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FINAL REPORT

IOWA RE-REFINED OIL FLEET TEST

Prepared for
U.S. Department of Energy
Contract EY-76-S-02-4074

ISU-ERI-Ames-79033
Project 1266

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ABSTRACT

The Iowa Re-refined Oil Fleet Test was designed to obtain comparative performance data on re-refined and virgin 10W-30 motor oils and hydraulic oils in fleet use. The vehicles were provided by the Iowa Department of Transportation (DOT). The re-refined oils were the commercial product from Motor Oils Refining Company and the experimental product was from the Bartlesville Energy Research Center; the virgin oil was DOT standard stock purchased on a low bid basis.

Forty-six vehicles, including 23 passenger cars, 13 pickups, and 10 trucks with hydraulic systems, were operated in normal use with 21 vehicles using virgin oil and 25 vehicles using re-refined oil. Both dipstick and oil drain samples were analyzed by standard ASTM methods. Oil drain intervals of 4,000, 8,000 and 10,000 miles were used.

Analytical results from drain samples were obtained. Twelve representative engines were dismantled and deposit ratings obtained after two years of operation. All pertinent data have been analyzed to compare oil performance and assess the effect of varying drain intervals.

Overall, the two re-refined oils performed at least as well as the virgin oil. In addition, the re-refined oils, particularly the MORCO oil, provided good engine deposit control. Vehicles using MORCO oil generally had higher oil consumption rates. The virgin oil had a marginally low base reserve (total base number) for an 8,000 mile drain interval and showed a larger viscosity increase than the other oils.

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1. INTRODUCTION

In 1975 the Iowa Department of Transportation (DOT) became interested in using re-refined oil in state vehicles. In order to properly assess the performance of re-refined oil, a road test, operating under normal fleet conditions, seemed desirable. The Bartlesville Energy Research Center (BERC), DOE, was also interested in road tests of the oil from their recently developed process [1]. An agreement among the Iowa State University Engineering Research Institute (ISU-ERI), the Iowa DOT, and BERC was reached to test SE-CC Service (10W30) oil from Motor Oils Refining Company (MORCO) and BERC on about 20 vehicles, with a comparable number of vehicles operating on the normal DOT virgin stock under similar conditions.

A lack of significant differences among the three oils would be a useful result and would permit the DOT and other state agencies to allow re-refined oil producers to bid for the state's business. It might also encourage environmentally favorable use of waste oil in Iowa. A closed loop recycle system would be the optimum result.

An evaluation of the potential for recycling oil in Iowa is another objective of this test. The cost of collecting and recycling oil from rural areas is assessed along with the attitude of rural Iowans in general toward using re-refined oil (Appendix E).

2. RE-REFINED MOTOR OIL PERFORMANCE TESTING

Engine-lubricating oils are specifically formulated with an additive package to provide a given level of lubricating performance under a given type of service (vehicle operating conditions). Bench tests of the motor oil properties, engine sequence tests, and controlled vehicle fleet tests are widely used to evaluate motor oil performance. Growing interest in lubricating oil recycling has prompted research in the area of comparative re-refined and virgin motor oil testing.

Whisman, Goetzinger, and Cotton [2] compared the bench-test properties of re-refined and virgin lubricating oils using standard ASTM tests. According to them, the three re-refined motor oils derived from Bureau of Mines (BERC) re-refining processes and the eight commercially re-refined lubricating oils studied could not be distinguished from the three virgin oils by the bench tests used to define quality.

A major objective of the National Bureau of Standards is an effort to evaluate the quality of recycled oil products ("Measurements and Standards for Recycled Oil"). This is to be accomplished by applying new and existing test methods that are currently being used on virgin oil. This work is intended to produce quality bench scale tests that provide an alternative method to the engine sequence tests for evaluating oil performance [3].

The first documentation in the United States of re-refined lubricating oils successfully passing engine sequence tests was performed by Reynolds, Whisman, and Thompson in 1977 [4]. Re-refined lubricating oils (SAE 10W-30 grade) derived from a BERC re-refining process and a commercially re-refined SAE 20 grade oil from MORCO designed for SE/CD service were subjected to engine test sequences IIC, IIIC, VC, and L-38. The first three test sequences are the basic specification tests for quality SE motor oils, while the L-38 test (method 3405) is required to meet the standards of military specification Mil-L-46152. These re-refined oils were expected to pass the test sequences, because earlier bench tests [2] indicated no differences between them and quality virgin motor oils.

A recent re-refined oil testing program [5] was completed by the ASTM Re-refined Oil Task Force, EPA, and the U.S. Army. The purpose was to examine possible re-refined oil basestock variations, in addition to estimating the effects that those variations have on the ability of the blended lubricant to qualify under existing U.S. military specifications.

Six different re-refined lubricants were selected, with quality levels ranging from "best" to "low." The base oils differed in chemical and physical properties. The purpose of selecting various quality levels was to determine the corresponding effect on overall engine performance. All six lubricants were formulated with identical additive packages at a specific treating level, and were then subjected to engine sequence and caterpillar 1-H2 tests.

According to J. A. Creedon [5], the test data demonstrates the capability of the six lubricants to meet the military specification requirements with a given additive package. Furthermore, re-refined oils do have satisfactory performance potential to be utilized in formulating lubricants to meet the U.S. military specifications.

Engine sequence tests are designed to evaluate lubricating oil performance under simulated high stress operating conditions that might occur in normal vehicle use. An oil that successfully passes these tests should perform adequately under even the most severe operating conditions. Vehicle fleet tests, on the other hand, can provide "actual" motor oil performance data on vehicles in normal use, providing deposit and wear ratings are performed and compared.

Since fleet tests require much more time to complete and are less controlled than sequence tests, sequence tests are usually preferred. Certain variables such as constant fuel composition and engine operating conditions are easier to monitor in sequence tests, but are generally difficult to control in fleet tests.

Fleet tests vary in complexity depending on the degree of control that a researcher requires. For example, fleet tests performed by Southwest Research Institute in Texas [6] have operated on a predetermined course with specified fuel supply and detailed used oil analyses. Other tests, such as the one conducted by the city of San Diego, simply operate the vehicles for a predetermined length of time, and then perform deposit and wear ratings on a representative sample [7].

In the past, very few fleet tests have been performed on re-refined motor oil. The San Diego fleet test, which operated solely on re-refined motor oil, was completed in August 1977. Conclusions drawn from the deposit ratings performed on representative vehicles should be used with caution. Overall, the results on the engines using re-refined oils were supportive. The Iowa Re-refined Oil Fleet Test, on the other hand, was designed to provide a more controlled testing program.

3. TEST PROGRAM

3.1. Summary

This test was designed to obtain comparative performance data on re-refined and virgin 10W-30 motor oils and hydraulic oils in fleet use. The vehicles were provided by the Iowa Department of Transportation. The re-refined oils were the commercial product from Motor Oils Refining Company and the experimental product from the Bartlesville Energy Research Center.

Forty-six vehicles, including 23 passenger cars, 13 pickups, and 10 trucks with hydraulic systems, were operated under normal conditions with 21 vehicles using virgin oil and 25 vehicles using re-refined oil. Both dipstick and oil change samples were analyzed by standard ASTM methods. Oil drain intervals of 4,000, 8,000 and 10,000 miles were used.

New vehicles were operated up to 3000 miles before the manufacturer's oil was drained, the system flushed and test oil installed. Used vehicles with 13,000 to 27,000 miles of use were similarly treated to determine the effects of switching oil.

Analytical results from oil drain samples were obtained. After two years of operation, twelve representative engines were dismantled and deposit ratings were obtained. All pertinent data were analyzed to compare oil performance and to assess the effect of varying drain interval.

3.2. Description

The new vehicles were run 1000 to 3000 miles on the "original equipment" oil before being switched to the test oil. The used vehicles had accumulated 13,000 to 27,000 miles before being switched to the test oil. The vehicles that completed the test are listed in Tables 1, 2, 3 and 4 by vehicle type. Information regarding engine size, oil drain interval, type of test oil, and initial and final dates and mileages is provided. In addition, the two vehicles that were dropped from the test are identified. A low mileage-accumulating vehicle, A17676 using BERC oil, was dropped to conserve a limited supply of that oil. Vehicle A20386, a Ford 750 truck using virgin oil, needed to be repaired because of excessive oil consumption.

The oils being tested were supplied by Motor Oils Refining Co., Bartlesville Energy Research Center, and the Iowa Department of Transportation from their standard stock. Each oil was formulated to 10W-30 grade and SE/CC service. Tables 5 and 6 present a complete oil characterization of each oil that includes a detailed laboratory analysis and an identified Lubrizol additive package.

All vehicles (except Vehicle 18718, which used Phillips fuel) used Amoco fuel, while the Ford 750 trucks used leaded fuel. Any test vehicle operators who bought fuel with credit cards were instructed to purchase Amoco fuel.

Conversion of the vehicles to the test oil required flushing the system by driving for 30 minutes on the test oil (with a new filter) and then changing oil and filter again (all vehicles used Fram specified air and oil filter types throughout the test). Appropriate labels

Table 1. 1976 Matador wagons.

Vehicle Number	Engine Size (in^3)	Test Oil	Drain Interval	Initial Mileage Date	Final Mileage Date
A17676[1]	360	BERC	4,000	2124 8/9/76	--
A17677	"	MORCO	8,000	2700 8/2/76	40833 5/10/78
A17678	"	VIRGIN	"	2777 8/9/76	45033 6/19/78
A17679	"	MORCO	"	1516 8/2/76	16942 11/1/77
A17680[2]	"	BERC	"	3074 7/26/76	45887 4/26/78
A17681	"	VIRGIN	"	1844 7/28/76	11351 5/8/76
A17682	"	MORCO	"	1164 7/28/76	36106 5/5/78
A17683[2]	"	VIRGIN	"	3144 7/12/76	49503 4/24/78
A17684	"	VIRGIN	"	2022 8/2/76	40562 5/15/78
A17685[2]	"	MORCO	"	3151 7/27/76	60174 4/24/78
A17686[2]	"	BERC	"	1410 8/11/76	27101 4/26/78
A17687[2]	"	MORCO	"	1597 7/16/76	48285 4/29/78
A17688[2]	"	VIRGIN	"	2173 7/27/76	54477 4/24/78

[1] This vehicle was dropped from the test to conserve a limited BERC oil supply.

[2] This vehicle was involved in the teardown and inspection.

Table 2. 1976 Dodge pickups.

Vehicle Number	Engine Size (in^3)	Test Oil	Drain Interval	Initial Mileage / Date	Final Mileage / Date
A18707	225	MORCO	10,000	2231 / 8/6/76	15177 / 12/22/77
A18710[2]	"	MORCO	"	1002 / 7/26/76	28617 / 4/24/78
A18712	"	VIRGIN	8,000	1149 / 8/18/76	24917 / 5/11/78
A18713	"	MORCO	"	1407 / 8/24/76	--
A18714	"	MORCO	"	2683 / 7/27/76	50560 / 5/10/78
A18716[2]	"	VIRGIN	10,000	2100 / 7/30/76	63900 / 4/28/78
A18717	"	VIRGIN	"	3677 / 9/15/77	28902 / 5/15/78
A18718	"	VIRGIN	8,000	1685 / 9/16/76	23143 / 5/17/78
A18722	"	MORCO	"	1853 / 7/28/76	26444 / 12/29/77
A18729[2]	"	VIRGIN	"	1095 / 8/10/76	31940 / 4/24/78
A18731[2]	"	MORCO	"	1509 / 11/1/76	45091 / 4/28/78
A18744[1]	360	MORCO	10,000	1004 / 7/26/76	28296 / 12/27/77
A18745[1]	"	VIRGIN	10,000	2255 / 7/26/76	33998 / 5/8/78

[1] Data from this vehicle was not reported in Figures 1-18 because the engine was different from the other pickups.

[2] This vehicle was involved in the teardown and inspection.

Table 3. 1976 F-750 Ford trucks.

Vehicle Number	Engine Size (in^3)	Test Oil	Drain Interval	Initial Mileage / Date	Final Mileage / Date
A20363	361	VIRGIN	4,000	2487 / 9/21/76	17799 / 5/5/78
A20364	"	VIRGIN	"	1218 / 9/21/76	29479 / 5/9/78
A20365	"	MORCO	"	1458 / 9/21/76	21234 / 5/16/78
A20366	"	VIRGIN	"	1256 / 11/12/76	10902 / 4/5/78
A20367	"	MORCO	"	1315 / 9/20/76	16102 / 12/21/77
A20368	"	MORCO	"	1568 / 9/20/76	14240 / 11/21/77
A20369[2]	"	MORCO	"	1364 / 9/20/76	31676 / 4/25/78
A20370	"	MORCO	"	1297 / 9/21/76	17162 / 12/6/77
A20371[2]	"	VIRGIN	"	1756 / 9/21/76	27207 / 4/25/78
A20386[1]	"	VIRGIN	"	1045 / 9/20/76	--

[1]This vehicle was dropped because of high oil consumption.

[2]This vehicle was involved in the teardown and inspection.

Table 4. 1975 Chevrolet Malibus.

Vehicle Number	Engine Size (in^3)	Test Oil	Drain Interval	Initial Mileage Date	Final Mileage Date
A16938	350	MORCO	4,000	19089 8/24/76	43514 11/23/77
A16947	"	VIRGIN	"	26472 8/11/76	62730 4/4/78
A16955	"	VIRGIN	"	16196 8/10/76	36152 3/27/78
A16964	"	MORCO	"	27866 8/11/76	48975 12/21/77
A17015	"	MORCO	"	24160 8/24/76	50389 10/29/77
A17029	"	VIRGIN	"	21236 8/11/76	46341 4/14/78
A17030	"	MORCO	"	19123 8/11/76	42760 3/20/78
A17035	"	VIRGIN	"	13117 8/11/76	39533 11/28/77
A17042	"	VIRGIN	"	25491 8/10/76	50116 3/30/78
A17059	"	MORCO	"	24557 8/12/76	47890 9/30/77

Table 5. Test oil laboratory analysis.

Laboratory Analyses	MORCO Oil	BERC Oil	VIRGIN Oil
Viscosity, SSU @ 100°F	316	375	318
Viscosity, SSU @ 210°F	61.60	67.85	63.72
Viscosity Index	136	137	141
TAN	2.15	2.35	1.63
TBN	5.43	3.92	3.33
Ash (sulfated) (%)	1.00	1.30	.71
pH		7.4	
Benzene Insol. Coag.	Nil	Nil	Nil
Pentane Insol. Coag.	Nil	Nil	Nil
Sulfur (%)	.58	.5	.46
Flash, °F	405	425	405
Pour, °F	Below -50	Below -50	Below -50
Gravity	29.2	29.2	29.2
Color	4-1/2	3	3
Water	-	-	-
Fuel Dilution	-	-	-
Spectrographic: ppm			
Iron	2	2	2
Zinc	980	830	820
Lead	0	0	0
Sodium	5	4	16
Calcium	1950	2600	1900
Silicon	4	2	5
Silver	0	0	0
Copper	0	0	0
Aluminum	0	0	0
Barium	24	25	35
Nickel	0	0	0
Chromium	0	0	0
Tin	1	1	1
Phosphorus	800	650	650
Boron	0	0	14
Magnesium	650	9	7
Vanadium	0	0	0
Molybdenum	0	0	0
Manganese	0	0	0
Cadmium	0	0	0
Titanium	0	0	0
3 hr @ 210°F Copper Corrosion	Class I	Class I	Class I

Table 6. Test oil additive packages.

Test Oil	Viscosity Index Improver	Multipurpose Additive
BERC Oil	Lubrizol 3702 (Dispersant Type) 2-10% (Vol.)	Lubrizol 4462 6.8% (Vol.) of Base Stock
MORCO Oil	Lubrizol 3135 (Non-Dispersant Polymethacrylate)	Hitec E-703 6.7% (Vol.) of Base Stock
VIRGIN Oil*	Lubrizol 7013 (Poly Ethylene-Propylene) 8% (Vol.)	Lubrizol 4454-E 6.7% (Vol.) of Base Stock

*i.e. Mid-Continent Crude.
= 70.8% High V.I. Solvent Extracted 100 Neutral Base.
= 14.8% 150 S.U.S. @ 210°F of Bright Stock.

were then placed on the vehicle to guard against the use of incorrect oil. A log book was placed in each vehicle to record gas consumption, unusual driving conditions, repairs, oil samples, changes, etc. The drivers and mechanics maintained excellent records in these books, and summary information was reported to Iowa State University at the time an oil sample was taken. The log books in the field were periodically inspected by test supervisors.

Oil drain samples were taken at 4,000, 8,000, or 10,000 miles, depending on the specifications for that particular vehicle. The vehicle was driven for 30 minutes to insure a hot oil sample that minimizes fuel dilution. The oil was then drained into a clean pan used only for test oils, thoroughly mixed in the pan, and two one-pint samples were obtained. One of these samples was labeled and stored at the site and the other was labeled and mailed to Motor Oils Refining Co. for analysis. The results of these analyses are reported in Appendix A. Standard ASTM analytical methods (Table 7) were used.

Those vehicles on 8,000 or 10,000 mile oil drain intervals were monitored by means of dipstick samples taken at 2,000 mile intervals for the first oil drain period. This provided a means of preventing possible engine damage resulting from unsatisfactory oil performance at these extended drain intervals.

These intermediate samples were obtained by means of a suction gun fitted with tubing that was inserted through the dipstick hole. The length of tubing was premeasured, and an end and side hole in the tubing was provided in order to get a representative sample.

Following a satisfactory period of oil performance at 8,000 and

Table 7. Used oil analyses.

Laboratory Analyses:	ASTM Designation	Spectrographic Analyses	
Flash, ^{o}F	D-92	Lead	Sodium
Viscosity, @ $100^{o}F$	D-445	Copper	Calcium
Viscosity, @ $210^{o}F$	D-445	Iron	Barium
Viscosity Index	D-2270	Aluminum	Zinc
Benzene Insolubles	D-893	Chromium	Phosphorus
Pentane Insolubles	D-893	Tin	Magnesium
Total Acid Number	D-664	Vanadium	Manganese
Total Base Number	D-664	Molybdenum	Cadmium
Fuel Dilution	D-332	Nickel	Titanium
Antifreeze		Boron	Silver
Water (on selected samples)	D-95		Silicon

10,000 mile drain intervals, the Matador wagons (Table 1), which were originally sampled every 4,000 miles, were switched to 8,000 mile drain intervals. This helped conserve a limited supply of BERC oil and provided increased stress on the oils. Hydraulic oil samples were taken (concurrently with oil drain samples) from the hydraulic reservoir, which was specially fitted with a standpipe/petcock sampler.

This fleet test terminated when the Iowa DOT dismantled 12 engines and Southwest Research Institute personnel performed deposit ratings. The ratings included a visual rating of sludge and varnish accumulation and observations of rust and corrosion.

4. FLEET OPERATION DATA

4.1. Introduction

The comparative analysis of re-refined and virgin lubricating oils in this fleet test includes: comprehensive laboratory analyses of oil drain samples; laboratory analyses of hydraulic oil samples; engine wear measurements on 12 vehicles selected for teardown and inspection; and sludge and varnish (deposit) ratings on the 12 vehicles.

It should be emphasized that the vehicles involved in the fleet test are operated under a variety of conditions which may range from high speed/high load to stop and go with high idling time. No attempt has been made to segregate the used oil analyses, wear measurements, or deposit ratings according to specific driving conditions.

Duplicate oil samples that were analyzed by Faber Laboratories of Chicago gave acceptable correlation with MORCO results. All laboratory data reported is from MORCO Laboratories.

The Chevrolet Malibus (Table 4) were operated on the re-refined MORCO oil to assess the effect of switching from a virgin to a re-refined oil. The data, obtained from 4,000 mile oil drain samples, displayed no distinguishing trends related to the switching of oil types, and yielded no additional information to the data obtained from the Matador wagons at a 4,000 mile oil drain interval. All vehicles performed satisfactorily with no engine problems or repairs. Therefore, the Chevrolet Malibus' data will not be analyzed further. Laboratory analyses of the oil drain samples are provided in Appendix A.

The comprehensive analysis of laboratory data from the oil drain samples includes a discussion of oil consumption, wear metal concentrations, total base number, viscosity, pentane insolubles, water concentrations, oil additive metals, and fuel additives.

4.2. Oil Consumption

The number of quarts of oil added per 1,000 miles during each vehicle's oil drain period is plotted as a function of mileage in Figs. 1, 2, and 3. The consumption of MORCO oil is somewhat higher than that of the BERC or VIRGIN oil, as shown in Fig. 1. Similar conclusions can be drawn from data presented in Fig. 2 for the Dodge pickups. The oil consumption data of the Ford trucks shown in Fig. 3 is scattered and inconclusive.

Furthermore, in Fig. 1 the first 24,000 miles represents a period of 4,000 mile oil drain samples, while the remaining samples were taken roughly every 8,000 miles. Oil consumption per 1,000 miles is relatively steady, although an increasing trend can be seen in the 40,000 to 50,000 mile region. This may be a function of the oil drain interval or simply of the mileage.

Generally, the oil consumption rates were higher for the MORCO oil than for the other test oils. In the Matador wagons the mean MORCO, VIRGIN, and BERC oil consumption rates were 0.62, 0.35, and 0.17 qts/1000 miles respectively. A similar trend was noted in the Dodge pickups, where the mean MORCO oil consumption rate was 0.60 qts/1000 miles and the VIRGIN oil was 0.43 qts/1000 miles. However, the mean oil consumption rates in the Ford trucks showed the opposite trend (a mean MORCO oil consumption rate of 1.0 qts/1000 miles and a mean VIRGIN oil consumption

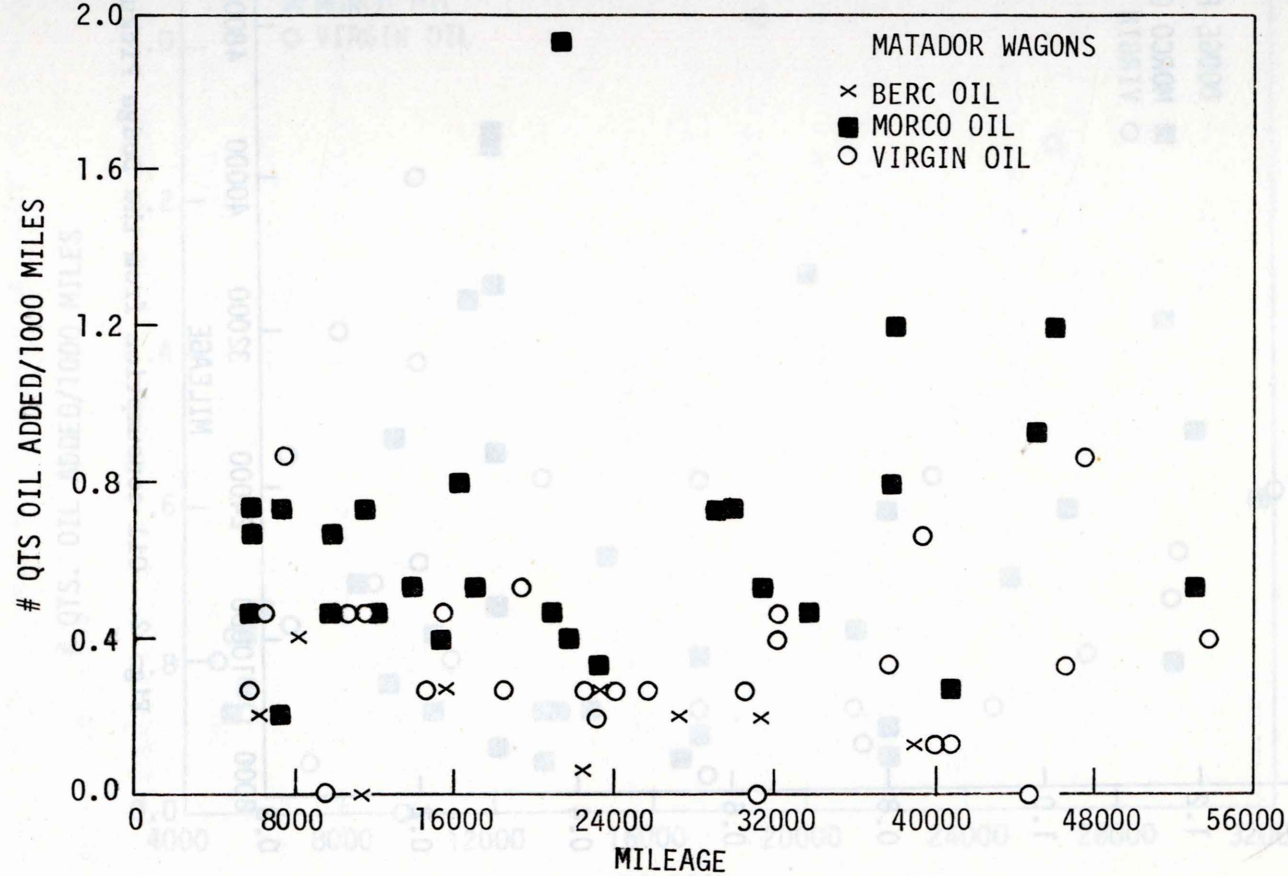

Fig. 1. Oil consumption from the Matador wagons.

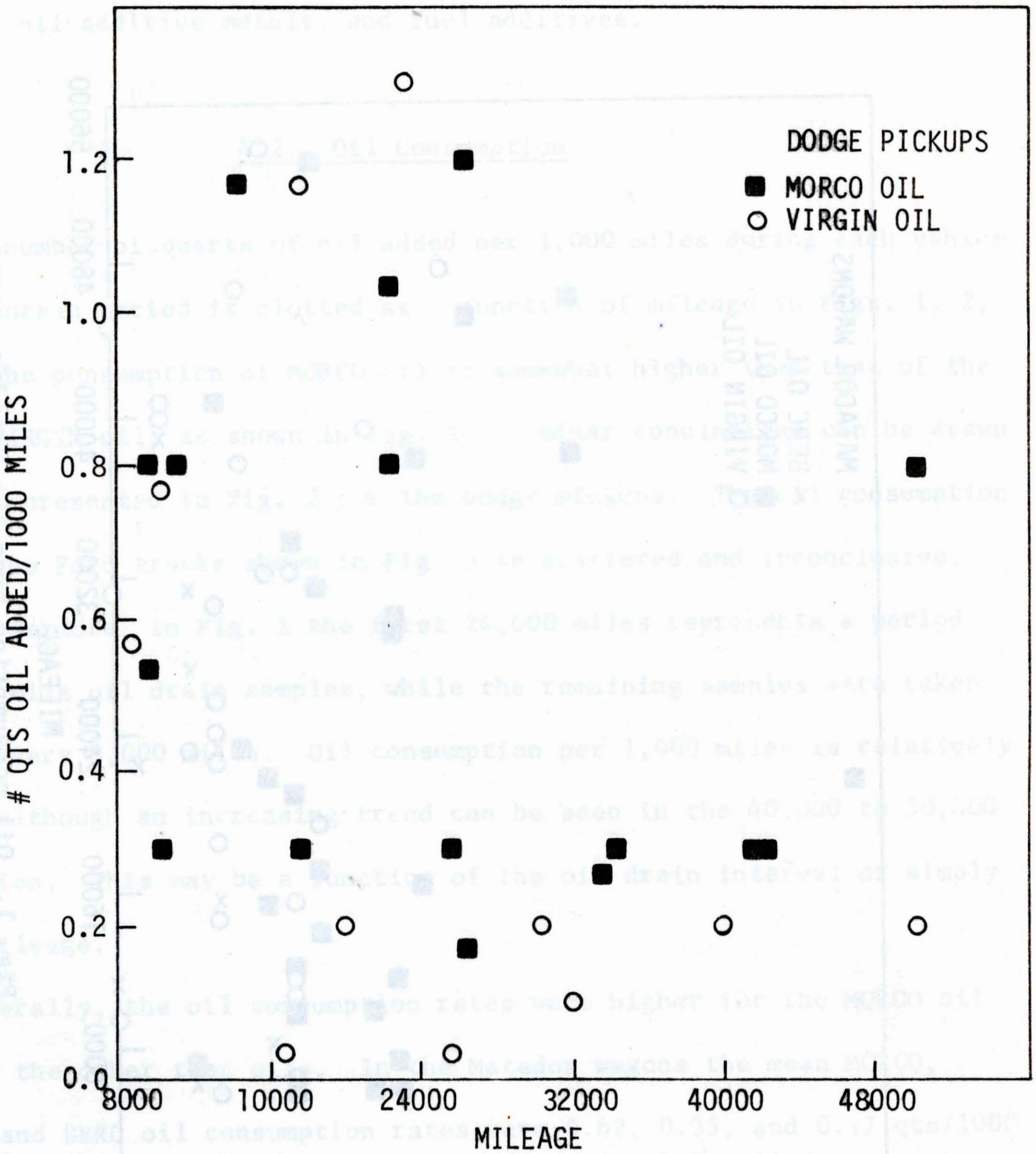

Fig. 2. Oil consumption from the Dodge Pickups.

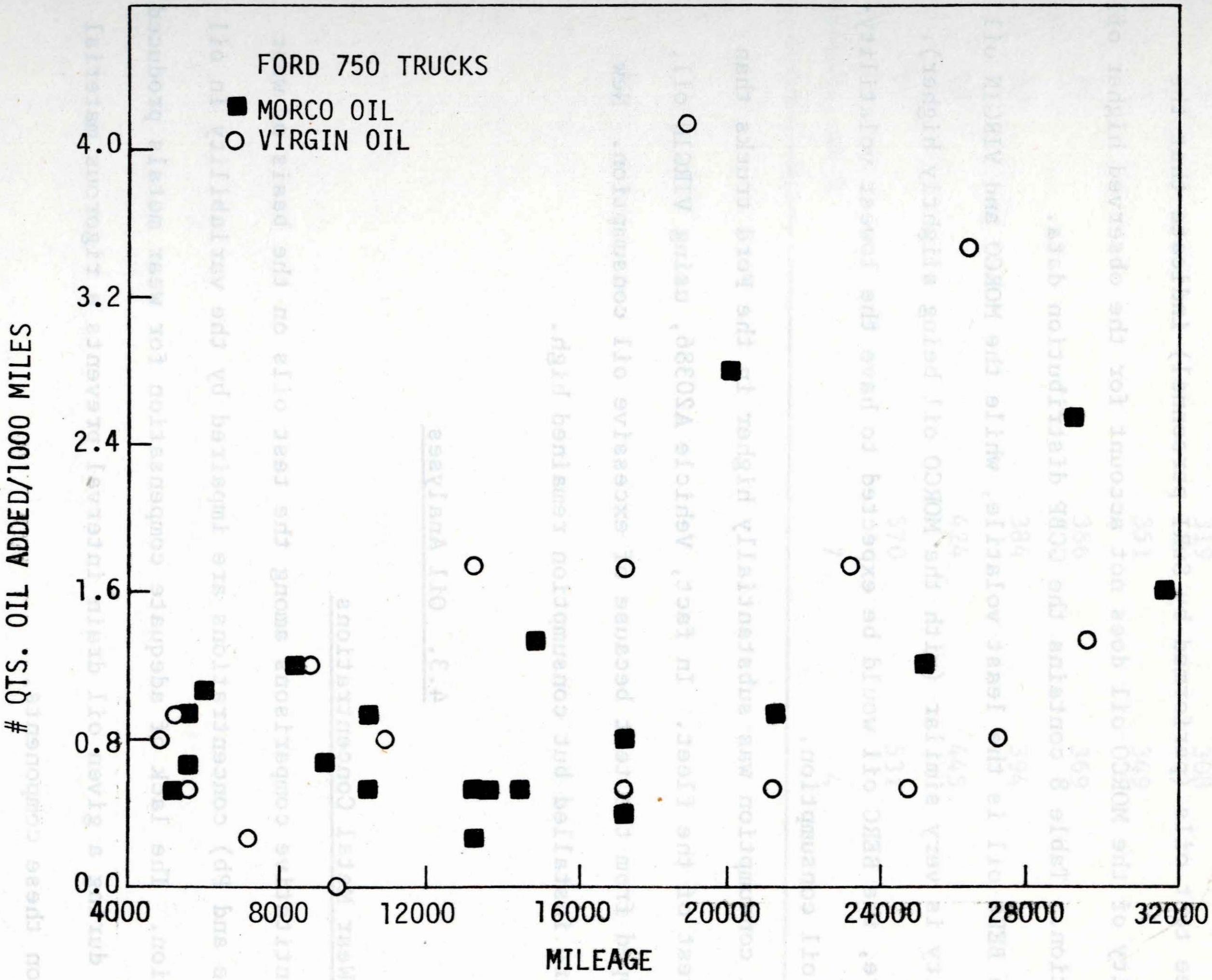

Fig. 3. Oil consumption from the Ford 750 trucks.

rate of 1.2 qts/1000 miles. The oil consumption rates of vehicles involved in the tear down and inspection corresponded favorably with the remainder of the fleet.

Results from the gas chromatograph boiling point distribution of the three test oils (performed by SwRI personnel) indicate that the volatility of the MORCO oil does not account for the observed higher oil consumption. Table 8 contains the GCBP distribution data.

The BERC oil is the least volatile, while the MORCO and VIRGIN oil volatility is very similar (with the MORCO oil being slightly higher). Therefore, the BERC oil would be expected to have the lowest volatility-related oil consumption.

Oil consumption was substantially higher in the Ford trucks than in the rest of the fleet. In fact, Vehicle A20386, using VIRGIN oil, was dropped from the test because of excessive oil consumption. New rings were installed but consumption remained high.

4.3. Oil Analyses

4.3.1. Wear Metal Concentrations

Quantitative comparisons among the test oils on the basis of wear metal (Fe and Pb) concentrations are impaired by the variability in oil consumption. The lack of adequate compensation for wear metals produced and lost during a given oil drain interval prevents a rigorous material balance on these components.

Several correction factors were proposed to compensate for the oil consumption variations, and varied simplistically with the number of

Table 8. Gas chromatographic boiling point distribution data.

wt % off @ ^{o}C	VIRGIN Oil	MORCO Oil	BERC Oil
1	319	308	337
5	351	349	388
10	366	369	403
20	384	394	421
50	424	445	455
90	570	531	525
Residue, wt %	7	4	4

quarts of oil added during the drain interval. For example, a correction factor, alpha, equal to one plus the ratio of the number of quarts of oil added to the total oil capacity (5 quarts in most cases) is proposed. Figures 4, 5, 6, and 7 illustrate the effect of alpha on the iron and lead concentrations (PPM) as a function of the oil drain interval (ODI) in the Matador wagons. A comparison of Fig. 4 with Fig. 5 and Fig. 6 with Fig. 7 demonstrates that no significant improvement in the spread of the data is noted. Similar conclusions were drawn from data plotted using other types of functional relationships. Therefore, we will compare the three oils using the iron and lead concentrations directly and overlook effects resulting from oil consumption.

Although the data is scattered, little difference is noted among the test oils for the iron concentrations at a 4,000 mile ODI. At 8,000 miles, however, MORCO oil iron concentrations are significantly lower than the VIRGIN oil concentrations. Similar plots using a limited quantity of data obtained from the other three types of test vehicles yield no additional information.

Extremely high lead concentrations were reported in the Ford trucks that used leaded fuel. According to Fig. 8, lead levels varied from 1% to 3% at a 4,000 mile ODI. Similarly, iron concentrations (Fig. 9) were generally higher than those of other vehicles and ranged from 100 PPM to 1,200 PPM. MORCO oil iron concentrations were generally higher than the VIRGIN oil concentrations, whereas the lead concentration trends displayed an inverse trend (MORCO lead levels lower than the VIRGIN levels).

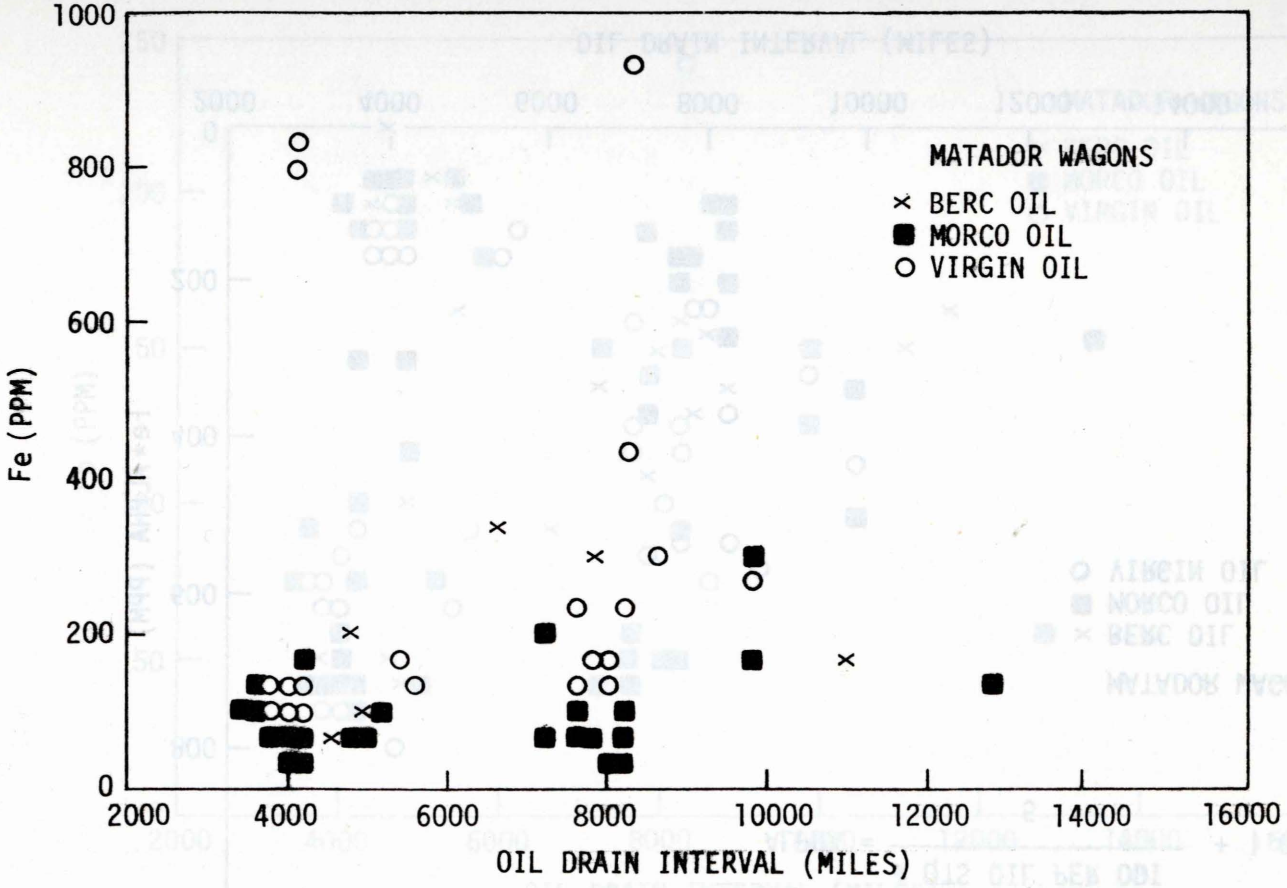

Fig. 4. Iron concentrations from the Matador wagons.

