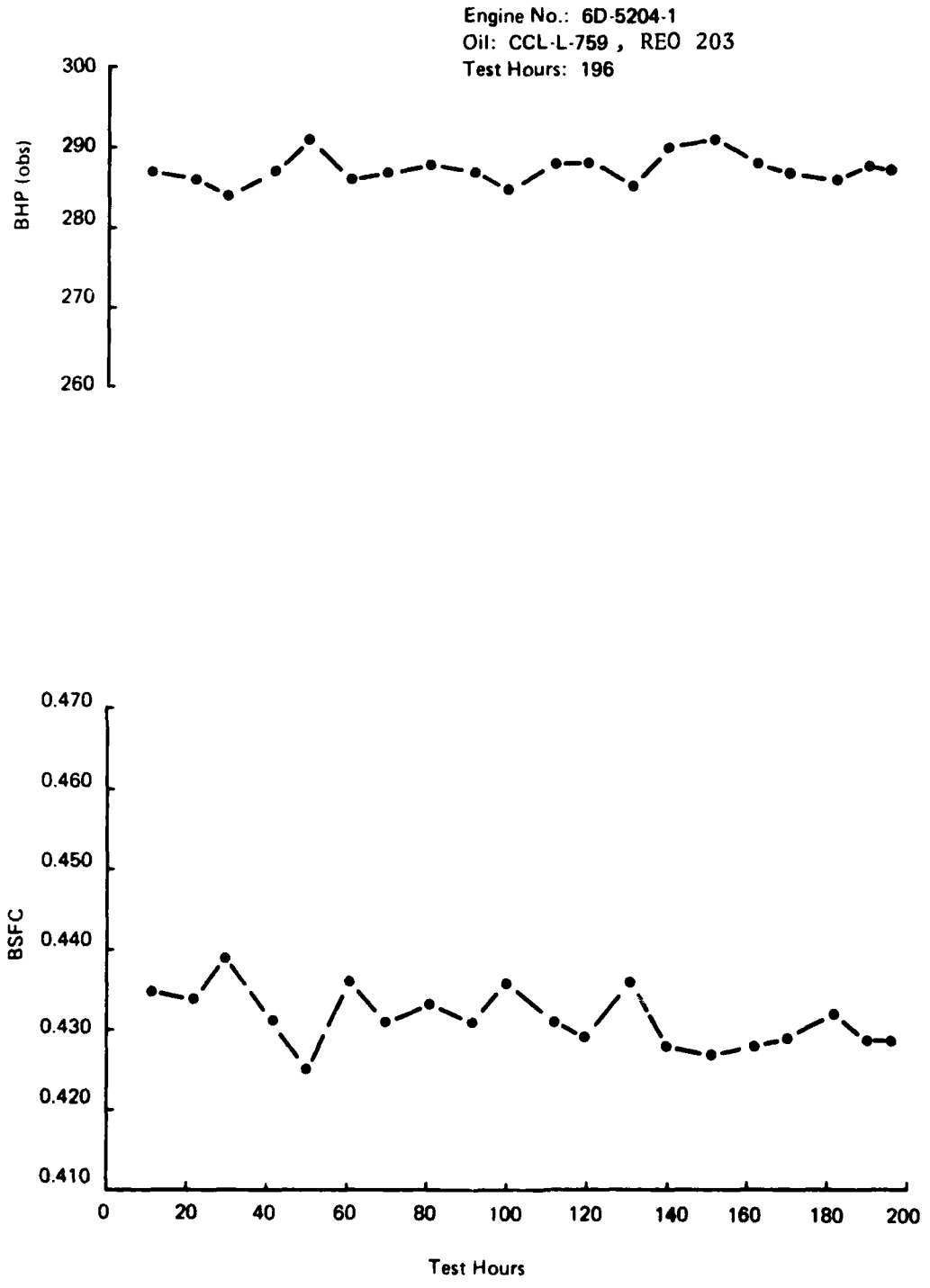

Engine No.: 6D-5204-1
Oil: CCL-L-759 , REO 203
Test Hours: 196
BHP (obs)
300
290
280
270
260
BSFC
0.470
0.460
0.450
0.440
0.430
0.420
0.410
0
20
40
60
80
100
120
140
160
180
200
Test Hours

FIGURE 3

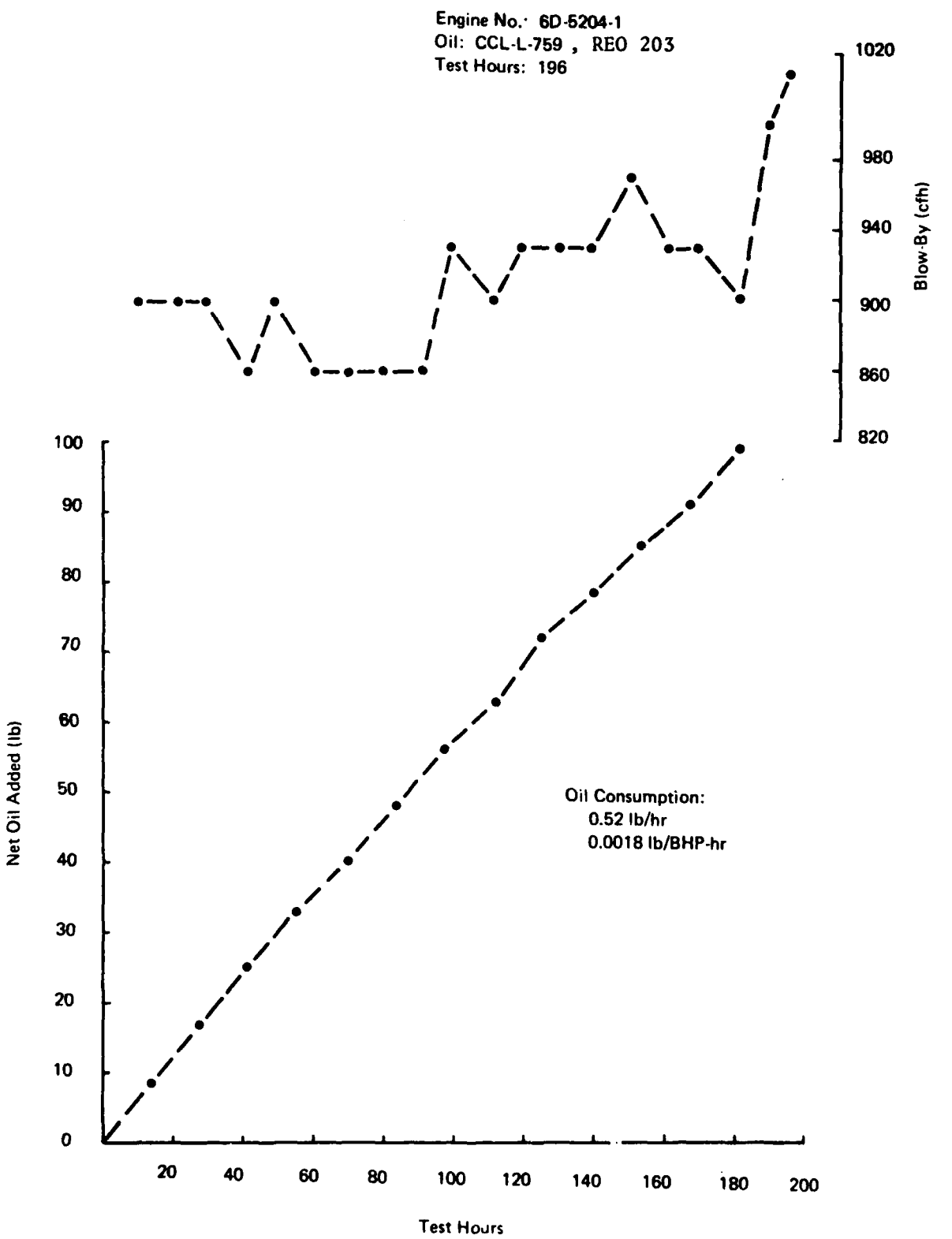
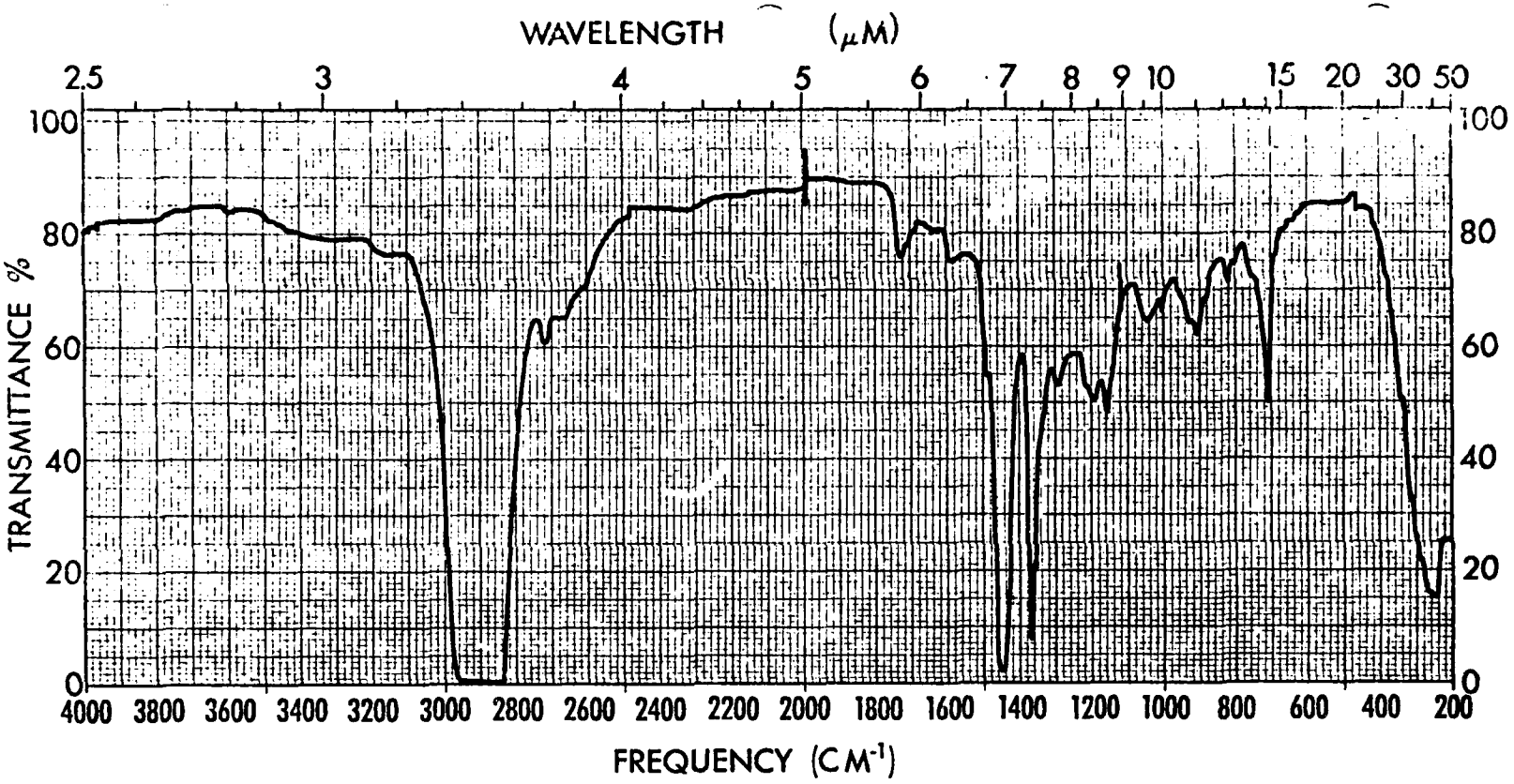

Engine No.· 6D-5204-1
Oil: CCL-L-759 , REO 203
Test Hours: 196
1020
980
940
900
860
820
Blow-By (cfh)
100
90
80
70
60
50
40
30
20
10
0
Net Oil Added (lb)
Oil Consumption:
0.52 lb/hr
0.0018 lb/BHP-hr
20
40
60
80
100
120
140
160
180
200
Test Hours

FIGURE 4

TABLE 3
LUBRICANT ANALYSES
6V53T - 6D5204-1
Oil: CCL-L-759 REO 203

Property	New Oil	Test Hours 42	70	98	140	168	196
K. Vis, Cs, 100	121.60	128.76	132.52	134.69	136.07	137.37	137.83
K. Vis, Cs, 210	12.61	13.00	13.24	13.38	13.54	13.58	13.73
V-I	94	103	102	102	103	103	104
TAN (D664)	3.6	3.01	4.22	3.59	4.48	3.69	4.48
TBN (D2896)	5.4	2.66	3.68	2.95	3.84	3.09	3.84
Insolubles (D893). %							
Pentane A	N.D.	0.04	0.04	0.05	0.05	0.06	0.05
Benzene A	N.D.	0.03	0.03	0.05	0.04	0.05	0.05
Pentane B	N.D.	0.14	0.21	0.30	0.22	0.43	0.32
Benzene B	N.D.	0.24	0.18	0.28	0.17	0.35	0.26
Gravity °API (D287)	27.5	N.D.	N.D.	N.D.	N.D.	N.D.	26.4
Pour (D97), °F	-5	N.D.	N.D.	N.D.	N.D.	N.D.	+5
Carbon Residue (D524),%	1.19	N.D.	N.D.	N.D.	N.D.	N.D.	1.85
Flash Pt. (D92),°F	465	473	476	470	477	470	479
S. Ash (D872),%	0.93	1.05	1.06	1.11	1.05	1.13	1.03
Metals PPM, A.A.							
Na	40	45	48	50	50	51	52
Cu	N.D.	8	9	9	8	10	10
Cr	N.D.	4	6	8	8	9	10
Pb	N.D.	28	26	26	29	27	29
Sn	N.D.	0	0	0	0	0	0
Fe	N.D.	74	102	132	155	163	183
Al	N.D.	0	0	0	0	0	0
I.R. Trace No.	252	308	309	310	311	312	313

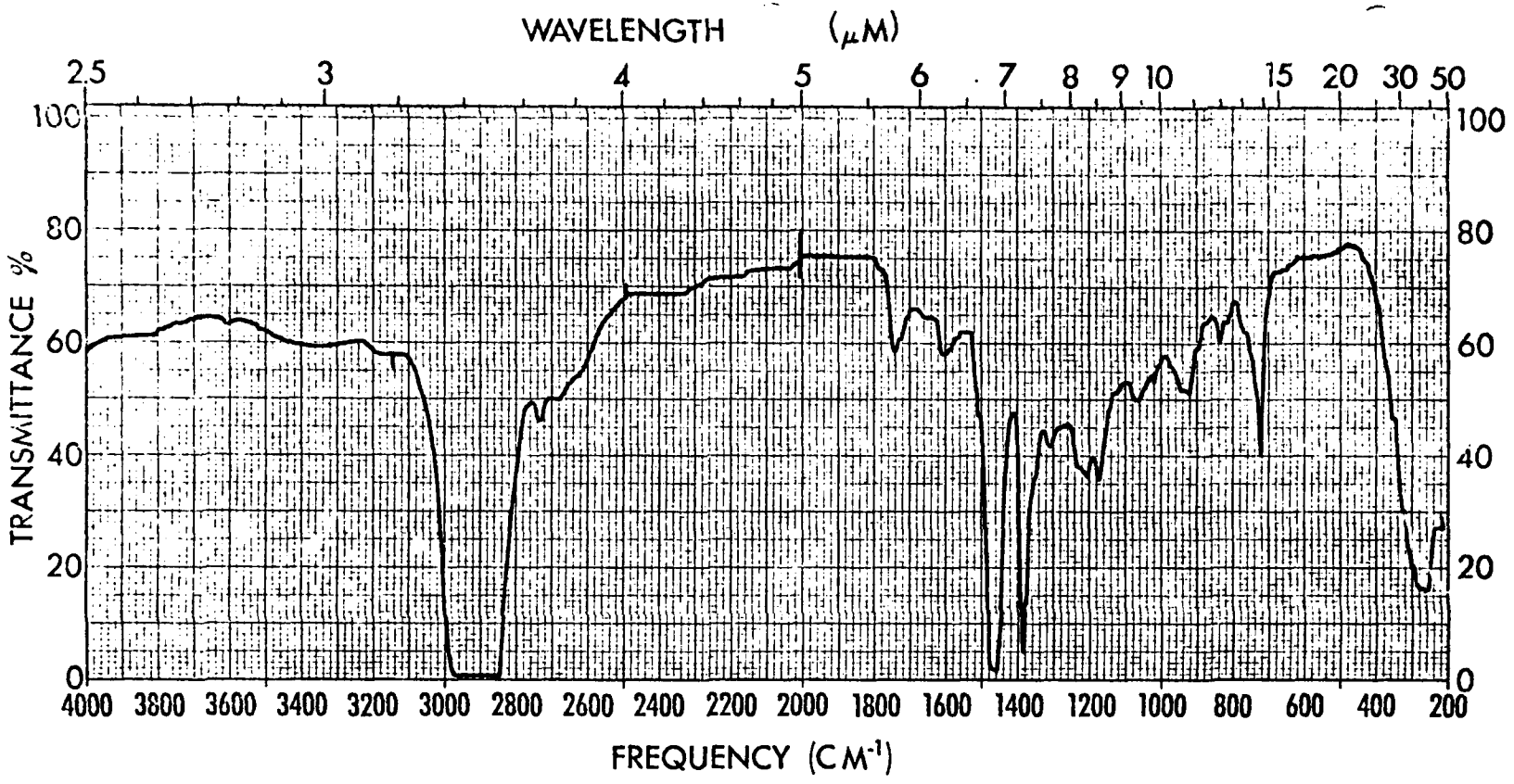
N.D. - Not Determined



SPECTRUM NO. 252	ORIGIN	LEGEND	REMARKS
SAMPLE AL-5062-L		1.	
REO 203-73 Dr No. 1	PURITY	2.	
New Oil	PHASE	DATE 7-19-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO. 252
SAMPLE