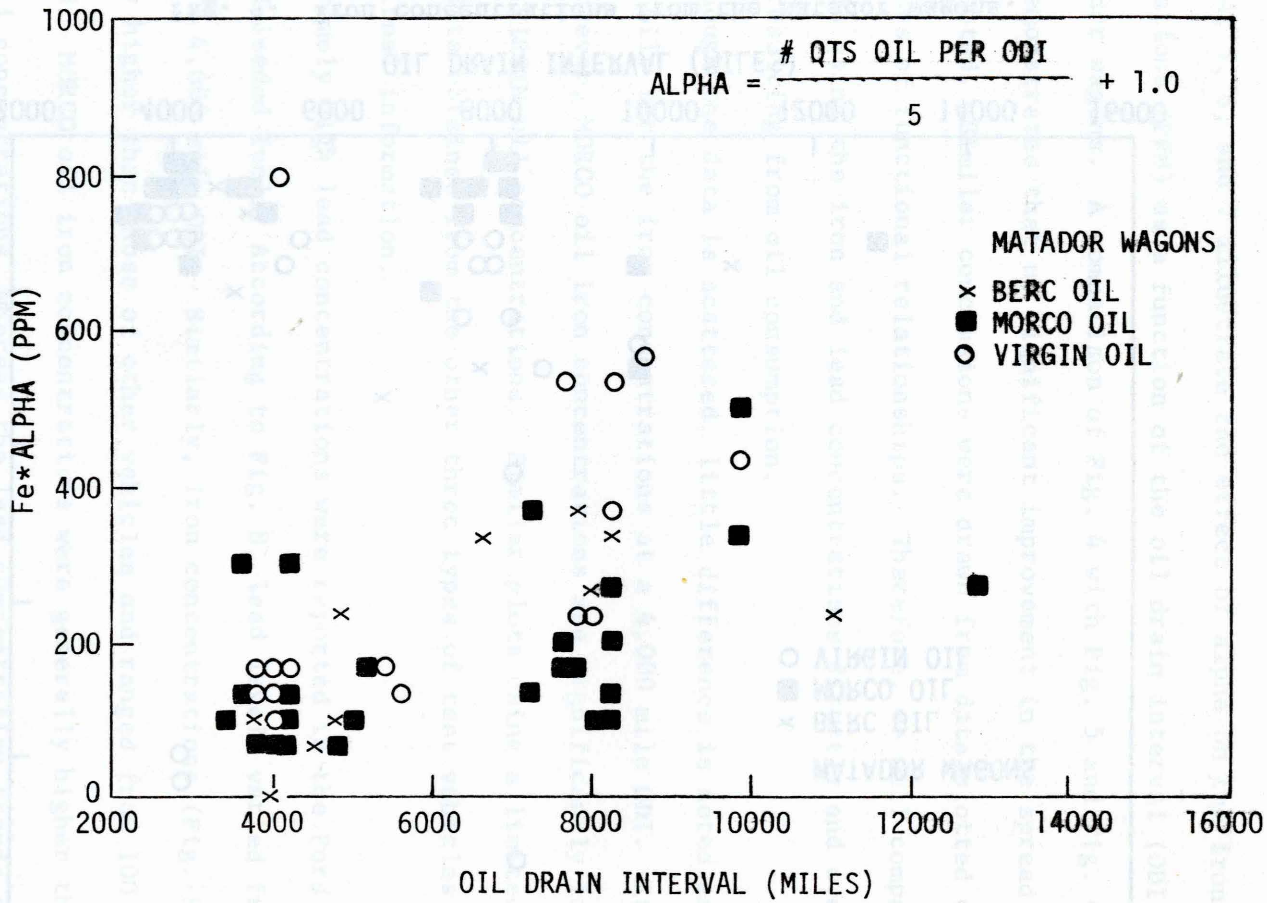

Fig. 5. Modified iron concentrations from the Matador wagons.

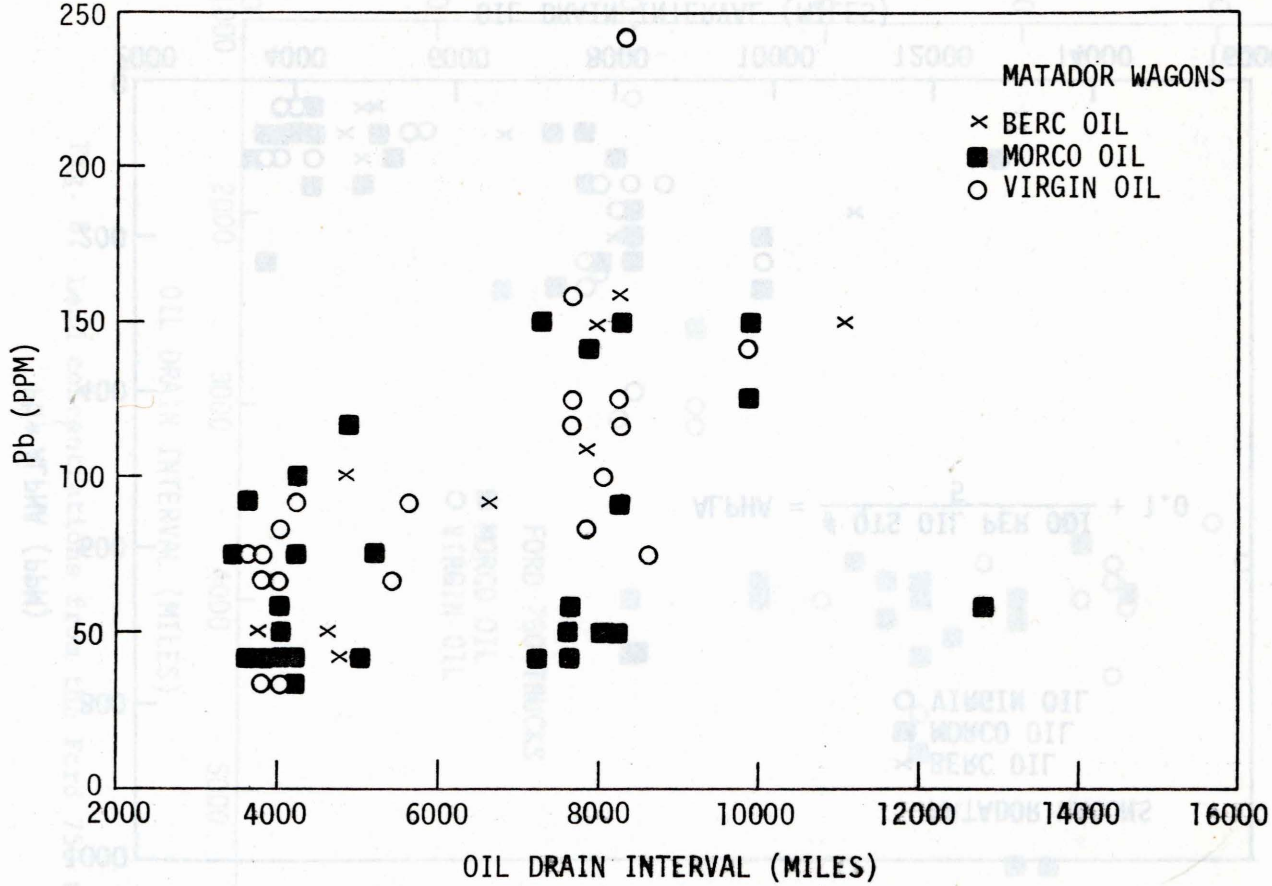

Fig. 6. Lead concentrations from the Matador wagons.

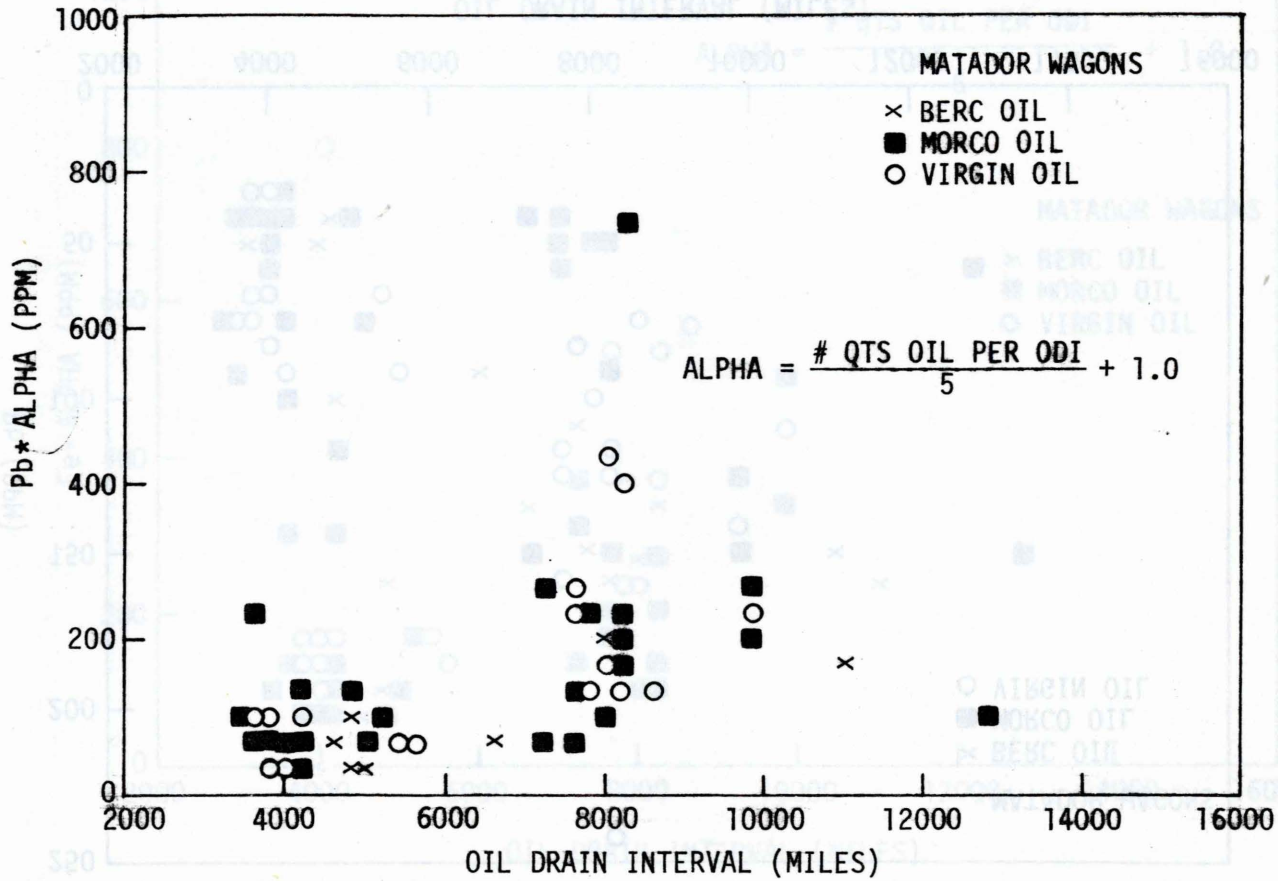

Fig. 7. Modified lead concentrations from the Matador wagons.

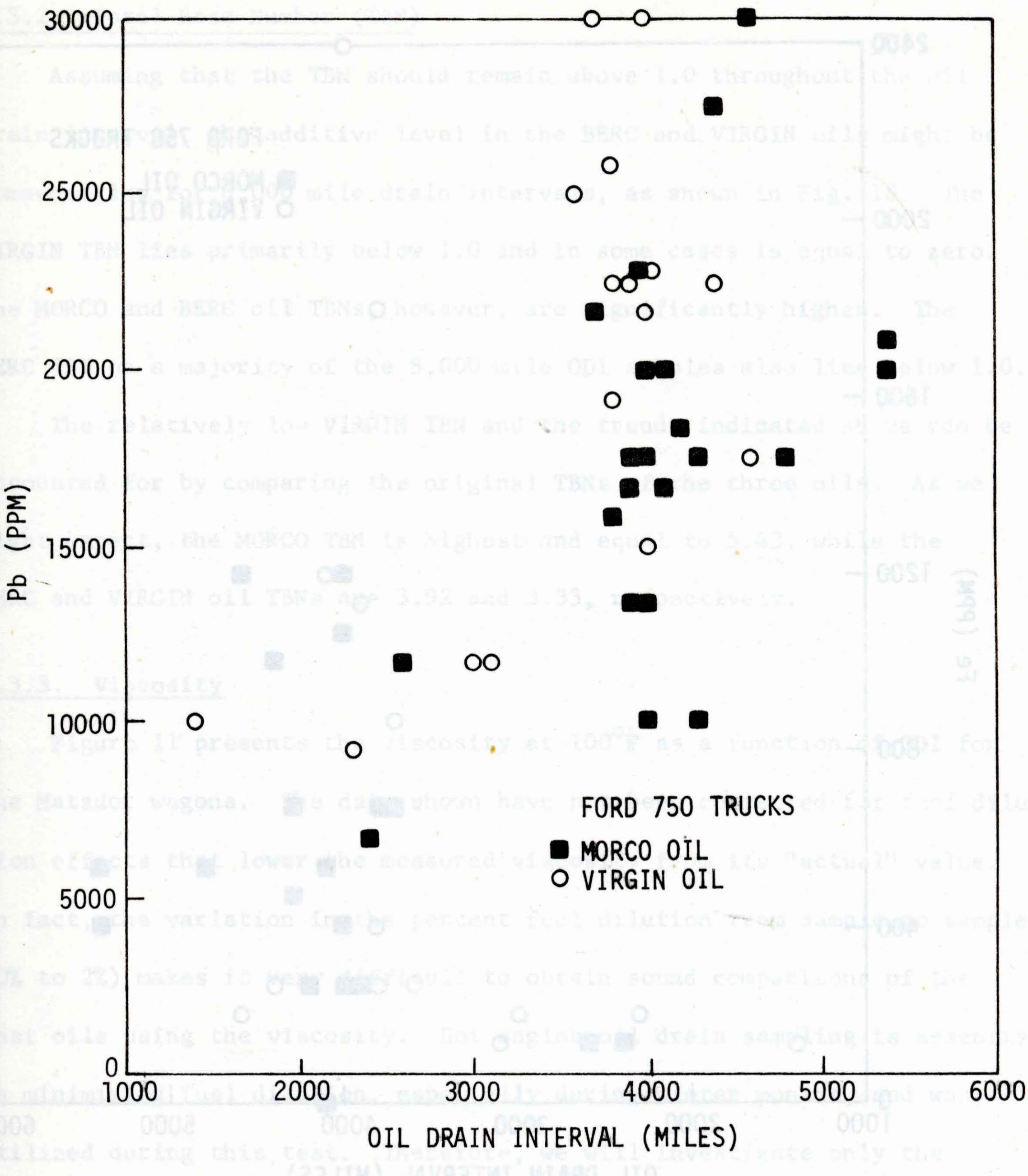

Fig. 8. Lead concentrations from the Ford 750 trucks.

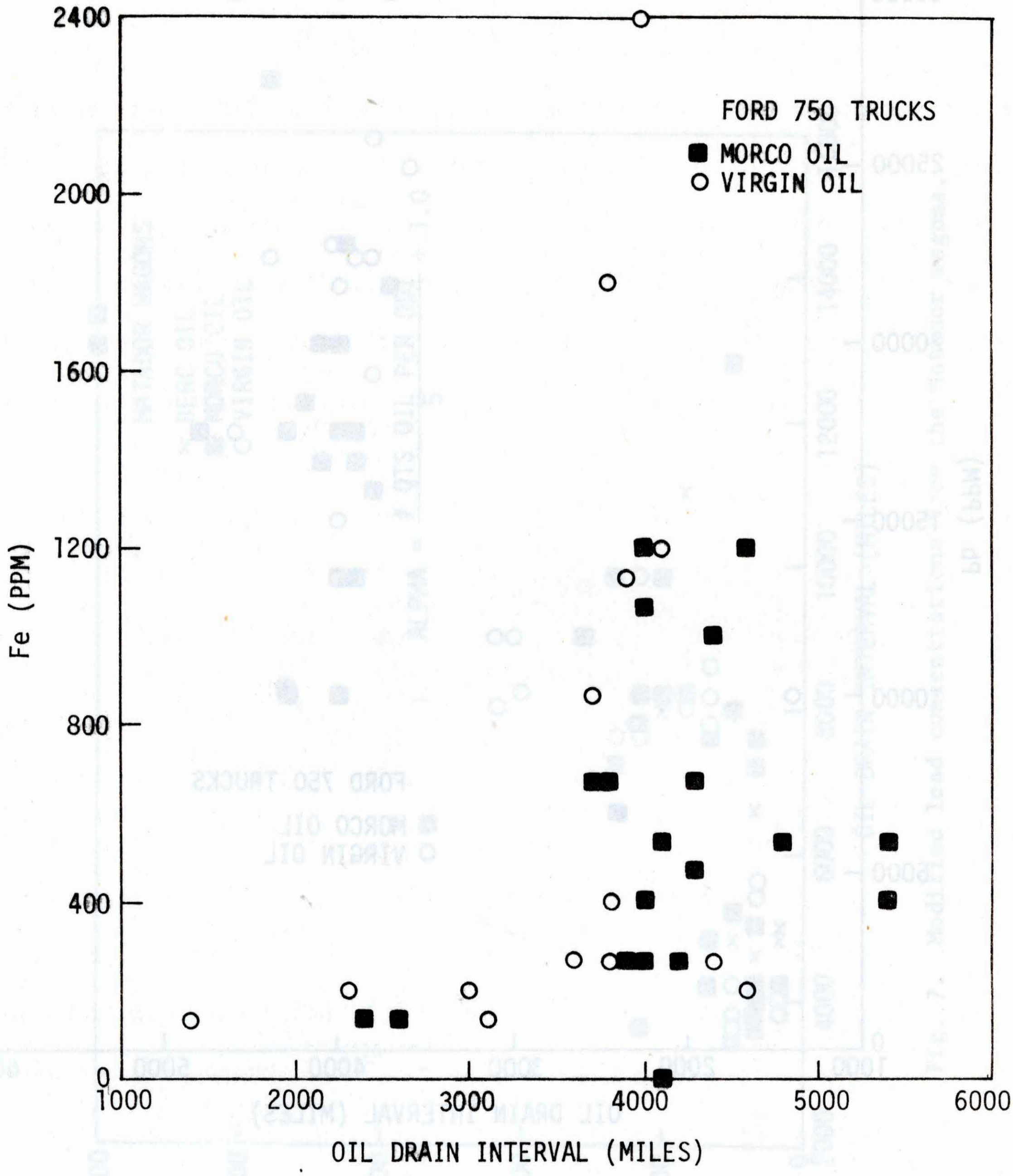

Fig. 9. Iron concentrations from the Ford 750 trucks.

4.3.2. Total Base Number (TBN)

Assuming that the TBN should remain above 1.0 throughout the oil drain interval, the additive level in the BERC and VIRGIN oils might be somewhat low for 8,000 mile drain intervals, as shown in Fig. 10. The VIRGIN TBN lies primarily below 1.0 and in some cases is equal to zero. The MORCO and BERC oil TBNs, however, are significantly higher. The BERC TBN on a majority of the 8,000 mile ODI samples also lies below 1.0.

The relatively low VIRGIN TBN and the trends indicated above can be accounted for by comparing the original TBNs of the three oils. As we might expect, the MORCO TBN is highest and equal to 5.43, while the BERC and VIRGIN oil TBNs are 3.92 and 3.33, respectively.

4.3.3. Viscosity

Figure 11 presents the viscosity at 100^{o}F as a function of ODI for the Matador wagons. The data shown have not been corrected for fuel dilution effects that lower the measured viscosity from its "actual" value. In fact, the variation in the percent fuel dilution from sample to sample (0% to 2%) makes it very difficult to obtain sound comparisons of the test oils using the viscosity. Hot engine oil drain sampling is essential in minimizing fuel dilution, especially during winter months, and was utilized during this test. Therefore, we will investigate only the general trends in the data of Fig. 11.

At the 4,000 mile ODI little difference can be seen among the three test oils. Similarly, the viscosity values at 8,000 miles for the test oils lie in the same region, although nearly half of the VIRGIN oil points lie significantly above it. Generally, the 4,000 mile ODI viscosity values lie between 310 SSU and 425 SSU, whereas the 8,000 mile ODI

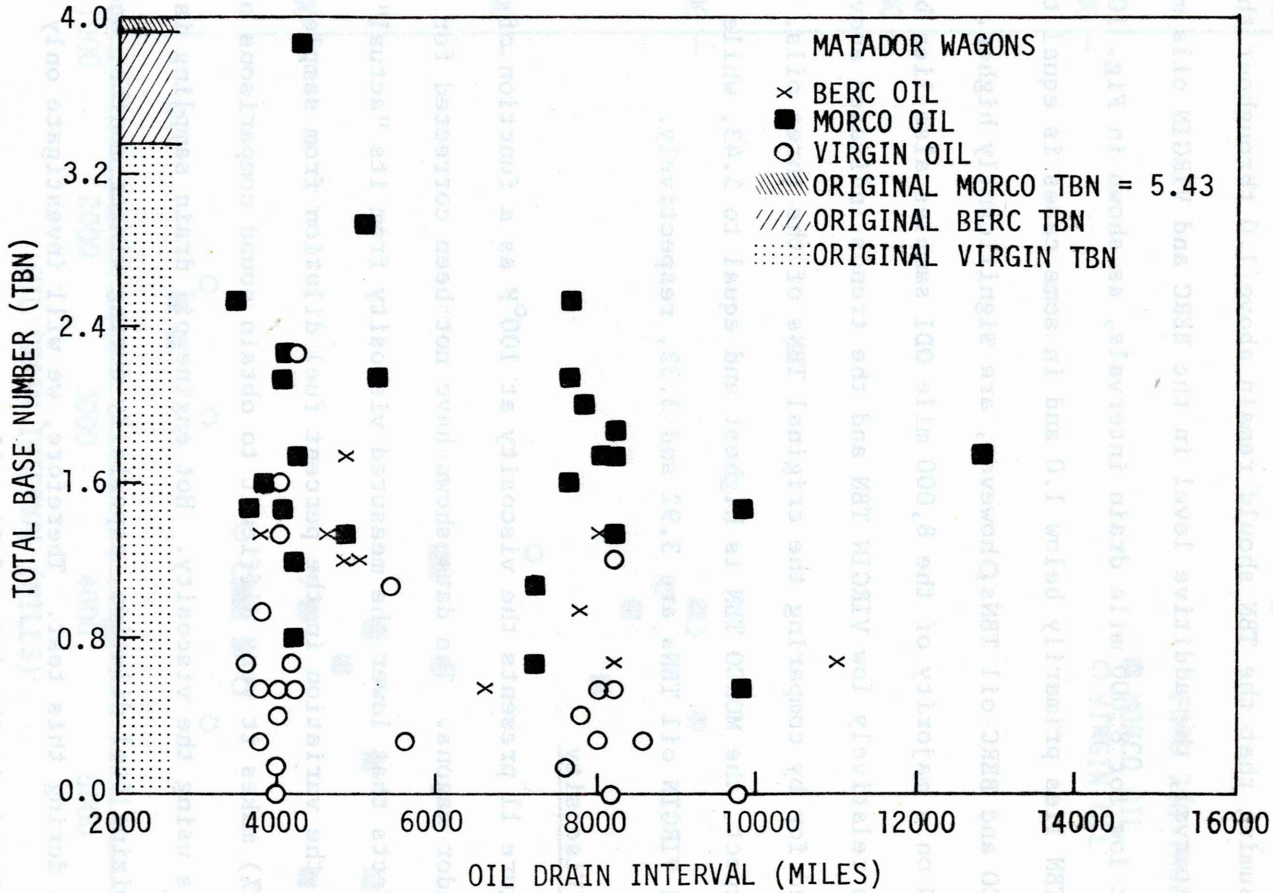

Fig. 10. Total base numbers from the Matador wagons.

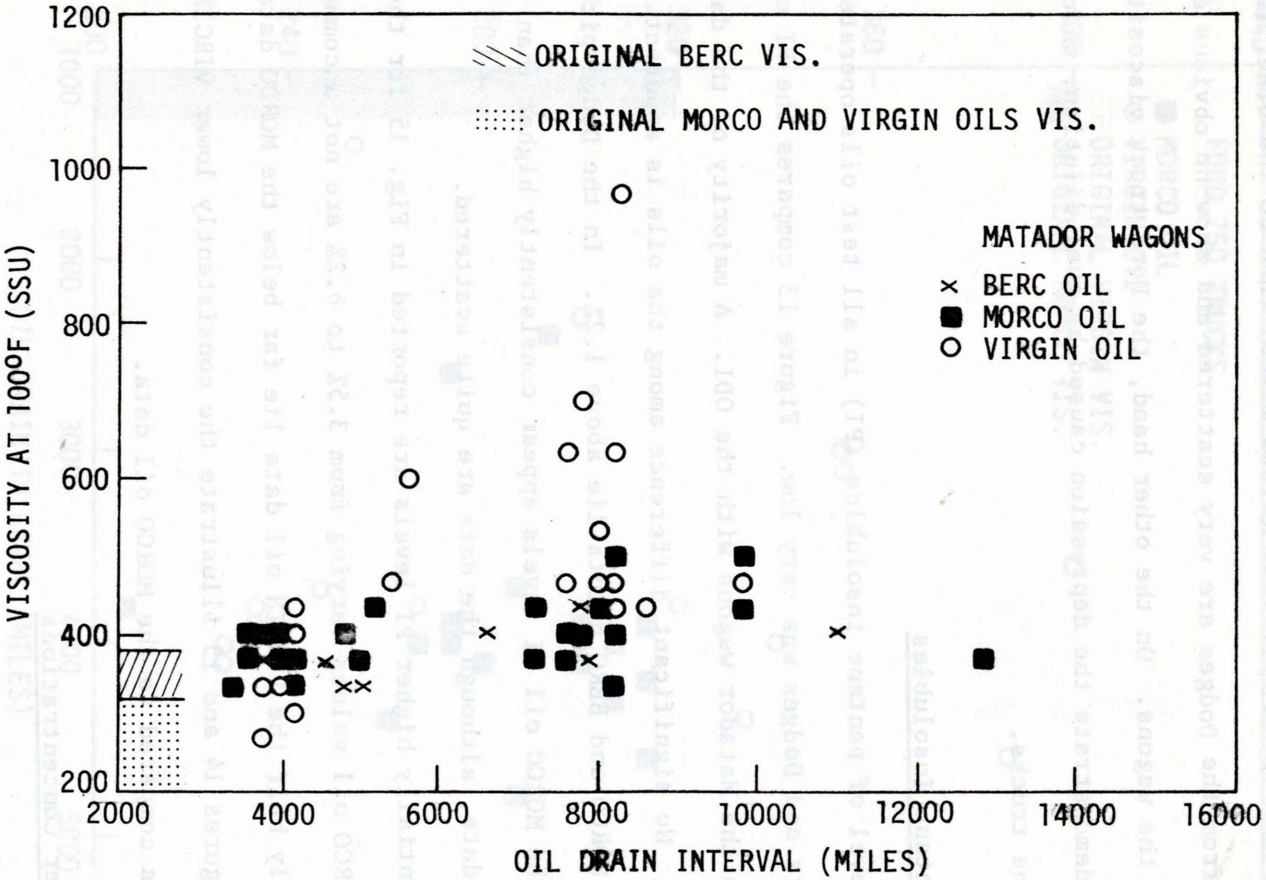

Fig. 11. Viscosity data from the Matador wagons.

viscosity values vary primarily from 340 SSU to 500 SSU. The unusually high VIRGIN viscosity data at an 8,000 mile ODI range from 600 to 1,000 SSU. Apparently, the VIRGIN oil has a slightly higher tendency to thicken at extended oil drain intervals (8,000 miles) than do the other test oils.

Data from the Dodges are very scattered and show no obvious differences from the wagons. On the other hand, the Ford truck viscosity data (Fig. 12) demonstrate the depression caused by fuel dilution, which was high for the trucks.

4.3.4. Pentane Insolubles

The level of pentane insolubles (PI) in all test oils operated in the Matadors and Dodges was very low. Figure 13 compares the PI concentrations in the Matador wagons with the ODI. A majority of the data lies below 0.8%. No significant difference among the oils is apparent. However, some MORCO and BERC points lie above 1.2%. In the Dodge pickups (Fig. 14) the MORCO oil PI levels appear consistently higher than the VIRGIN oil data, although the data are quite scattered.

Substantially higher PI levels are reported in Fig. 15 for the Ford trucks. MORCO oil values varying from 3.5% to 6.2% are not uncommon. Approximately half the VIRGIN oil data lie far below the MORCO data region. Figures 14 and 15 illustrate the consistently lower VIRGIN oil PI levels as compared to the MORCO oil data.

4.3.5. Water Concentrations

To assess the effect of a cold weather test on the degree of water contamination of these oils, various duplicate oil drain samples were analyzed using the ASTM D-95 (H_2O by distillation) technique. Figure 16

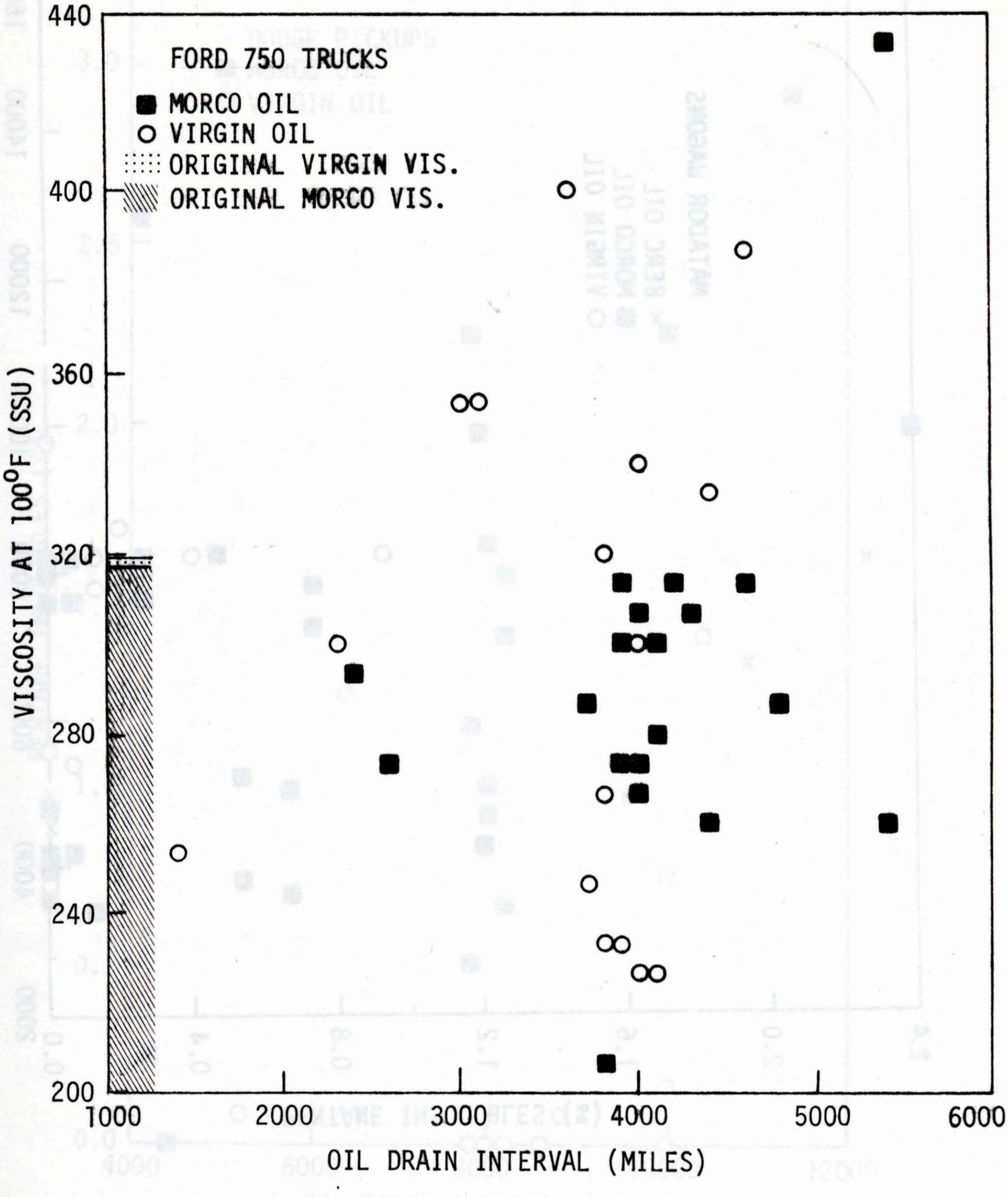

Fig. 12. Viscosity data from the Ford 750 trucks.

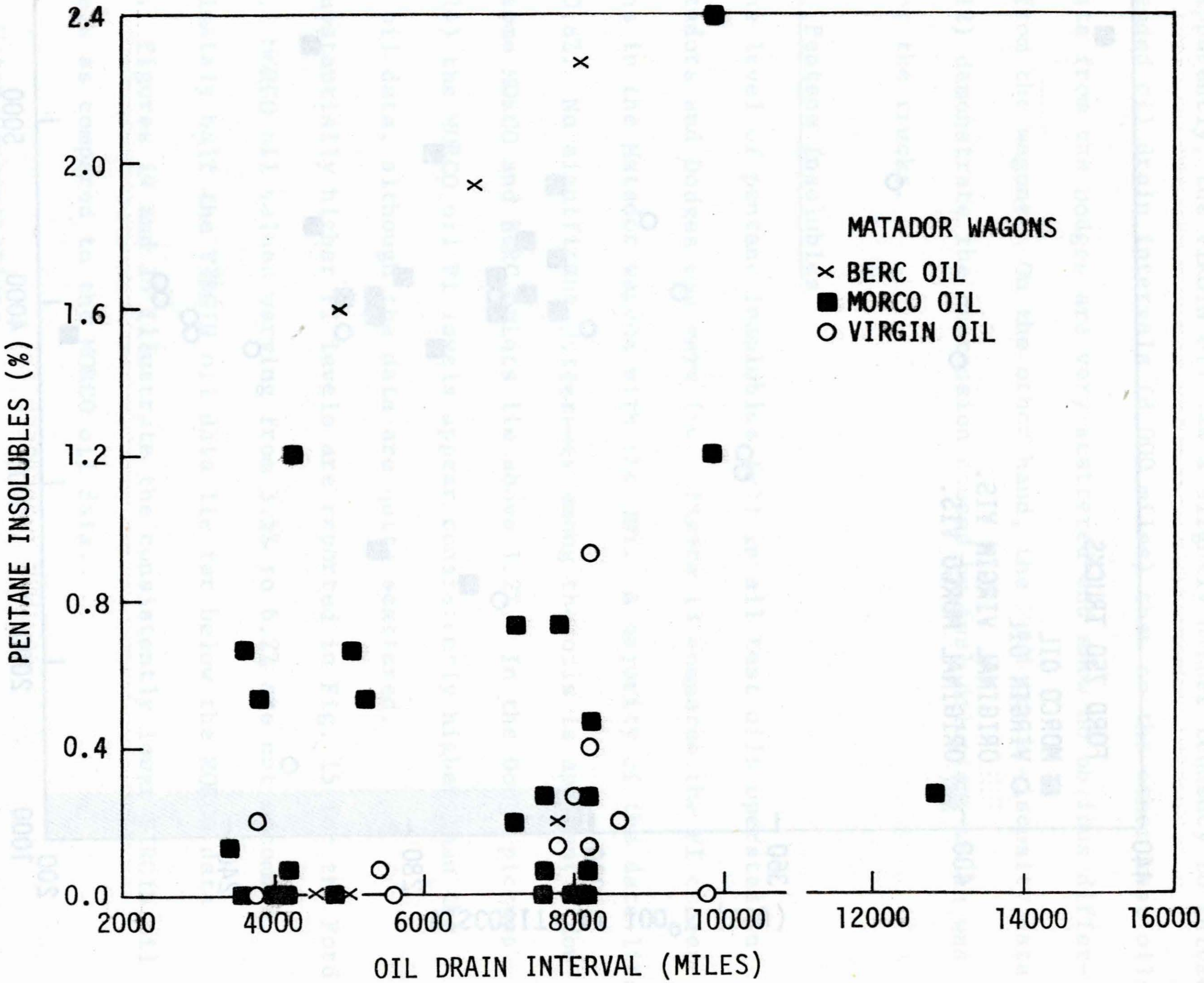

Fig. 13. Pentane insolubles from the Matador wagons.