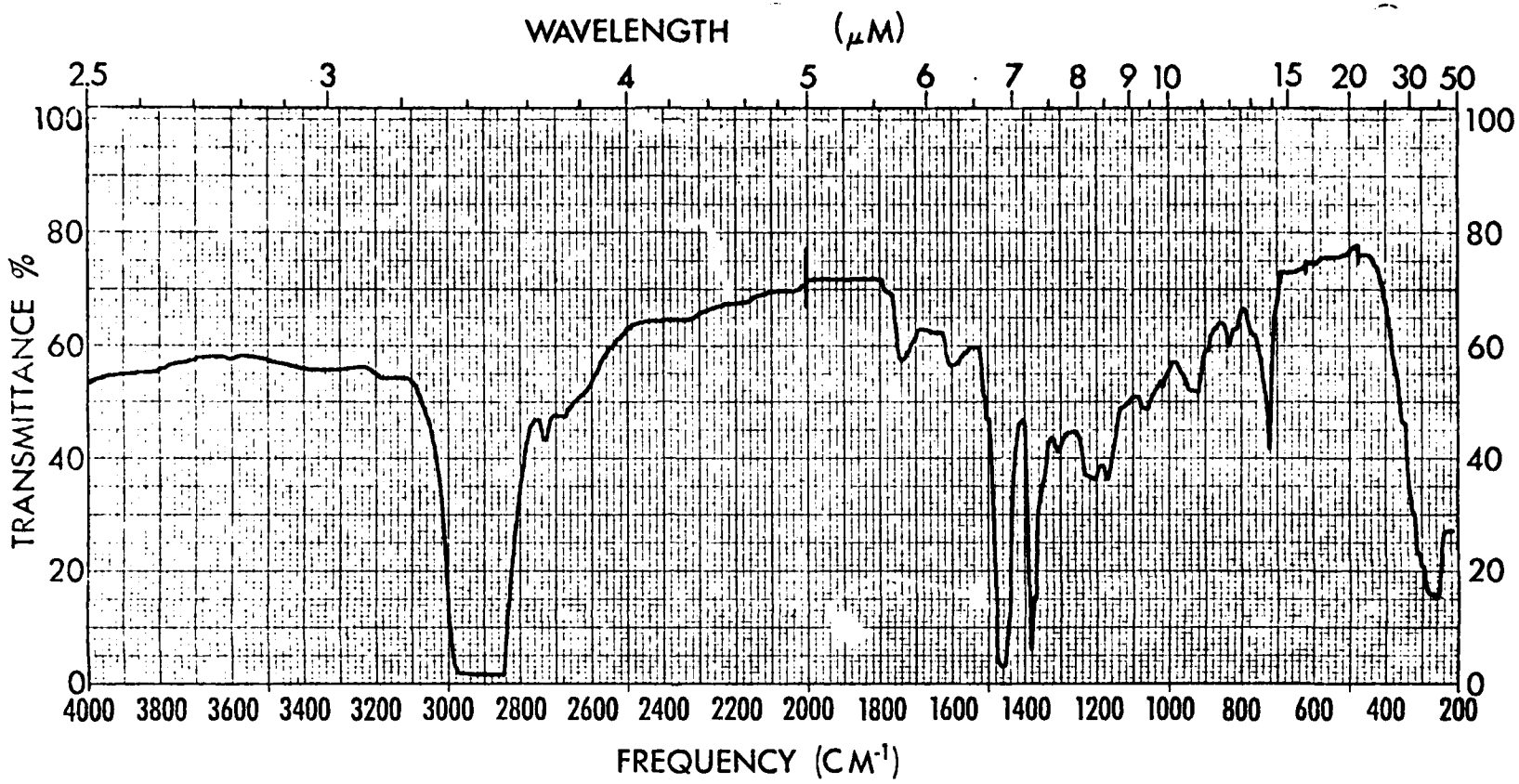
FIGURE 5-1



SPECTRUM NO. 308	ORIGIN	LEGEND	REMARKS
SAMPLE AL-5062-L		1.	
42 Hr	PURITY	2.	
REO 20	PHASE	DATE 8-17-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO. SAMPLE

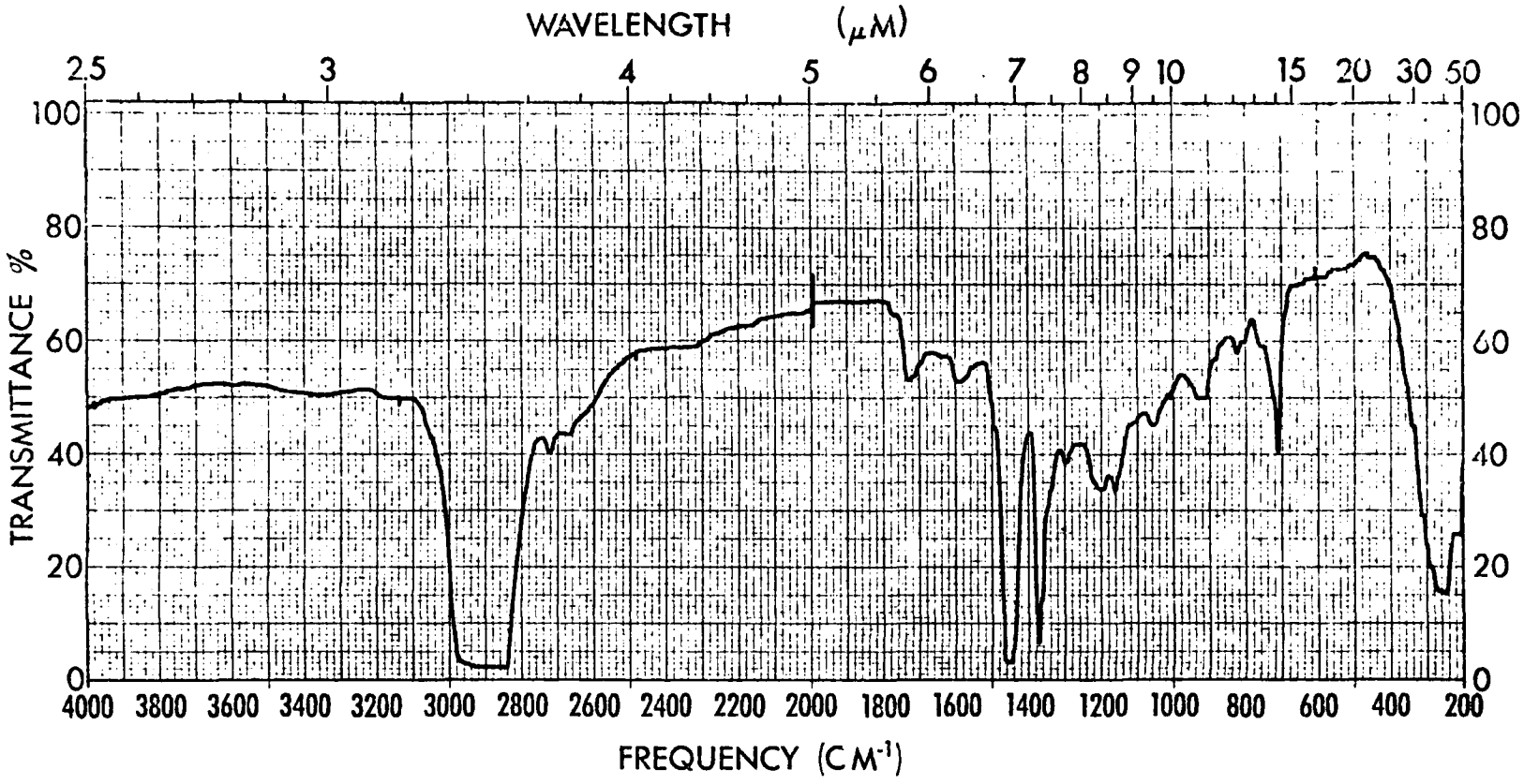
FIGURE 5-2



SPECTRUM NO. 309	ORIGIN	LEGEND	REMARKS
SAMPLE AL-5062-L		1.	
70 Hr	PURITY	2.	
REO 203	PHASE	DATE 8-17-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO.
SAMPLE

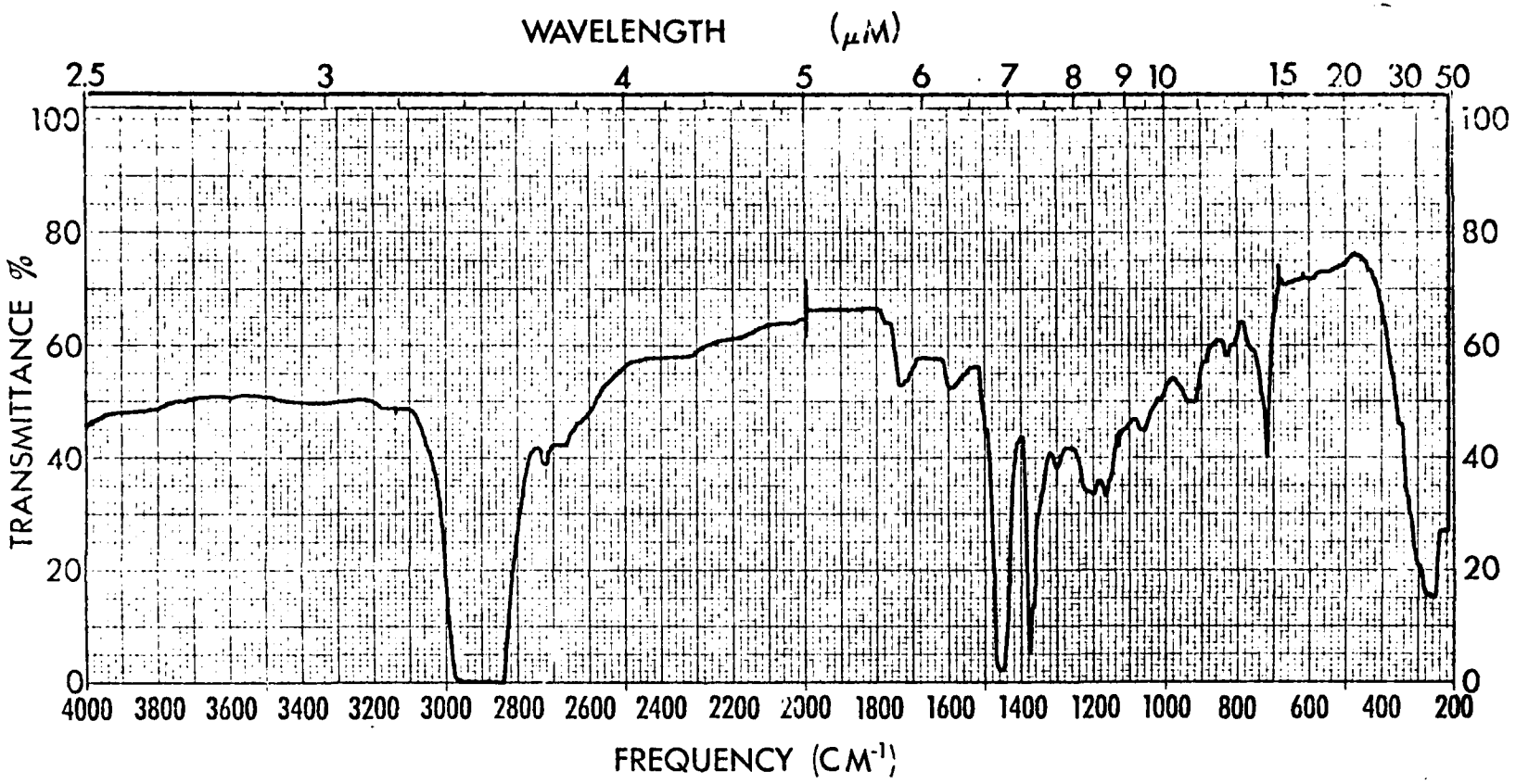
FIGURE 5-3



SPECTRUM NO. 310	ORIGIN	LEGEND	REMARKS
SAMPLE AL-5062-L		1.	
98 Hr	PURITY	2.	
REO 203	PHASE	DATE 8-17-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO.
SAMPLE

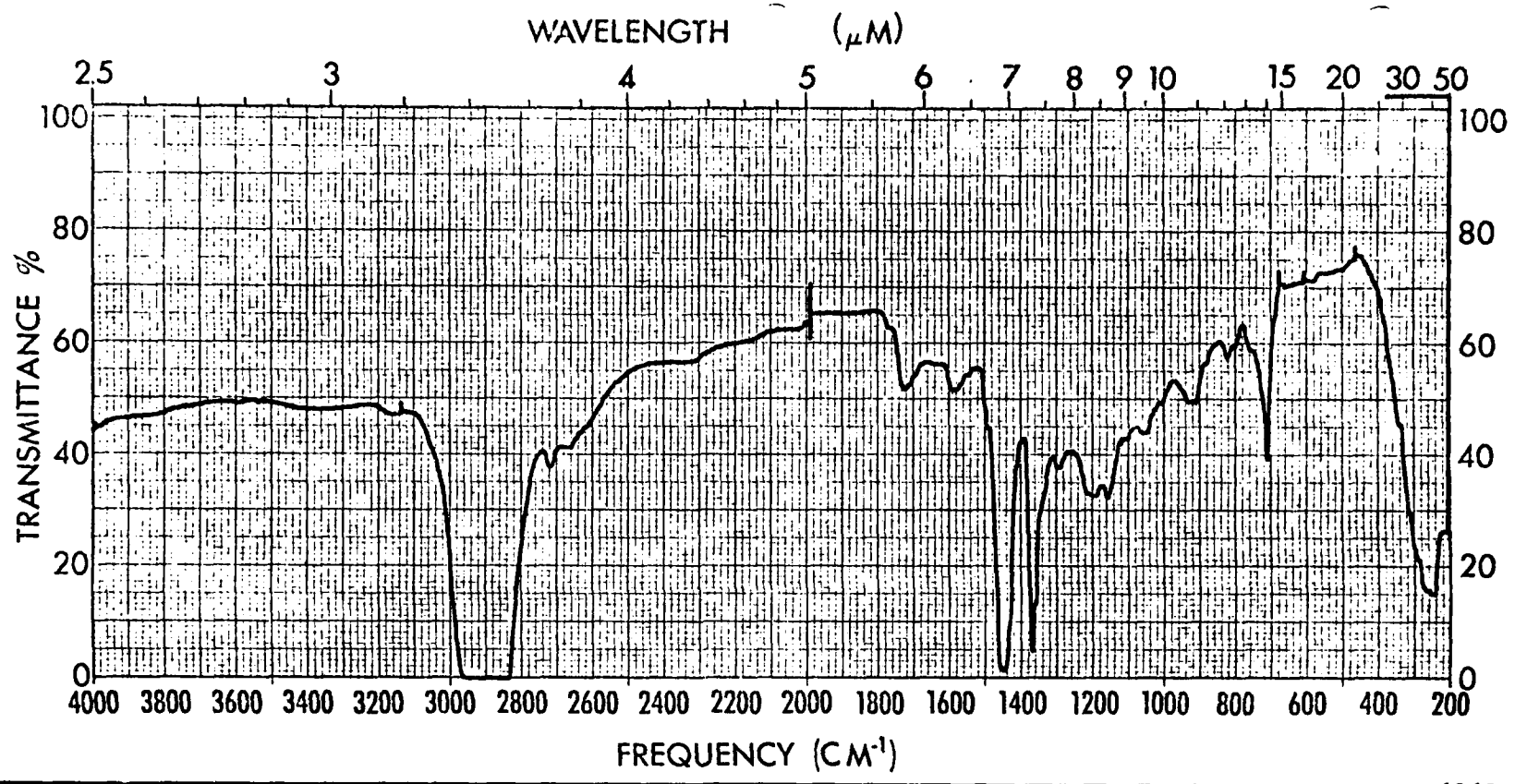
FIGURE 5-4



SPECTRUM NO. 311	ORIGIN	LEGEND	REMARKS
SAMPLE AL-5062-L		1.	
140 Hr	PURITY	2.	
REO 203	PHASE	DATE 8-17-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO.
SAMPLE

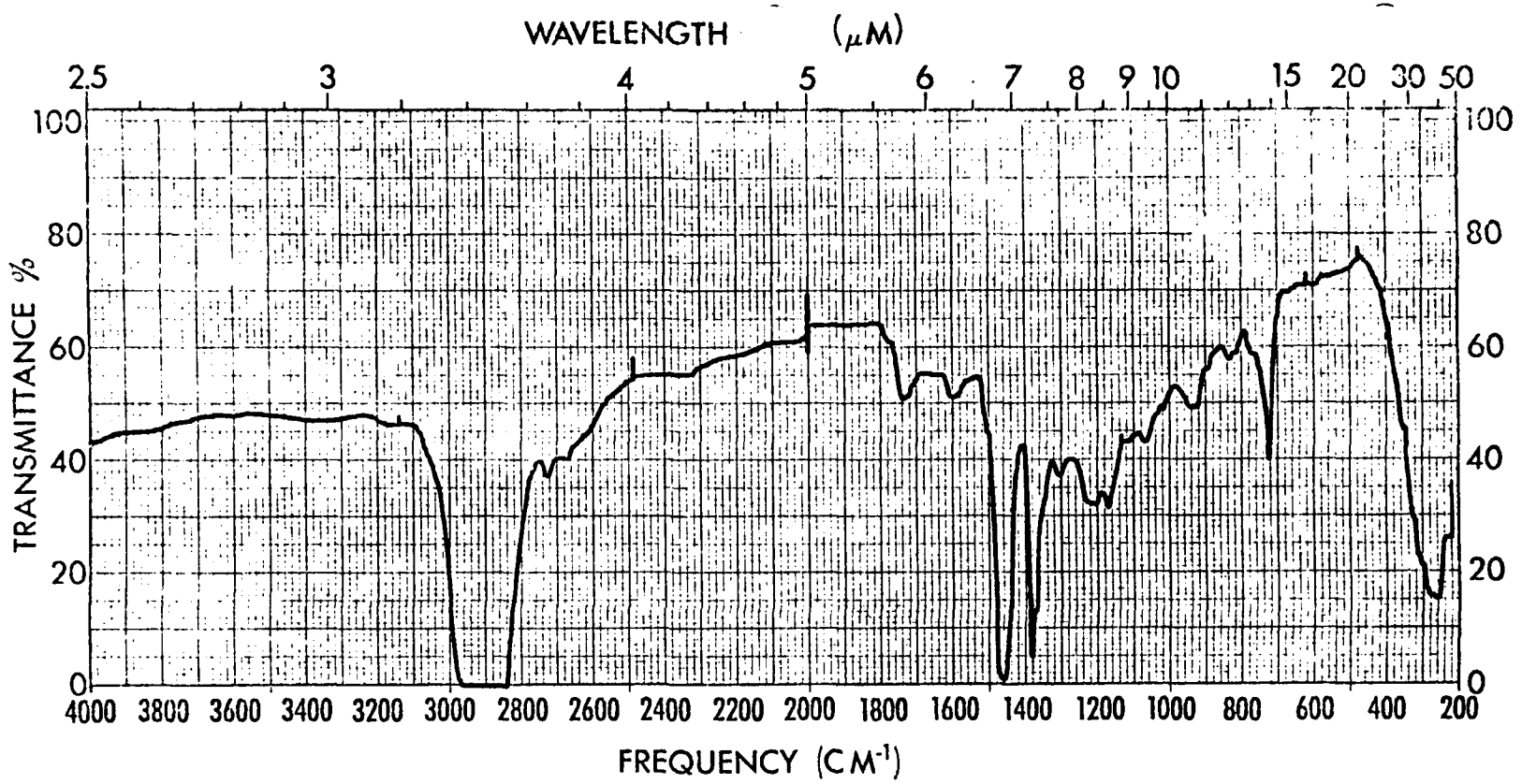
FIGURE 5-5



SPECTRUM NO. 312	ORIGIN	LEGEND	REMARKS
SAMPLE AL-5062-L		1.	
168 Hr	PURITY	2.	
REO 203	PHASE	DATE 8-17-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO.
SAMPLE

FIGURE 5-6



SPECTRUM NO. 313	ORIGIN	LEGEND	REMARKS
SAMPLE AL-5062-L		1.	
196 Hr	PURITY	2.	
REQ 203	PHASE	DATE 8-17-73	
	THICKNESS 0.05	OPERATOR D.B.	

SPECTRUM NO.
SAMPLE

FIGURE 5-7

WEAR MEASUREMENTS
(INCHES)
TABLE 4-1
ENGINE NUMBER 6D 5204-1
OIL: CCL-L-759, REO 203
Hrs: 196

Piston No.	Piston Ring Gap						
	1	2	3	4	5	6	7
1L Before	0.038	0.030	0.032	0.032	0.022	0.022	0.022
After	.049	.034	.034	.035	.030	.035	.033
Change	.011	.004	.002	.003	.008	.013	.011
2L Before	0.024	0.024	0.030	0.028	0.026	0.024	0.024
After	.045	.028	.033	.032	.042	.034	.034
Change	.021	.004	.003	.004	.016	.010	.010
3L Before	0.028	0.027	0.025	0.025	0.024	0.018	0.020
After	.042	.032	.031	.030	.038	.034	.030
Change	.014	.005	.006	.005	.014	.016	.010
1R Before	0.035	0.028	0.025	0.040	0.025	0.020	0.020
After	.042	.032	.030	.044	.040	.035	.033
Change	.007	.004	.005	.004	.015	.015	.013
2R Before	0.030	0.029	0.036	0.029	0.022	0.024	0.024
After	.044	.034	.041	.035	-	.040	.040
Change	.014	.005	.005	.006	-	.016	.016
3R Before	0.028	0.032	0.033	0.034	0.024	0.018	0.018
After	.040	0.035	.035	.036	.035	.028	.028
Change	.012	.003	.002	.002	.011	.010	.010