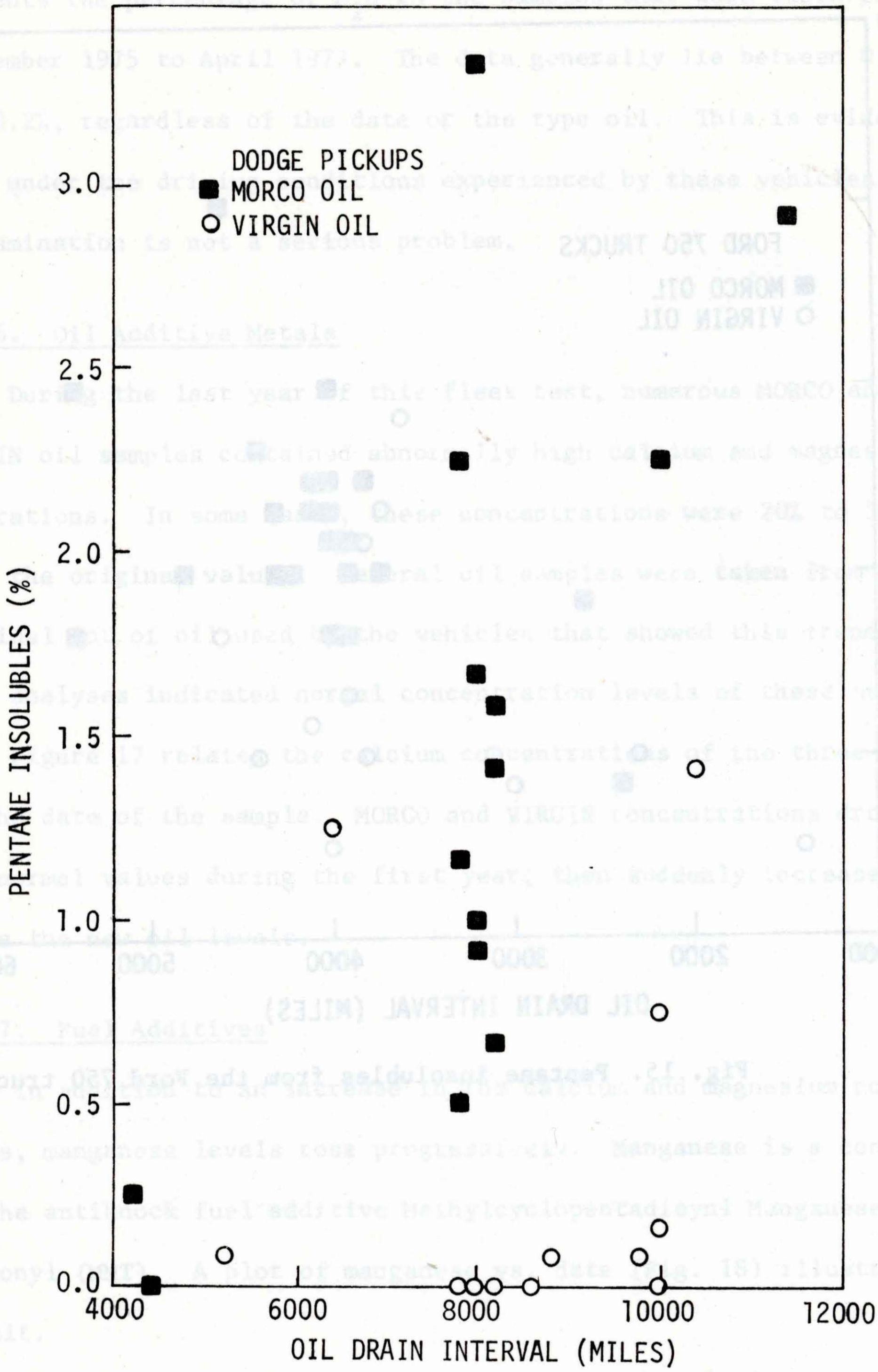

Fig. 14. Pentane insolubles from the Dodge pickups.

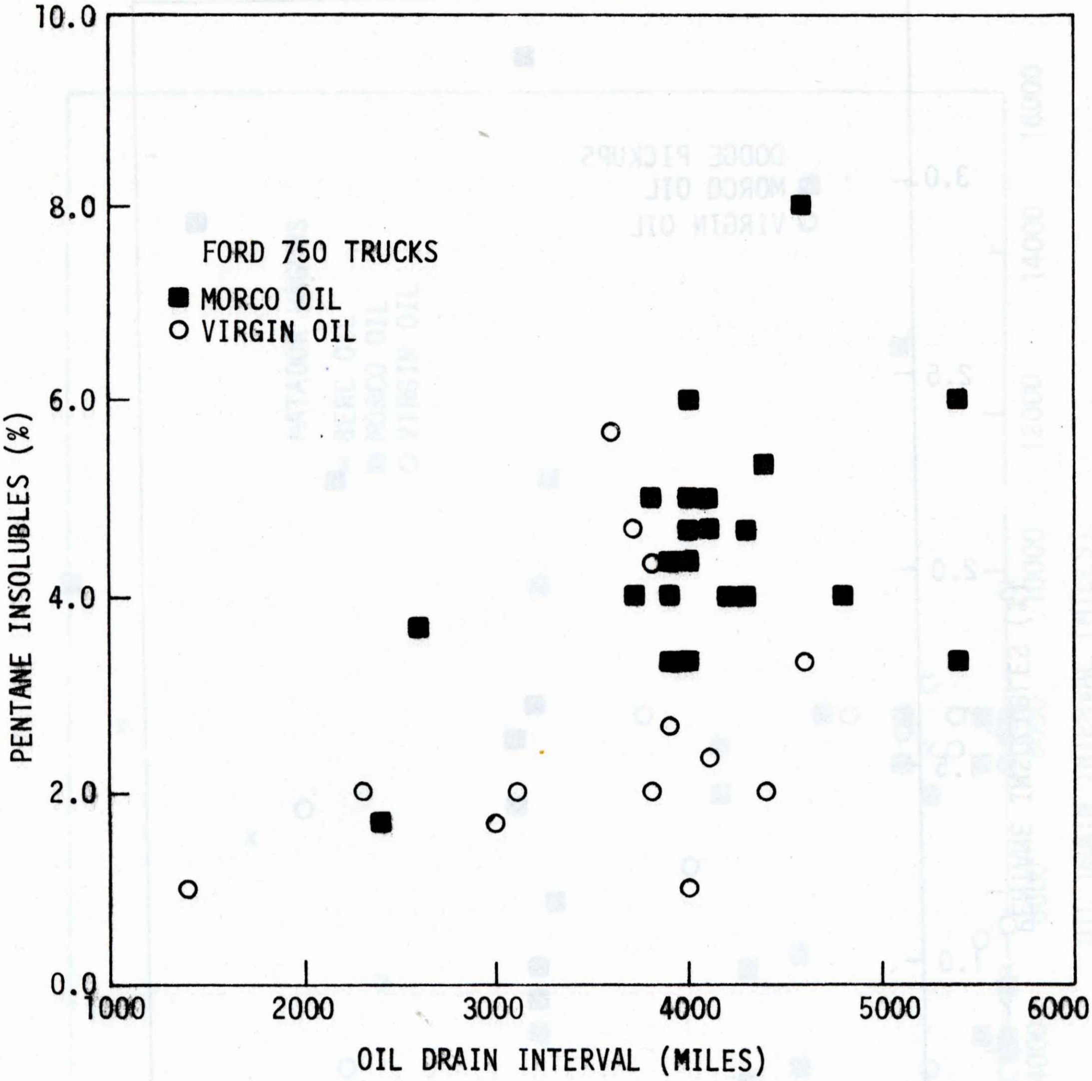

Fig. 15. Pentane insolubles from the Ford 750 trucks.

presents the percentage of H_2O in the samples that were taken from September 1975 to April 1977. The data generally lie between 0.1% and 0.2%, regardless of the date or the type oil. This is evidence that under the driving conditions experienced by these vehicles, water contamination is not a serious problem.

4.3.6. Oil Additive Metals

During the last year of this fleet test, numerous MORCO and a few VIRGIN oil samples contained abnormally high calcium and magnesium concentrations. In some cases, these concentrations were 20% to 50% higher than the original values. Several oil samples were taken from the original lot of oil used by the vehicles that showed this trend. Laboratory analyses indicated normal concentration levels of these metals.

Figure 17 relates the calcium concentrations of the three test oils to the date of the sample. MORCO and VIRGIN concentrations drop from the normal values during the first year, then suddenly increase to above the new oil levels.

4.3.7. Fuel Additives

In addition to an increase in the calcium and magnesium concentrations, manganese levels rose progressively. Manganese is a constituent of the antiknock fuel additive Methylcyclopentadieynl Manganese Tricarbonyl (MMT). A plot of manganese vs. date (Fig. 18) illustrates this result.

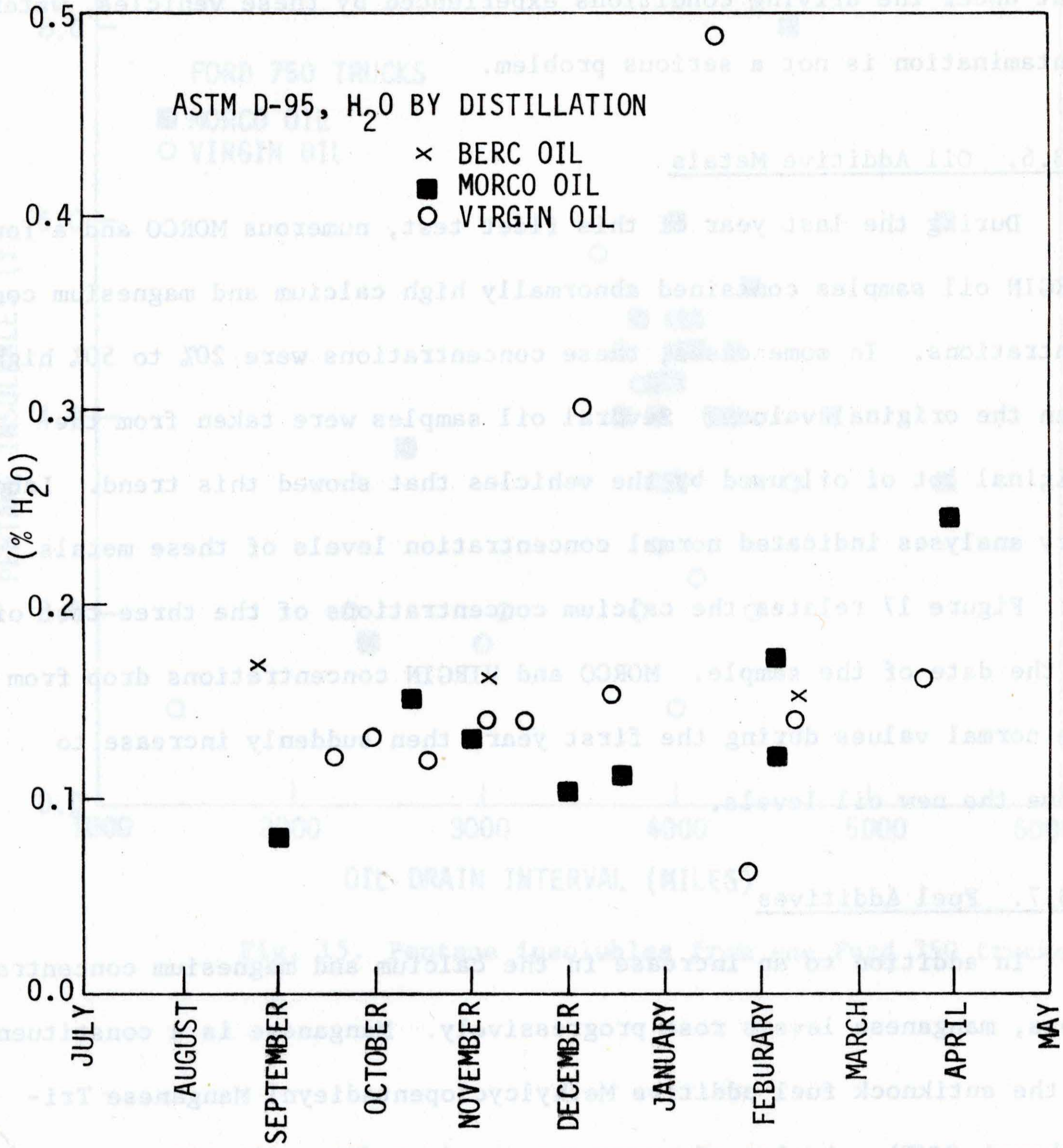

Fig. 16. Water analysis of used oil.

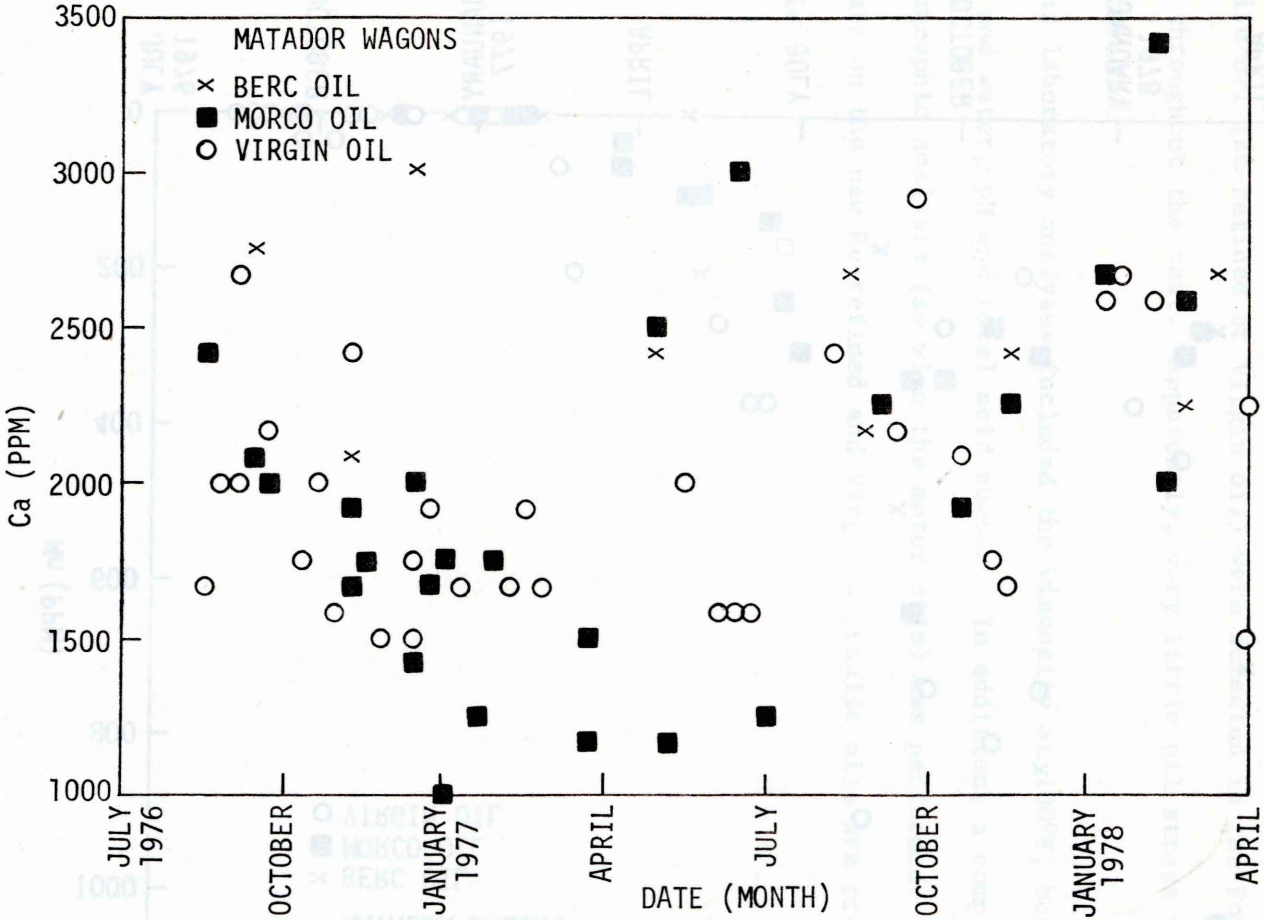

Fig. 17. Calcium concentrations from the Matador wagons.

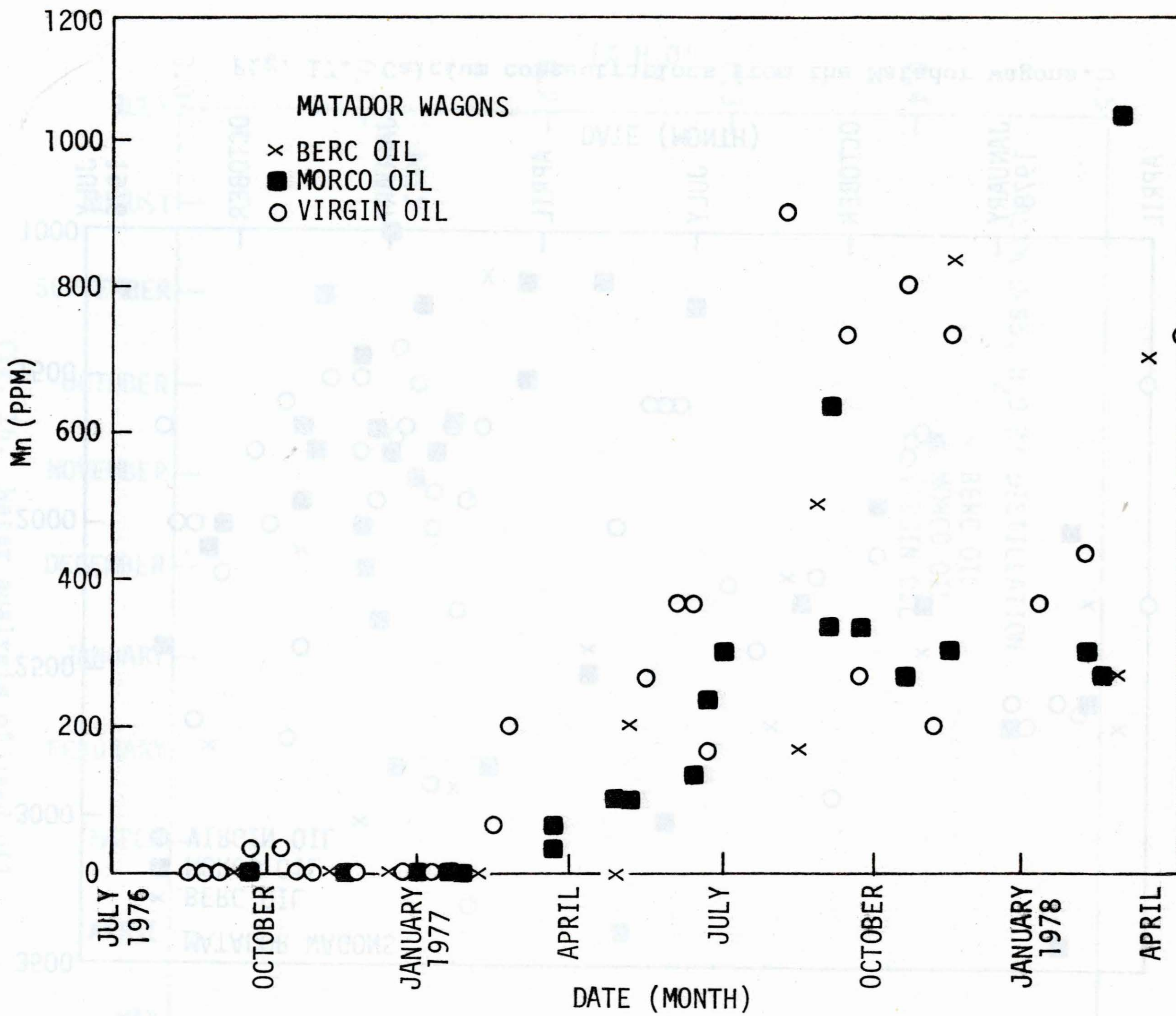

Fig. 18. Manganese concentrations from the Matador wagons.

4.4. Hydraulic Oil Sample Analysis

No significant differences between the new hydraulic oil and used hydraulic oil (Re-refined or Virgin oil) were detected in the Ford 750 trucks throughout the test. Apparently, very little oil stress was encountered.

The laboratory analyses included the viscosity at 100°F, bottoms sludge and water, pH and total acid number. In addition, a complete spectrographic analysis (as with the motor oils) was performed. Laboratory data on the new Re-refined and Virgin hydraulic oils are provided in Table 9.

Table 9. Hydraulic oil laboratory analyses.

Laboratory Analyses	Re-refined Oil	Virgin Oil
Viscosity, SSU @ 100°F	159	156
Bottom Sludge and Water	Nil	Nil
pH	6.8	6.1
Total Acid Number	0.36	1.29
Spectrographic & PPM		
Iron	1	2
Zinc	210	760
Lead	2	3
Sodium	77	2
Calcium	21	21
Silicon	2	3
Silver	0	0
Copper	10	8
Aluminum	0	0
Barium	1	5
Nickel	0	0
Chromium	0	1
Tin	1	1
Phosphorus	100	320
Boron	0	0
Magnesium	5	0
Vanadium	0	0
Molybdenum	0	0
Manganese	0	0
Cadmium	0	0
Titanium	0	0

5. DEPOSIT INSPECTION AND WEAR MEASUREMENTS

Twelve engines were dismantled by the Iowa DOT and deposit ratings were performed by Southwest Research Institute (SwRI) representatives. Engines from six Matador wagons, four Dodge pickups, and two Ford trucks were chosen with the assistance of Southwest Research Institute (Table 10). The criteria used to choose the various engines included a reasonably high mileage, comparable accumulated mileage within each vehicle type when possible, an oil consumption that was representative of other vehicles of that type, and low initial iron concentrations in the oil for the purpose of avoiding engines with high initial wear. In addition, engines with operating problems or major repairs were excluded. Appendix B contains the inspection report prepared by Southwest Research Institute.

Engine wear measurements were made on the 12 inspected vehicles and are presented in Appendix D. These measurements were reviewed by SwRI personnel in conjunction with the deposit ratings.

The major conclusions drawn in the SwRI report were:

1. No major engine failures occurred during the test program. The engines which were inspected were generally in acceptable condition. Based on engine condition, the two re-refined oils and the virgin-based oil were judged to have performed satisfactorily. In some cases the re-refined oils had better deposition performance than the virgin-based oil.

2. The observed difference in performance between the re-refined oils and the virgin oil could be either basestock effects and/or additive package effects.

Table 10. Final mileages on the vehicles involved in the deposit ratings.

Vehicle Identification	Type of Oil	Mileage
Matador Wagons		
A17680	BERC	45667
A17686	BERC	77101
A17685	MORCO	60174
A17687	MORCO	48285
A17683	VIRGIN	49503
A17688	VIRGIN	54477
Dodge Pickups		
A18731	MORCO	45091
A18710	MORCO	25617
A18716	VIRGIN	63910
A18729	VIRGIN	31940
Ford 750 Trucks		
A20369	MORCO	31576
A20371	VIRGIN	27207

3. The MORCO oil had a tendency towards superior deposit control, but generally had higher oil consumption rates. It is recommended that the MORCO oil consumption be further investigated using a technique such as gas chromatographic boiling point distribution to determine if the higher oil consumption rate can be correlated to base oil volatility. Some of the vehicles inspected had rather brittle valve guide seals which could be contributing to oil consumption. The engine manufacturers (AMC, Ford, Dodge) should be contacted to determine if they have experienced any unusual valve guide seal problems.
4. Two AMC engines had a least one very heavily deposited intake valve which could cause engine problems in the future.
5. The wear measurements made by IDOT were reviewed. For the most part, the measurements tend to indicate that very little wear took place. Some notable exceptions were:
   - A20369 (F-750, MORCO) had three ring gaps which were excessive.
   - Two AMC s (MORCO) each had from one to three rings with rather high gap.
   - Two Dodges (VIRGIN oil) and one Dodge (MORCO) had some rather high exhaust valve guide wear.

   The ring gap wear observed for the AMCs and the Ford F-750 using MORCO oil may have contributed to their higher oil consumption rates.
6. Overall, the results were very positive with respect to the field performance of the two lubricants made from re-refined components.

Pictorial documentation of representative piston skirts, intake valves, and intake valve lifters from selected engines is provided in Appendix C. Engine parts that rated (deposit rating) approximately the same as the vehicle's average were chosen.

6. CONCLUSIONS

A comprehensive analysis of the Iowa Re-refined Oil Fleet Test was provided by SwRI. The major conclusions drawn in their report are provided in the Engine Inspection Results section. Although the analyses and conclusions that were derived are complete and sound, additional comments are appropriate.

Results from the boiling point distribution analyses of the three test oils indicated that the higher MORCO oil consumption rates were not caused by a larger fraction of light ends. Furthermore, AMC representatives emphasized that the use of nylon valve guide seals in their 360 in^3 engines (used in the Matador wagons) were an improvement over previously used seals, and that there had been no reported problems with the newer product.

The VIRGIN oil used in this test may be underformulated with respect to the two re-refined oils. Evidence of inferior performance of the VIRGIN oil at an 8,000 mile ODI is based primarily on a total base number which approached zero on several occasions.

The 8,000 versus 10,000 mile oil drain interval tests on the Dodge vehicles were inconclusive. There were not enough vehicles with comparable mileage and performance. In switching the Matadors from 4,000 to 8,000 mile oil drain intervals, there was no obvious degradation of performance except for the low base reserve on the VIRGIN oil previously mentioned. Wear metal concentrations and oil consumption also increased at the 8,000 mile ODI, but not generally beyond acceptable levels. On the other hand, the VIRGIN oil viscosity in a significant number of samples at the 8,000 mile ODI was unacceptably high. In these cases, severe oil degradation has occured.

When operating a fleet test there are several possible ways of selecting the oil. If several base stocks are purchased and a common additive package used, then the claim can be made that the additive package was inappropriate for one or more of the oils. If formulated oils are purchased, then the base stocks are not being directly tested. We chose the latter alternative because the Iowa DOT was interested in testing the commercially available MORCO product in comparison with the Virgin oil they had been purchasing on a low bid contract. In addition, the BERC oil was to be tested with a formulation that had performed satisfactorily in sequence tests. Our objective, therefore, was to compare oils which the supplier thought were properly formulated.

The variability in performance which one expects from fleet tests was also present here. Only two general conclusions are therefore offered:

1. There is need for a more meaningful or enforceable bid specification to ensure a minimum oil quality from bidders.
2. The re-refined oils generally performed at least as well as the Virgin oil.

A preliminary assessment of the feasibility of collecting waste oil in Iowa was made. Collection of oil from farms does not appear economically attractive. Collection from urban areas has been assessed by others and these results should apply in Iowa. The feasibility of collecting waste oil from state fleets or DOT garages has not been adequately determined. The DOT is continuing to study the possibility of establishing a closed loop recycle system.

7. RECOMMENDATIONS

This test has demonstrated that at least two re-refined oils perform satisfactorily in comparison with a virgin oil. These results should be sufficient evidence for permitting re-refiners to bid for fleet business along with virgin oil suppliers.

Continued efforts to develop methods for checking the quality and variability of re-refined products are warranted. These tests should also be applied to and be used for similar checks on virgin products; particularly from blenders where variability may be at least as large as for re-refined oil.

Resource conservation and environmental considerations would now seem to be even more compelling reasons for government to encourage recycling of waste oil. The Iowa DOT should continue evaluation of a closed loop recycle system for state vehicles. State operation of recycling centers at each of its garages may be another way to encourage recycling.

Based on reasonable oil consumption rates and good performance on the sludge and varnish ratings, the Iowa DOT should move toward longer oil drain intervals which at least meet the new vehicle recommendations.

8. ACKNOWLEDGMENTS

This research was supported by the Engineering Research Institute of Iowa State University through funds provided by the U.S. Department of Energy.

This project required the extensive cooperation of many individuals and organizations. The Motor Oils Refining Co. provided all of the oil analyses at no charge and promptly notified us of any abnormal results. Mr. Robert Pedall was particularly helpful.

The Iowa Department of Transportation provided the vehicles and oil and permitted nearly unlimited access to their organization to facilitate day-to-day contact with drivers, garages and mechanics. The personnel that we wish to thank especially are Mr. John Ford, Mr. Bill McCall, Mr. Ernie Shilak, Mr. Jim Dale, and Mr. Dave Slater.

The Southwest Research Institute helped select the 12 vehicles and performed the deposit ratings. Mr. Ed Frame and Mr. Ed Lyons deserve special thanks.

The encouragement, consultation and particularly the financial support from the Bartlesville Energy Research Center, in particular from Mr. Charles J. Thompson and Mr. Marvin Whisman, are gratefully acknowledged.

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APPENDIX A

OIL DRAIN SAMPLE ANALYSES

This appendix contains oil drain sample laboratory data from the fleet test vehicles. Information regarding the vehicle's specified oil drain interval, initial test mileage and date, and type of test oil used are reported. In addition to the data from laboratory analyses, the vehicle mileage and date of oil drain sample are shown. Listed below the laboratory data are the mileages and quantities of oil added during the drain interval.

VEHICLE #A16938
Drain Interval: 4,000
Initial Test Mileage: 19,089 on 8/24/76
Test Oil: MORCO

Mileage Date	22,966 11/10/76	27,272 2/7/77	32,941 5/20/77	43,514 11/23/77
Flash °F	405	350	380	410
Viscosity, SSU @ 100°F	380	368	401	430
Viscosity, SSU @ 210°F	63.22	63.41	64.64	67.37
V.I.	124	127	124	125
Benzene Insol.	0.01	0.33	0.20	0.08
Pentane Insol.	0.03	0.38	0.28	0.35
T.A.N.	4.45	3.94	4.24	4.44
T.B.N.	2.12	1.87	1.54	1.04
Anti-freeze	neg.	neg.	trace	neg.
Fuel Dilution	0.1%	0.5%	0.0%	0.2%
Ag	0	0	0	0
Na	18	18	17	16
Zn	1000	1200	1200	1100
Cu	12	6	4	4
Al	13	27	14	21
Ba	60	90	100	78
Ni	0	2	5	1
Cr	4	17	10	8
Ca	1200	1400	2300	1800
Fe	32	50	54	50
Si	8	15	9	12
Sn	13	23	10	11
Pb	55	90	110	120
P	750	1000	820	950
B	3	1	1	0
Mg	800	450	580	950
V	1	5	5	9
Mo	0	1	1	0
Mn	8	7	85	260
Cd	3	2	3	3
Ti	0	2	1	0
Oil Additions/Mi	1 qt/22,071	1 qt/27,272		

VEHICLE #A16947
Drain Interval: 4,000
Initial Test Mileage: 26,472 on 8/11/76
Test Oil: VIRGIN

Mileage Date	30,805 10/28/76	34,311 3/17/77	38,403 5/31/77	45,856 8/29/77	50,331 10/27/77	62,730 4/4/78
Flash ^{o}F	405	345	390	415	425	380
Viscosity, SSU @ $100^{o}F$	333	325	351	444	437	422
Viscosity, SSU @ $210^{o}F$	60.26	59.54	60.83	68.96	66.46	66.20
V.I.	127	127	123	126	121	123
Benzene Insol.	<0.01	0.02	<0.01	0.02	0.01	0.02
Pentane Insol.	<0.01	0.04	0.01	0.03	0.02	0.03
T.A.N.	2.76	3.41	3.77	3.15	3.69	3.58
T.B.N.	1.63	1.49	1.60	0.57	1.31	1.88
Anti-freeze	neg.	neg.	neg.	neg.	trace	trace
Fuel Dilution	0.5%	0.4%	0.4%	0.5%	0.4%	0.8%
Ag	0	0	0	0	0	0
Na	20	3	14	9	18	20
Zn	820	1000	970	900	1100	1000
Cu	11	4	3	4	5	4
Al	13	19	11	22	18	13
Ba	65	110	100	110	110	82
Ni	1	3	3	0	1	1
Cr	8	16	11	19	8	10
Ca	1700	1500	2300	1500	2700	1800
Fe	54	88	38	57	53	48
Si	11	20	10	13	10	9
Sn	--	18	14	24	12	7
Pb	210	110	900	140	110	74
P	660	750	550	650	850	760
B	10	6	1	0	1	32
Mg	36	150	43	21	30	450
V	2	0	6	8	2	5
Mo	0	1	1	2	0	0
Mn	7	9	50	210	280	320
Cd	2	4	2	7	2	1
Ti	2	0	0	0	0	0

Oil Additions/Mi 1 qt/28,682

VEHICLE #A16955
Drain Interval: 4,000
Initial Test Mileage: 16,196 on 8/10/76
Test Oil: VIRGIN

Mileage Date	20,494 12/13/76	31,868 9/2/77	36,132 3/27/78
Flash ^{o}F	410	395	435
Viscosity, SSU @ $100^{o}F$	370	473	426
Viscosity, SSU @ $210^{o}F$	62.08	69.71	65.06
V.I.	123	122	119
Benzene Insol.	<0.01	0.1	0.04
Pentane Insol.	0.01	0.2	0.05
T.A.N.	4.70	3.25	3.10
T.B.N.	1.48	1.61	1.58
Anti-freeze	neg.	trace	trace
Fuel Dilution	0.3%	0.0%	0.8%
Ag	0	0	0
Na	25	3	22
Zn	800	1000	900
Cu	13	5	6
Al	23	25	47
Ba	70	120	74
Ni	0	1	3
Cr	11	16	22
Ca	2100	2100	2600
Fe	98	61	230
Si	18	16	31
Sn	13	29	--
Pb	75	140	140
P	630	760	980
B	8	5	2
Mg	35	0	28
V	3	10	4
Mo	1	2	1
Mn	22	180	420
Cd	2	9	4
Ti	3	0	2

VEHICLE #A16964
Drain Interval: 4,000
Initial Test Mileage: 27,866 on 8/11/76
Test Oil: MORCO

Mileage Date	32,256 11/1/76	37,420 6/14/77	48,975 12/21/77
Flash $^{\circ}F$	395	380	420
Viscosity, SSU @ $100^{\circ}F$	361	400	415
Viscosity, SSU @ $210^{\circ}F$	62.64	65.40	65.91
V.I.	127	126	124
Benzene Insol.	<0.01	0.42	0.25
Pentane Insol.	0.02	0.49	0.28
T.A.N.	3.89	4.38	3.55
T.B.N.	1.69	0.94	1.61
Anti-freeze	neg.	neg.	trace
Fuel Dilution	0.4%	0.2%	0.3%
Ag	0	0	0
Na	21	25	30
Zn	1100	1200	1000
Cu	12	4	4
Al	14	16	20
Ba	65	89	90
Ni	0	2	5
Cr	6	12	6
Ca	1600	2500	1800
Fe	45	120	54
Si	10	13	12
Sn	--	16	10
Pb	68	110	80
P	1000	950	800
B	3	0	0
Mg	600	820	650
V	4	3	5
Mo	0	0	0
Mn	9	65	240
Cd	4	3	7
Ti	1	1	0

VEHICLE #A17015
Drain Interval· 4,000
Initial Test Mileage: 24,160 on 8/24/76
Test Oil: MORCO

Mileage Date	28,296 10/8/76	32,939 12/27/76	37,153 4/4/77	41,434 6/2/77	46,053 8/17/77	50,384 10/20/77
Flash °F	365	375	420	405	405	425
Viscosity, SSU @ 100°F	368	359	366	437	465	500
Viscosity, SSU @ 210°F	63.43	61.88	62.60	68.49	69.89	71.78
V.I.	127	126	126	126	124	123
Benzene Insol.	<0.01	0.35	<0.01	0.87	0.05	0.09
Pentane Insol.	0.01	1.29	0.01	1.29	0.12	0.18
T.A.N.	4.12	5.36	4.14	3.73	4.61	3.10
T.B.N.	1.51	1.42	0.83	1.27	1.54	1.94
Anti-freeze	neg.	neg.	neg.	neg.	neg.	trace
Fuel Dilution	0.5%	0.7%	0.4%	nil	0.4%	0.3%
Ag	0	0	0	0	0	0
Na	20	35	15	15	12	15
Zn	1100	1100	1100	1300	1100	1100
Cu	11	7	5	5	5	4
Al	7	21	23	17	10	23
Ba	60	65	120	110	85	90
Ni	3	4	0	7	3	2
Cr	7	13	20	15	19	13
Ca	1800	1700	1600	2500	1500	1900
Fe	26	82	82	48	41	58
Si	7	15	14	11	9	13
Sn	12	20	18	20	14	15
Pb	70	90	170	180	180	88
P	450	1000	900	1100	850	900
B	3	2	2	1	0	0
Mg	500	520	250	800	700	450
V	4	3	6	6	4	4
Mo	0	1	0	1	2	1
Mn	14	34	27	120	180	290
Cd	4	5	2	9	5	4
Ti	2	2	0	1	1	1
Oil Additions/Mi	1 qt/26,545	1 qt/30,115	1 qt/34,624	1 qt/39,050	1 qt/43,564	1 qt/46,940
	1 qt/28,206	1 qt/32,259	1 qt/36,621	1 qt/40,844	1 qt/45,030	1 qt/48,390
						1 qt/49,927

VEHICLE #A17029
Drain Interval: 4,000
Initial Test Mileage: 21,236 on 8/11/76
Test Oil: VIRGIN

Mileage Date	25,391 12/13/76	31,030 7/1/77	41,290 1/13/78	46,341 4/14/78
Flash ^{o}F	375	380	380	380
Viscosity, SSU @ 100^{o}F	338	408	494	469
Viscosity, SSU @ 210^{o}F	59.98	64.58	73.01	71.52
V.I.	125	122	126	127
Benzene Insol.	0.03	<0.01	0.95	0.04
Pentane Insol.	0.05	0.01	2.20	0.06
T.A.N.	4.88	2.94	3.68	4.46
T.B.N.	1.33	1.43	1.78	1.94
Anti-freeze	neg.	neg.	present	present
Fuel Dilution	0.4%	0	0.2%	1.2%
Ag	0	0	0	0
Na	30	25	20	27
Zn	800	880	1200	1200
Cu	18	13	8	5
Al	28	56	26	12
Ba	70	88	100	100
Ni	0	1	2	1
Cr	17	30	13	7
Ca	2000	2300	1900	3400
Fe	140	200	76	52
Si	25	39	18	12
Sn	17	20	13	9
Pb	75	230	110	72
P	660	600	950	1000
B	7	7	5	3
Mg	37	32	23	22
V	3	2	5	6
Mo	1	0	1	3
Mn	8	76	240	250
Cd	2	1	4	1
Ti	2	0	1	1
Oil Additions/Mi		1 qt/--		

VEHICLE #A17030
Drain Interval: 4,000
Initial Test Mileage: 19,123 on 8/11/76
Test Oil: MORCO

Mileage Date	23,789 11/5/76	27,832 2/24/77	32,753 5/18/77	36,152 7/27/77	42,760 3/20/78
Flash ^{o}F	430	360	420	425	375
Viscosity, SSU @ $100^{o}F$	375	358	409	374	369
Viscosity, SSU @ $210^{o}F$	62.75	62.57	65.09	63.83	63.76
V.I.	124	128	123	127	128
Benzene Insol.	0.06	0.02	<0.01	0.09	0.31
Pentane Insol.	0.53	0.04	<0.01	0.12	0.34
T.A.N.	4.32	3.84	5.85	4.14	5.00
T.B.N.	1.94	2.54	1.88	1.67	1.94
Anti-freeze	trace	trace	neg.	neg.	neg.
Fuel Dilution	0.5%	0.4%	0.5%	0.3%	1.7%
Ag	0	0	0	0	0
Na	23	7	25	15	17
Zn	1100	1150	1300	1180	1100
Cu	13	6	4	5	5
Al	13	17	11	10	28
Ba	60	70	110	87	70
Ni	1	6	6	1	4
Cr	7	15	15	10	17
Ca	1600	1500	2700	1700	2300
Fe	56	100	47	31	120
Si	11	15	9	8	19
Sn	19	26	21	15	--
Pb	60	58	140	120	540
P	1050	1100	1100	800	1400
B	2	3	1	0	0
Mg	800	540	630	200	700
V	4	6	7	5	6
Mo	0	2	1	0	4
Mn	8	10	89	92	390
Cd	3	3	5	4	6
Ti	1	2	2	0	2

Oil Additions/Mi 1 qt/21,660

VEHICLE #A17035
Drain Interval: 4,000
Initial Test Mileage: 13,117 on 8/11/76
Test Oil: VIRGIN

Mileage Date	17,718 11/4/76	22,912 2/8/77	27,644 5/7/77	39,533 11/28/77
Flash ^{o}F	405	310	400	385
Viscosity, SSU @ $100^{o}F$	325	309	361	431
Viscosity, SSU @ $210^{o}F$	58.18	57.48	60.89	67.12
V.I.	122	124	122	123
Benzene Insol.	<0.01	<0.01	<0.01	0.01
Pentane Insol.	<0.01	0.01	<0.01	0.03
T.A.N.	3.46	2.95	5.23	3.36
T.B.N.	1.69	0.12	0.77	0.81
Anti-freeze	neg.	neg.	neg.	present
Fuel Dilution	0.5%	<0.10%	0.4%	0.8%
Ag	0	0	0	0
Na	22	50	21	18
Zn	840	800	950	1100
Cu	15	6	5	5
Al	11	13	8	18
Ba	65	65	110	100
Ni	1	1	5	1
Cr	3	8	8	6
Ca	1400	1750	2300	1800
Fe	47	80	42	48
Si	8	9	7	12
Sn	20	20	20	12
Pb	73	64	115	98
P	500	650	530	900
B	8	6	5	4
Mg	35	35	27	37
V	5	3	4	12
Mo	0	1	1	0
Mn	7	6	88	200
Cd	2	3	4	2
Ti	1	2	1	0
Oil Additions/Mi	1 qt/15,610 1 qt/17,215	1 qt/21,144		

VEHICLE #A17042
Drain Interval: 4,000
Initial Test Mileage: 25,491 on 8/10/76
Test Oil: VIRGIN

Mileage	29,960	41,673	46,093	50,116
Date	12/13/76	9/7/77	12/1/77	3/30/78
Flash °F	425	410	375	375*
Viscosity, SSU @ 100°F	321	586	442	369
Viscosity, SSU @ 210°F	59.32	74.63	67.34	63.76
V.I.	127	115	122	128
Benzene Insol.	<0.01	0.2	0.01	0.31
Pentane Insol.	0.01	0.3	0.02	0.34
T.A.N.	2.07	3.44	4.07	5.00
T.B.N.	1.78	0.30	1.07	1.94
Anti-freeze	neg.	neg.	present	neg.
Fuel Dilution	1.2%	0.1%	0.3%	1.7%
Ag	0	0	0	0
Na	25	5	19	13
Zn	800	1000	1000	1000
Cu	11	8	4	3
Al	11	27	17	20
Ba	70	110	89	76
Ni	0	1	1	2
Cr	5	27	8	11
Ca	2000	1300	1800	2600
Fe	55	100	56	76
Si	9	17	11	12
Sn	11	26	11	--
Pb	40	375	130	100
P	660	750	870	1400
B	9	19	2	5
Mg	33	250	52	26
V	3	8	9	5
Mo	1	2	0	1
Mn	7	310	230	280
Cu	2	19	3	2
Ti	2	0	0	1

*Foaming from 200-340°F

VEHICLE #A17059
Drain Interval: 4,000
Initial Test Mileage: 24,557 on 8/12/76
Test Oil: MORCO

Mileage Date	30,331 10/14/76	34,316 12/16/76	38,770 4/1/77	42,947 7/8/77	47,890 9/30/77
Flash ^{o}F	405	405	380	390	390
Viscosity, SSU @ $100^{o}F$	478	410	340	400	397
Viscosity, SSU @ $210^{o}F$	70.71	68.65	61.17	65.55	64.56
V.I.	123	124	128	126	124
Benzene Insol.	0.01	0.03	0.02	0.01	0.01
Pentane Insol.	0.03	0.17	0.03	0.02	0.02
T.A.N.	4.62	6.05	3.80	3.26	2.74
T.B.N.	1.88	1.42	2.10	2.73	2.69
Anti-freeze	neg.	neg.	neg.	neg.	present
Fuel Dilution	1.0%	1.6%	0.4%	0.1%	0.2%
Ag	0	0	0	0	0
Na	220	250	145	150	85
Zn	1300	1200	1100	1100	1100
Cu	15	8	4	11	5
Al	16	22	16	11	1
Ba	80	70	95	100	90
Ni	1	2	3	2	0
Cr	8	10	14	12	11
Ca	1300	1600	1500	1800	1900
Fe	45	80	63	38	35
Si	16	19	13	10	10
Sn	--	25	13	14	7
Pb	80	75	56	88	90
P	1140	950	500	750	850
B	24	29	11	12	17
Mg	600	450	380	550	650
V	2	4	8	8	4
Mo	0	1	0	0	0
Mn	8	41	12	110	140
Cd	4	4	1	5	6
Ti	0	1	3	0	0
Oil Additions/Mi	1 qt/26,859 1 qt/28,341 1 qt/28,691 1 qt/32,437	1 qt/--			

VEHICLE #A17677
Drain Interval: 4,000; 8,000
Initial Vehicle Mileage: 2,773 on 8/2/76
Test Oil: MORCO

Mileage Date	7,490 9/28/76	11,704 12/10/76	15,053 2/24/77	23,300 6/22/77	31,072 10/27/77	40,883 5/10/78
Flash, ^{o}F	390	370	395	420	390	365
Viscosity, SSU @ $100^{o}F$	407	354	338	356	395	498
Viscosity, SSU @ $210^{o}F$	64.34	60.61	59.84	60.70	64.36	69.9
V.I.	121	122	124	123	124	118
Benzene Insol.	< 0.01	< 0.01	0.05	0.26	0.4	2.24
Pentane Insol.	0.01	0.01	0.13	0.30	0.74	2.39
T.A.N.	5.32	4.84	3.76	3.32	3.73	6.32
T.B.N.	1.39	3.90	2.59	1.32	2.03	0.58
Anti-freeze	neg.	neg.	trace	neg.	neg.	present
Fuel Dilution	0.8%	2.4%	0.8%	0.4%	0.2%	0.8%
Ag	0	0	0.3	0	0	0
Na	40	30	10	25	35	38
Zn	1,100	1,100	1,200	1,000	3,350	2,800
Cu	32	21	8	3	7	8
Al	20	22	18	14	22	25
Ba	70	65	90	60	100	80
Ni	5	0	6	1	0	3
Cr	5	6	8	1	4	11
Ca	2,000	1,800	1,300	1,200	2,300	2,600
Fe	70	85	95	60	90	320
Si	25	19	16	6	18	27
Sn	35	15	25	1	21	14
Pb	120	100	80	150	140	130
P	500	900	1,100	600	1,000	1,400
B	3	1	3	0	0	3
Mg	550	480	540	450	1,150	750
V	4	3	5	0	4	3
Mo	6	8	1	3	9	17
Mn	10	9	9	110	650	1,050
Cd	1	0	1	0	0	0
Ti	3	2	2	0	0	0
		1 qt/ 9,100		1 qt/17,896	1 qt/26,330	1 qt/33,220
Oil additions/Mi	1 qt/4,100	1 qt/10,921	1 qt/13,199	1 qt/19,900	1 qt/27,050	1 qt/35,177
				1 qt/21,262	1 qt/29,570	1 qt/36,438
					1 qt/29,990	

VEHICLE #A17678
Drain Interval: 4,000; 8,000
Initial Test Mileage: 2,776 on 8/9/76
Test Oil: VIRGIN

Mileage Date	7,051 9/29/76	11,078 11/18/76	14,793 1/19/77	18,392 3/16/77	25,999 7/26/77	31,525 11/15/77	39,729 3/31/78	45,033 6/19/78
Flash, °F	380	380	270	410	385	375	400	390
Viscosity, SSU @ 100°F	347	332	283	388	646	618	988	488
Viscosity, SSU @ 210°F	60.74	59.30	56.50	63.20	79.97	79.14	97.66	69.24
V.I.	124	124	129	123	117	119	111	119
Benzene Insol.	<0.01	<0.01	0.10	0.01	<0.01	0.01	0.22	0.05
Pentane Insol.	≤0.01	<0.01	0.20	0.02	0.01	0.02	0.43	0.07
T.A.N.	3.05	3.63	4.02	4.23	7.32	4.17	5.67	3.31
T.B.N.	0.67	0.54	0.30	0.66	0.12	0.36	0.0	1.04
Anti-freeze	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.
Fuel Dilution	0.6%	0.4%	1.6%	0%	0.9%	0.3%	0.8%	0.7%
pH							4.0	
Ag	0	0	0	0	0	0	0	0
Na	50	30	65	9	46	50	94	54
Zn	800	800	900	950	1,000	900	980	920
Cu	37	23	14	11	20	24	23	8
Al	56	24	27	23	59	51	72	29
Ba	90	70	90	110	80	100	94	98
Ni	3	1	4	4	4	0	5	2
Cr	5	5	12	6	14	8	20	6
Ca	2,000	2,000	1,800	1,500	1,600	2,200	2,700	1,500
Fe	125	95	140	110	140	150	440	170
Si	18	13	13	12	20	22	30	17
Sn	30	25	23	21	27	25	19	30
Pb	40	50	68	78	160	90	130	65
P	280	700	700	600	700	700	960	780
B	15	8	5	5	3	8	23	17
Mg	15	33	30	22	18	22	22	14
V	4	2	4	0	5	5	4	8
Mo	10	2	7	8	13	11	21	10
Mn	9	6	8	11	370	750	1,150	750
Cd	1	0	0	2	3	0	1	0
Ti	2	1	5	0	0	0	1	0
		1 qt/8,000			1 qt/20,108			
Oil additions/Mi	1 qt/5,218	1 qt/9,665	1 qt/12,268	1 qt/16,748	1 qt/21,207		1 qt/35,000	

VEHICLE #A17679
Drain Interval: 4,000
Initial Vehicle Mileage: 1,516 on 8/2/76
Test Oil: MORCO

Mileage Date	5,728 2/7/77	15,556 8/26/77
Flash, °F	365	380
Viscosity, SSU @ 100°F	353	452
Viscosity, SSU @ 210°F	61.28	67.26
V.I.	125	120
Benzene Insol.	0.02	0.88
Pentane Insol.	0.04	1.24
T.A.N.	3.38	5.26
T.B.N.	1.21	1.56
Anti-freeze	trace	neg.
Fuel Dilution	0.4%	0.1%
Ag	0	0
Na	20	12
Zn	1,100	1,000
Cu	21	17
Al	26	23
Ba	70	80
Ni	5	8
Cr	11	12
Ca	1,800	1,300
Fe	80	180
Si	32	26
Sn	45	30
Pb	80	150
P	1,000	700
B	1	0
Mg	500	1,000
V	3	10
Mo	10	11
Mn	12	300
Cd	1	3
Ti	2	0
Oil additions/Mi	1 qt/2,787 1 qt/3,825 1 qt/5,699	1 qt/ 9,191 1 qt/ 9,973 1 qt/11,847 1 qt/14,006

VEHICLE #A17680
Drain Interval: 4,000; 8,000
Initial Vehicle Mileage: 3,074 on 7/26/76
Test Oil: BERC

Mileage Date	7,605 9/11/76	11,530 11/5/76	15,370 2/11/77	23,383 5/25/77	31,537 9/29/77	39,375 1/18/78	45,887 4/26/78
Flash, °F	410	380	430	380	385	360	440
Viscosity, SSU @ 100°F	375	380	373	460	472	437	423
Viscosity, SSU @ 210°F	62.42	63.38	63.22	66.71	68.52	67.25	65.8
V.I.	123	124	126	117	119	123	122
Benzene Insol.	<0.01	<0.01	0.01	1.30	0.211	0.63	1.10
Pentane Insol.	<0.01	0.03	0.03	2.28	0.124	0.21	1.95
T.A.N.	3.29	3.89	3.50	3.53	5.05	3.90	4.84
T.B.N.	1.33	2.18	1.38	1.38	0.72	0.97	0.52
Anti-freeze	neg.	neg.	neg.	neg.	neg.	neg.	neg.
Fuel Dilution	0.8%	0.3%	0.2%	0.4%	0.2%	0.8%	0.7%
Ag	0	0	0	0	0	0	0
Na	15	25	10	0	3	65	50
Zn	950	950	930	1,100	850	900	980
Cu	3	12	6	5	5	12	15
Al	15	19	21	28	35	74	60
Ba	80	90	100	150	110	97	95
Ni	2	2	3	9	0	4	3
Cr	1	4	8	12	9	13	10
Ca	2,800	2,100	2,800	4,300	2,200	2,400	2,700
Fe	58	72	100	190	250	300	350
Si	15	14	15	19	18	33	32
Sn	15	30	33	32	36	23	16
Pb	52	55	54	150	160	110	90
P	650	500	800	800	650	825	770
B	0	2	3	4	4	16	9
Mg	11	17	17	22	22	20	14
V	1	5	3	7	10	4	4
Mo	2	5	7	10	11	11	12
Mn	1	7	5	200	520	850	700
Cd	0	0	0	1	3	1	0
Ti	0	1	4	2	1	1	0
Oil additions/Mi	1 qt/4,679 1 qt/7,052		1 qt/14,335	1 qt/19,270 1 qt/22,322	1 qt/28,213 2 qt low @ change	1 qt/37,028	

VEHICLE #A17681
Drain Interval: 4,000
Initial Vehicle Mileage: 1,844 on 7/28/76
Test Oil: VIRGIN

Mileage Date	5,798 3/15/77	9,736 1/6/78	11,851 5/8/78
Flash, °F	405	360	370
Viscosity, SSU @ 100°F	328	339	354
Viscosity, SSU @ 210°F	59.04	59.88	62.43
V.I.	124	124	128
Benzene Insol.	6.01	0.01	0.02
Pentane Insol.	0.01	0.02	0.03
T.A.N.	4.20	399	3.24
T.B.N.	0.16	0	1.49
Anti-freeze	neg.	neg.	trace
Fuel Dilution	0.4%	0.8%	1.3%
pH		3.5	
Ag	0	0	0
Na	11	32	20
Zn	900	760	1,150
Cu	8	9	7
Al	29	46	21
Ba	120	92	95
Ni	6	6	3
Cr	8	9	6
Ca	1,700	1,800	2,000
Fe	830	800	230
Si	33	33	16
Sn	32	22	15
Pb	37	82	40
P	700	650	980
B	10	10	4
Mg	17	15	16
V	0	4	6
Mo	11	14	8
Mn	12	210	210
Cd	2	2	0
Ti	0	1	0
	1 qt/4,030		
Oil additions/Mi	1 qt/4,551		

VEHICLE #A17682
Drain Interval: 4,000; 8,000
Initial Vehicle Mileage: 1,164 on 7/28/76
Test Oil: MORCO

Mileage Date	5,428 10/15/76	9,674 1/18/77	16,947 6/9/77	26,565 11/17/77	33,292 3/15/78	36,106 5/5/78
Flash, °F	400	360	405	395	370	390
Viscosity, SSU @ 100°F	366	363	456	421	367	353
Viscosity, SSU @ 210°F	62.69	61.67	67.59	66.33	63.1	62.6
V.I.	126	123	120	124	127	129
Benzene Insol.	<0.01	0.79	0.65	0.15	0.25	0.02
Pentane Insol.	<0.01	1.19	0.78	0.66	0.26	0.03
T.A.N.	4.51	4.23	5.61	4.30	4.05	3.58
T.B.N.	1.75	0.79	0.72	1.55	1.75	1.68
Anti-freeze	neg.	neg.	neg.	neg.	trace	neg.
Fuel Dilution	0.4%	0.7%	0	0.2%	1.2%	0.4%
Ag	0	0	0	0	0	0
Na	32	57	20	25	17	17
Zn	1,100	1,150	1,200	1,200	1,000	1,100
Cu	17	11	5	6	3	2
Al	17	19	18	34	21	16
Ba	60	70	90	95	68	76
Ni	1	4	2	0	1	1
Cr	4	7	5	4	6	4
Ca	2,000	2,000	2,500	2,900	2,700	2,400
Fe	60	185	210	130	130	58
Si	15	20	18	19	15	11
Sn	30	33	20	20	20	9
Pb	35	45	150	95	50	39
P	480	900	1,000	920	1,300	980
B	2	2	0	0	0	0
Mg	500	440	850	1,100	850	650
V	3	3	2	4	2	5
Mo	3	11	10	10	8	4
Mn	8	11	120	340	360	210
Cd	1	0	2	0	0	0
Ti	3	2	0	0	2	0
Oil additions/Mi	1 qt/3,280	1 qt/6,119	1 qt/10,974	1 qt/18,406	1 qt/27,421	2 qt/34,275
	1 qt/4,766	1 qt/7,786	1 qt/12,352	2 qt/20,041	1 qt/28,493	1 qt/35,305
		1 qt/9,638	1 qt/13,113	2 qt/21,844	2 qt/30,542	1 qt/36,005
			1 qt/15,532	1 qt/22,887	2 qt/32,086	
				2 qt/25,687	1 qt/32,944	

VEHICLE #A17683
Drain Interval: 4,000; 8,000
Initial Vehicle Mileage: 3,144 on 7/12/76
Test Oil: VIRGIN

Mileage Date	7,075 9/10/76	11,076 10/18/76	15,336 12/7/76	19,204 1/26/77	23,345 3/21/77	31,635 8/9/77	39,310 11/18/77	46,945 3/17/78	49,503 4/24/78
Flash, °F	410	355	405	405	400	405	225	310	385
Viscosity, SSU @ 100°F	421	378	396	403	432	435	359	466	412
Viscosity, SSU @ 210°F	66.69	63.91	64.25	64.30	66.29	65.38	63.00	72.74	66.44
V.I.	124	127	128	122	122	118	129	130	127
Benzene Insol.	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.05	0.24	0.02
Pentane Insol.	<0.01	0.01	0.01	0.02	0.03	0.02	0.08	0.30	0.03
T.A.N.	3.72	3.36	2.12	3.16	3.37	3.14	2.34	4.07	4.39
T.B.N.	1.63	1.33	2.30	0.91	0.50	0.59	1.61	2.13	1.68
Anti-freeze	neg.	neg.	neg.	neg.	trace	trace	trace	trace	present
Fuel Dilution	0.2%	0.5%	1.2%	0.4%	0.4%	0.7%	2.0%	2.0%	1.4%
Fire Pt. °F							415	410*	
Ag	0	0	0	0	0	0	0	0	0
Na	27	32	23	70	4	20	50	46	32
Zn	1,000	900	900	980	980	1,000	3,750	1,500	1,150
Cu	12	13	10	4	4	4	5	7	3
Al	12	10	13	18	17	28	28	34	18
Ba	80	70	65	100	110	130	115	88	95
Ni	1	2	1	2	1	0	0	4	2
Cr	4	5	4	8	6	11	15	11	5
Ca	1,700	2,200	2,400	1,900	1,900	1,600	2,900	2,600	2,400
Fe	51	45	80	100	100	84	100	230	90
Si	11	14	12	13	13	16	15	18	12
Sn	--	30	21	25	25	35	20	23	13
Pb	40	50	35	75	90	240	125	120	47
P	870	350	780	800	850	750	900	1,250	880
B	3	3	3	3	6	10	8	16	14
Mg	13	16	13	17	17	56	29	31	18
V	5	4	1	4	0	9	7	5	5
Mo	3	4	4	7	5	9	7	10	6
Mn	15	30	17	12	58	180	270	370	150
Cd	1	1	1	1	1	5	0	0	0
Ti	2	3	2	2	2	0	0	2	0
	1 qt/3,144	1 qt/8,119	1 qt/12,219	1 qt/16,953		1 qt/25,540	1 qt/34,300	1 qt/41,462	
Oil additions/Mi	½ qt/4,675	1 qt/9,560	1 qt/14,076	1 qt/18,505	1 qt/21,111	1 qt/26,932	1 qt/35,410	1 qt/43,060	1 qt/48,874
	1 qt/6,225					1 qt/30,090	1 qt/36,407	1 qt/43,812	
	1 qt/6,663						1 qt/37,673	1 qt/45,320	
							1 qt/38,246	1 qt/46,800	

*Bubbling around 190

VEHICLE #A17684
Drain Interval: 4,000; 8,000
Initial Vehicle Mileage: 2,022 on 8/2/76
Test Oil: VIRGIN

Mileage Date	5,897 9/23/76	10,005 11/30/76	14,057 2/25/77	23,763 8/2/77	32,346 12/21/77	40,562 5/15/78
Flash, °F	405	375		395	385	380
Viscosity, SSU @ 100°F	326	322		481	426	628
Viscosity, SSU @ 210°F	59.32	59.13		69.46	68.20	77.84
V.I.	126	126		120	127	116
Benzene Insol.	<0.01	<0.01		0.01	0.11	0.34
Pentane Insol.	<0.01	<0.01		0.03	0.24	0.93
T.A.N.	2.93	3.50		4.67	4.03	6.41
T.B.N.	0.61	0.80		0	0.24	0
Anti-freeze	neg.	neg.		trace	neg.	neg.
Fuel Dilution	0.4%	0.7%		0.8%	0.9%	1.0%
pH				3.5		3.8
Ag	0	0		0	0	0
Na	25	45		37	110	60
Zn	960	850		980	920	1,000
Cu	22	19		20	9	10
Al	23	19		52	40	46
Ba	130	100		90	92	85
Ni	4	1		7	7	5
Cr	6	7		19	11	12
Ca	2,700	1,600		1,600	2,100	2,300
Fe	95	120		280	310	950
Si	32	25		35	31	38
Sn	14	23		32	15	23
Pb	34	42		143	80	130
P	620	480		600	775	1,120
B	12	14		6	6	16
Mg	9	12		32	22	16
V	5	2		10	7	5
Mo	5	3		17	11	20
Mn	3	5		360	800	1,300
Cd	0	1		4	0	0
Ti	0	0		0	0	0
		1 qt/8,379		1 qt/15,430	1 qt/25,990	
Oil additions/Mi	1 qt/3,033	1 qt/7,117		1 qt/17,891	1 qt/26,687	1 qt/33,920
				1 qt/21,166	1 qt/27,298	
					1 qt/ --	

VEHICLE #A17685
Drain Interval: 4,000; 8,000
Initial Test Mileage: 3,151 on 7/27/76
Test Oil: MORCO

Mileage Date	7,262 9/1/76	11,212 10/12/76	16,160 12/1/77	21,377 2/9/77	29,459 5/6/77	37,756 8/9/77	45,350 10/26/77	50,057 1/25/78	60,174 4/24/78
Flash, °F	410	400	415	415	405	400	405	390	405
Viscosity, SSU @ 100°F	355	360	376	433	427	394	401	378	390
Viscosity, SSU @ 210°F	61.52	61.79	64.12	66.58	67.88	65.67	66.37	64.36	65.3
V.I.	125	124	127	0.22	127	0.28	0.28	128	128
Benzene Insol.	0.06	<0.01	0.14	0.39	0.02	0.02	0.26	0.07	0.13
Pentane Insol.	0.08	0.01	0.68	0.52	0.04	0.03	0.30	0.08	0.23
T.A.N.	3.70	4.62	4.97	4.58	4.92	4.20	3.30	3.74	3.94
T.B.N.	1.20	1.51	2.93	2.15	1.71	1.73	2.51	1.68	1.16
Anti-freeze	none	neg.	neg.	trace	neg.	neg.	neg.	neg.	neg.
Fuel Dilution	0.4%	0.3%	1.2%	0.7%	0.2%	0.2%	0	0.4%	0.8%
Ag	0	0	0	0.4	0	0	0	0	0
Na	15	19	25	11	2	1	20	37	55
Zn	950	1,150	1,200	1,400	1,050	1,200	3,400	1,150	2,200
Cu	6	12	12	9	2	5	5	3	4
Al	20	16	16	25	10	17	24	22	17
Ba	50	70	70	100	55	110	100	100	90
Ni	1	0	0	5	1	4	7	1	1
Cr	1	4	5	14	1	11	3	7	6
Ca	2,400	1,700	1,700	1,000	1,200	1,600	2,300	2,300	2,000
Fe	50	2	62	120	43	50	72	100	80
Si	14	12	13	17	8	11	13	13	12
Sn	10	26	10	30	1	15	12	13	14
Pb	45	40	45	80	52	55	55	40	47
P	850	1,000	900	1,400	950	800	950	1,150	1,050
B	0	2	1	5	1	0	0	5	7
Mg	570	540	480	550	340	800	1,150	850	900
V	2	1	3	4	1	4	2	2	5
Mo	2	2	7	11	1	7	3	7	7
Mn	1	5	12	9	73	230	350	300	280
Cd	0	0	0	1	0	0	0	1	0
Ti	0	0	1	1	0	1	0	2	0
Oil additions/Mi	1 qt/4,584 1 qt/5,800 1 qt/6,718	1 qt/ 8,281 1 qt/ 9,462 1 qt/10,409	1 qt/12,860 1 qt/13,460 1 qt/14,660 1 qt/15,900	1 qt/18,659 1 qt/20,159	1 qt/23,244 1 qt/23,739 1 qt/24,800 1 qt/26,317 1 qt/27,732 1 qt/28,800	1 qt/30,454 1 qt/31,559 1 qt/32,707 1 qt/33,609 1 qt/34,589 1 qt/35,250 1 qt/35,973 1 qt/36,839 2 qt/37,375 down 1 qt @ OD.	1 qt/38,756 1 qt/39,556 1 qt/40,163 1 qt/41,007 1 qt/42,115 1½ qt/44,349 1½ qt/45,153	1 qt/46,250 1½ qt/47,350 1½ qt/48,920	1½ qt/54,210 1½ qt/55,570 1½ qt/56,700 1 qt/57,490

VEHICLE #A17686
Drain Interval: 4,000; 8,000
Initial Vehicle Mileage: 1,410 on 8/11/76
Test Oil: BERC

Mileage Date	6,186 10/29/76	11,092 1/10/77	22,124 9/9/77	26,987 4/5/78
Flash, °F	405 Bubbled	385	365	325
Viscosity, SSU @ 100°F	345	353	461	350
Viscosity, SSU @ 210°F	60.86	61.10	67.86	61.58
V.I.	126	124	120	127
Benzene Insol.	<0.01	0.02	0.01	0.52
Pentane Insol.	<0.01	0.03	0.02	1.60
T.A.N.	3.80	3.50	3.95	3.58
T.B.N.	1.82	1.21	0.66	1.23
Anti-freeze	neg.	neg.	neg.	neg.
Fuel Dilution	0.4%	0.6%	0.1%	1.7%
Ag	0	0	0	0
Na	28	54	43	16
Zn	860	930	1000	880
Cu	16	9	9	6
Al	21	20	44	30
Ba	80	100	44	110
Ni	1	3	3	3
Cr	3	9	16	12
Ca	2400	3000	2700	2300
Fe	88	105	180	200
Si	26	17	23	20
Sn	20	33	21	13
Pb	40	40	150	98
P	700	700	850	700
B	2	1	0	0
Mg	17	17	22	19
V	2	3	4	4
Mo	2	8	1	10
Mn	9	7	190	280
Cd	0	0	5	0
Ti	1	3	0	1
Oil additions/Mi	1 qt/5,030		1 pt/13,455 1 qt/14,452	

VEHICLE #A17687
Drain Interval: 4,000; 8,000
Initial Vehicle Mileage: 1,594 on 7/16/76
Test Oil: MORCO

Mileage Date	5,610 9/10/76	9,560 11/1/76	13,362 12/17/76	16,992 2/9/77	20,974 3/31/77	29,197 6/28/77	37,465 11/17/77	45,125 3/17/78	48,285 4/24/78
Flash, °F	430	400	415	375	320	425	385	355	410
Viscosity, SSU @ 100°F	413	397	417	363	364	496	399	405	406
Viscosity, SSU @ 210°F	64.72	64.33	65.55	65.23	62.50	72.39	68.51	66.07	68.97
V.I.	121	0.24	123	133	126	124	126	126	126
Benzene Insol.	0.02	0.01	0.18	0.01	0.02	0.07	0.25	0.02	0.03
Pentane Insol.	0.03	0.03	0.58	0.02	0.03	0.08	0.51	0.03	0.04
T.A.N.	4.48	5.10	4.48	3.33	4.40	4.32	3.21	4.19	4.79
T.B.N.	1.51	2.30	1.66	1.45	2.15	1.82	1.85	2.20	1.88
Anti-freeze	neg.	neg.	neg.	neg.	trace	trace	neg.	trace	trace
Fuel Dilution	0.4%	0.1%	0.8%	0.8%	1.2%	0	1.2%	1.2%	0.6%
Ag	0	0	0	0	0	0	0	0	0
Na	16	23	25	7	21	20	34	28	29
Zn	1,100	1,200	1,000	1,200	1,350	1,400	4,300	1,100	1,220
Cu	18	23	15	11	7	18	10	5	4
Al	18	23	21	22	22	41	32	19	14
Ba	60	70	70	70	105	110	80	75	85
Ni	6	1	3	2	3	0	4	1	1
Cr	4	5	7	9	8	5	4	6	4
Ca	2,100	1,900	1,400	1,800	1,500	3,000	1,900	3,400	2,300
Fe	56	62	60	105	54	120	80	92	52
Si	15	14	11	12	10	13	15	11	9
Sn	32	28	25	25	22	21	22	22	11
Pb	45	52	45	46	62	330	90	56	60
P	550	1,000	700	1,100	640	1,250	950	1,400	950
B	1	2	2	2	0	0	0	6	4
Mg	580	500	430	500	560	900	1,250	950	15
V	3	3	1	2	8	4	6	2	5
Mo	5	8	7	10	7	6	8	8	5
Mn	10	18	12	9	28	140	270	300	170
Cd	0	1	1	0	0	0	0	0	0
Ti	2	2	2	4	2	0	0	3	0
	1 qt/3,154	1 qt/6,960	1 qt/10,689	1 qt/14,698	1 qt/18,430	1 qt/22,110	1 qt/30,464	1 qt/38,574	1 qt/46,240
Oil additions/Mi	1 qt/3,531	1 qt/9,088	1 qt/12,235	1 qt/15,515	1 qt/19,328	1 qt/23,380	1 qt/31,342	1 qt/39,566	1 qt/46,880
	1 qt/4,100					1 qt/23,983	1 qt/32,303	1 qt/40,574	1 qt/47,576
						1 qt/24,810	1 qt/33,000	1 qt/41,275	
						1 qt/25,674	1 qt/33,775	1 qt/42,430	
						1 qt/27,041	1 qt/35,428	1 qt/43,478	
							1 qt/36,460	1 qt/44,666	

VEHICLE #A17688
Drain Interval: 4,000; 8,000
Initial Vehicle Mileage: 2,173 on 7/27/76
Test Oil: VIRGIN

Mileage Date	6,115 9/20/76	10,115 11/4/76	14,100 12/21/76	18,093 2/14/77	22,040 3/31/77	30,083 6/29/77	38,000 10/4/77	46,256 1/19/78	53,992 4/19/78	54,477 4/24/78
Flash, ^{o}F	360	390	390	390	370	390	380	350	380	400
Viscosity, SSU @ $100^{o}F$	331	380	359	343	367	531	476	483	718	378
Viscosity, SSU @ $210^{o}F$	59.57	63.80	61.27	60.33	80.76	72.27	69.16	71.30	85.80	65.64
V.I.	125	125	123	124	119	119	120	124	119	131
Benzene Insol.	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.19	0.10	0.14	0.01
Pentane Insol.	<0.01	<0.01	<0.01	0.02	0.01	0.02	0.28	0.17	0.18	0.02
T.A.N.	3.36	3.41	4.23	3.46	3.54	4.79	3.75	4.42	5.63	5.17
T.B.N.	0.61	1.63	0.21	0.39	0.39	0.5	0.36	1.23	0.45	0.91
Anti-freeze	neg.	neg.	neg.	trace	trace	neg.	neg.	trace	trace	neg.
Fuel Dilution	0.8%	0.6%	0.4%	0.8%	0.4%	0.4%	0.4%	0.7%	0.8%	0.4%
Ag	0	0	0.2	0.2	0	0	0	0	0	0
Na	45	27	65	11	10	20	19	24	34	0.7
Zn	800	1,000	770	800	850	1,000	900	1,050	3,000	1,400
Cu	12	13	3	5	2	5	7	5	5	2
Al	20	13	17	19	13	32	34	30	25	8
Ba	85	80	80	90	100	100	120	96	110	95
Ni	3	1	0	5	0	2	1	4	2	1
Cr	5	3	5	7	8	7	11	10	0	4
Ca	2,000	1,800	1,500	1,650	1,700	2,000	2,400	1,700	2,600	2,200
Fe	78	45	87	140	70	170	150	240	160	4
Si	20	16	13	15	10	18	22	20	19	8
Sn	30	23	25	25	11	27	13	18	8	11
Pb	60	57	61	70	72	320	160	120	85	28
P	270	800	500	750	580	720	750	890	1,220	1,050
B	16	3	11	11	4	5	0	7	4	4
Mg	9	20	35	52	33	26	18	18	20	16
V	5	5	3	4	4	4	7	6	8	5
Mo	4	3	7	9	3	10	11	10	10	2
Mn	7	29	6	7	3	200	900	750	430	100
Cd	1	1	1	1	0	0	0	2	1	0
Ti	3	1	0	2	0	0	0	1	0	0
	1 qt/3,667	1 qt/8,100				1 qt/24,568	1 qt/32,132	1 qt/44,310	1 qt/47,888	
Oil additions/Mi	1 qt/4,831	1 qt/8,700	1 qt/12,600	1 qt/16,115	1 qt/19,710	1 qt/27,938	1 qt/34,038	1 qt/42,920	1 qt/51,775	
							1 qt/36,649	1 qt/39,777	1 qt/50,265	

VEHICLE #A18712
Drain Interval: 8,000
Initial Test Mileage: 1,149 on 8/18/76
Test Oil: VIRGIN

Mileage Date	3,146*	5,120* 12/7/76	7,151* 1/24/76	9,231 4/1/77	11,710* 6/8/77	16,805 9/30/77	24,917 5/11/78
Flash °F	395	310	435	400	370		330
Viscosity, SSU @ 100°F	271	240	291	302	311		329
Viscosity, SSU @ 210°F	56.28	54.12	57.02	58.18	59.00		59.54
V.I.	132	135	128	129	129		126
Benzene Insol.	<0.01	<0.01	0.12	0.01	<0.01		0.05
Pentane Insol.	0.01	0.10	0.24	0.02	0.01		0.07
T.A.N.	2.74	3.28	3.45	3.11	2.94		5.02
T.B.N.	1.39	1.51	0.48	0.66	1.49		0.19
Anti-freeze	trace	neg.	neg.	present	neg.		trace
Fuel Dilution	0.6%	1.0%	1.0%	1.2%	0.4%		1.6%
Ag	0	0	0	0	-		0
Na	30	42	74	19	-		27
Zn	700	800	800	900	920		930
Cu	48	55	53	50	42		22
Al	3	7	10	13	8		16
Ba	65	75	100	110	100		90
Ni	1	2	6	0	2		3
Cr	4	7	12	17	6		12
Ca	2000	1600	1600	1600	2500		1800
Fe	75	140	180	210	120		520
Si	8	10	10	13	9		14
Sn	20	21	22	23	16		12
Pb	24	38	290	61	41		52
P	300	650	550	700	600		810
B	16	12	10	3	1		1
Mg	13	14	15	13	14		12
V	4	4	3	6	3		6
Mo	1	0	0	0	0		2
Mn	6	8	11	7	40		530
Cd	2	1	2	2	0		3
Ti	3	2	1	0	0		0
Oil Additions/Mi	1 qt/2,499 ½ qt/3,146	1 qt/5,120 ½ qt/5,120	1 qt/7,151	1 qt/8,782	1 qt/10,870	1 qt/14,949	2½ qts/--

*Dipstick samples.

VEHICLE #A18713
Drain Interval: 8,000
Initial Vehicle Mileage: 1,407 on 8/24/76
Test Oil: MORCO

Mileage	3,608*
Date	2/7/77
Flash, °F	250
Viscosity, SSU @ 100°F	246
Viscosity, SSU @ 210°F	54.11
V.I.	132
Benzene Insol.	0.01
Pentane Insol.	0.03
T.A.N.	2.99
T.B.N.	1.27
Anti-freeze	neg.
Fuel Dilution	2.0%
Ag	0
Na	10
Zn	1050
Cu	50
Al	12
Ba	65
Ni	3
Cr	10
Ca	1500
Fe	140
Si	11
Sn	25
Pb	90
P	1000
B	1
Mg	420
V	4
Mo	1
Mn	9
Cd	3
Ti	2
Oil addition/Mi	wrong type of oil used here

*Dipstick sample.