TABLE 4-2
ENGINE NO. 6D5204-1
OIL: CCL-L-759, REO 203
Hrs: 196

Cylinder No.	Cylinder Liner Perpendicular to Crankshaft Top	Middle	Bottom	Cylinder Liner Parallel to Crankshaft Top	Middle	Bottom
1L Before	3.8760	3.8770	3.8771	3.8768	3.8769	3.8767
After	3.8779	3.8782	3.8780	3.8772	3.8772	3.8763
Change	.0019	.0012	.0009	.0004	.0003	-.0004
2L Before	3.8762	3.8771	3.8767	3.8766	3.8770	3.8766
After	3.8781	3.8784	3.8776	3.8769	3.8773	3.8768
Change	.0019	.0013	.0009	.0003	.0003	.0002
3L Before	3.8765	3.8769	3.8763	3.8761	3.8767	3.8761
After	3.8798	3.8777	3.8771	3.8768	3.8774	3.8759
Change	.0033	.0008	.0008	.0007	.0007	-.0002
1R Before	3.8755	3.8765	3.8764	3.8760	3.8760	3.8762
After	3.8791	3.8775	3.8771	3.8765	3.8771	3.8766
Change	.0036	.0010	.0007	.0005	.0011	.0004
2R Before	3.8774	3.8775	3.8767	3.8760	3.8776	3.8775
After	3.8790	3.8785	3.8771	3.8775	3.8781	3.8780
Change	.0016	.0010	.0004	.0015	.0005	.0005
3R Before	3.8761	3.8770	3.8755	3.8761	3.8770	3.8768
After	3.8775	3.8782	3.8762	3.8770	3.8775	3.8769
Change	.0014	.0012	.0007	.0009	.0005	.0001

TABLE 4-3
ENGINE NO. 6D-5204-1
OIL: CCL-L-759, REO 203
Hrs. 196

Cylinder No.	Piston O. D.
1L Before	3.8685
After	3.8679
Change	.0006
2L Before	3.8690
After	3.8675
Change	.0015
3L Before	3.8689
After	3.8672
Change	.0017
1R Before	3.8679
After	3.8669
Change	.0010
2R Before	3.8688
After	3.8674
Change	.0014
3R Before	3.8682
After	3.8669
Change	.0013

TABLE 4-4

ENGINE NO. 6D-5204-1
OIL: CCL-L-759, REO 203
Hrs. 196

Number		Main Bearing Journal AA	Main Bearing Journal BB	Main Bearing F	Main Bearing R
1	Before	3.4996	3.4995	3.5032	3.5031
	After	3.4992	3.4993	3.5033	3.5031
	Change	.0004	.0002	.0001	.0000
2	Before	3.4995	3.4995	3.5039	3.5038
	After	3.4992	3.4993	3.5039	3.5041
	Change	.0003	.0002	.0000	.0003
3	Before	3.4994	3.4993	3.5043	3.5042
	After	3.4992	3.4992	3.5044	3.5048
	Change	.0002	.0001	.0001	.0006
4	Before	3.4997	3.4995	3.5040	3.5042
	After	3.4994	3.4994	3.5048	3.5048
	Change	.0003	.0001	.0008	.0006

Number		Crankshaft Thrust Washers 1	2	3	4
A	Before	.1202	.1208	.1201	.1209
	After	.1202	.1208	.1200	.1204
	Change	.0000	.0000	.0001	.0005
B	Before	.1198	.1202	.1207	.1205
	After	.1186	.1202	.1207	.1204
	Change	.0012	.0000	.0000	.0001

Exhaust Valve Clearances

Before Test - All .024" to .026"
After Test - Not Recorded

TABLE 4-5

ENGINE NO. 6D-5204-1
OIL: CCL-L-759 , REO 203
Hrs. 196

Cylinder No.	Rod Bearing Journal AA	Rod Bearing Journal BB	Rod Bearing F	Rod Bearing R
1L Before	2.7497	2.7495	2.7518	2.7519
After	2.7496	2.7495	2.7518	2.7522
Change	.0001	.0000	.0000	.0003
2L Before	2.7492	2.7491	2.7522	2.7528
After	2.7493	2.7493	2.7529	2.7532
Change	-.0001	-.0002	.0007	.0004
3L Before	2.7492	2.7493	2.7522	2.7523
After	2.7492	2.7493	2.7529	2.7530
Change	.0000	.0000	.0007	.0007
1R Before	2.7495	2.7494	2.7515	2.7515
After	2.7491	2.7494	2.7523	2.7523
Change	.0004	.0000	.0008	.0008
2R Before	2.7493	2.7493	2.7518	2.7511
After	2.7492	2.7492	2.7525	2.7520
Change	.0001	.0001	.0007	.0009
3R Before	2.7490	2.7493	2.7514	2.7520
After	2.7490	2.7491	2.7519	2.7525
Change	.0000	.0002	.0005	.0005

TABLE 5-1

RING STICKING

Engine Model 6V53T Serial No. 6D5204-1 Date 20 Aug 1973
Fuel MIL-F-16884 (DFM) Lubricant CCL-L-759 (REO 203) Observer J. Simpson

Ring No.	Piston Number 1L	2L (A)	3L	1R	2R	3R (W)
1	Free	Free	Free	Free	Free	Free
2	Free	Free	Free	Free	Free	Free
3	Free	Free	Free	Free	Free	Free
4	Free	Free	Free	Free	Free	Free

Indicate by letter—Free or Sluggish, or by number and letter—percent Pinched (cold stuck) or percent Hot stuck (Pages 6 and 7 of Manual).

(A) and (W) denote average and worst from deposit standpoint.

TABLE 5-2

RING DEPOSITS

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 1973
Fuel MIL-F-16884 (DFM) Lubricant CCL-L-759 (REO 203) Observer J. Simpson

Cylinder Number			1L		2L		3L		1R		2R		3R	
			CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Piston Ring	Top	1	55AH	45-6	30AH	70-5	20AH	80-6	5AH	80-6 15-3	10AH	(3)	-	100-6
		2	60AH	40-6	45AH	(2)	75AH	10-4 10-4	30AH	65-7 5-3	65AH	5-6 30-4	-	25-4 70-6
		3	-	100-4	-	25-5 35-3	-	100-5	-	80-3	-	100-5	-	90-3
		4	-	90-3	-	40-3	-	75-3	-	65-3	-	80-4	-	5-5 60-4
	ID	1	5-BH 30AH	5-7	95AH	5-7	100AH	-	80AH	20-9	70AH	30-6	100AH	-
		2	15BH 85AH	-	45BH 55AH	-	20BH 80AH	-	45BH 55AH	-	80BH 20AH	-	50BH 50AH	-
		3	100AH	-	100AH	-	100AH	-	100AH	-	100AH	-	100AH	-
		4	-	100-8	70AH	30-8	-	100-7	-	100-6	50AH	50-7	-	100-7
	Bottom	1	-	(1)	-	(1) excessive	-	(1)	-	70-4	5AH	(1)	-	(1)
		2	-	(1)	-	5-9 20-3	-	20-3	-	5-5 55-3	5AH	30-3	-	20-3
		3	-	20-3	-	60-3	-	60-3	-	60-3	-	100-3	-	80-3
		4	-	50-4	-	30-3	-	70-3	-	60-3	-	70-3	-	60-4

See pages 4, 36 and 37 of Manual. Areas previously rated for carbon, rate 0 for lacquer

(1) Worn thru chrome
(2) 20-9, 20-4, 15-2
(3) 40-6, 30-5, 20-4

TABLE 5-3

RING FACE CONDITION

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 1973
Fuel MIL-F-16884 Lubricant CCL-L-759 (REO 203) Observer J. Simpson

	Cylinder Number					
	1L	2L	3L	1R	2R	3R
First Ring	(2) Mod Otherwise satis-factory	HeavyWear HeavyPart Chipping (2)Mod	HeavyWear PartChip-ing (2)Lt	HeavyWear &(1) Lt (2)ModAmt	Excessive Wear	Excessive Wear
Second Ring	(2) Mod Otherwise satisfac-tory	(5)Mod (4)Heavy Deposit Build-up LargeBlowby Path	(4) Lt Heavy Chrome Wear	Excessive Chrome displacement (4)Heavy (3)Sm Amt	(5)Heavy	(5)Lt (4)Mod PartChip
Third Ring	(4) Mod	(4) Mod Blowby Streaks	(4) Mod	(5) Mod (4) Heavy	(5) Heavy (4) Mod	(4) Heavy
Fourth Ring	(5) Lt (4) Mod	(4) Mod	(4) Mod	(5) Mod (4) Mod	(5) Mod (4) Heavy	(5) Lt (4) Mod
Oil Ring Slots—% Open	100	100	100	100	100	100

Pages 1 and 2 and 59 through 65 of Manual.

(1) Scuffing
(2) Chrome Cracking
(3) Burning
(4) Carbon Cutting
(5) Chrome Displacement (cast iron visible) though ring does not display heavy wear.

TABLE 5-4

PISTON SURFACE DEPOSITS

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 1973
Fuel MIL-F-16884 Lubricant CCL-L-759 (REO 203) Observer J. Simpson

		Piston Number					
		1L	2L	3L	1R	2R	3R
Top*		10 CSA+ 90 AS	40 CSA 60-5*	30 DSA 70-5*	25-9 75-5	5 CSA 75-9 20-5*	25-9 75-5*
Combustion Chamber*		10 CSA 90 AS	5 CSA 40 ASA 55 AS	20 CSA 30 ASA 50 AS	5 CSA 95 ASA	3 CSA 97 ASA	100 ASA
Under Head*		100-3	100-3	100-3	100-3	100-3	100-3
Skirts*	Thrust	3.9	4.1	4.0	3.9	4.1	4.1
	Anti-Thrust	4.1	3.9	3.8	4.1	3.8	3.8
Relief Areas*		-----	-----	NA	-----	-----	-----
		C L	C L	C L	C L	C L	C L
Lands	1	80AH 20-9	85AH 15-9	80 AH 20-9	55AH 45-9	85AH 15-8	65AH 35-7
	2	40BH - 60AH	45BH - 55AH	30BH 5-4 65AH	55BH - 45AH	45BH 5-5 50AH	85BH - 15AH
	3	35BH - 65AH	25BH 5-7 70AH	20BH 10-9 65AH 5-6	50BH - 50AH	25BH 15-4 60AH	50BH 5-5 45AH
	4	10-9 - 15-6 75-4	30AH 15-9 15-6 40-4	- 5-9 95-4	5AH 25-7 70-4	5BH 5-5 30AH 60-4	25-9 15AH 10-5 50-3