VEHICLE #A18714
Drain Interval: 8,000
Initial Vehicle Mileage: 2,683 on 7/27/76
Test Oil: MORCO

Mileage Date	4,831* 9/7/76	7,858* 10/28/76	10,687 12/8/76	17,999 2/28/77	26,789 7/1/77	34,646 10/18/77	42,703 1/24/78	50,560 5/10/78
Flash, °F	370	345	360		370	350	350	345
Viscosity, SSU @ 100°F	307	330	318		426	434	415	407
Viscosity, SSU @ 210°F	58.86	60.01	59.24		66.47	67.15	65.64	65.6
V.I.	130	127	128		123	123	123	125
Benzene Insol.	<0.01	0.03	1.26		0.49	1.14	1.81	1.10
Pentane Insol.	<0.01	0.84	1.04		0.98	2.26	3.32	1.19
T.A.N.	2.93	4.15	5.62		4.00	4.35	5.42	5.92
T.B.N.	1.51	2.78	3.42		1.62	3.22	1.55	0.91
Anti-freeze	neg.	neg.	neg.		neg.	neg.	trace	present
Fuel Dilution	1.2%	1%	1.6%		0.5%	0.3%	1.3%	1.2%
Ag	0	0	0		0	--	0	0
Na	10	26	32		30	32	19	25
Zn	1,000	1,200	1,100		1,440	1,200	1,100	1,200
Cu	14	27	27		27	20	8	10
Al	2	10	13		11	14	17	13
Ba	30	65	70		100	100	79	80
Ni	0	1	3		3	0	2	2
Cr	0	4	9		16	7	10	9
Ca	2,200	1,600	1,500		2,100	2,300	1,900	2,500
Fe	52	100	120		78	72	120	70
Si	7	11	13		12	12	13	10
Sn	9	--	25		20	10	14	9
Pb	50	115	200		1,120	370	160	150
P	880	1,040	980		800	1,000	1,200	1,000
B	0	2	2		0	0	0	0
Mg	660	800	500		680	1,100	900	800
V	0	2	6		5	6	3	3
Mo	0	0	1		0	0	1	1
Mn	0	8	11		110	700	700	600
Cd	0	1	1		8	3	3	1
Ti	0	2	2		0	0	1	0
Oil additions/Mi	1 qt/4,056 ½ qt/4,831	1 qt/5,951 ½ qt/7,858			1 qt/21,818 1 qt/24,096 1 qt/25,095	2 qt/30,468	1 qt/39,570 1 qt/40,766	1 qt/44,230 1 qt/47,132 2 qt/49,137

*Dipstick samples

VEHICLE #A18716
Drain Interval: 10,000
Initial Vehicle Mileage: 2,100 on 7/30/76
Test Oil: VIRGIN

Mileage Date	4,043* 8/24/76	6,155* 9/27/76	8,588* 10/22/76	10,222 11/22/76	20,016 1/31/77	30,033 5/27/77	40,020 10/7/77	50,116 1/10/78	60,613 3/16/78	63,900 4/25/78
Flash, °F	390	400	330	320	325	300	360	345	280	310
Viscosity, SSU @ 100°F	266	294	289	270	315	370	351	329	393	340
Viscosity, SSU @ 210°F	56.24	57.39	56.75	55.92	58.36	62.71	61.52	58.37	67.95	60.93
V.I.	134	129	128	131	125	125	126	121	133	127
Benzene Insol.	<0.01	<0.01	0.05	<0.01	0.04	0.01	0.14	0.64	0.66	0.06
Pentane Insol.	<0.01	<0.01	0.08	0.01	0.07	0.02	0.19	0.74	1.44	0.08
T.A.N.	1.88	3.14	3.20	3.37	3.33	5.70	3.10	4.11	3.97	5.47
T.B.N.	1.03	0.85	0.85	0.73	0.30	0.39	0.30	0.19	0.12	1.88
Anti-freeze	trace	neg.	neg.	trace	neg.	neg.	neg.	trace	present	present
Fuel Dilution	0.8%	0.6%	0.8%	1.2%	0.8%	0.7%	0	1.4%	2.4%	1.7%
Ag	0	0	0	0	0	0	0	0	0	0
Na	20	18	40	35	30	32	22	17	25	18
Zn	930	810	830	800	900	1,100	940	800	940	1,100
Cu	160	110	100	80	38	23	16	8	9	8
Al	2	3	11	12	15	15	16	14	15	9
Ba	75	45	80	85	80	120	98	76	76	90
Ni	4	1	1	1	4	9	0	3	2	2
Cr	5	1	7	7	17	16	8	9	11	6
Ca	2,600	2,000	1,600	1,800	1,800	2,700	1,900	1,800	2,900	1,900
Fe	45	70	110	115	220	200	120	170	210	100
Si	8	10	14	14	13	13	11	11	13	9
Sn	8	4	10	10	17	21	9	12	10	10
Pb	20	30	52	45	170	240	160	88	140	80
P	650	530	730	700	700	600	720	700	1,400	950
B	16	10	13	13	5	2	0	0	5	8
Mg	10	10	16	16	16	11	15	12	13	15
V	3	1	3	2	4	7	8	4	2	6
Mo	0	0	0	0	1	2	0	1	1	2
Mn	0	0	8	6	6	130	300	850	950	380
Cd	0	0	1	0	2	3	1	1	2	1
Ti	1	0	2	1	2	1	1	1	1	0
	1 qt/3,821	1 qt/5,502	1 qt/7,142		1 qt/15,730	1 qt/24,250	1 qt/34,350	1 qt/43,894	1 qt/ --	
Oil additions/Mi	1 qt/4,043	1 qt/6,155	1 qt/8,588	1 qt/9,627	1 qt/18,999	1 qt/27,914	1 qt/37,309	1 qt/46,104	1 qt/ --	

*Dipstick samples

VEHICLE #A18717
Drain Interval: 10,000
Initial Vehicle Mileage: 3,677 on 5/20/76
Test Oil: VIRGIN

Mileage Date	5,636* 11/23/76	7,696* 1/12/77	9,631* 2/23/77	11,633* 4/5/77	13,669 5/26/77	15,667* 6/20/77	23,753 12/28/77	28,902 5/15/78
Flash, °F	290	340	380	360	405		365	335
Viscosity, SSU @ 100°F	236	380	282	276	317		340	370
Viscosity, SSU @ 210°F	53.47	55.95	56.82	55.69	58.89		62.02	63.25
V.I.	133	128	130	128	127		130	1.27
Benzene Insol.	<0.01	0.01	0.11	0.01	0.01		1.35	1.15
Pentane Insol.	<0.01	0.03	0.16	0.03	0.02		1.42	1.26
T.A.N.	2.46	3.02	2.80	4.10	3.26		4.68	5.47
T.B.N.	1.80	1.30	1.32	1.60	1.60		1.49	0.91
Anti-freeze	trace	neg.	trace	neg.	neg.		neg.	present
Fuel Dilution	1.7%	0.8%	0.8%	1.0%	0.4%		1.7%	0.3%
Ag	0	0	0	0	0		--	0
Na	27	44	8	10	15		16	21
Zn	900	820	840	930	900		3,500	1,150
Cu	38	34	29	22	8		14	16
Al	6	7	13	12	5		18	16
Ba	70	70	50	100	4		95	90
Ni	1	3	6	0	1		18	3
Cr	9	12	12	15	2		25	9
Ca	1,700	1,700	1,800	2,200	2,700		2,200	2,300
Fe	60	88	130	110	50		450	160
Si	9	10	13	10	6		17	12
Sn	20	17	26	17	13		15	13
Pb	35	30	46	63	33		9,000	56
P	500	550	800	270	650		950	1,050
B	6	5	7	1	0		1	3
Mg	50	42	57	43	19		30	12
V	3	3	4	4	3		3	6
Mo	1	0	2	0	0		45	2
Mn	5	5	14	6	48		48	400
Cd	1	1	2	0	0		0	0
Ti	1	2	2	0	0		2	0
Oil additions/Mi	1 qt/5,000 ½ qt/5,636	1 qt/ -- ½ qt/7,696		2 qt/11,145	1 qt/12,153	1 qt/14,468 ½ qt/15,667	1 qt/14,468 1 qt/16,340 2 qt/18,462 1 qt/19,655 1 qt/21,632 1 qt/23,569	

*Dipstick samples

VEHICLE #A18718
Drain Interval: 8,000
Initial Test Mileage: 1,685 on 9/16/76
Test Oil: VIRGIN

Mileage Date	3,677* 11/16/76	5,731* 2/8/77	7,900* 4/29/77	9,736 6/15/77	17,849 1/19/78	23,143 5/17/78
Flash °F	255	390	370	405	325	360
Viscosity, SSU @ 100°F	215	276	301	319	266	284
Viscosity, SSU @ 210°F	52.09	56.02	57.43	59.32	56.21	56.38
V.I.	137	129	127	128	134	128
Benzene Insol.	<0.01	<0.01	0.02	<0.01	0.11	0.10
Pentane Insol.	<0.01	0.01	0.03	0.01	0.13	0.13
T.A.N.	2.64	2.16	3.60	3.17	2.44	2.50
T.B.N.	1.21	0.54	0.83	0.39	1.03	1.23
Anti-freeze	neg.	trace	trace	neg.	neg.	trace
Fuel Dilution	1.6%	0.8%	0.8%	0.2%	2.2%	1.2%
Ag	0	0	0	0	0	0
Na	20	9	10	15	13	16
Zn	860	850	830	920	860	910
Cu	22	24	15	12	11	12
Al	5	8	8	8	15	12
Ba	70	75	80	98	88	95
Ni	1	1	0	1	2	2
Cr	5	6	1	5	7	6
Ca	1700	2000	800	2700	1900	1600
Fe	40	70	64	78	86	57
Si	8	10	7	9	10	8
Sn	16	15	5	15	14	11
Pb	29	52	60	120	100	60
P	560	700	600	600	650	700
B	7	5	0	3	0	0
Mg	320	34	25	34	18	10
V	5	1	0	2	4	5
Mo	1	0	0	0	1	2
Mn	27	45	47	60	110	160
Cd	1	1	0	0	1	0
Ti	2	4	0	0	1	0
Oil Additions/Mi	1 qt/3,304	1½ qt/5,731	1 qt/6,532	1 qt/9,236	1 qt/11,644	1 qt/19,602
	½ qt/3,677		1½ qt/7,900		1 qt/12,374	1 qt/20,538
					1 qt/13,639	1 qt/21,578
					1 qt/14,808	1 qt/22,795
					1 qt/16,181	
					1 qt/17,706	

*Dipstick samples.

VEHICLE #A18722
Drain Interval: 8,000
Initial Test Mileage: 1,853 on 7/28/76
Test Oil: MORCO

Mileage Date	3,877* 9/22/76	5,915* 11/22/76	7,690* 12/30/76	9,838 2/1/77	14,177 5/18/77	22,169 8/31/77	26,444 12/29/77
Flash °F	330	265	290	295	380	400	355
Viscosity, SSU @ 100°F	279	279	254	290	306	339	289
Viscosity, SSU @ 210°F	57.01	55.78	54.70	57.06	58.72	60.82	57.59
V.I.	132	127	132	128	130	127	130
Benzene Insol.	<0.01	0.09	0.01	0.70	0.01	0.87	0.22
Pentane Insol.	<0.01	0.16	0.85	0.95	0.02	1.05	0.26
T.A.N.	3.03	4.30	6.74	5.26	5.67	4.23	3.22
T.A.B.	1.94	2.06	1.24	1.39	1.60	0.77	2.91
Anti-freeze	neg.	trace	neg.	trace	neg.	present	neg.
Fuel Dilution	2.0%	2.0%	1.7%	1.2%	0.7%	1.3%	1.7%
Ag	0	0	0.4	0	0	0	0
Na	10	21	45	31	21	20	8
Zn	930	1000	1100	1100	1300	1100	1050
Cu	21	29	35	39	65	79	23
Al	3	9	13	17	11	13	12
Ba	40	70	60	75	100	100	88
Ni	1	1	6	4	8	0	1
Cr	1	6	9	13	9	13	5
Ca	2600	1600	1600	1700	2300	1300	1800
Fe	32	40	85	130	54	54	50
Si	6	9	12	14	8	11	8
Sn	10	-	30	26	11	23	17
Pb	24	33	45	52	100	85	55
P	1000	800	850	990	1000	750	900
B	0	2	1	2	0	0	0
Mg	700	400	450	450	800	900	750
V	4	3	3	4	5	9	6
Mo	0	1	1	1	1	2	1
Mn	2	5	11	8	59	190	200
Cd	0	1	2	2	2	6	1
Ti	0	1	3	2	1	0	1
Oil Additions/Mi	1 qt/3,270 ½ qt/3,877	1 qt/4,536 1 qt/5,915	1 qt/7,590	1 qt/9,575	1 qt/11,237 1 qt/12,704 1 qt/13,672	1 qt/15,955 1 qt/17,455 1 qt/19,186 1 qt/21,645	1 qt/24,368 1 qt/25,526 1 qt/26,260

*Dipstick sample.

VEHICLE #A18729
Drain Interval: 8,000
Initial Test Mileage: 1,095 on 8/10/76
Test Oil: VIRGIN

Mileage Date	3,227* 10/19/76	5,382* 12/3/76	7,399* 1/17/76	8,977 2/16/77	16,980 6/29/77	25,599 12/13/77	31,940 4/24/78
Flash ^{o}F	345	395	345	385	365	320	345
Viscosity, SSU @ $100^{o}F$	265	286	290	295	361	360	404
Viscosity, SSU @ $210^{o}F$	55.93	57.21	56.99	57.40	61.90	61.44	66.78
V.I.	133	131	128	128	125	124	128
Benzene Insol.	<0.01	<0.01	0.02	0.01	<0.01	0.02	0.88
Pentane Insol.	<0.01	<0.01	0.04	0.03	0.01	0.04	1.26
T.A.N.	2.21	2.94	2.98	3.02	3.91	3.34	4.68
T.B.N.	1.51	1.82	0.73	0.77	1.71	0.24	0.45
Anti-freeze	neg.	neg.	neg.	neg.	neg.	trace	present
Fuel Dilution	1.2%	1.0%	1.2%	1.2%	0.9%	1.2%	0.6%
Ag	0	0	0.2	0.2	0	0	0
Na	40	35	85	15	23	40	23
Zn	940	820	850	820	800	930	1150
Ca	42	37	37	34	26	28	17
Al	7	5	180	10	6	16	11
Ba	100	100	80	100	90	100	90
Ni	0	1	3	6	2	7	2
Cr	4	5	6	7	6	8	6
Ca	1800	1600	1400	1600	2600	1700	2300
Fe	95	110	130	190	100	160	130
Si	10	9	10	11	8	13	9
Sn	-	20	18	26	15	10	13
Pb	52	60	70	80	100	110	70
P	740	500	550	700	550	700	1150
B	17	14	11	12	3	0	4
Mg	15	14	14	16	14	16	17
V	5	2	4	4	5	8	4
Mo	0	3	0	1	0	0	1
Mn	9	10	9	21	180	370	500
Cd	1	1	1	3	3	1	0
Ti	1	0	1	2	0	0	0

Oil Additions/Mi	1 qt/2,172 ½ qt/3,272	1 qt/5,144 ½ qt/5,382	1 qt/6,542 1 qt/7,399		1 qt/14,135	1 qt/22,276	1 qt/29,211

*Dipstick samples.

VEHICLE #A18731
Drain Interval: 8,000
Initial Vehicle Mileage: 1,509 on 11/1/76
Test Oil: MORCO

Mileage Date	3,829* 12/10/76	5,551* 1/10/77	7,760* 2/10/77	9,643 3/18/77	17,806 6/24/77	25,535 9/8/77	33,805 12/16/77	41,755 3/27/78	45,091 4/28/78
Flash, °F	320	335	340	310	410	370	340	325	375
Viscosity, SSU @ 100°F	276	312	329	381	409	390	409	382	356
Viscosity, SSU @ 210°F	56.32	58.89	60.41	61.20	65.20	64.05	65.30	63.25	62.17
V.I.	130	129	128	118	123	124	124	124	124
Benzene Insol.	<0.01	<0.01	0.03	0.25	0.61	0.38	0.88	1.50	0.52
Pentane Insol.	0.01	0.01	0.07	1.40	0.71	0.52	1.59	1.72	0.72
T.A.N.	3.20	3.91	3.28	6.13	3.94	3.74	4.93	4.60	3.98
T.B.N.	3.36	2.30	1.27	1.87	1.54	2.63	2.09	1.29	2.46
Anti-freeze	neg.	neg.	neg.	neg.	trace	neg.	trace	trace	neg.
Fuel Dilution	0.5%	0.7%	0.8%	0.4%	0	0.3%	0.4%	1.6%	0.8%
Ag	0	0	0	0	0	0	0	0	0
Na	25	70	15	9	20	1	30	19	20
Zn	1,000	1,100	1,200	1,300	1,200	2,500	3,900	1,000	1,200
Cu	28	33	32	37	23	15	8	7	6
Al	5	6	11	12	7	11	16	12	7
Ba	60	70	75	110	95	110	90	66	90
Ni	0	2	2	5	0	2	5	2	1
Cr	6	11	13	13	8	13	8	16	6
Ca	1,700	1,400	1,600	1,700	2,300	1,800	1,500	2,600	1,700
Fe	39	47	70	90	47	44	50	78	30
Si	8	8	11	12	9	11	11	9	6
Sn	18	23	23	27	12	12	11	11	10
Pb	28	36	42	65	180	120	110	79	50
P	800	780	1,100	1,200	1,000	1,000	1,200	1,370	920
B	2	1	2	1	0	0	0	0	0
Mg	450	400	440	630	750	1,950	1,100	800	750
V	3	2	3	0	4	4	11	3	5
Mo	1	0	0	1	0	1	0	0	1
Mn	8	5	7	16	140	270	360	420	270
Cd	1	1	2	3	0	5	0	1	0
Ti	3	2	4	0	0	0	0	3	0
Oil additions/Mi	1 qt/3,441 ½ qt/3,829	1 qt/5,432 1 qt/5,551	1 qt/7,734 ½ qt/7,760		1 qt/12,866 1 qt/15,475	1 qt/21,495 1 qt/23,366	1 qt/29,300 1 qt/31,420	1 qt/37,785 1 qt/39,580	

*Dipstick Sample

VEHICLE #A18744
Drain Interval: 10,000
Initial Test Mileage: 1,004 on 7/26/76
Test Oil: MORCO

Mileage Date	3,138* 9/2/76	5,035* 10/12/76	8,155* 12/30/76	10,174* 2/7/77	11,056 2/18/77	21,367 8/24/77	28,296 12/27/77
Flash °F	420	390	370	365	385	375	365
Viscosity, SSU @ 100°F	345	386	371	423	422	443	446
Viscosity, SSU @ 210°F	61.10	63.88	62.33	65.23	66.89	68.84	68.71
V.I.	126	125	124	121	125	126	125
Benzene Insol.	<0.01	<0.01	<0.01	0.65	0.42	0.43	0.39
Pentane Insol.	<0.01	0.01	0.51	0.74	0.76	0.62	0.63
T.A.N.	3.43	4.47	5.70	4.11	4.45	3.60	3.96
T.B.N.	0.91	1.63	0.70	0.66	1.77	1.07	1.94
Anti-freeze	none	neg.	neg.	trace	trace	neg.	neg.
Fuel Dilution	0.6%	0.5%	2.0%	0.0%	0.2%	0.7%	0.8%
Ag	0	0	0.5	0	0.3	-	-
Na	16	50	100	45	25	18	19
Zn	960	1200	1300	1200	1200	2350	3300
Cu	14	26	28	31	35	20	9
Al	4	10	17	18	15	14	19
Ba	20	60	70	70	70	110	89
Ni	0	5	6	2	6	0	1
Cr	1	6	8	9	8	11	4
Ca	2000	1900	1600	1800	1600	1600	2000
Fe	60	60	120	200	190	86	100
Si	9	13	20	23	17	13	13
Sn	10	45	55	50	45	31	15
Pb	64	120	160	180	180	140	90
P	800	470	900	1000	1100	800	1150
B	0	5	6	5	7	0	0
Mg	500	550	500	450	480	1000	900
V	0	4	5	3	4	8	4
Mo	0	0	1	1	1	2	1
Mn	0	8	11	12	11	200	400
Cd	0	1	1	1	1	4	0
Ti	0	2	2	2	2	0	1
						1 qt/12,731	1 qt/22,630
Oil Additions/Mi	1 qt/2,359	1 qt/4,378	2 qt/6,508	1 qt/9,368	1 qt/10,541	2 qt/14,528	2 qt/24,030
	½ qt/3,138	½ qt/5,035	½ qt/8,155	½ qt/10,174		2 qt/17,279	2 qt/26,151
						2 qt/20,439	2 qt/27,268

*Dipstick samples.

VEHICLE #A18745
Drain Interval: 10,000
Initial Vehicle Mileage: 2,255 on 7/26/76
Test Oil: VIRGIN

Mileage Date	4,374* 8/27/76	6,327* 10/6/76	8,363* 11/3/76	9,940 12/10/76	12,020* 1/22/77	19,974 7/22/77	30,464 2/9/78	33,998 5/8/78
Flash, °F	415		390	375			365	370
Viscosity, SSU @ 100°F	303		351	366			358	360
Viscosity, SSU @ 210°F	58.67		61.56	62.12			61.52	63.0
V.I.	130		126	124			125	128
Benzene Insol.	<0.01		<0.01	<0.01			0.05	0.02
Pentane Insol.	<0.01		<0.01	<0.01			0.07	0.03
T.A.N.	2.47		3.28	3.84			3.39	4.81
T.B.N.	0.97		0.036	1.48			--	1.23
Anti-freeze	none		neg.	neg.			neg.	trace
Fuel Dilution	0.6%		0.7%	1.4%			0.7%	0.8%
Ag	0		0	0			0	0
Na	30		55	90			75	43
Zn	850		830	850			950	1,100
Cu	18		23	35			15	6
Al	4		13	16			27	10
Ba	50		70	80			100	80
Ni	0		1	3			2	1
Cr	0		3	9			10	7
Ca	2,200		1,600	1,500			2,700	3,000
Fe	48		95	150			280	65
Si	9		13	14			18	10
Sn	7		31	37			19	9
Pb	60		135	130			120	43
P	680		500	500			900	850
B	14		19	15			13	12
Mg	12		16	17			16	11
V	0		4	4			3	4
Mo	0		0	1			1	0
Mn	0		9	15			750	230
Cd	0		0	0			0	0
Ti	0		1	2			1	0
		1½ qt/5,100	1 qt/6,800					
Oil additions/Mi	½ qt/4,374	½ qt/6,327	1 qt/8,363	1 qt/9,129	½ qt/12,020			

*Dipstick Samples

VEHICLE #A20363
Drain Interval: 4,000
Initial Test Mileage: 2,457; Hrs 127
Test Oil: VIRGIN

Mileage/Hrs Date	3,719*/269 1/4/77	6,908/467 5/12/77	11,372/753 11/3/77	14,061/-- 12/15/77		17,799/-- 5/5/78
Flash °F	295	390	365	360	330	305
Viscosity, SSU @ 100°F	232	321	308	270	381	309
Viscosity, SSU @ 210°F	52.73	58.72	57.50	55.25	64.25	59.0
V.I.	132	125	124	128	127	130
Benzene Insol.	1.92	1.44	2.42	1.41	2.09	0.39
Pentane Insol.	2.32	2.12	4.60	1.89	3.58	0.57
T.A.N.	4.45	10.70	7.18	5.76	5.75	3.74
T.B.N.	0.79	1.10	0.48	0.36	0.78	1.23
Anti-freeze	neg.	neg.	neg.	neg.	neg.	neg.
Fuel Dilution	1.6%	1.2%	1.2%	1.7%	2.4%	2.0%
Ag	0.2	--	--	--	0	0
Na	43	20	17	33	57	13
Zn	720	900	900	820	1150	1000
Cu	24	27	33	26	32	7
Al	11	16	21	18	42	4
Ba	50	75	100	75	98	76
Ni	6	16	18	16	10	3
Cr	22	43	30	24	27	6
Ca	2000	2500	2800	2100	2200	3200
Fe	160	300	380	270	440	52
Si	10	13	16	17	21	6
Sn	16	21	18	15	32	10
Pb	11,500	19,000	3050	18,500	17,000	4400
P	480	540	750	700	1000	870
B	5	2	0	0	3	6
Mg	30	18	23	24	21	18
V	0	2	2	5	2	4
Mo	15	29	37	30	16	6
Mn	45	34	38	180	110	48
Cd	0	0	0	0	2	0
Ti	5	1	0	0	2	1
Oil Additions/Mi/Hrs	1 qt/--/152 1 qt/--/220	1 qt/5,722/366 2 qt/6,207/403 1 qt/6,635/453	1 qt/8,348/545 2 qt/9,293/598 2 qt/10,451/672	2 qts/--		

*Speedometer broken

VEHICLE #A20364
Drain Interval: 4,000
Initial Vehicle Mileage: 1,218; Hrs 127 on 9/20/76
Test Oil: VIRGIN

Mileage/Hrs Date	4,888/271 12/7/76	8,938/616 3/21/77	13,338/914 8/3/77	17,309/1151 11/29/77	18,741/1282 12/11/77	23,362/1607 1/30/78	26,504/1845 3/7/78	29,479/-- 5/9/78
Flash, °F	330	360	370	385	365	350	355	365
Viscosity, SSU @ 100°F	245	339	337	266	253	386	356	355
Viscosity, SSU @ 210°F	53.39	58.45	59.04	55.86	54.34	64.40	62.06	61.24
V.I.	130	118	121	132	130	126	127	125
Benzene Insol.	1.98	2.83	1.64	0.89	0.60	2.57	1.54	1.40
Pentane Insol.	4.90	4.43	2.02	1.11	0.95	3.38	2.01	1.64
T.A.N.	5.76	8.12	5.85	4.21	3.80	6.58	4.52	4.72
T.B.N.	1.78	0.61	1.60	1.19	0.97	1.10	2.00	0.84
Anti-freeze	neg.	neg.	neg.	neg.	neg.	trace	trace	trace
Fuel Dilution	0.8%	0.8%	1.4%	1.2%	2.0%	2.0%	1.6%	1.6%
Ag	0.2	0	0	0	0	0	0	0
Na	45	13	37	23	13	29	24	26
Zn	850	960	1,000	940	840	1,100	1,000	1,150
Cu	25	30	32	18	10	20	17	31
Al	13	16	21	19	9	15	10	16
Ba	60	90	91	85	75	74	68	80
Ni	20	22	13	10	4	6	3	11
Cr	20	25	35	20	8	16	11	14
Ca	2,100	3,700	2,300	2,000	1,800	3,300	2,800	2,300
Fe	860	2,400	300	300	120	230	150	230
Si	15	18	17	16	8	14	10	14
Sn	21	30	21	12	13	12	14	18
Pb	30,000	22,000	22,500	15,000	10,500	18,000	12,000	11,500
P	700	850	700	750	600	960	875	870
B	7	3	11	0	0	7	10	7
Mg	50	24	16	16	11	13	15	14
V	1	0	5	8	3	5	2	5
Mo	60	50	28	18	7	8	3	8
Mn	62	18	13	64	34	38	18	17
Cd	2	1	3	0	1	1	0	0
Ti	3	2	0	0	0	2	1	0
Oil additions	1 qt/3,130/193 1 qt/3,852/230 1 qt/4,882/271	1 qt/5,599 1 qt/ -- 2 qt/7,475/486 1 qt/8,227/571	1 qt/ 9,788/695 1 qt/ 9,970/711 2 qt/ -- 1 qt/11,633/821 1 qt/12,119/ 2 qt/12,598/881	2 qt/14,350/ -- 1 qt/15,622/ 986 2 qt/15,820/1035 2 qt/16,421/1077 2 qt/16,823/1110	2 qt/ -- 1 qt/17,809/1177 2 qt/18,086/1198 1 qt/18,505/1231	1 qt/19,299/1320 2 qt/19,659/1351 2 qt/20,432/1407 2 qt/20,877/1435 2 qt/21,393/1468 2 qt/22,758/1548 1 qt/23,208/1600	2 qt/23,712 2 qt/24,177 1 qt/24,499 2 qt/24,775 2 qt/25,289 2 qt/26,269	2 qt/27,177/1882 2 qt/28,309/1954 1 qt/29,241/2007

VEHICLE #A20365
Drain Interval: 4,000
Initial Test Mileage: 1,458; Hrs 66
Test Oil: MORCO

Mileage/Hrs Date	6,081/337 1/27/77	10,429/626 6/9/77	14,717/-- 11/29/77	20,130/218 3/14/78	21,234/320 5/16/78
Flash °F	350	330	370	360	335
Viscosity, SSU @ 100°F	312	311	305	437	298
Viscosity, SSU @ 210°F	57.19	57.89	57.84	66.15	58.08
V.I.	122	125	127	120	130
Benzene Insol.	5.32	4.00	3.15	4.56	1.07
Pentane Insol.	8.12	4.14	4.68	6.21	1.68
T.A.N.	8.09	6.68	6.37	7.19	5.20
T.B.N.	1.33	1.66	1.49	3.10	2.26
Anti-freeze	neg.	neg.	neg.	neg.	neg.
Fuel Dilution	1.0%	0.4%	0.8%	1.2%	1.8%
Ag	0	0	0	0	0
Na	25	27	27	33	48
Zn	1120	1100	1100	1550	1200
Cu	31	11	17	24	14
Al	37	25	26	25	18
Ba	70	67	70	68	75
Ni	30	13	14	8	3
Cr	43	40	30	33	17
Ca	1900	1900	2000	2600	2100
Fe	1200	470	700	410	300
Si	65	19	33	22	16
Sn	53	12	17	18	12
Pb	30,000	18,000	16,000	20,500	8000
P	1200	800	980	1200	980
B	5	0	0	0	0
Mg	500	620	1000	1000	750
V	3	0	6	2	4
Mo	90	20	31	17	8
Mn	60	10	64	90	39
Cd	2	0	0	1	0
Ti	3	0	0	1	0
	1 qt/2,794/138	1 qt/6,985/391	1 qt/11,476/673	3 qt/15,852/823	
	2 qt/3.534/174	1 qt/8,251/484	1 qt/12,281/715	1 qt/16,507/ 22*	
Oil Additions/Mi/Hrs	1 qt/4,450/223	1 qt/9,282/563	1 qt/12,541/737	2 qt/17,309/ 62	1 qt/20,421/--
	1 qt/5,212/282	1 qt/9,791/606	1 qt/13,169/750	2 qt/17,589/ 79	2 qt/20,980/--
			1 qt/13,648/788	2 qt/18,100/118	
			1 qt/14,021/812	1 qt/18,493/137	
				2 qt/18,993/164	
				1 qt/19,686/202	
				2 qt/19,863/208	

*New hour meter at 823.

VEHICLE #A20366
Drain Interval: 4,000
Initial Test Mileage: 1,256; Hrs 66 on 11/12/76
Test Oil: VIRGIN

Mileage/Hrs Date	5,308/333 11/28/77	7,330/433 1/6/78	10,902/672 4/5/78
Flash ^{o}F	350	360	340
Viscosity, SSU @ $100^{o}F$	230	321	402
Viscosity, SSU @ $210^{o}F$	52.58	60.33	64.95
V.I.	132	130	124
Benzene Insol.	1.76	1.61	4.07
Pentane Insol.	2.46	1.94	5.57
T.A.N.	5.51	4.42	6.88
T.B.N.	0.30	1.94	0.65
Anti-freeze	neg.	neg.	trace
Fuel Dilution	1.7%	1.7%	2.4%
Ag	0	0	0
Na	28	14	36
Zn	880	1150	1200
Cu	32	9	19
Al	28	9	15
Ba	80	84	98
Ni	52	7	6
Cr	44	14	35
Ca	1800	2100	2700
Fe	1200	180	280
Si	33	9	17
Sn	24	11	10
Pb	1700	10,500	25,000
P	700	850	730
B	5	4	3
Mg	79	26	18
V	6	3	2
Mo	110	14	14
Mn	34	12	15
Cd	0	1	0
Ti	0	2	3
Oil Additions/Mi/Hrs	1 qt/2,472/173 1 qt/3,994/254 1 qt/4,446/290 1 qt/4,759/309	1 qt/6,323/-- 1 qt/6,915/--	1 qt/8,481/507 1 qt/9,411/568 1 qt/9,609/604

VEHICLE #A20367
Drain Interval: 4,000
Initial Test Mileage: 1,315; Hrs 54
Test Oil: MORCO

Mileage/Hrs Date	5,678/261* 2/7/77	9,263/412 6/16/77	13,622/581 10/26/77	16,102/689 12/21/77
Flash °F	350	390	355	
Viscosity, SSU @ 100°F	262	276	261	
Viscosity, SSU @ 210°F	53.62	55.26	54.13	
V.I.	124	126	127	
Benzene Insol.	3.71	2.47	1.72	
Pentane Insol.	5.49	3.65	3.56	
T.A.N.	7.17	5.70	6.31	
T.B.N.	1.66	1.10	1.31	
Anti-freeze	neg.	neg.	neg.	
Fuel Dilution	1.6%	0.4%	0.8%	
Ag	0	0	0	
Na	11	12	13	
Zn	1050	1000	1100	
Cu	26	10	14	
Al	13	11	25	
Ba	50	80	80	
Ni	14	5	20	
Cr	23	20	32	
Ca	1600	1300	2300	
Fe	1000	150	550	
Si	17	9	16	
Sn	35	1	15	
Pb	28,000	12,000	21,000	
P	1000	600	800	
B	4	0	0	
Mg	450	470	21	
V	2	0	1	
Mo	26	24	30	
Mn	37	17	17	
Cd	2	0	0	
Ti	3	0	0	
Oil Additions/Mi/Hrs	1 qt/21,100/103	1 qt/7,298/321	1 qt/10,114/439	1 qt/15,995/685
	1 qt/27,773/129	1 qt/7,762/355	1 qt/12,501/530	
	2 qts/4,059/187	1 qt/8,467/383	1 qt/12,899/548	

*Replaced Gasket (oil pan) at 4 ,092/190

VEHICLE #A20368
Drain Interval: 4,000
Initial Test Mileage: 1,568; Hr 1 on 8/15/76
Test Oil: MORCO

Mileage/Hrs Date	5,620/194 1/31/77	10,420/434 8/9/77	14,240/618 11/21/77
Flash °F	355	365	340
Viscosity, SSU @ 100°F	283	290	208
Viscosity, SSU @ 210°F	55.68	56.82	50.8
V.I.	126	127	133
Benzene Insol.	3.08	3.64	3.03
Pentane Insol.	4.71	4.21	5.11
T.A.N.	6.36	9.23	6.87
T.B.N.	1.45	0.48	0.46
Anti-freeze	neg.	neg.	neg.
Fuel Dilution	0.4%	0.8%	2.8%
Ag	0	0	0
Na	340	1	17
Zn	1100	1100	1000
Cu	25	18	16
Al	15	24	21
Ba	60	75	68
Ni	13	15	18
Cr	18	40	22
Ca	1800	1600	1800
Fe	550	520	700
Si	15	15	20
Sn	30	16	13
Pb	20,000	17,500	16,000
P	1100	750	840
B	4	0	0
Mg	450	700	850
V	2	2	6
Mo	28	36	40
Mn	30	21	42
Cd	1	0	0
Ti	2	2	0
Oil Additions/Mi/Hrs	1 qt/1,568/-- 1 qt/3,759/106 1 qt/5,379/181	1 qt/6,849/262 1 qt/7,600/320 1 qt/8,100/440	1 qt/12,640/542 1 qt/13,661/530

VEHICLE #A20369
Drain Interval: 4,000
Initial Vehicle Mileage: 1,364; Hrs 45
Test Oil: MORCO

Mileage/Hrs Date	5,329/265 12/29/76	9,368/504 3/22/77	13,310/696 5/25/77	17,369/855 8/3/77	21,363/1,042 11/15/77	25,325/1,260 1/5/78	29,267/1,473 3/9/78	31,676/ -- 4/25/78
Flash, °F	355	350	385	390	365	355	370	340
Viscosity, SSU @ 100°F	266	310	300	299	272	309	317	292
Viscosity, SSU @ 210°F	54.83	56.14	56.30	56.90	56.02	58.72	58.41	57.96
V.I.	127	118	122	125	131	129	125	131
Benzene Insol.	2.93	4.29	3.43	3.59	3.78	4.36	3.81	1.29
Pentane Insol.	4.46	6.12	3.33	5.03	5.12	4.83	4.00	1.77
T.A.N.	8.25	8.73	9.49	7.05	7.09	7.53	5.73	7.56
T.B.N.	0.88	1.16	1.05	0.59	1.19	0.84	1.16	0.97
Anti-freeze	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.
Fuel Dilution	1.4%	0.9%	0.9%	0.8%	1.2%	0.6%	2.0%	1.8%
Ag	0.2	0	0	0	0	0	0	0
Na	52	3	15	20	14	0	22	19
Zn	1,200	1,200	1,200	1,200	1,100	1,150	1,100	1,200
Cu	25	25	14	18	14	14	16	10
Al	12	11	7	18	16	10	16	8
Ba	60	75	72	28	68	78	88	75
Ni	13	13	13	12	1	6	7	2
Cr	23	24	21	37	16	17	23	9
Ca	1,000	1,800	2,100	1,600	2,500	1,800	2,300	2,200
Fe	1,200	1,100	290	36	400	280	310	120
Si	17	14	10	14	13	12	18	8
Sn	33	25	14	21	15	11	14	10
Pb	22,500	20,000	18,600	17,000	18,000	16,500	13,500	7,000
P	940	1,100	800	950	900	450	1,000	900
B	3	2	0	0	0	0	0	0
Mg	420	510	560	800	1,000	850	800	750
V	2	0	2	6	1	4	3	4
Mo	32	27	24	28	25	16	19	7
Mn	61	18	13	19	52	100	56	50
Cd	1	1	1	3	0	1	0	0
Ti	3	1	1	0	0	1	1	0
	1 qt/3,739/169	2 qt/7,054/375		1 qt/15,522/784	1 qt/18,847/ 934	1 qt/22,728/1114	1 qt/26,101/1309	1 qt/29,829/1501
Oil additions/Mi	1 qt/5,047/246	1 qt/8,383/490	1 qt/12,427/668	1 qt/16,010/803	1 qt/19,326/ 955	2 qt/23,341/1185	1 qt/26,542/1327	1 qt/30,193/1519
					1 qt/20,459/1003	1 qt/23.970/1181	2 qt/27,000/1354	1 qt/31,093/1561
					1 qt/21,071/1032	1 qt/24,150/1192	1 qt/27,199/1363	1 qt/31,453/1585
							1 qt/27,410/1380	
							1 qt/27,806/1395	
							1 qt/28,340/1428	
							1 qt/28,658/1443	
							1 qt/28,899/1458	

VEHICLE #A20370
Drain Interval: 4,000
Initial Test Mileage: 1,297; Hrs 59
Test Oil: MORCO

Mileage/Hrs Date	5,022/237 1/21/77	9,250/476 5/23/77	13,281/657 8/23/77	17,162/846 12/6/77
Flash ^{o}F	360	390	370	355
Viscosity, SSU @ $100^{o}F$	287	317	277	274
Viscosity, SSU @ $210^{o}F$	56.21	58.11	55.95	55.88
V.I.	126	123	129	129
Benzene Insol.	2.57	3.95	2.55	3.28
Pentane Insol.	3.98	4.23	3.46	4.44
T.A.N.	6.30	6.88	7.82	6.60
T.B.N.	1.63	1.00	0.60	0.60
Anti-freeze	neg.	neg.	neg.	neg.
Fuel Dilution	1.2%	0.0%	0.8%	2.4%
Ag	0	0	0	0
Na	35	20	17	21
Zn	1150	1100	1100	1100
Cu	25	11	11	12
Al	15	12	14	14
Ba	65	1	65	72
Ni	9	8	10	7
Cr	21	3	34	19
Cn	1800	1900	1500	1700
Fe	650	310	260	290
Si	14	11	12	14
Sn	30	14	24	12
Pb	22,000	15,400	13,750	17,000
P	1100	800	600	840
B	4	0	0	0
Mg	500	600	950	1050
V	3	0	5	5
Mo	24	23	25	25
Mn	22	11	21	82
Cd	1	0	3	0
Ti	3	0	0	0
Oil Additions/Mi/Hrs	1 qt/2,707/126 1 qt/3,773/ --	1 qt/7,064/350 1 qt/7,860/404 1 qt/8,478/444	1 qt/11,632/583 1 qt/12,398/623	1 qt/15,000/738 1 qt/16,099/783 1 qt/16,560/812

VEHICLE #A20371
Drain Interval: 4,000
Initial Test Mileage: 1,756;Hrs 66
Test Oil: VIRGIN

Mileage/Hrs Date	5,768/281 2/2/77	9,535/456 5/3/77	13,393/717 9/29/77	17,150/910 12/7/77	21,139/1,088 1/18/78	24,956/-- 3/6/78	27,207/-- 4/25/78
Flash ^{o}F	330	355	345	365	315	350	355
Viscosity, SSU @ 100°F	229	266	236	238	299	324	304
Viscosity, SSU @ 210°F	52.69	54.77	52.63	53.80	58.98	60.76	58.4
V.I.	133	128	129	134	133	131	129
Benzene Insol.	3.12	1.56	2.07	4.06	3.69	2.91	1.23
Pentane Insol.	4.85	2.15	2.87	4.31	4.86	5.23	1.91
T.A.N.	6.00	7.82	8.18	7.00	5.49	6.23	6.03
T.B.N.	0.24	0.33	0.06	0.18	0.52	2.20	0.64
Anti-freeze	neg.	neg.	neg.	neg.	neg.	neg.	neg.
Fuel Dilution	2.0%	1.2%	2.8%	2.10%	2.9%	2.5%	1.2%
Ag	0	0	0	0	0	0	0
Na	17	3	1	40	22	27	24
Zn	770	600	800	850	1100	1000	1100
Cu	30	17	26	50	17	14	11
Al	14	22	31	25	15	12	10
Ba	55	38	69	80	78	86	80
Ni	14	13	34	44	10	5	3
Cr	26	29	70	50	25	28	14
Ca	1800	1000	1400	1800	1900	2700	3000
Fe	1200	270	1150	1800	440	400	220
Si	17	10	22	38	16	13	15
Sn	32	3	19	18	16	15	12
Pb	30,000	26,000	22,500	23,000	18,000	19,000	9000
P	680	420	680	700	900	1000	860
B	7	2	0	0	4	4	6
Mg	43	14	17	15	17	16	30
V	1	0	8	9	3	3	4
Mo	33	38	110	100	19	8	5
Mn	40	7	26	110	81	63	48
Cd	1	0	5	1	1	0	0
Ti	5	0	1	0	1	1	0
Oil Additions/Mi	1 qt/4,158/202 1 qt/3,083/159		1 qt/12,062	1 qt/16,562/-- 1 qt/16,883/--	2 qt/19,918/--	1 qt/22,924/-- 1 qt/24,056/--	2 qt/26,940/--

APPENDIX B

SwRI REPORT: INSPECTION OF ENGINES FROM THE

IOWA RE-REFINED OIL FLEET TEST

SOUTHWEST RESEARCH INSTITUTE
Post Office Drawer 28510, 6220 Culebra Road
San Antonio, Texas 78284

INSPECTION OF ENGINES FROM THE IOWA RE-REFINED OIL FLEET TEST

FINAL REPORT
MED REPORT No. 107

by

Edwin A. Frame

prepared by

Mobile Energy Division
Southwest Research Institute
San Antonio, Texas

under contract to

Iowa State University
Ames, Iowa

May 1978

Approved by:

R.D. Quillian, Jr.
Vice President
Mobile Energy Division

TABLE OF CONTENTS

I. Introduction

For the past two years Iowa State University (ISU) has conducted an oil fleet test using Iowa Department of Transportation (IDOT) vehicles (Ref 1). The test was designed to provide a direct comparison of the performance of two re-refined oils and a virgin based oil. Southwest Research Institute (SwRI) assisted in selecting 12 engines to be disassembled for deposit ratings and wear measurements. The wear measurements were made by IDOT personnel. This report includes the deposit ratings made by SwRI, and a technical interpretation of the overall fleet test results.

IA. Test Lubricants (Ref-1)

Two re-refined engine oils and one virgin based engine oil were included in the fleet test. All three oils were SAE viscosity grade 10W/30 and had SE-CC API service classifications. The two re-refined oils were produced from different re-refining methods. The Motor Oils Refining Company (MORCO) oil was re-refined using conventional acid/clay treatment, while The Bartlesville Energy Research Center (BERC) oil was re-refined using a BERC developed solvent extraction technique. The virgin oil was purchased by IDOT on a bid basis and was described as being composed of mid-continent high V.I. solvent extracted neutral basestocks. Table 1 contains inspection properties of the three test oils.

IB. Test Vehicles (Ref-1)

The IDOT test fleet consisted of twelve 1976 AMC Matadors, twelve 1976 Dodge pickups (1/2 ton, light duty emissions), ten 1975 Chevrolet Malibus and ten 1976 Ford F-750 trucks (heavy duty emissions). The twelve vehicles which were selected for engine tear down and inspection included representative Matadors, Dodges and Ford F-750's listed in Table 2. These vehicles operated on their factory fill engine oil for their first 1000 to 3000 miles at which time they were switched to a test oil.

II. Deposit Ratings

Deposit ratings for the twelve engines shown in Table 2 were made by SwRI during the week of 15 May 1978. The engines had been removed from the vehicles and disassembled by IDOT personnel. The engines were rated for sludge and varnish deposits according to the methodology of standard CRC Engine Rating Manuals No. 12 & No. 9 (Ref-2 & 3). The sludge and varnish ratings were made following the guidelines of the ASTM Sequence VC procedure (Ref-4), which specifies the locations on various engine parts where ratings are to be made. In addition, each engine was visually examined for valve lifter rust, unusual wear, and other significant conditions which included:

TABLE 1

LUBRICANT ANALYSES

PROPERTY	TEST OILS MORCO	BERC	VIRGIN
Vis., 38°C, SSu	316	375	318
Vis., 99°C, SSu	61.6	67.8	63.7
VI	136	137	141
TAN	2.2	2.4	1.6
TBN	5.4	3.9	3.3
API°	29.2	29.2	29.9
Flash Point, °C	207	218	207
Sulfated Ash, w%	1.00	1.30	0.71
Elemental			
Ba, ppm	29	25	35
Mg, ppm	650	9	7
Ca, ppm	1950	2600	1900
Zn, ppm	980	830	820
p, ppm	800	650	650
S, %	0.58	0.50	0.46
Na, ppm	5	4	16
Basestock Description	Re-refined	Re-refined	Mid-Cont.Hi VI
Process Description	Acid/clay	BERC solvent	solvent extracted
Formulated Quality Level	SE-CC	SE-CC	SE-CC

TABLE 2

TEST FLEET VEHICLES INSPECTED

Vehicle Type	Engine Size (in.^{3})	Fuel Type	Oil Drain Interval	BERC Vehicles	MORCO Vehicles	Virgin Oil Vehicles
1976 Matador Wagons	360	Unleaded	8,000	A17680 A17686	A17685 A17687	A17688 A17683
1976 Dodge Pickups	225	Unleaded	8,000	-	A18731	A18729
	225	Unleaded	10,000	-	A18710	A18716
1976 Ford 750-Trucks	361	Leaded	4,000	-	A20369	A20371

- o intake and exhaust valve condition including recession and burning
- o Connecting rod bearing condition
- o piston scuffing
- o valve lifter wear patterns
- o piston rings condition

The complete rating worksheets including a summary cover page for each of the twelve engines are in the Appendix. The ratings of all engines inspected are summarized in Table 3. In the following section the results of the deposit ratings will be discussed and interpreted.

III. Interpretation of Results

In attempting to interpret the results of this oil fleet test several key variables must be considered when comparing oil performance through deposit ratings. The following variables all impact on the deposition results:

- o lubricant base stocks (origin and refining treatment)
- o lubricant additive package composition
- o fuel composition variations (e.g. leaded or unleaded, presence of manganese)
- o type of vehicle operation/service (e.g. highway or city, amount of idling time)
- o oil drain interval
- o oil consumption rate
- o accumulated mileage

In comparing like vehicles from the Iowa fleet test, type of operation will be considered a constant as will fuel composition. As well as can be established, like vehicles were used in about the same type of service. While variations in fuel composition occurred during the test (e.g. manganese started appearing in the used oil of vehicles using unleaded gasoline about one year after test initiation), it is assumed that all vehicles experienced about the same change in fuel composition. The other variables were either well controlled or known.

One additional point needs clarification before the results are interpreted. Because each of the three lubricants contained a different additive package in addition to differences in base

TABLE 3
DEPOSIT RATINGS

(10=clean)

VEH ID	MILES	OIL*	SLUDGE: ROCKER COVERS	SLUDGE: INT. MANIF.	SLUDGE: OIL PAN	SLUDGE: VALVE DECK	SLUDGE: PUSH ROD CHAMBER	SLUDGE: TIMING COVER	SLUDGE: AVG	VARNISH: PIST. SKIRT	VARNISH: ROCKER COVERS	VARNISH: LIFTER BODIES	VARNISH: CYL WALLS	VARNISH: OIL PAN	VARNISH: AVG	DEPOSIT: INT. VALVES
A17686	27,000	B	9.7	9.7	9.7	10.0	10.0	9.7	9.8	8.2	8.3	7.4	9.0	9.5	8.5	6.8
A17680	45,888	B	9.6	9.9	9.7	9.7	9.7	9.7	9.7	5.8	8.8	7.2	8.2	8.7	7.7	7.0
A17687	48,285	M	9.7	10.0	9.7	10.0	10.0	10.0	9.9	9.8	9.0	7.9	9.5	9.0	9.0	7.4
A17685	60,174	M	9.7	9.9	9.7	10.0	10.0	10.0	9.9	9.5	8.5	7.6	8.8	9.0	8.7	4.1
A17683	49,503	V	9.9	9.8	9.8	10.0	10.0	9.7	9.9	7.9	8.7	7.3	8.8	9.0	8.3	4.9
A17688	54,477	V	9.6	9.7	9.8	10.0	9.9	10.0	9.8	6.0	6.2	5.0	6.1	8.6	6.4	6.6
A20369	31,576	M	9.4	9.6	9.2	9.4	9.7	9.7	9.5	9.0	5.3	8.1	9.5	7.4	7.9	6.9
A20371	27,207	V	9.3	9.4	9.5	6.2	9.7	9.5	8.9	6.4	3.6	7.3	7.0	6.2	6.1	7.1
A18731	45,091	M	9.7	NA	9.7	10.0	NA	9.8	9.8	7.4	8.7	9.0	9.5	7.5	8.4	6.2
A18729	31,950	V	9.2	NA	9.2	9.7	NA	9.1	9.3	6.1	5.0	8.9	6.7	5.5	6.4	7.4
A18710	25,617	M	9.5	NA	9.7	9.7	NA	9.3	9.6	9.0	7.0	9.5	9.1	7.6	8.4	7.7
A18716	63,910	V	8.3	NA	9.1	9.7	NA	8.6	8.9	5.7	4.8	7.6	5.1	5.1	5.7	6.5

* Oil Codes
B = BERC oil
M = MORCO oil
V = Virgin based oil

NA = Not Applicable

stock composition, it is nearly impossible to differentiate between basestock effects and additive package effects when reviewing the deposition results. The fact that all three oils were of SE-CC quality helps minimize the differences in additive package effectiveness; however, small subtle differences in additive package effectiveness can mask the effects of basestock differences. This point does not reduce the importance of the Iowa oil fleet test, but is made to help insure that only valid conclusions are drawn from the data.

IIIA. AMC Matadors

Three of the AMC Matador wagons provided the best overall performance comparison of the different lubricants. Table 4 shows key ratings for these three engines. All three engines had about the same mileage and all three switched from the 4000 mile oil drain interval to an 8000 mile oil drain interval

TABLE 4
AMC ENGINES
WITH SIMILAR MILEAGE
(10=clean)

VEH ID	OIL	MILES	OIL CONSUMP. QT/1000mi	VARNISH PIST. SKIRTS	VARNISH CYL WALLS	VARNISH AVG ENG	AVG ENG SLUDGE	INT VALV DEPOSITS AVG	INT VALV DEPOSITS WORST
A17680	B	45,888	0.19	5.8	8.2	7.7	9.7	7.0	5.5
A17687	M	48,285	0.70	9.8	9.5	9.0	9.9	7.4	5.5
A17683	V	49,503	0.55	7.9	8.8	8.3	9.9	4.9	1.5

at about the same mileage. The MORCO oil gave superior results in controlling engine varnish and had a 9.8 average piston skirt varnish rating which is exceptional. The pistons from the BERC oil had significantly more varnish than the other two oils; however, the BERC oil had excellent oil consumption performance. Engine sludge results for all three engines were nearly the same. The virgin oil had rather dirty intake valves, including one which had a 1.5 deposit rating. The MORCO oil had significantly higher oil consumption than the other two oils. This resulted in the engine being exposed to more "fresh" oil containing undepleted additives which may be a contributing factor to the excellent varnish ratings observed with the MORCO oil.

The other three AMC vehicles did not have mileages which were directly comparable; however, some generalizations can be made based on the data shown in Table 5.

with the virgin oil engine being slightly more severe. Overall, engine A20369 which used MORCO oil was in better condition than A20371 which used virgin oil.

IIIC. Dodge 1/2 Ton Pickups

Two of the Dodge pickups inspected had operated using 8000 mile oil drain intervals (ODI), while the other two had 10,000 mile ODI. Table 7 shows key deposit ratings for the vehicles having 8000 mile ODI. While the mileages of the two vehicles were quite different, some interesting results were observed. A18731 (MORCO) had accumulated >13,000 more miles than A18729, but had

TABLE 7
DODGE PICKUPS

8000 mi ODI

				VARNISH				SLUDGE		
VEH ID	OIL	MILES	OIL CONSUMP QT/1000mi	PIST. SKIRT	ROC. COVER	CYL WALLS	AVG ENG	AVG ENG	INT VALV DEPOSITS AVG	WORST
A18731	M	45,091	0.23	7.4	8.7	9.5	8.4	9.8	6.2	5.0
A18729	V	31,950	0.21	6.1	5.0	6.7	6.4	9.3	7.4	7.0

much less varnish and slightly less sludge deposition. Oil consumption rates were about the same; however, A19731 (MORCO) had heavier intake valve deposits and slightly more piston scuffing. In comparing these two vehicles, the overall performance of the MORCO oil was far superior based on its better ratings at higher mileage.

The two Dodge pickups with 10,000 mile ODI did not provide a good comparison of MORCO and virgin oil performance. The vehicle using virgin oil had accumulated >38,000 more miles than the MORCO lubricated vehicle. As would be expected under these conditions the virgin oil engine had much more sludge and varnish deposition. The only unusual results from these two vehicles was the MORCO oil engine, despite its lower mileage, had twice the oil consumption rate as the virgin oil engine. Also, the MORCO oil engine had several compression rings with very light corrosion.

IV. Summary/Conclusions/Recommendations

Several significant points can be made in summarizing the results of the Iowa re-refined oil fleet test.

1. No major engine failures occurred during the test program. The engines which were inspected were generally in acceptable condition. Based on engine condition, the two re-refined oils and the virgin based oil were judged to have performed satisfactorily. In some cases the re-refined oils had better deposition performance than the virgin based oil.

TABLE 5
AMC ENGINES

(10=clean)

VEH ID	OIL	MILES	OIL CONSUMP. QT/1000mi	VARNISH PIST. SKIRTS	VARNISH CYL BODS	VARNISH CYL WALLS	VARNISH AVG ENG	INT VALV DEPOSITS AVG	INT VALV DEPOSITS WORST
A17686	B	27,000	0.13	8.2	4.4	9.0	7.9	6.8	5.0
A17685	M	60,174	0.77	9.5	7.6	8.8	8.7	4.1	1.5
A17688	V	54,477	0.39	6.0	5.0	6.1	6.4	6.6	5.0

No significant differences in sludge ratings existed for any of the six AMC engines inspected. Once again the MORCO oil gave excellent varnish protection in all areas; however, this engine had heavy intake valve deposits and as with other engine using MORCO oil, high oil consumption was observed. The engine using BERC oil once again had the lowest oil consumption rate. Despite higher mileage, the engine from A17688 (virgin oil) had less intake valve deposits than the other AMC engine which used virgin oil (A17683). Reasons for this annomoly are unknown.

IIIB. Ford F-750's

The two Ford F-750's which were inspected provided a good comparison between the MORCO and virgin oil. Key areas of major differences are shown in Table 6.

TABLE 6
Ford F-750 ENGINES

(361 cu. in.)

VEH ID	OIL	MILES	OIL CONSUMP QT/1000mi	VARNISH PIST. SKIRT	VARNISH ROC. COVER	VARNISH AVG ENG	SLUDGE VALV DECK	SLUDGE AVG ENG	INT VALV DEPOSITS AVG	INT VALV DEPOSITS WORST
A20369	M	31,576	1.06	9.0	5.3	7.9	9.4	9.5	6.9	5.5
A20371	V	27,207	0.46	6.4	3.6	6.1	6.2	8.9	7.1	6.0

Despite having slightly higher mileage, the engine operated on MORCO oil (A20369) had significantly less overall sludge and varnish deposits than the engine operated on virgin oil (A20371). However, A20369 had twice as high an oil consumption rate as A20371. As observed in the AMC engines, the MORCO oil generally provided very good deposition control, but had a significantly higher oil consumption rate. Despite being fueled with leaded gasoline, neither engine had appreciable rust on the valve lifters. A very light "lead paint" type deposit was found throughout both engines. A20371 (Virgin oil) had very light corrosion on seven of the compression rings, while A20369 (MORCO) had very light corrosion on only two compression rings. Both engines had some dished valve lifters

2. The observed differences in performance between the re-refined oils and virgin oil could be either basestock effects and/or additive package effects.

3. The MORCO oil had a tendency towards superior deposit control, but generally had higher oil consumption rates in the AMC and Ford engines which were inspected. It is recommended that the MORCO oil composition be further investigated using a technique such as gas chromatographic boiling point distribution to determine if the higher oil consumption rate can be correlated to base oil volatility. Some of the vehicles inspected had rather brittle valve guide seals which could be contributing to oil consumption. The engine manufacturers (AMC, Ford, Dodge) should be contacted to determine if they have experienced any unusual valve guide seal problems.

4. Two AMC engines had at least one very heavily deposited intake valve which could cause engine problems in the future.

5. The wear measurements made by IDOT were reviewed. For the most part, the measurements tend to indicate very little wear took place. Some notable exceptions were:

- A20369 (F-750, MORCO) had three ring gaps which were excessive.
- Two AMC's (MORCO) each had from 1 to 3 rings with rather high gap.
- Two Dodges (Virgin oil) and one Dodge (MORCO) had some rather high exhaust valve guide wear.

The ring gap wear observed for the AMC's and the Ford F-750 using MORCO oil may have contributed to their higher oil consumption rate.

6. Overall, the results were very positive with respect to the field performance of the two lubricants made from re-refined components.

V. Acknowledgements

The author wishes to acknowledge the help and co-operation of Iowa State University and The Iowa Department of Transportation in arranging the engine inspection details. Also special recognition is made of Mr. E.R. Lyons who provided the expert deposit ratings.

VI. References

1. D.L. Ulrichson, D.E. Yake, "Iowa Re-refined Oil Fleet Test" Engineering Research Institute, Iowa State University, Ames, IA, ERI-78143, November, 1977.

2. CRC Sludge Rating Manual No. 12, Sept, 1977.

3. CRC Varnish Rating Manual No. 9, June, 1971.

4. Multicylinder Test Sequences for Evaluating Automotive Engine Oils, ASTM STP 315F p. 168-200.

5. D.L. Ulrichson, D.E. Yake, "Iowa Re-refined Oil Fleet Test", Final Report under DOE Contract ET-76-S-03-1803, to be published Fall, 1978.

APPENDIX

INDIVIDUAL DETAILED ENGINE DEPOSIT RATING FORMS

VI. References

1. D.L. Ulrichson, D.R. Yake, "Iowa Re-refined Oil Fleet Test" Engineering Research Institute, Iowa State University, Ames, IA, ERI-78143, November, 1977.

2. CRC Sludge Rating Manual No. 12, Sept, 1977

3. CRC Varnish Rating Manual No. 12, Sept. 1971.

4. Multicylinder Test Sequences for Evaluating Automotive Engine Oils, ASTM STP 315F p. 168-206.

5. D.L. Ulrichson, D.R. Yake, "Iowa Re-refined Oil Fleet Test", Final Report under DOE Contract ET-76-S-03-1801, to be published Fall, 1978.

ENGINE INSPECTION SUMMARY

Vehicle I.D.:	A17686
Engine Type:	AMC,,360 CID
Miles:	27,000
Oil Type:	BERC Rerefined
Oil Drain Interval:	4000 mi for 11,000 miles 8000 mi for balance

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	9.7	Piston Skirts	8.2
Intake Manifold	9.7	Rocker Arm Covers	8.3
Oil Pan	9.7	Valve Lifters	7.4
Valve Deck Area	10.0	Cylinder Wall (BRT)	9.0
Push Rod Chamber	10.0	Oil Pan	9.5
Timing Gear Cover	9.7		
AVG. SLUDGE	9.8	AVG. VARNISH	8.5

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	9.4
Stuck Compression Rings	0	Piston Varnish, Min.	6.4
Stuck Oil Rings	0	Intake Valve Deposits, Max.	8.0
		Intake Valve Deposits, Min.	5.0
		Intake Valve Deposits, Avg.	6.8

Clogging

Push Rods, No.	0
Oil Ring, %	0
Oil Screen, %	0

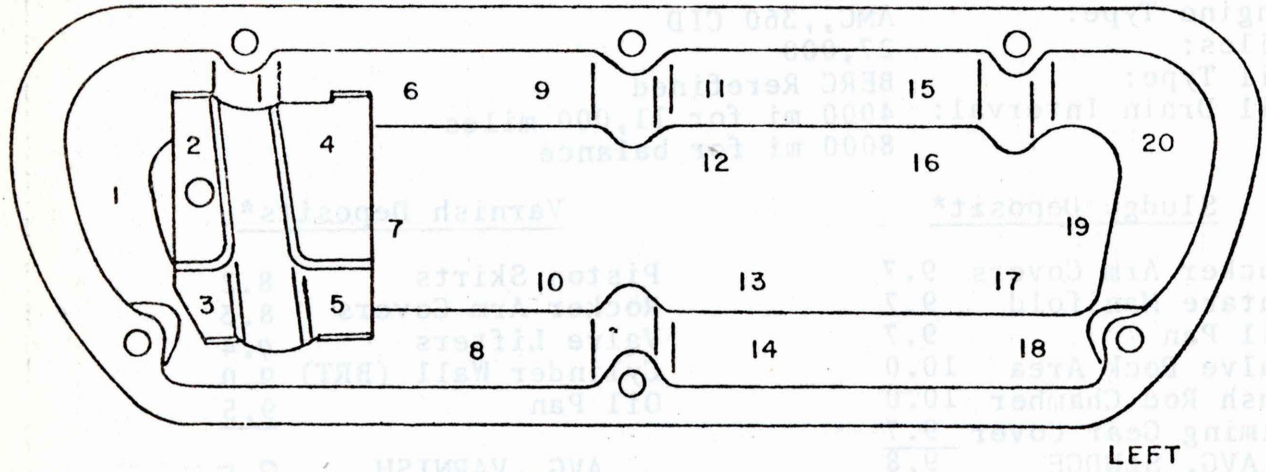
Observations, Comments

Date: 5-78
Rater: E.R. Lyons

* 10=Clean

Rating Work Sheet No. 1

SLUDGE RATING OF LEFT ROCKER ARM COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A		x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	18	90	.22
1/2A x	x			x																	2	10	.05
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.27

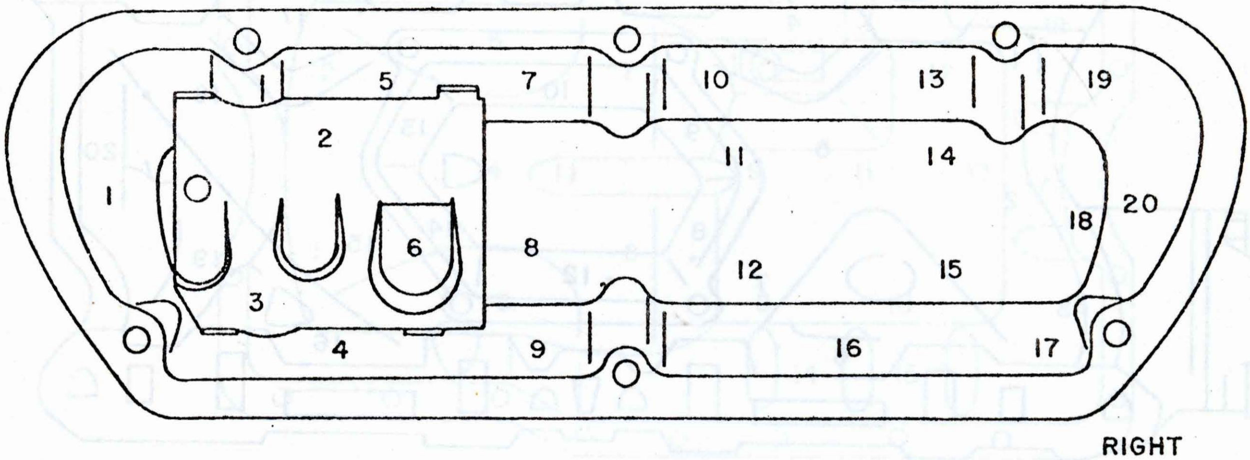
Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Rating Work Sheet No. Ia

SLUDGE RATING OF RIGHT ROCKER ARM COVER



Note Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	18	90	.22
1/2A	x					x															2	10	.05
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.27

Inspector ERL

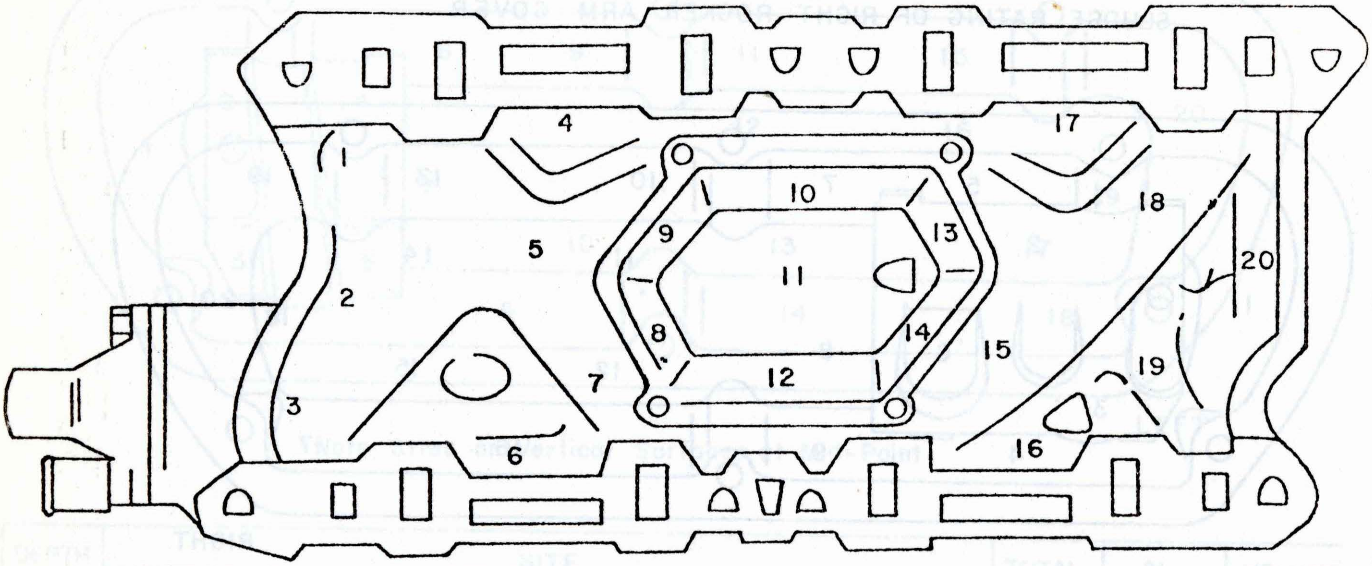
Sludge Merit Rating 9.7

Date 5-78

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 9.7

Rating Work Sheet No. 2

SLUDGE RATING OF UNDERSIDE OF INTAKE MANIFOLD



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	

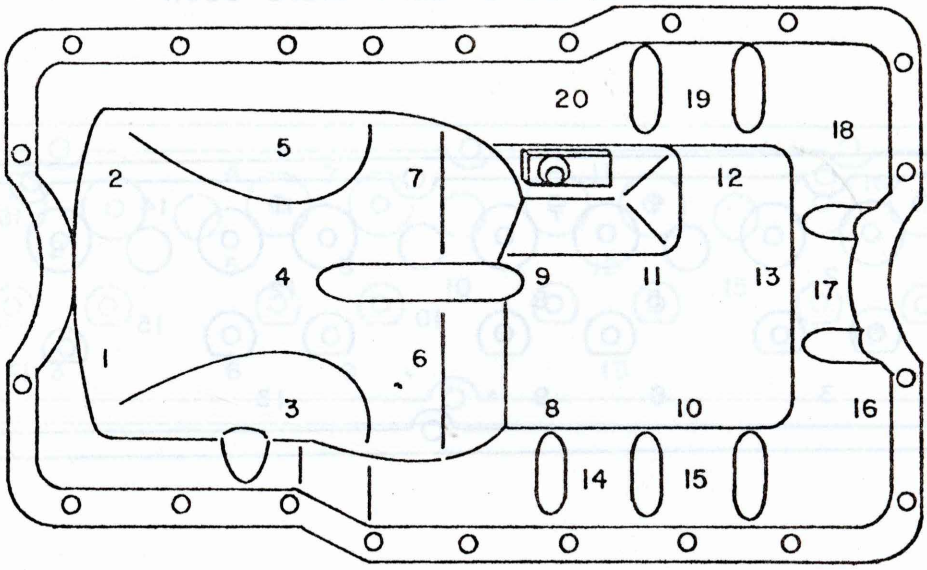
Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 3

SLUDGE RATING OF OIL PAN



DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTO
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

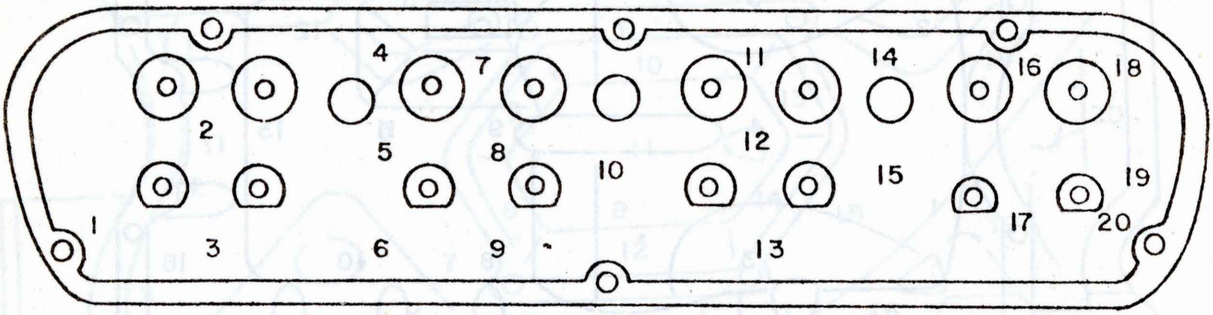
Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 4

SLUDGE RATING OF LEFT VALVE DECK



Left

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUX FACTO
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

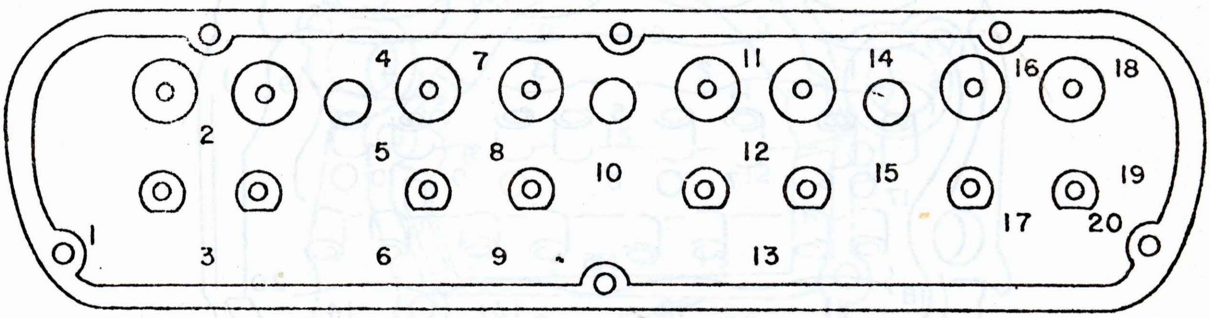
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 4a

SLUDGE RATING OF RIGHT VALVE DECK



Right

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOF
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

Inspector ERL

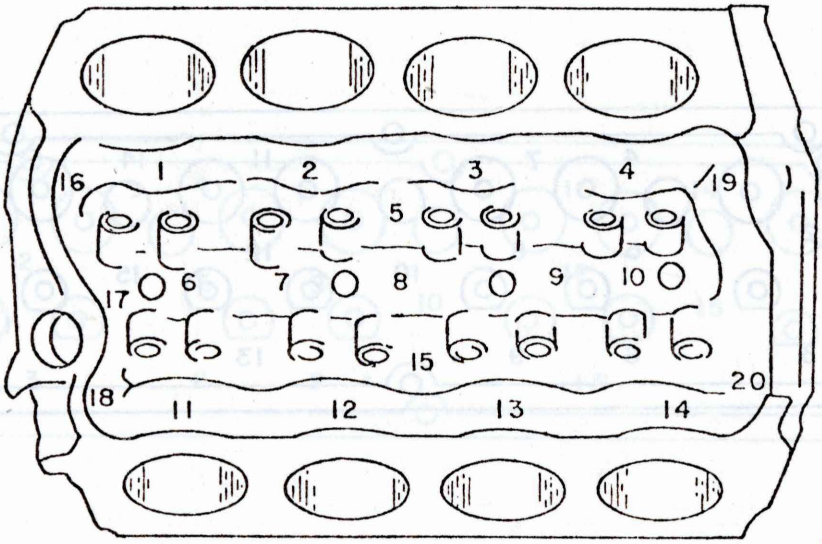
Date 5-78

Sludge Merit Rating 10.0

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 10.