Lacquer—Pages 4, 36, 37 of Manual.
*Carbon and Ash: Use Volume Factor (Pages 5 and 40 through 47)
Indicate H, M, or S (Page 5)

*Non Carbonacous Fuel Deposit
+CSA - C-depth, S-soft, A-ash type deposit

TABLE 5-5

PISTON RING GROOVE DEPOSITS

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 73
Fuel MIL-F-16884 Lubricant CCL-L-759 Observer J. Simpson
(REO 203)

		Cylinder Number											
		1L		2L		3L		1R		2R		3R	
		CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ
Top of Groove	1	-	100-8	-	100-5	15AH	70-5 15-4	-	100-5	-	15-9 85-6	-	30-9 70-6
	2	-	10-9 10-6 80-4	30AH	5-9 65-4	40AH	10-9 50-4	-	100-4	-	10-9 90-5	45AH	10-9 10-6 35-4
	3	-	100-4	-	100-4	-	100-4	-	100-4	-	40-5 60-4	-	20-5 80-4
	4	-	100-4	-	100-4	-	100-4	-	100-4	-	100-4	-	100-4
Back of Groove *	1	-	100-6	-	100-6	1	-	3	-	-	100-6	-	100-6
	2	55	-	50	-	55	-	80	-	55	-	85	-
	3	15	-	3	-	8	-	13	-	15	-	20	-
	4	-	100-4	-	20-6 80-4	-	100-4	-	100-4	-	100-4	-	100-4
Bottom of Groove	1	-	15-9 85-4	-	60-5 40-4	-	50-5 50-4	10AH	10-9 80-7	-	30-6 70-5	-	60-6 40-5
	2	15AH	5-7 80-4	20AH	20-8 60-4	10AH	5-9 85-4	15AH	20-9 65-5	20AH	80-4	-	100-4
	3	-	100-4	-	25-6 75-4	-	100-4	-	100-4	-	100-4	-	100-4
	4	-	100-4	-	100-4	-	100-4	-	100-4	-	100-4	-	100-4
Drain Holes--% Blocked		0		0		0		0		0		0	

Lacquer: Pages 4, 36, and 37
*Carbon and Ash: Use Volume Factor (Pages 5 and 40 through 47)
Indicate H, M, or S (Page 5)
†Carbon and Ash: Indicate Percent Filled and H, M, or S (Page 5)

* % Volume Fill

Table 5-5a

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 196
TEST LABORATORY AFLRL
LUBRICANT REO 203

RATER J. Simpson DATE 20 Aug 1973
LABORATORY TEST NUMBER 6D5204-1 (Test No. 7)
STAND NO. 5 ENGINE NO. 6D5204
FUEL MIL-F-16884 (DFM)

PISTON NO. 1L

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	143.58

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1		GROOVES NO. 2		GROOVES NO. 3		GROOVES NO. 4		LANDS NO. 1		LANDS NO. 2		LANDS NO. 3		LANDS NO. 4		UNDER-CROWN	
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00	1	1.00	55	55.00	15	15.00												
CARBON	MHC	0.75																		
CARBON	MC	0.50																		
CARBON	LC	0.25											40	10.00	35	8.75				
CARBON	VLC	0.15									80	1.20	60	9.00	60	9.00				
	CARBON RATING		1.00		55.00		15.00		-		1.20		19.00		17.75		-			
LACQUER	BL	0.100	90	9.00			10	10.00			20	2.00					10	1.00		
LACQUER	DBrL	0.075							10	0.75							15	1.13		
LACQUER	AL	0.050							90	4.50							75	3.75		
LACQUER	LAL	0.025																	100	2.50
LACQUER	VLAL	0.010																		
LACQUER	RL	0.001																		
	LACQUER RATING		9.00				10.00		5.25		2.00		-		-		5.88		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			10.00		55.00		25.00		5.25		3.20		19.00		17.75		5.88		2.50	

*WEIGHTED TOTAL DEPOSITS

Table 5-5b

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 196
TEST LABORATORY AFLRL
LUBRICANT REO 203

RATER J. Simpson DATE 20 Aug 1973
LABORATORY TEST NUMBER 6D5204-1 (Test No. 7)
STAND NO. 5 ENGINE NO. 6D5204
FUEL MIL-F-16884 (DFM)

PISTON NO. 2L

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	133.38

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES								LANDS								UNDER-CROWN	
			NO. 1		NO. 2		NO. 3		NO. 4		NO. 1		NO. 2		NO. 3		NO. 4			
			AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT	AREA-%	DEMERIT
CARBON	HC	1.00	4	4.00	50	50.00	3	3.00												
	MHC	0.75																		
	MC	0.50																		
	LC	0.25											45	11.25	25	6.25				
	VLC	0.15									85	12.75	55	8.25	70	10.50	30	4.50		
	CARBON RATING		4.00		50.00		3.00		-		12.75		19.50		16.75		4.50			
LACQUER	BL	0.100									15	1.50					15	1.50		
	DBrL	0.075	60	4.50			40	3.00	20	1.50							15	1.13		
	AL	0.050					20	1.00	80	4.00					5	0.25	40	2.00		
	LAL	0.025																	100	2.50
	VLAL	0.010																		
	RL	0.001																		
	LACQUER RATING		4.50		-		4.00		5.50		1.50		-		0.25		4.63		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			8.50		50.00		7.00		5.50		14.25		19.50		17.00		9.13		2.50	

*WEIGHTED TOTAL DEPOSITS

Table 5-5c

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 196
TEST LABORATORY AFLRL
LUBRICANT REO 203

RATER J. Simpson DATE 20 Aug 1973
LABORATORY TEST NUMBER 6D5204-1 (Test No. 7)
STAND NO. 5 ENGINE NO. 6D5204
FUEL MIL-F-16884 (DFM)

PISTON NO. 3L

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	138.71

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	10	1.00	55	55.0	8	8.00												
	MHC	0.75																		
	MC	0.50																		
	LC	0.25											30	7.50	20	5.00				
	VLC	0.15									80	12.00	65	9.75	65	9.75	30	4.50		
	CARBON RATING		1.00		55.00		8.00		-		12.00		17.25		14.75		4.50			
LACQUER	BL	0.100	40	4.00			65	6.50			20	2.00			10	1.00	15	1.50		
	DBrL	0.075													5	0.38	15	1.13		
	AL	0.050							100	5.00			4	0.20			40	2.00		
	LAL	0.025																	100	2.50
	VLAL	0.010																		
	RL	0.001																		
	LACQUER RATING		4.00		-		6.50		5.00		2.00		0.20		1.38		4.63		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			5.00		55.00		14.50		5.00		14.00		17.45		16.13		9.13		2.50	

*WEIGHTED TOTAL DEPOSITS

Table 5-5d

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 196
TEST LABORATORY AFLRL
LUBRICANT REO 203

RATER J. Simpson DATE 20 Aug 1973
LABORATORY TEST NUMBER 6D5204-1 (Test No. 7)
STAND NO. 5 ENGINE NO. 6D5204
FUEL MIL-F-16884 (DFM)

PISTON NO. 1R

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	149.26

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	10	10.00	55	55.00	8	8.00														
	MHC	0.75																				
	MC	0.50																				
	LC	0.25											55	13.75	50	12.50						
	VLC	0.15									55	8.25	45	6.75	50	7.50	5	0.75				
	CARBON RATING		10.00		55.00		8.00		-		8.25		20.50		20.00		0.75					
LACQUER	BL	0.100	40	4.00			65	6.50														
	DBrL	0.075									45	3.38					25	1.88				
	AL	0.050							100	5.00							70	3.50				
	LAL	0.025																	100	2.50		
	VLAL	0.010																				
	RL	0.001																				
	LACQUER RATING		14.00		-		6.50		5.00		3.38		-		-		5.38		2.50			
CLEAN		0																				
ZONAL RATING																						
LOCATION FACTOR																						
WEIGHTED RATING			14.00		55.00		14.50		5.00		11.63		20.50		20.00		6.13		2.50			

*WEIGHTED TOTAL DEPOSITS

Table 5-5e

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 196
TEST LABORATORY AFLRL
LUBRICANT REO 203

RATER J. Simpson DATE 20 Aug 1973
LABORATORY TEST NUMBER 6D5204-1 (Test No. 7)
STAND NO. 5 ENGINE NO. 6D520[illegible]
FUEL MIL-F-16884 (DFM)

PISTON NO. 2R

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	133.38

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	NO. 1 DEMERIT	NO. 2 AREA-%	NO. 2 DEMERIT	NO. 3 AREA-%	NO. 3 DEMERIT	NO. 4 AREA-%	NO. 4 DEMERIT	LANDS NO. 1 AREA-%	NO. 1 DEMERIT	NO. 2 AREA-%	NO. 2 DEMERIT	NO. 3 AREA-%	NO. 3 DEMERIT	NO. 4 AREA-%	NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	3	3.00	55	55.00	15	1.50												
	MHC	0.75																		
	MC	0.50																		
	LC	0.25											45	11.25	25	6.25	5	1.25		
	VLC	0.15									85	12.75	50	7.50	60	9.00	30	4.50		
	CARBON RATING		3.00		55.00		1.50		-		12.75		18.75		15.25		5.75			
LACQUER	BL	0.100	60	6.00							15	1.50								
	DBrL	0.075					40	3.00												
	AL	0.050					20	1.00	25	1.25			5	0.25	15	0.75	65	3.25		
	LAL	0.025							75	1.88									100	2.50
	VLAL	0.010																		
	RL	0.001																		
	LACQUER RATING		6.00		-		4.00		3.13		1.50		0.25		0.75		3.25		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			9.00		55.00		5.50		3.13		14.25		19.00		16.00		9.00		2.50	

*WEIGHTED TOTAL DEPOSITS

Table 5-5f

CRC DIESEL RATING SYSTEM

STANDARD COMPUTATION SHEET FOR PISTON RATING

TEST PROCEDURE 6V53T
TEST HOURS 196
TEST LABORATORY AFLRL
LUBRICANT REO 203

RATER J. Simpson DATE 20 Aug 1973
LABORATORY TEST NUMBER 6D5204-1 (Test No. 7)
STAND NO. 5 ENGINE NO. 6D5204
FUEL MIL-F-16884 (DFM)

PISTON NO. 3R

NO. 1 GROOVE, VOLUME-%	
PISTON WTD* RATING	180.38

DEPOSIT TYPE		DEPOSIT FACTOR	GROOVES NO. 1 AREA-%	GROOVES NO. 1 DEMERIT	GROOVES NO. 2 AREA-%	GROOVES NO. 2 DEMERIT	GROOVES NO. 3 AREA-%	GROOVES NO. 3 DEMERIT	GROOVES NO. 4 AREA-%	GROOVES NO. 4 DEMERIT	LANDS NO. 1 AREA-%	LANDS NO. 1 DEMERIT	LANDS NO. 2 AREA-%	LANDS NO. 2 DEMERIT	LANDS NO. 3 AREA-%	LANDS NO. 3 DEMERIT	LANDS NO. 4 AREA-%	LANDS NO. 4 DEMERIT	UNDER-CROWN AREA-%	UNDER-CROWN DEMERIT
CARBON	HC	1.00	1	1.00	85	85.00	20	20.00													
	MHC	0.75																		
	MC	0.50																		
	LC	0.25											85	21.25	50	12.50				
	VLC	0.15									65	9.75	15	2.25	45	6.75	15	2.25		
	CARBON RATING		1.00		85.00		20.00		-		9.75		23.50		19.25		2.25			
LACQUER	BL	0.100	90	9.00			50	5.00									25	2.50		
	DBrL	0.075									35	2.63								
	AL	0.050							100	5.00					5	0.25	10	0.50		
	LAL	0.025															50	1.25	100	2.50
	VLAL	0.010																		
	RL	0.001																		
	LACQUER RATING		9.00		-		5.00		5.00		2.63		-		0.25		4.25		2.50	
CLEAN		0																		
ZONAL RATING																				
LOCATION FACTOR																				
WEIGHTED RATING			10.00		85.00		25.00		5.00		12.38		23.50		19.50		6.50		2.50	

*WEIGHTED TOTAL DEPOSITS

TABLE 5-6

PISTON GROOVE INSIDE DIAMETER–% RING SUPPORTING CARBON

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 73
Fuel MIL-F-16884 Lubricant CCL-L-759 (REO 203) Observer J. Simpson

Piston Ring	Quadrant	Piston Number					
		1L	2L	3L	1R	2R	3R
1	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	4	0	0	0	0	0	0
2	1	25	90	30	65	90	80
	2	10	85	40	75	30	70
	3	75	40	80	25	25	100
	4	25	25	15	40	25	90

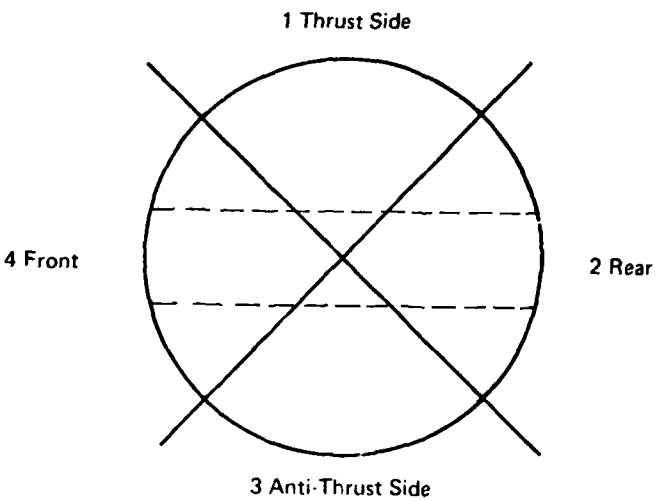


TABLE 5-7

PISTON SURFACE CONDITION

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 73
Fuel MIL-F-16884 Lubricant CCL-L-759 (REO 203) Observer J. Simpson

	Piston Number					
	1L	2L	3L	1R	2R	3R
Top Land	----------	----------	----------NORMAL----------			
Skirt	10% Lt Scuffing	10% Lt Scuffing	15% Lt Scuffing	20% Lt Scuffing	15% Lt Scuffing	5% Lt Scuffing
Piston Pin	----------	----------	----------NORMAL----------			

Pages 1 through 2 and 59 through 65 of Manual.

TABLE 5-8

VALVE DEPOSITS

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 73

Fuel MIL-F-16884 Lubricant CCL-L-759 (REO 203) Observer J. Simpson

		Cylinder Number											
		1L		2L		3L		1R		2R		3R	
		CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LACQ	CARB	LARQ
Head*	INT												
	EXH	100-BHA		60-BHA 40 AH		60-BHA 40 AH		75-BHA 25 AH		55-BHA 45 AH		5-AHA 95-AH	
Face	INT												
	EXH	------	------	--Normal, with signs of slight leakage on some valves---									
Tulipt	INT												
	EXH	------	------	------	------	----0.5	DEMERIT	------	------	------	------	------	------
Stem	INT												
	EXH	------	------	------	------	----0.5	DEMERIT	------	------	------	------	------	------

*Carbon and Ash: Use Volume Factor Technique (Pages 5 and 40 through 47 of Manual).

†Use Chart, Page 21—Indicate H, M, or S (Page 5).

Lacquer: Pages 4, 36 and 37.

TABLE 5-9

EXHAUST VALVE SURFACE CONDITIONS

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 73

Fuel MIL-F-16884 Lubricant CCL-L-759 (REO 203) Observer J. Simpson

	1L	2L	3L	1R	2R	3R
Freeness in Guide	Free	Free	Free	Free	Free	Free
Head	----------	----------	----------	NORMAL	----------	----------
Face	----------	----------	----------	NORMAL	----------	----------
Seat	----------	----------	----------	NORMAL	----------	----------
Stem	----------	----------	----------	NORMAL	----------	----------
Tip	----------	----------	----------	NORMAL	----------	----------

See Pages 1, 2, 16 through 23, and 54 through 65 of Manual.

TABLE 5-10

TAPPETS, CAMS, AND ROCKER ARMS

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 73
Fuel MIL-F-16884 Lubricant CCL-L-759 (REO 203) Observer J. Simpson

			Cylinder Number					
			1L	2L	3L	1R	2R	3R
Tappet Deposit		INT						
		EXH	----------	----------	---------- NOT	RATED	----------	----------
Tappet Surface Condition		INJ	----------	----------	---------- NOT	RATED	----------	----------
		INT						
		EXH	----------	----------	---------- NOT	RATED	----------	----------
Cam Lobes			----------	----------	---------- NORMAL		----------	----------
Rocker Arms	Tip	INT						
		EXH	----------	----------	---------- NOT	RATED	----------	----------
	Bushing	INT						
		EXH	----------	----------	---------- NOT	RATED	----------	----------
	Shaft	INT						
		EXH	----------	----------	---------- NOT	RATED	----------	----------

Lacquer: Pages 4, 36 and 37 of Manual
See Pages 1, 2, 16 through 23, and 54 through 65.

TABLE 5-11

CYLINDER LINERS AND CYLINDER HEADS

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 73
Fuel MIL-F-16884 Lubricant CCL-L-759 (REO 203) Observer J. Simpson

Cylinder Number	Percent Port Restriction	Cylinder Liner Scuffing — Percent of Total Ring Travel Area[1]				
		Percent Scuffed		% Total Area Scuffed	% Glazed	% Lacquer
		Thrust	Anti-Thrust			
1L	1	2	1	1.5	30	15
2L	2	10	8	9	50	25
3L	1	30	6	18	50	15
1R	3	20	30	25	65	20
2R	7	10	25	17.5	70	30
3R	44	8	15	11.5	60	35
Average	-	13	14	14	54	23

[1] Percent scuffed in compression ring travel area.

Cylinder Head Deposits

%	1L	2L	3L	1R	2R	3R
HC	-	35	20	35	25	35
MC	-	-	-	-	-	-
SC	50	40	40	30	40	50

Carbon and Ash: Use Volume Factor Pages 5 and 40 through 47
Indicate H, M, or S
Lacquer: Use Pages 4, 36, and 37
For Surface Condition–See Pages 1, 2, 16 through 23 and 54 through 65

TABLE 5-12

SURFACE CONDITION

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 73
Fuel MIL-F-16884 Lubricant CCL-L-759 (REO 203) Observer J. Simpson

Bearing No.	1	2	3	4			
Main–Bearing	Fatigue in of checking of finish	Fatigue as #1 & Lt Wiping	Small amt of embedment	Lt Wiping & Small Amt of Embedment			
–Journal	----------	----------	----------	NORMAL---			
Rod–Bearing	1L	2L	3L	1R			
	----------	----------	----------	NORMAL---	----------	----------	
–Journal	----------	----------	----------	NORMAL---	----------	----------	
Piston Pin	----------	----------	----------	NORMAL---	----------	----------	
Bushing	----------	----------	----------	NORMAL---	----------	----------	

Note surface condition. See pages 1, 2, 16 through 23 and 54 through 65 of Manual.

TABLE 5-13

SLUDGE DEPOSITS

Engine Model 6V53T Serial No. 6D-5204-1 Date 20 Aug 73
Fuel MIL-F-16884 Lubricant CCL-L-759 Observer J. Simpson
(REO 203)

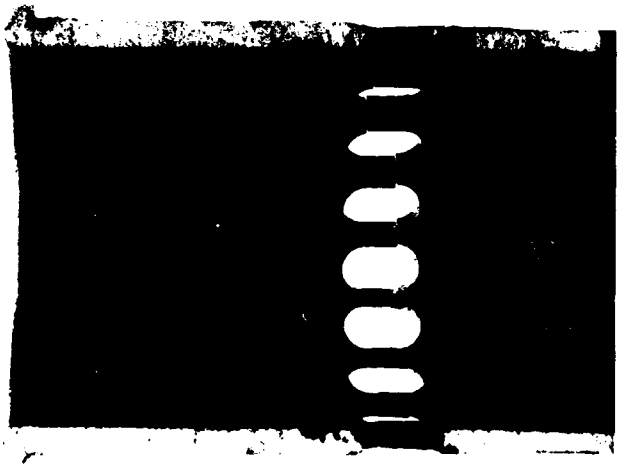
	Rating
Connecting Rods	Clean
Rocker Arm Covers	0.5
Top Deck	0.5
Push Rod Covers	-
Push Rod Chamber	-
Timing Gear Cover	-
Oil Pan	0.5
Oil Screen	Clean

See pages 5 and 40 to 47 of Manual.