Rating Work Sheet No. 5

SLUDGE RATING OF PUSH ROD CHAMBER



Note: Sites on Vertical Surfaces at Mid-Point

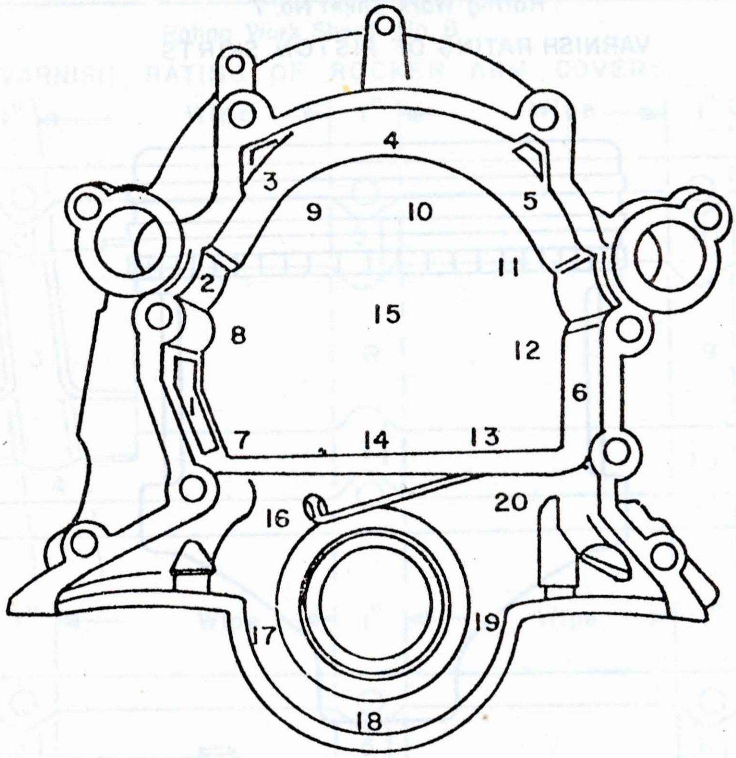
DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No.6
SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTC
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
																					GRAND TOTAL		

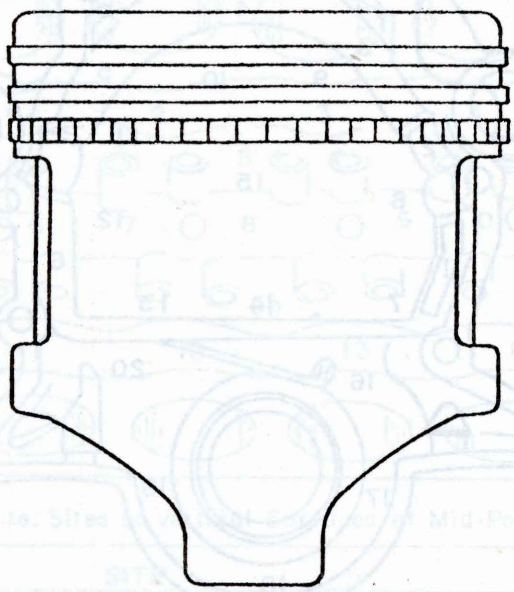
Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	CAM SIDE	OUT-SIDE	AVERAGE	CON. ROD BRGS APPEARANCE
Lt Scuff Camside	Lt 1	9.4	8.8	9.1	Normal
Normal	2	9.2	8.8	9.0	Normal
Normal	3	8.0	6.9	7.5	Normal
Normal	4	7.4	6.9	7.2	Normal
Normal	Rt 1	8.9	9.0	9.0	Normal
Normal	2	8.9	9.0	9.0	Normal
Normal	3	6.4	7.6	7.0	Normal
Normal	4	7.6	8.5	8.1	Normal
	TOTAL	65.8	65.5		
	AVERAGE	8.2	8.2		

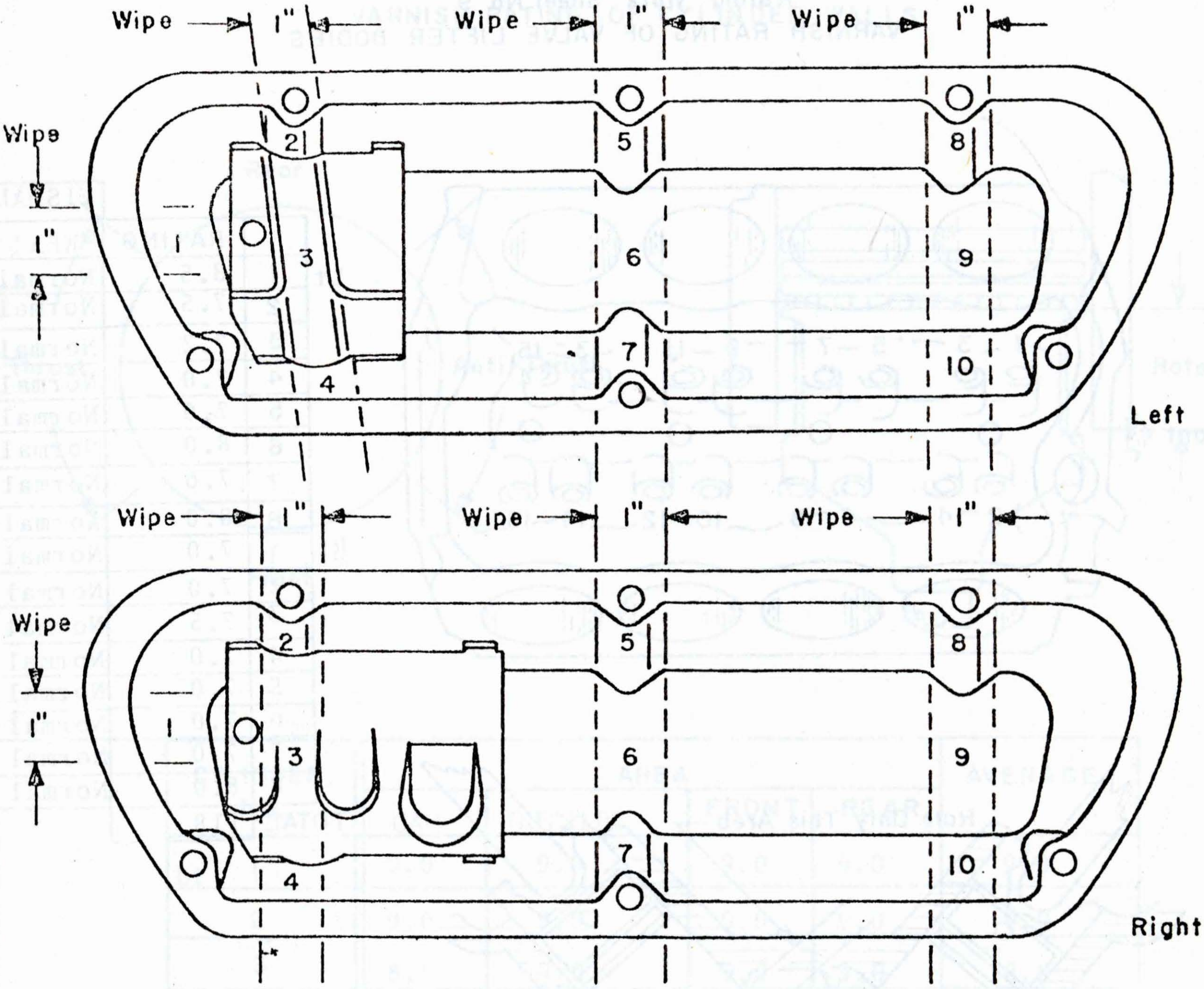
Inspector ______________

Date ______________

$$\text{VARNISH RATING} = \frac{\text{AvgThrust} + \text{Avg Antithrust}}{2} = 8.2$$

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



Left

AREA	RATING
1	8.0
2	8.5
3	9.0
4	8.5
5	8.5
6	8.5
7	9.0
8	8.5
9	8.5
10	9.0
TOTAL	86.0

Avg. Varnish Rating = $\frac{\text{Left + Right}}{2}$ = 8.3

Right

AREA	RATING
1	9.5
2	9.0
3	9.5
4	9.0
5	9.0
6	5.0
7	7.0
8	9.0
9	5.0
10	7.0
TOTAL	79.0

Varnish Rating = $\frac{\text{Total}}{10}$ = 8.6

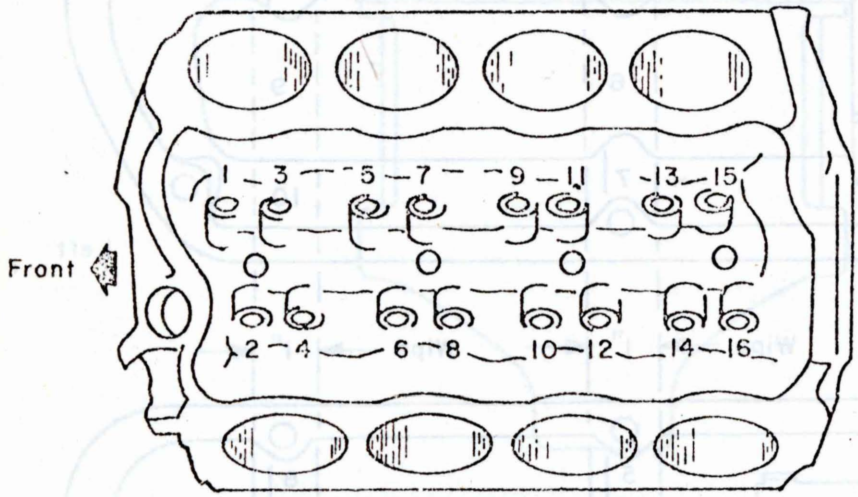
Inspector ERL

Date 5-78

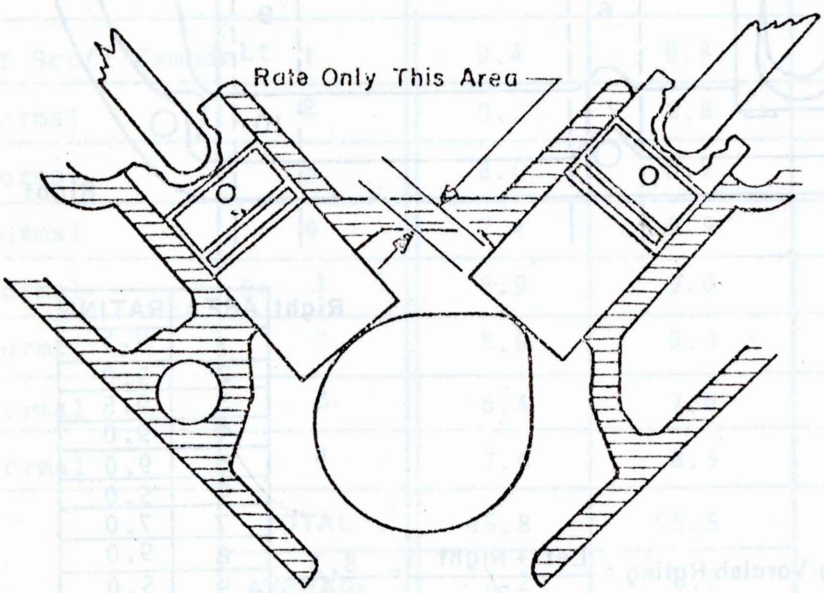
Varnish Rating = $\frac{\text{Total}}{10}$ = 7.9

Rating Work Sheet No. 9

VARNISH RATING OF VALVE LIFTER BODIES



		RATING	VISUAL WEAR
Lt	1	8.5	Normal
	2	7.5	Normal
	3	7.2	Normal
	4	7.0	Normal
	5	7.0	Normal
	6	8.0	Normal
	7	7.6	Normal
	8	8.0	Normal
Rt	1	7.0	Normal
	2	7.0	Normal
	3	7.5	Normal
	4	7.0	Normal
	5	7.0	Normal
	6	7.0	Normal
	7	7.0	Normal
	8	8.0	Normal
TOTAL		118.3	



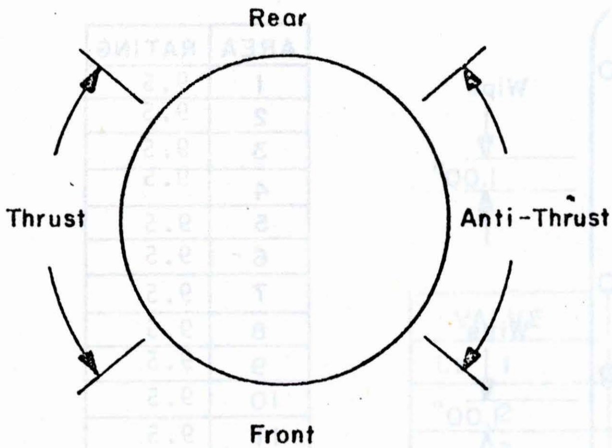
Inspector ERL

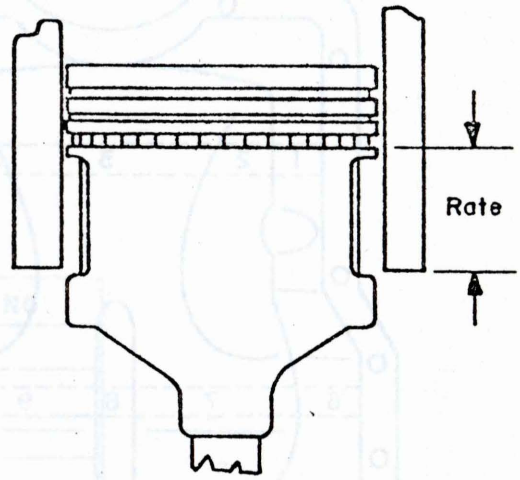
Varnish Rating = $\frac{\text{Total}}{16}$ = 7.4

Date 5-78

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.		AREA				AVERAGE
		CAM	OUTSIDE	FRONT	REAR	
Lt	1	9.0	9.0	9.0	9.0	9.0
	2	9.0	9.0	9.0	9.0	9.0
	3	8.5	9.0	9.0	9.0	8.9
	4	9.0	9.0	9.0	9.0	9.0
Rt	1	9.0	9.0	9.0	9.0	9.0
	2	9.0	9.0	9.0	9.0	9.0
	3	9.0	9.0	9.0	9.0	9.0
	4	9.0	9.0	9.0	9.0	9.0
					TOTAL	9.0

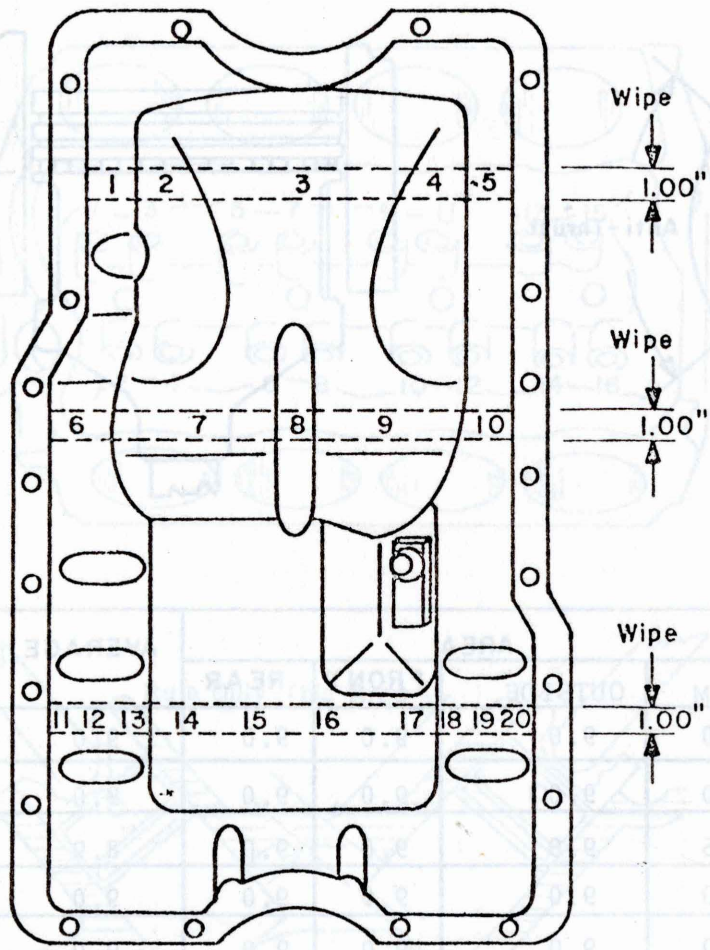
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 9.0

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	9.5
2	9.5
3	9.5
4	9.5
5	9.5
6	9.5
7	9.5
8	9.5
9	9.5
10	9.5
11	9.5
12	9.5
13	9.5
14	9.5
15	9.5
16	9.5
17	9.5
18	9.5
19	9.5
20	9.5
TOTAL	190.0

Inspector ERL

Varnish Rating = $\frac{\text{Total}}{20}$ = 9.5

Date 5-78

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

VALVE	RATING
Lt 1	6.5
2	6.0
3	9.0
4	5.0
Rt 1	8.0
2	8.0
3	8.0
4	5.0
TOTAL	54.5

Visual Observation of Seat, recession, or burning: Recess-Normal Burn-None
ALL OK

Avg. Rating $= \frac{\text{total}}{8} =$ 6.8

Inspector ERL

Date 5-78

ENGINE INSPECTION SUMMARY

Vehicle I.D.: A17680
Engine Type: AMC, 360 CID
Miles: 45,888
Oil Type: BERC Rerefined
Oil Drain Interval: 4000 mi for 15,000 miles
8000 mi for balance

Sludge Deposit*	
Rocker Arm Covers	9.6
Intake Manifold	9.9
Oil Pan	9.7
Valve Deck Area	9.7
Push Rod Chamber	9.7
Timing Gear Cover	9.7
AVG. SLUDGE	9.7

Varnish Deposits*	
Piston Skirts	5.8
Rocker Arm Covers	8.8
Valve Lifters	7.2
Cylinder Wall (BRT)	8.2
Oil Pan	8.7
AVG. VARNISH	7.7

Additional Ratings*

Stuck Valve Lifters	0
Stuck Compression Rings	0
Stuck Oil Rings	0
Piston Varnish, Max.	6.9
Piston Varnish, Min.	5.4
Intake Valve Deposits, Max.	8.0
Intake Valve Deposits, Min.	5.5
Intake Valve Deposits, Avg.	7.0

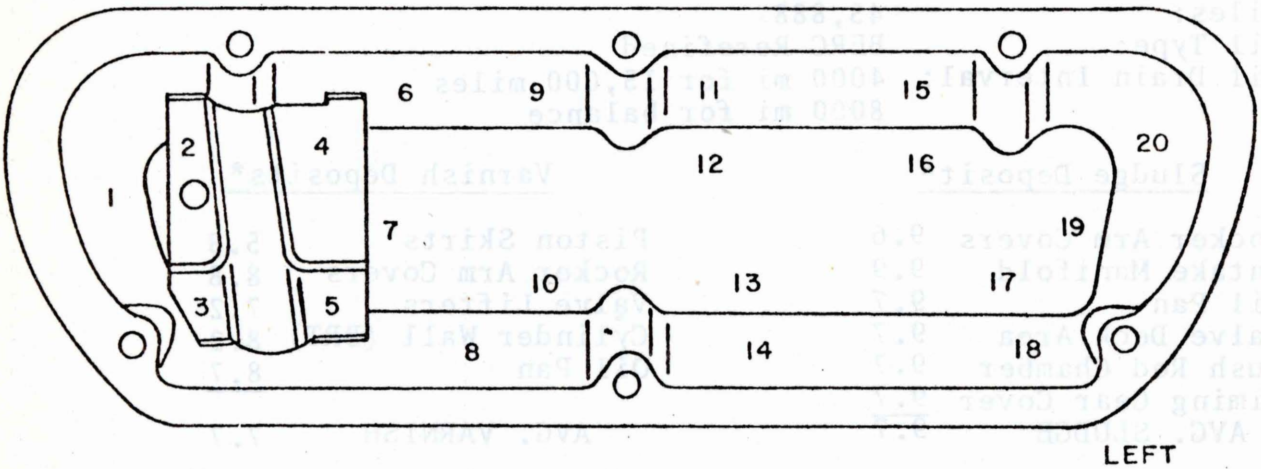
Clogging	
Push Rods, No.	0
Oil Ring, %	0
Oil Screen, %	0

Observations, Comments

Date: 5-78
Rater: E.R. Lyons

* 10=Clean

Rating Work Sheet No. 1
SLUDGE RATING OF LEFT ROCKER ARM COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A		x		x				x	x		x			x				x			7	35	.09
1/2A x	x		x		x	x	x			x		x	x		x	x	x		x	x	13	65	.32
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.41

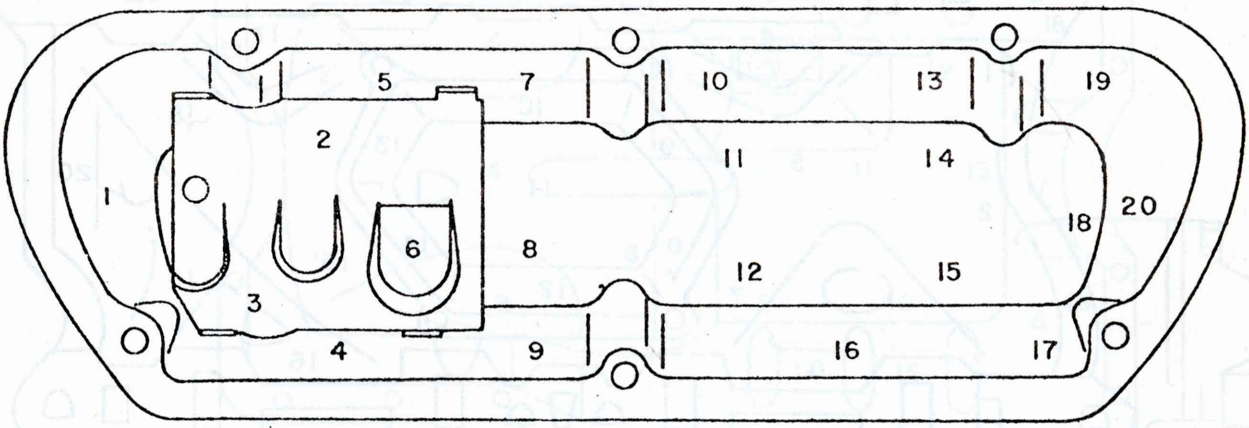
Inspector ERL

Sludge Merit Rating 9.6

Date 5-78

Rating Work Sheet No. 1a

SLUDGE RATING OF RIGHT ROCKER ARM COVER



Note Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x			x	x	x	x		x	x	x	x	x			x	x		x		13	65	.16
1/2A		x	x					x						x	x			x			6	30	.15
3/4A																				x	1	5	.04
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.35

Inspector ERL

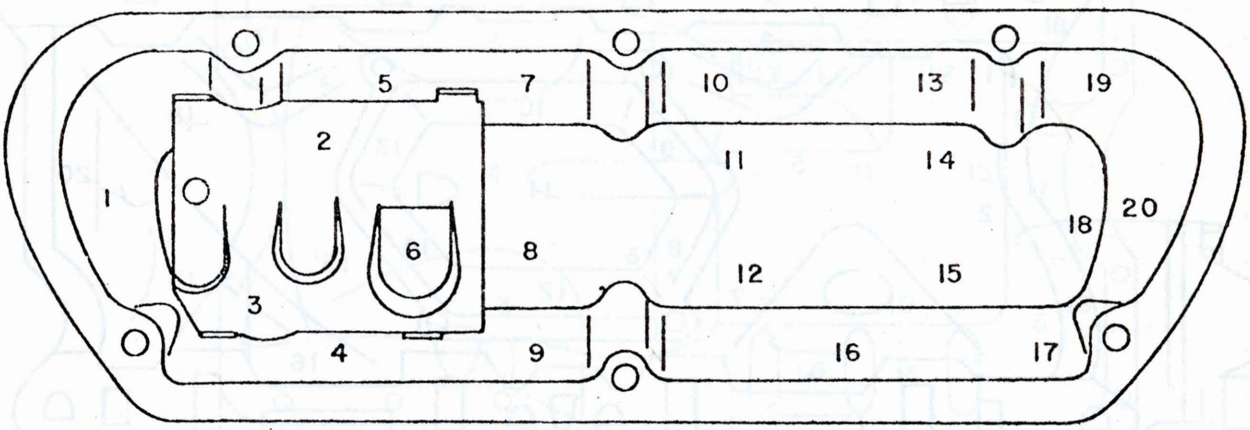
Date 5-78

Sludge Merit Rating 9.6

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 9.6

Rating Work Sheet No. Ia

SLUDGE RATING OF RIGHT ROCKER ARM COVER



RIGHT

Note Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x			x	x	x	x		x	x	x	x	x			x	x		x		13	65	.16
1/2A		x	x					x						x	x			x			6	30	.15
3/4A																				x	1	5	.04
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.35

Inspector ERL

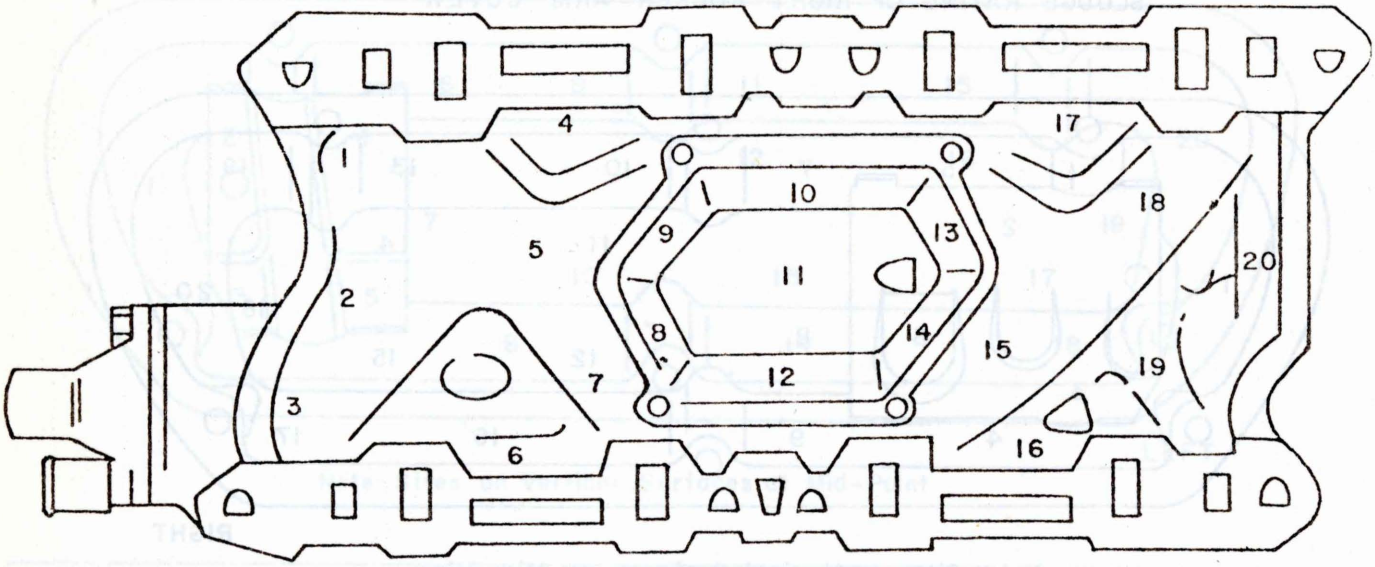
Date 5-78

Sludge Merit Rating 9.6

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 9.6

Rating Work Sheet No. 2

SLUDGE RATING OF UNDERSIDE OF INTAKE MANIFOLD



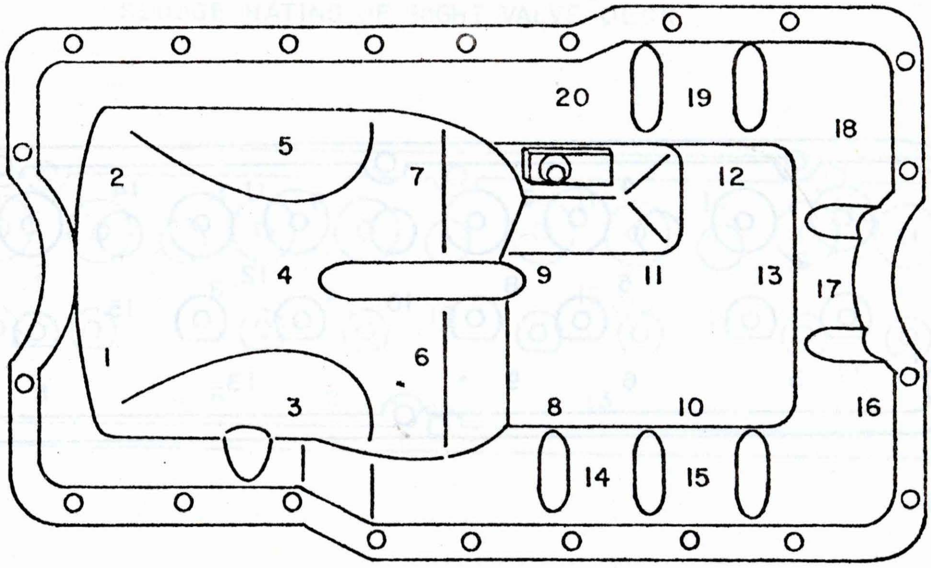
DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x							14	70	
1/4A															x	x	x	x	x	x	6	30	.08
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	

Inspector ERL

Date 5-78

Sludge Merit Rating 9.9

Rating Work Sheet No. 3
SLUDGE RATING OF OIL PAN



DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTO
CLEAN																							
1/4A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	

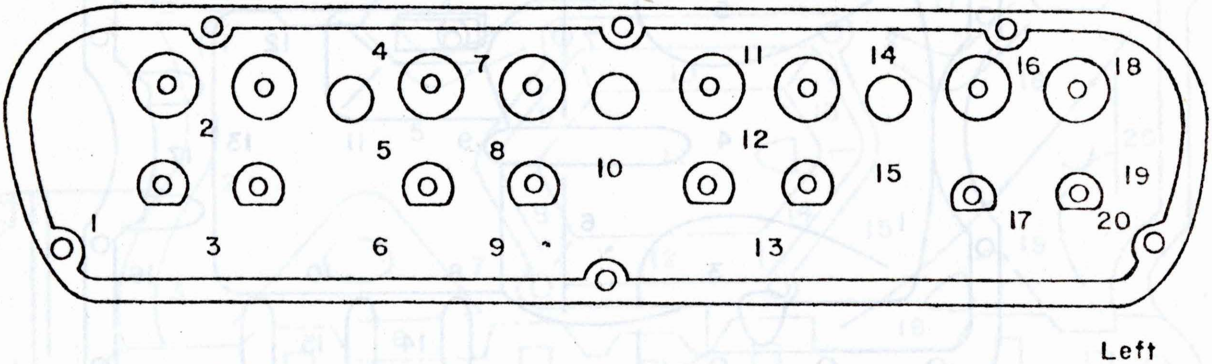
Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Rating Work Sheet No. 4

SLUDGE RATING OF LEFT VALVE DECK



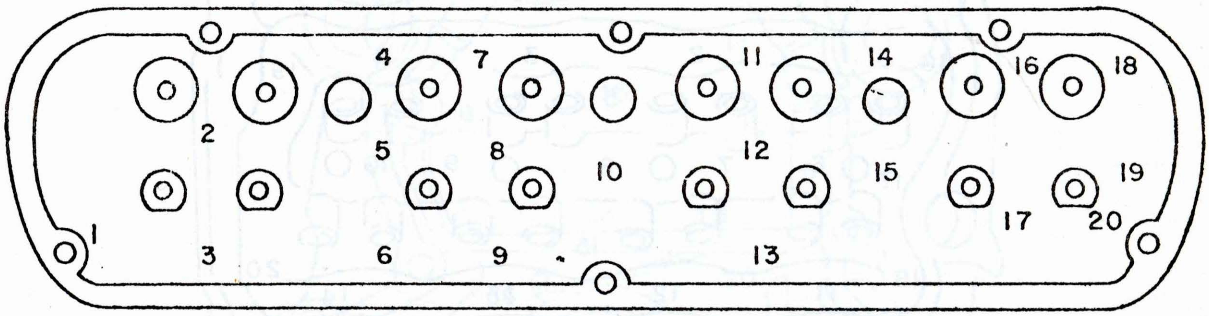
DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTO
CLEAN																							
1/4A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
																				GRAND TOTAL			

Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 4a
SLUDGE RATING OF RIGHT VALVE DECK



Right

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

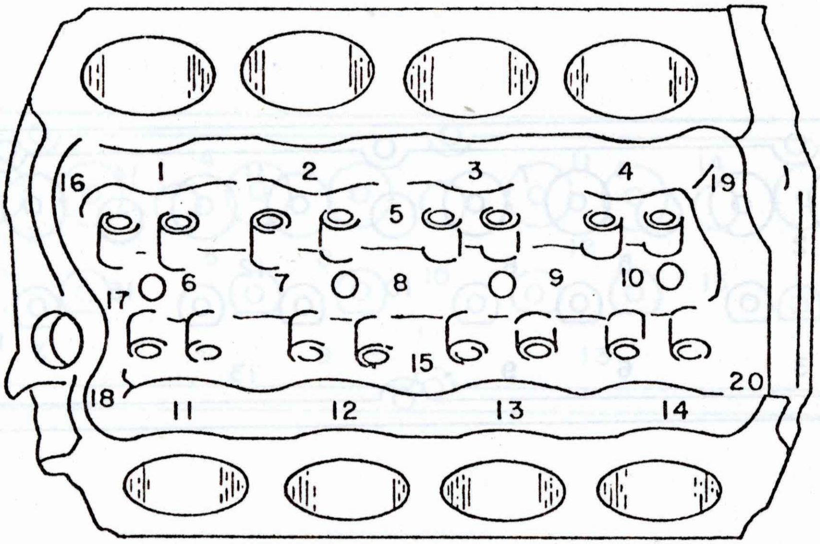
Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Avg. Sludge Merit Rating = $\frac{\text{Left+Right}}{2}$ = 9.7

Rating Work Sheet No. 5
SLUDGE RATING OF PUSH ROD CHAMBER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECXS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

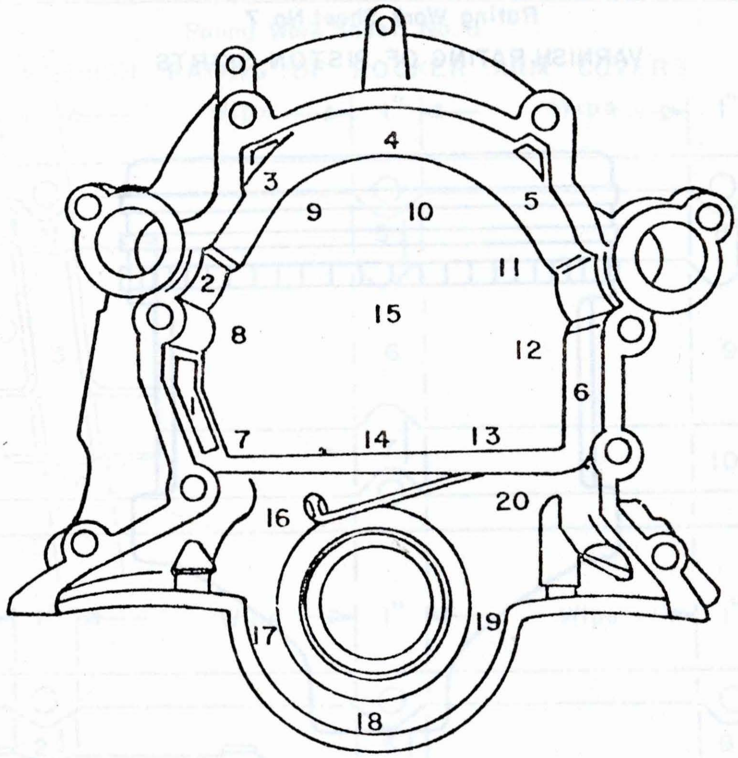
I

Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Rating Work Sheet No. 6
SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTC
CLEAN																							
1/4A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							

Inspector ERL

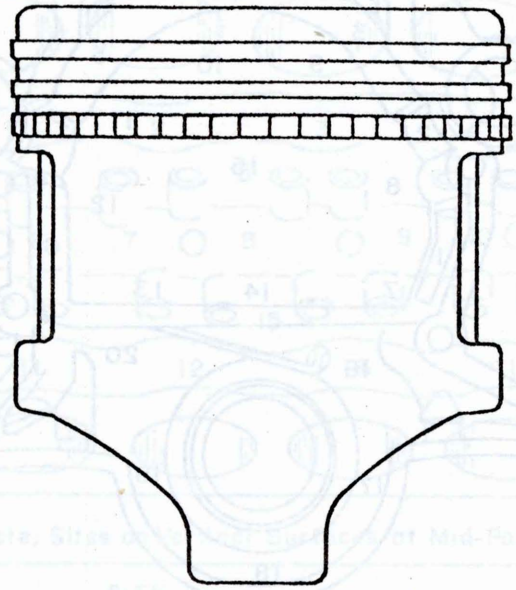
GRAND TOTAL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	CAM SIDE	OUT-SIDE	AVERAGE	CON. ROD BRGS APPEARANCE
	Lt 1	6.0	6.5	6.3	Normal
	2	5.8	5.9	5.9	Normal
	3	5.5	5.7	5.6	Normal
	4	5.6	5.9	5.8	Normal
	Rt 1	6.9	5.8	6.4	Normal
	2	6.4	5.4	5.9	Normal
	3	6.0	5.4	5.7	Normal
	4	6.0	5.4	5.7	Normal
	TOTAL	48.2	46.0		
	AVERAGE	6.0	5.6		

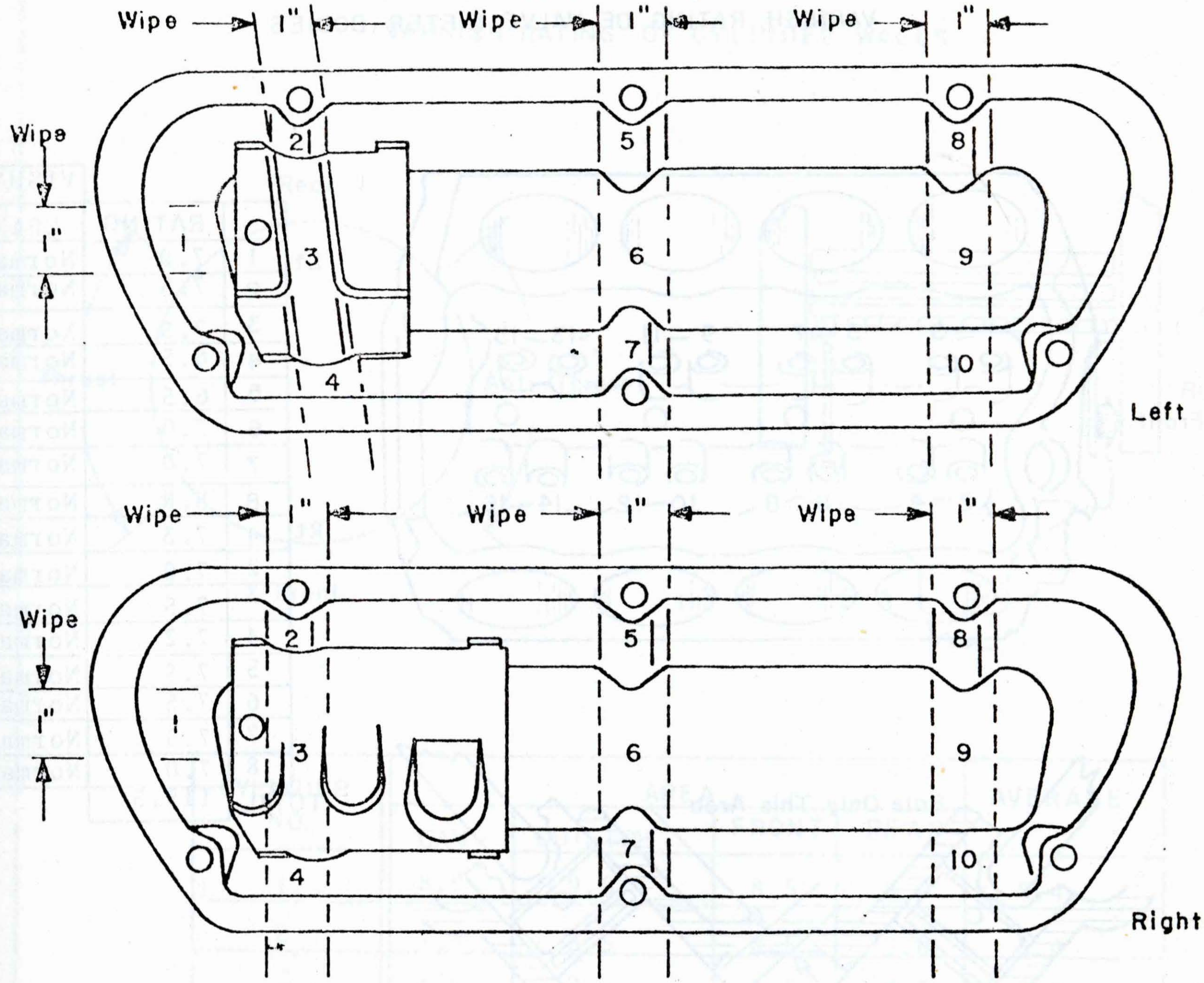
Inspector ____________

Date ____________

$$\text{VARNISH RATING} = \frac{\text{AvgThrust} + \text{Avg Antithrust}}{2} = 5.8$$