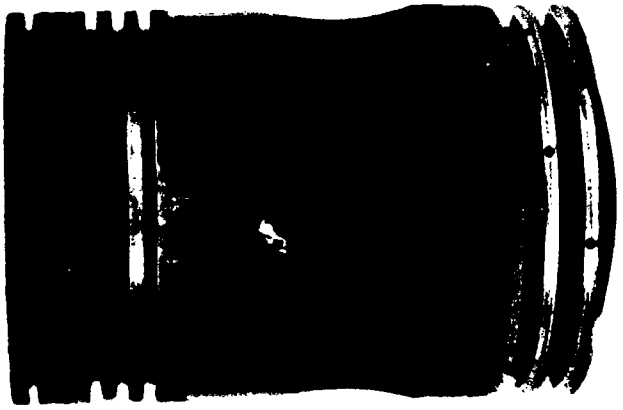
Use CRC Volume Factor Technique.

Figure 6-1

TEST 7 196 HRS OIL CODE
CCL-L-759 (REO 203)



2 Left Thrust
A



2 Left Thrust
A

Figure 6-2

TEST 7 196 HRS OIL CODE
CCL-L-759 (REO 203)

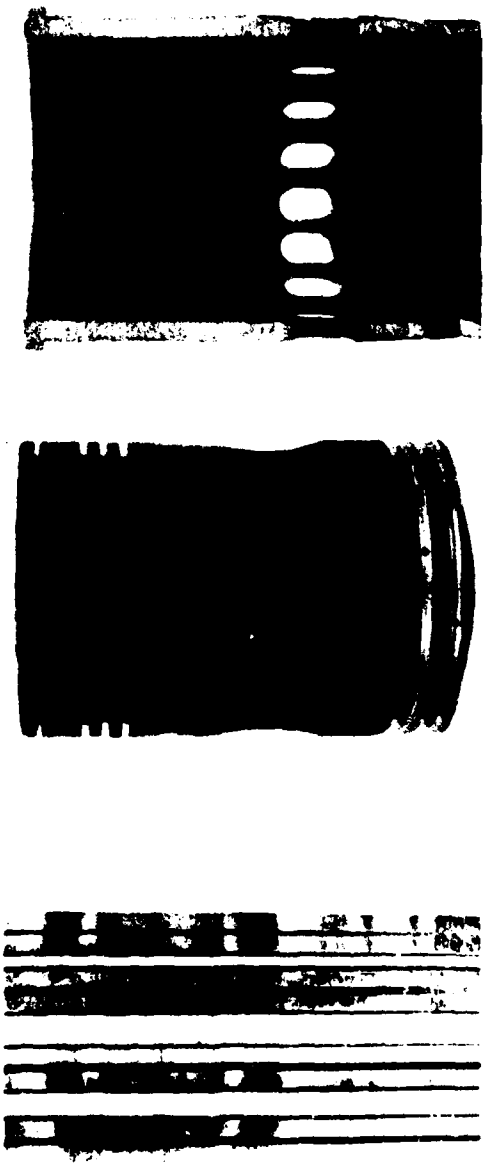
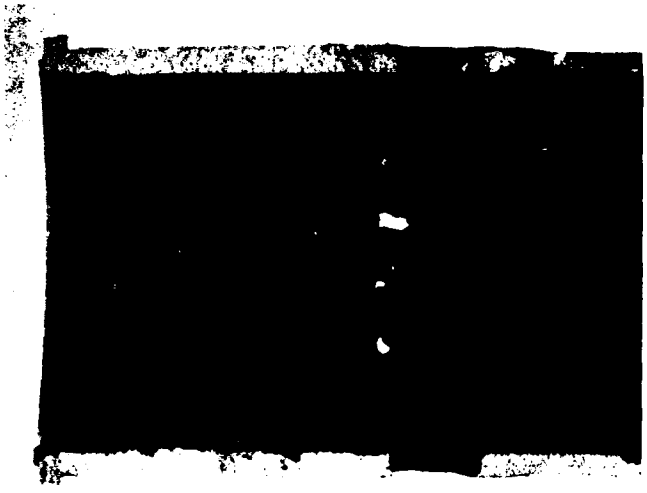
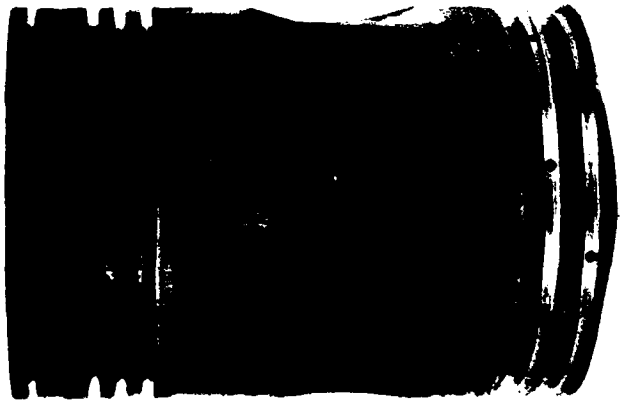


Figure 6-3

TEST 7 196 HRS OIL CODE
CCL-L-759 (REO 203)



3 Right Thrust
W



3 Right Thrust
W

Figure 6-4

TEST 7 196 HRS OIL CODE CCL-L-759 (REO 203)

APPENDIX V

CRC Army Combat Engine Fuels and Lubricants Group Inspection Results

On 14-15 February 1974, this CRC group met at USAFLRL to inspect critical test engine parts from 6V53T engine-lubricant compatibility test numbers 6, 7, 8, 9 and 10. Participants in this inspection are shown in the attached table. The details of this meeting are presented in the CRC official minutes. However, the following is a summary of the group's specific and general conclusions with regard to the effect of fuel type (DFM vs No. 2 Ref. DF) on overall engine performance (Test Nos. 6 and 7 vs. 2 and 3:

Specific engine areas:

a) Piston Deposits and Ring Sticking

Using the high sulfur fuel and CCL-L-759 oil, there was an overall increase in the deposit level. With the CCL-L-758 oil, there was an overall increase in the deposit level with occurrence of ring sticking. As a result, it was concluded that the high sulfur fuel had a marked adverse effect on engine-fuel-lubricant compatibility in the piston area.

b) Piston Ring Condition

The high sulfur DMF fuel significantly increased test severity with respect to ring face condition, ring wear, and ring sticking and pinching as judged by comparing Tests 6 and 7 to Tests 2 and 3.

c) Cylinder Liners

The high sulfur fuel appeared to give an increase in liner deposits (both lacquer and port plugging). Scuffing,

glazing and wear data showed no consistent fuel related trend with oil CCL-L-758. These three parameters all increased with high sulfur fuel on CCL-L-759.

d) Cylinder Heads

Messrs. Crosthwait and Crowe reported that, based on ratings, all oils except CCL-L-758 appeared compatible with the fuels, engine, and test cycles. The test on CCL-L-758 using high sulfur fuel showed exhaust valve distress with one broken valve and valve seat. Since this failure was similar to that observed with the low sulfur fuel test on this oil, it was suggested that analysis of valve faces and valve seat inserts be considered to determine if corrosion fatigue might be involved.

Specific engine area performance, summarized in table form, is shown as follows:

	Wheeled Cycle Test Fuel*			
Fuel =	No. 2 Ref DF		DFM	
Performance Area / Lube =	758	759	758	759
Piston Ring Gap Increase	ND	LS	ND	MS
Cylinder Liner Wear	ND	LS	ND	MS
Ring Freedom	LS	ND	ND	ND
% Ring Groove Fill	ND	ND	ND	ND
% Ring Support Carbon	ND	LS	ND	MS
Piston Skirt Demerit	ND	ND	ND	ND
Cylinder Liner Scuff	ND	LS	ND	MS
Used Oil (Final) Wear Metals	ND	LS	ND	MS

*Fuel: The high sulfur fuel (DFM) was more severe.
ND - No difference
MS - More severe
LS - Less severe

General Conclusions (Fuel Sulfur Effect (Tests 2, 7 and 3,6))

The high sulfur fuel was more severe than the low sulfur fuel.

1. Deposit Control and Ring Freedom: The high sulfur fuel caused more ring sticking with the high ash oil (758) than with the low sulfur fuel. In other deposit areas, there appeared to be no fuel/sulfur effect. With the low ash oil (759), the only significant change was that port plugging increased with the high sulfur fuel.
2. Wear Control: With the high ash oil (758), there was no change in wear level between the two fuels. With the low ash oil (759) there was an increase in wear level when the high sulfur fuel was used, and it was about equal to the wear level of the high ash oil using either fuel.

CRC INSPECTION PARTICIPANTS AT USAFLRL

14-15 February 1974

Name	Connection
*J. A. McLain, Chairman	Caterpillar Tractor Company
*D. C. Bardy	Lubrizol Corporation
*P. A. Bennett	Rohm and Haas Company
T. C. Bowen	U. S. Army Mobility Equipment Research and Development Center (CCL)
*P. I. Brown	Chevron Research Company
D. C. Carlson	Shell Development Company
T. D. Cook	Automotive Research Associates
*R. E. Crosthwait	Mobil Research and Development Corp.
*J. R. Crowe	Mack Trucks, Inc.
*J. P. Graham	PARAMINS Technology Division, Exxon Chemical Co.
*S. J. Lestz	U. S. Army Fuels and Lubricants Research Laboratory
R. K. Nelson	Coordinating Research Council, Inc.
%C. F. Schwarz	U. S. Army Mobility Equipment Research and Development Center (CCL)
J. L. Simpson	U. S. Army Fuels and Lubricants Research Laboratory
J. J. Sommer(1)	Detroit Diesel Allison Division, GMC
*K. W. Thurston	Koppers Company, Inc.
G. W. Wilkins	Sun Oil Company
*H. L. Wittek	List-Rosen-Wittek Associates, Inc.

*Member, CRC-Diesel Army Combat Engine Fuels and Lubricants Group
%Project Officer
(1) Representing *J. G. Brandes