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



Left AREA	RATING
1	9.0
2	9.0
3	8.5
4	9.0
5	8.9
6	8.9
7	8.9
8	8.5
9	8.5
10	9.0
TOTAL	88.2

Right AREA	RATING
1	8.8
2	9.0
3	8.8
4	8.8
5	9.0
6	8.0
7	8.5
8	9.0
9	9.0
10	9.0
TOTAL	89.9

$$\text{Avg. Varnish Rating} = \frac{\text{Left} + \text{Right}}{2} = \underline{\quad}$$

Varnish Rating = $\frac{\text{Total}}{10}$ = 8.8 (Left)

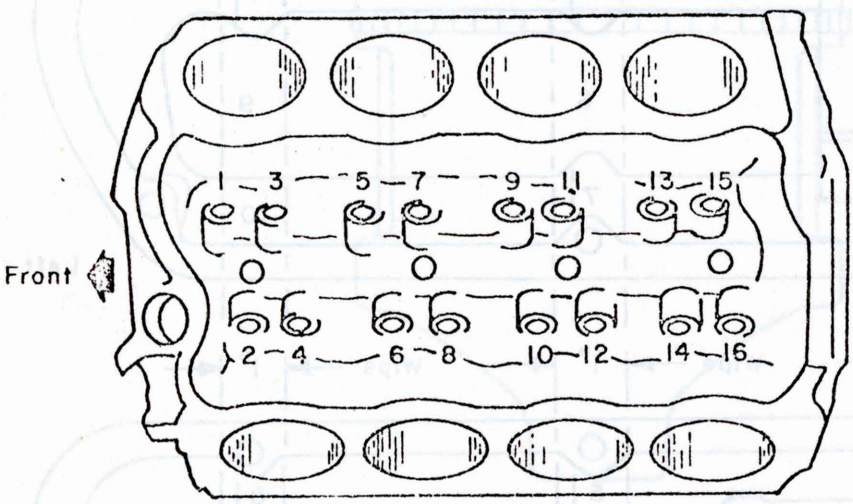
Inspector ERL

Date 5-78

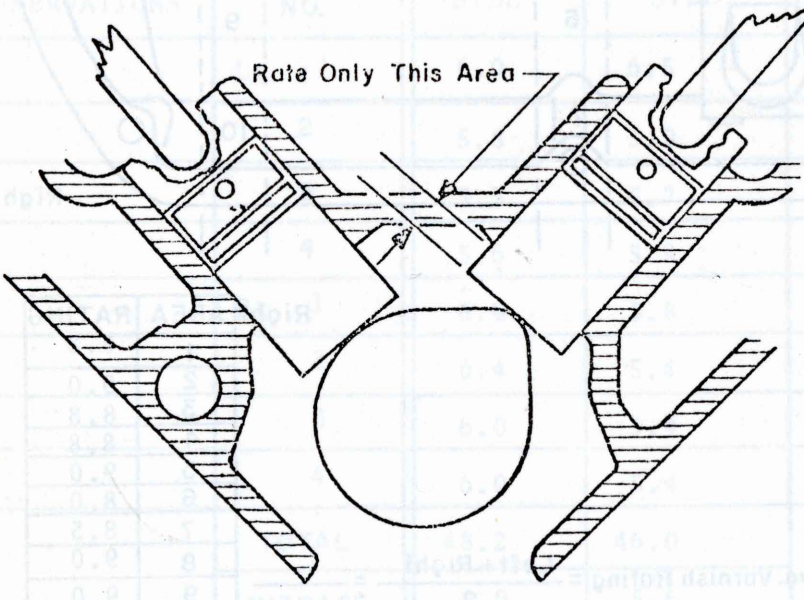
Varnish Rating = $\frac{\text{Total}}{10}$ = 8.8 (Right)

Rating Work Sheet No. 9

VARNISH RATING OF VALVE LIFTER BODIES



		RATING	VISUAL WEAR
Lt	1	7.0	Normal
	2	7.5	Normal
	3	7.5	Normal
	4	6.5	Normal
	5	6.5	Normal
	6	7.0	Normal
	7	7.0	Normal
	8	8.0	Normal
Rt	1	7.3	Normal
	2	7.0	Normal
	3	7.5	Normal
	4	7.2	Normal
	5	7.5	Normal
	6	7.5	Normal
	7	7.5	Normal
	8	7.0	Normal
TOTAL		115.5	



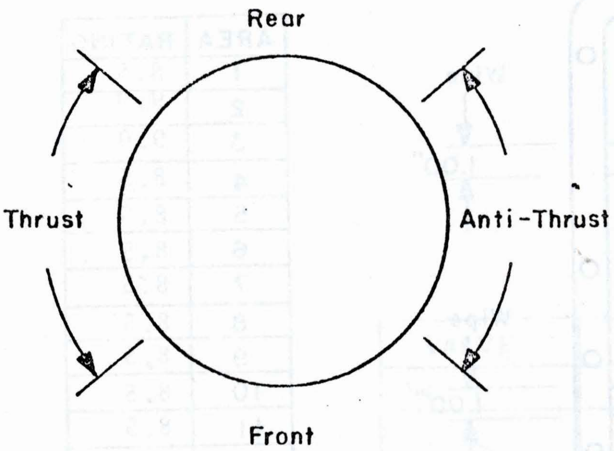
Inspector ERL

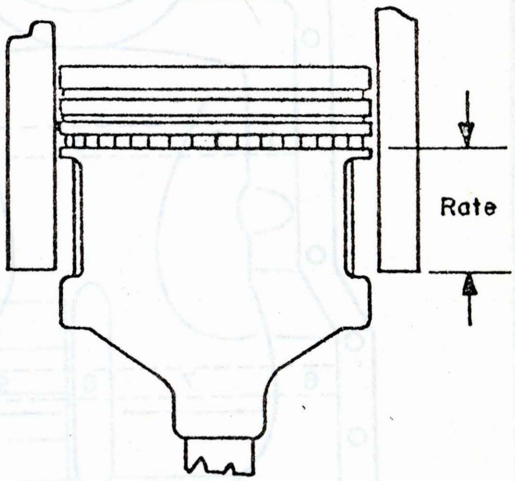
Date 5-78

Varnish Rating = $\frac{\text{Total}}{16}$ = 7.2

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.		AREA				AVERAGE
		CAM	OUTSIDE	FRONT	REAR	
Lt	1	8.0	9.0	8.5	8.0	8.4
	2	7.5	8.5	8.5	9.0	8.4
	3	8.0	9.0	8.5	8.5	8.5
	4	8.5	9.0	8.0	8.0	8.4
Rt	1	8.5	8.0	7.0	7.5	7.8
	2	8.5	8.0	7.0	7.5	7.8
	3	9.0	8.5	8.0	7.5	8.3
	4	8.0	8.0	8.0	7.5	7.9
					TOTAL	655

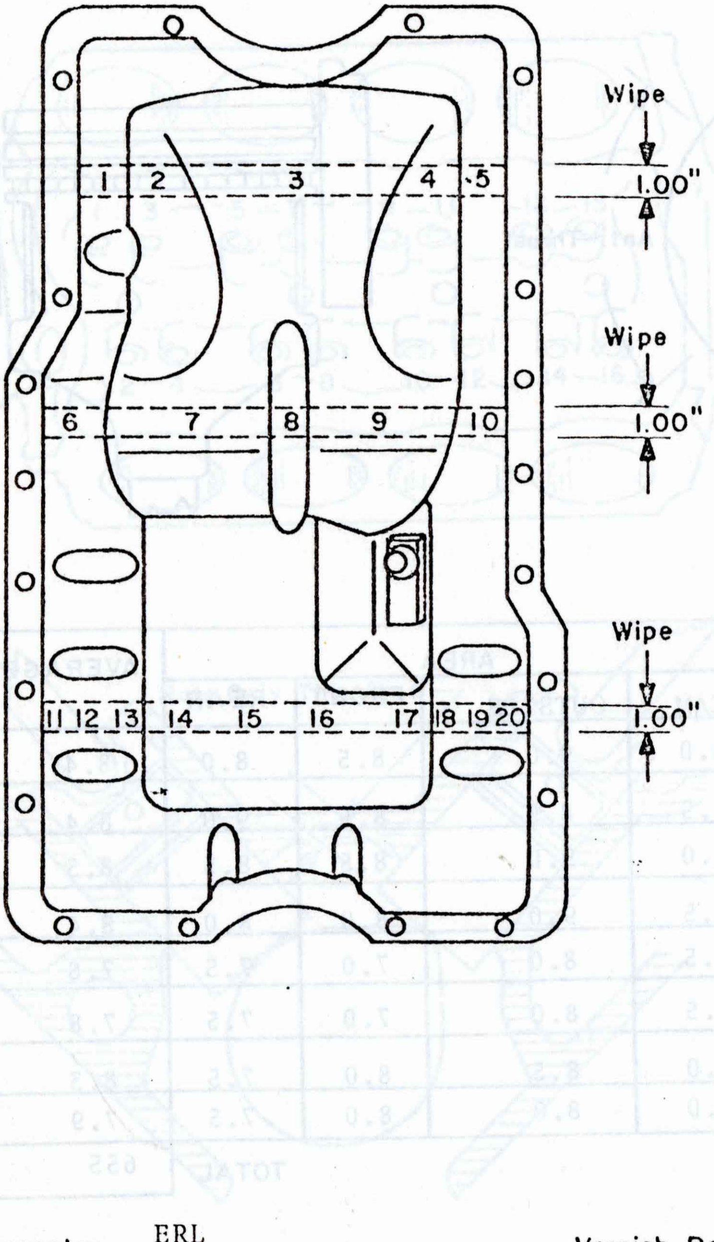
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 8.2

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	8.5
2	9.0
3	9.0
4	8.5
5	8.5
6	8.5
7	8.5
8	8.5
9	8.5
10	8.5
11	8.5
12	8.5
13	8.5
14	9.0
15	9.0
16	9.0
17	9.0
18	8.5
19	8.5
20	8.5
TOTAL	173

Inspector ERL

Varnish Rating = $\frac{\text{Total}}{20}$ = 8.7

Date 5-78

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

VALVE	RATING
Lt 1	7.5
2	7.0
3	5.5
4	6.0
Rt 1	8.0
2	7.0
3	7.5
4	7.3
TOTAL	558

Visual Observation of Seat, recession, or burning: All normal

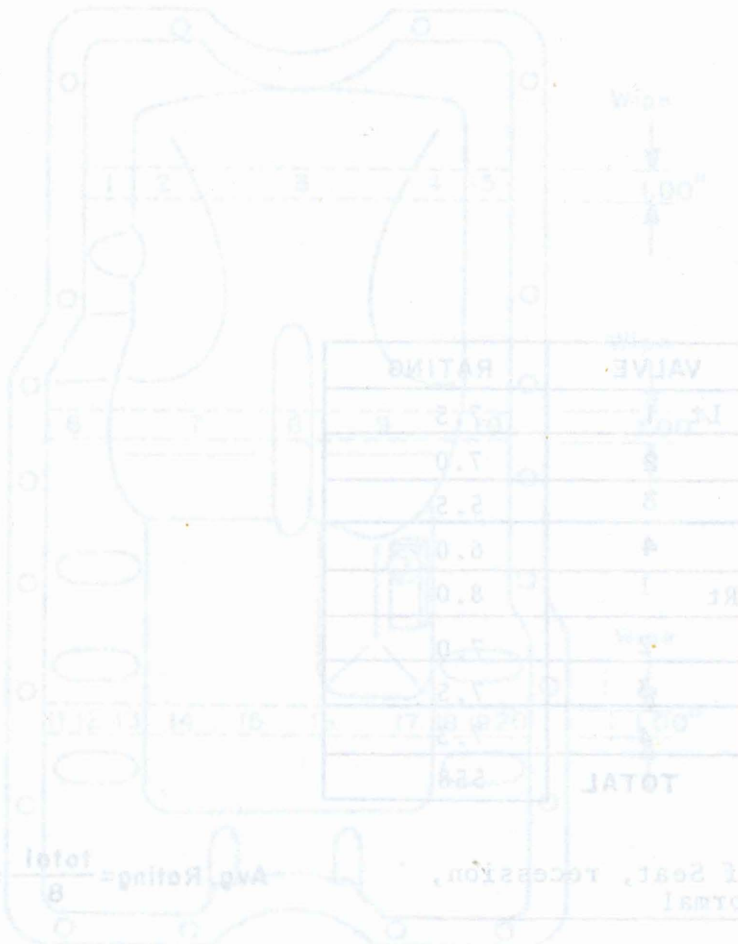
Avg. Rating = $\frac{\text{total}}{8}$ = 7.0

Inspector ERL

Date 5-78

Rating Work Sheet No 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	8.5
2	9.0
3	9.0
4	8.5
5	8.5
6	8.5
7	8.5
8	8.5
9	8.5
10	8.5
11	8.5
12	8.5
13	8.5
14	9.0
15	9.0
16	9.0
17	9.0
18	8.5
19	8.5
20	8.5
TOTAL	173

Inspector ERL

Date 5-76

Varnish Rating = $\frac{\text{Total}}{20}$ = 8.7

ENGINE INSPECTION SUMMARY

Vehicle I.D.:	A17687
Engine Type:	AMC, 360 CID
Miles:	48,285
Oil Type:	MORCO Rerefined
Oil Drain Interval:	4000 mi for 21,000 miles 8000 mi for balance

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	9.7	Piston Skirts	9.8
Intake Manifold	10.0	Rocker Arm Covers	9.0
Oil Pan	9.7	Valve Lifters	7.9
Valve Deck Area	10.0	Cylinder Wall (BRT)	9.5
Push Rod Chamber	10.0	Oil Pan	9.9
Timing Gear Cover	10.0		
AVG. SLUDGE	9.9	AVG. VARNISH	9.0

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	9.9
Stuck Compression Rings	0	Piston Varnish, Min.	9.7
Stuck Oil Rings	0	Intake Valve Deposits, Max.	9.0
		Intake Valve Deposits, Min.	5.5
		Intake Valve Deposits, Avg.	7.4

Clogging

Push Rods, No.	0
Oil Ring, %	0
Oil Screen, %	0

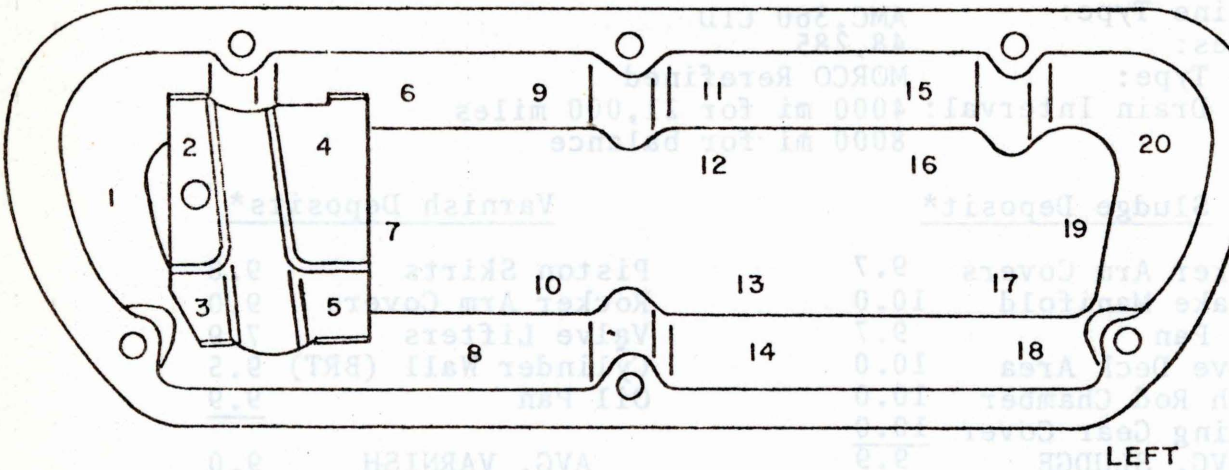
Observations, Comments

Date: 5-78
Rater: E.R. Lyons

* 10=Clean

Rating Work Sheet No. 1

SLUDGE RATING OF LEFT ROCKER ARM COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.25

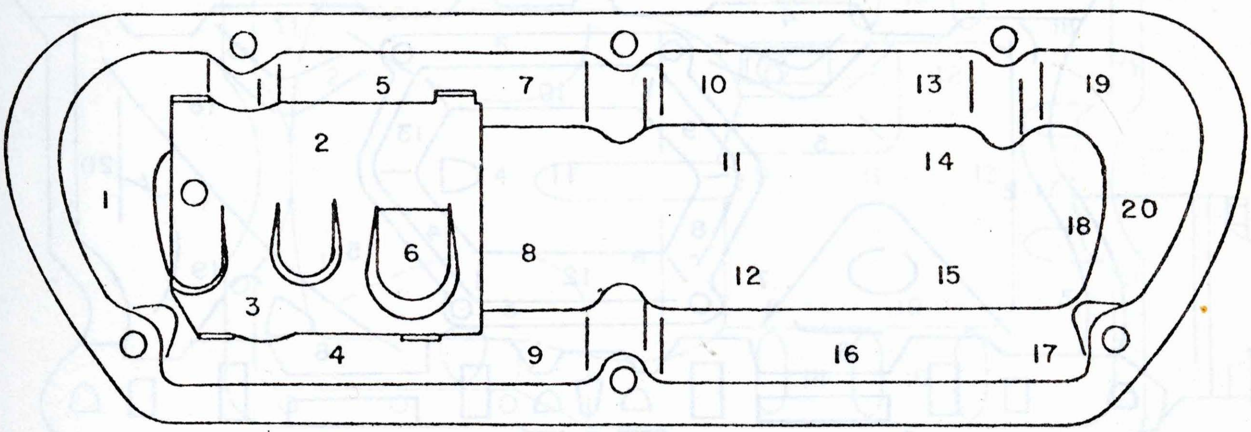
Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Rating Work Sheet No. Ia

SLUDGE RATING OF RIGHT ROCKER ARM COVER



Note Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							.25

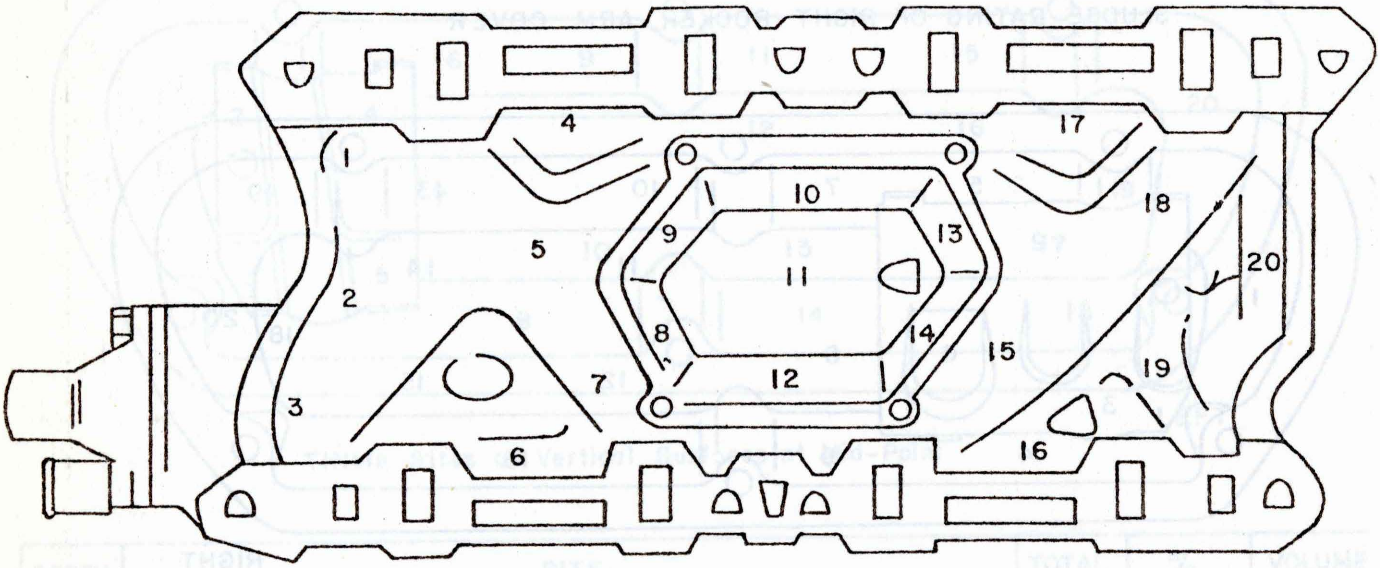
Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Avg. Sludge Merit Rating = $\frac{\text{Left+Right}}{2}$ = 9.7

Rating Work Sheet No. 2
SLUDGE RATING OF UNDERSIDE OF INTAKE MANIFOLD



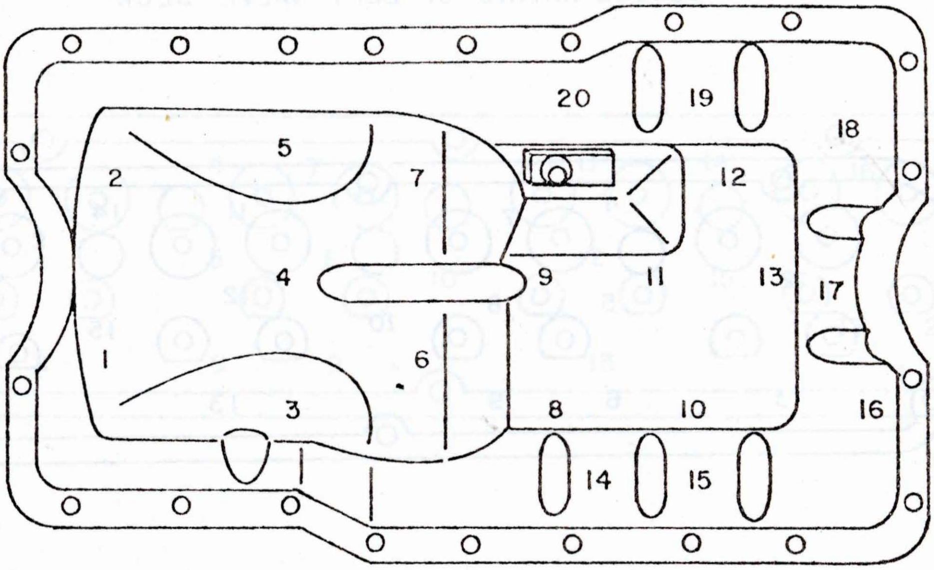
DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
																				GRAND TOTAL			

Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 3
SLUDGE RATING OF OIL PAN



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTO
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

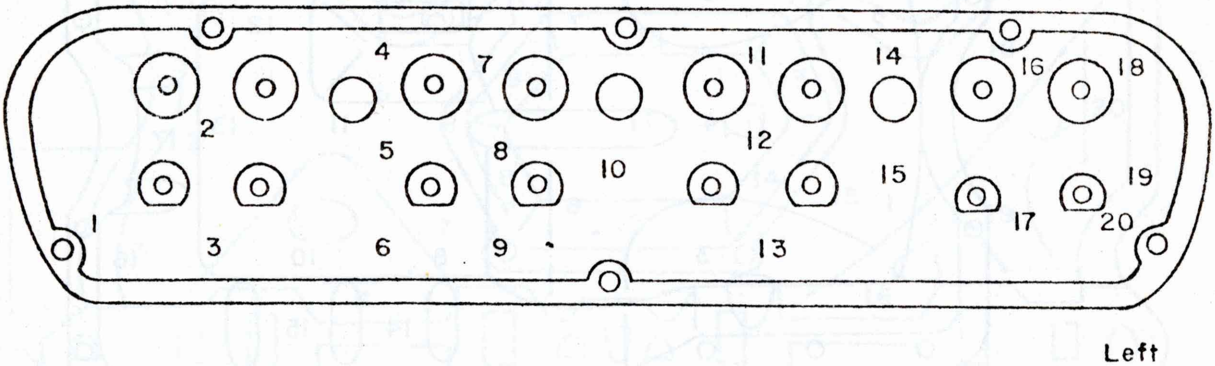
Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Rating Work Sheet No. 4

SLUDGE RATING OF LEFT VALVE DECK



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTO
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

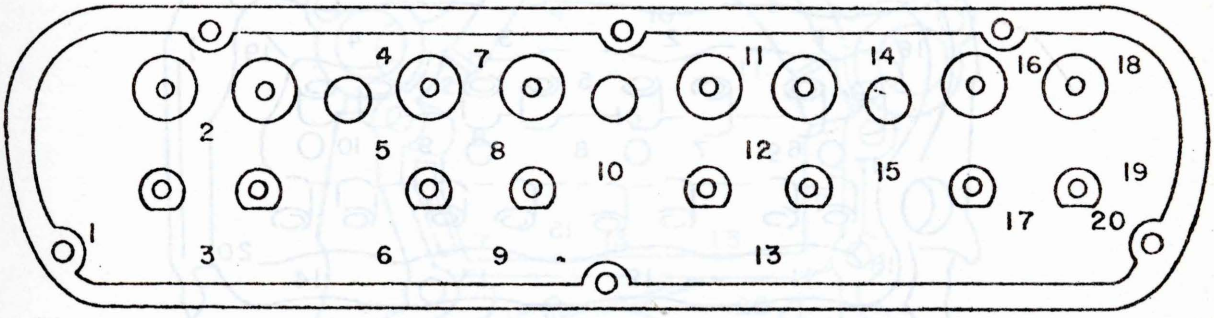
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 4a

SLUDGE RATING OF RIGHT VALVE DECK



Right

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

Inspector ERL

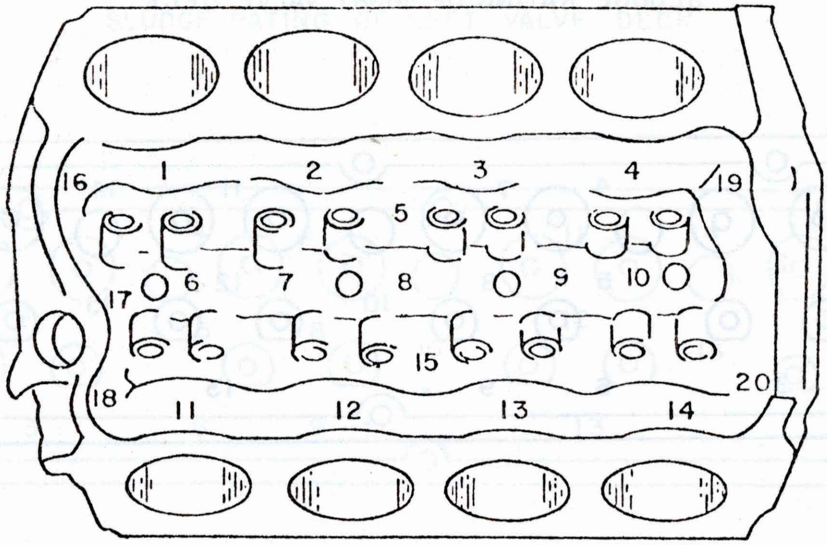
Date 5-78

Sludge Merit Rating 10.0

Avg. Sludge Merit Rating $= \frac{\text{Left+Right}}{2} =$ 10.

Rating Work Sheet No.5

SLUDGE RATING OF PUSH ROD CHAMBER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE																				TOTAL CHECKS	% COVERED	VOLUME FACTOR
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			
CLEAN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
															GRAND TOTAL								

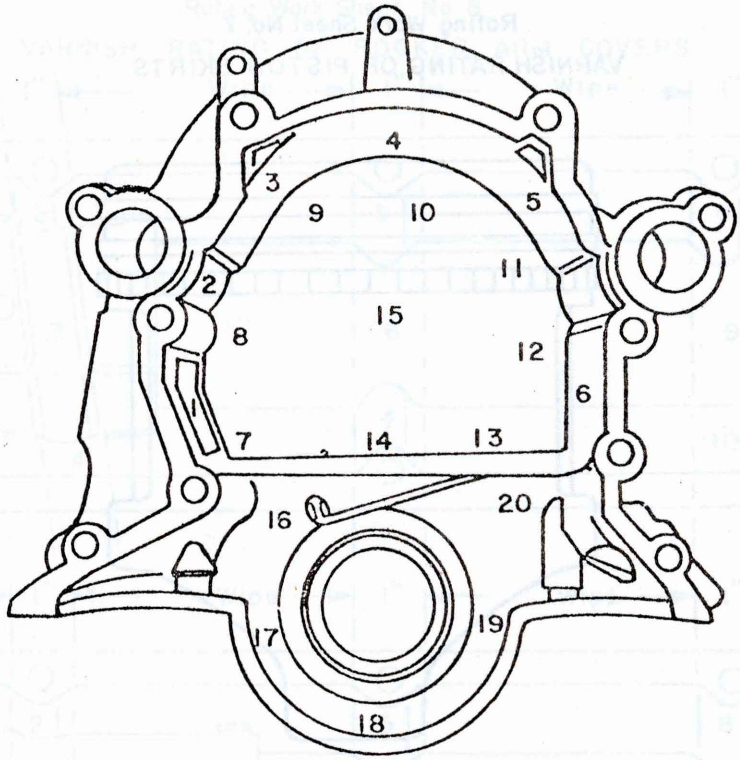
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 6

SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTC
CLEAN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							

Inspector ERL

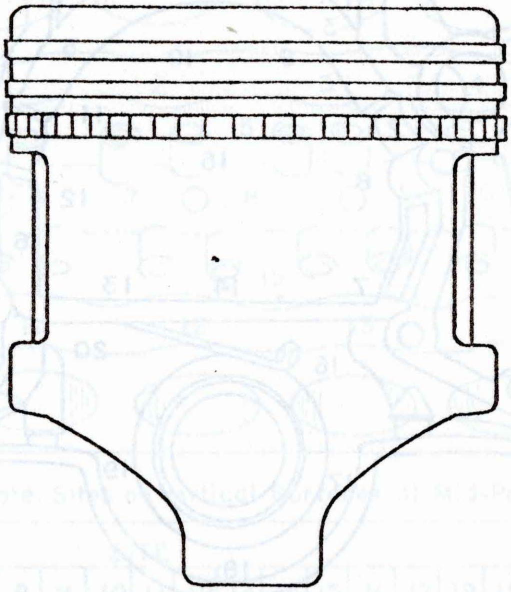
Date 5-78

GRAND TOTAL

Sludge Merit Rating 10.0

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	CAM SIDE	OUT-SIDE	AVERAGE	CON. ROD BRGS APPEARANCE
v. lt. scuff camside	Lt 1	9.9	9.9	9.9	Normal
Normal	2	9.8	9.8	9.8	Normal
lt scuff camside	3	9.8	9.8	9.8	*
lt scuff camside **	4	9.8	9.8	9.8	Normal
v. lt scuff outside	Rt 1	9.9	9.9	9.9	v. light scratch
Normal	2	9.8	9.8	9.8	Normal
Normal	3	9.7	9.8	9.8	Normal
lt scuff camside	4	9.8	9.9	9.9	Normal
	TOTAL	78.5	78.7		
	AVERAGE	9.8	9.8		

* Distress marks from foreign material, also on crank

Inspector ERL

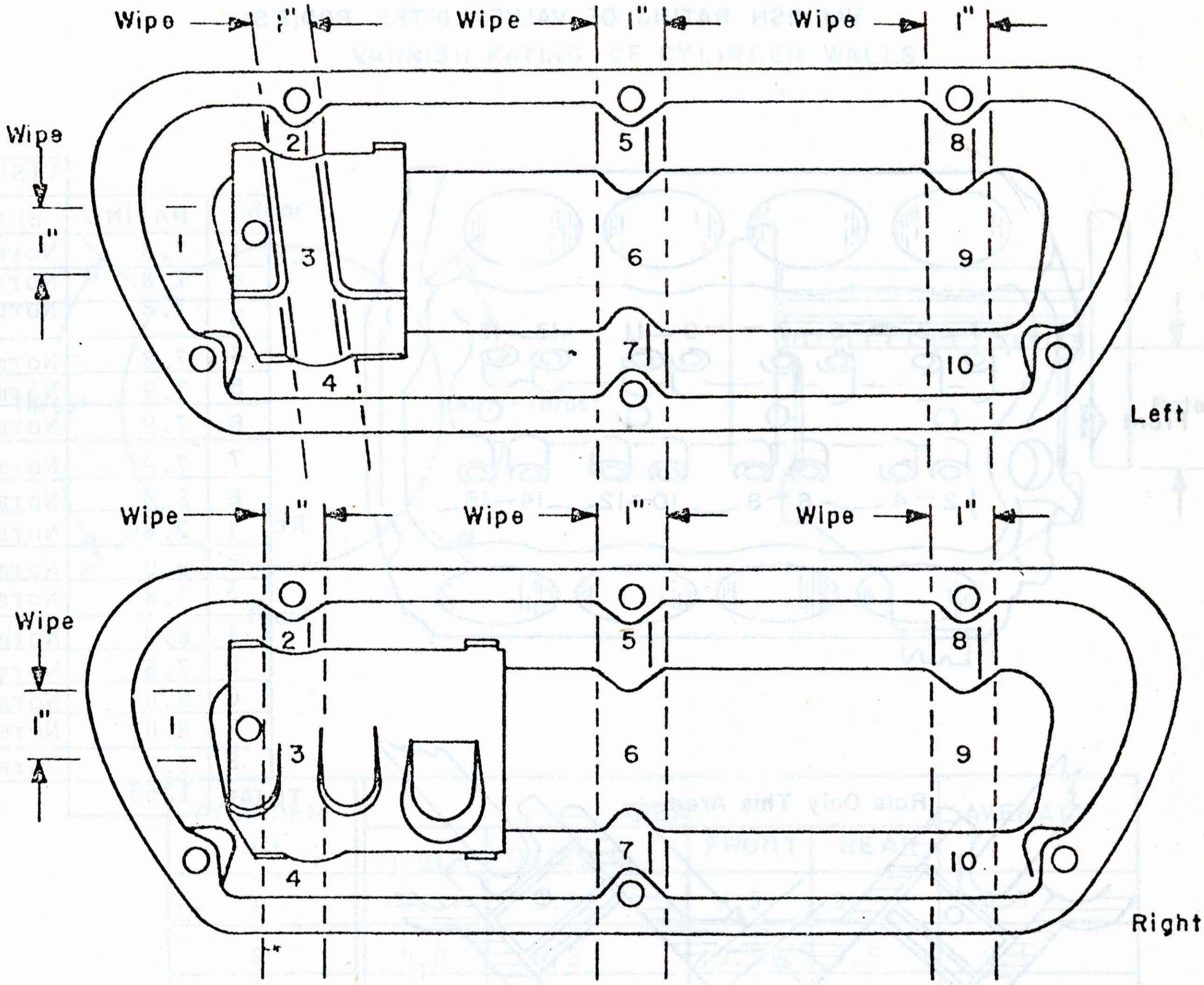
Date 5-78

$$\text{VARNISH RATING} = \frac{\text{AvgThrust} + \text{Avg Antithrust}}{2} = 9.8$$

** 15% of FACE MATL Missing from #1 Compress. Ring

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



Left

AREA	RATING
1	9.0
2	9.0
3	9.0
4	9.0
5	9.0
6	9.0
7	9.0
8	9.0
9	9.0
10	9.0
TOTAL	9 0

$$\text{Avg. Varnish Rating} = \frac{\text{Left} + \text{Right}}{2} = 9.0$$

Right

AREA	RATING
1	9.0
2	9.0
3	9.0
4	9.0
5	9.0
6	9.0
7	9.0
8	8.5
9	9.0
10	9.0
TOTAL	89.5

$$\text{Varnish Rating} = \frac{\text{Total}}{10} = 9.0$$

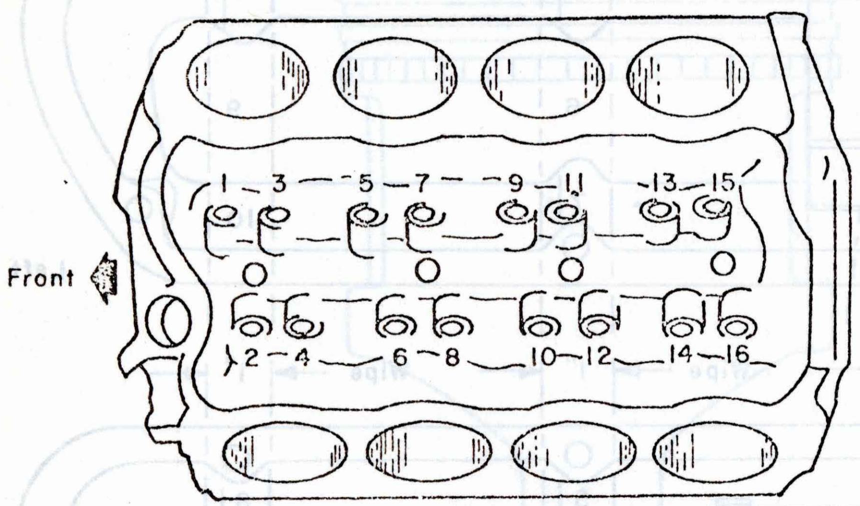
Inspector ERL

Date 5-78

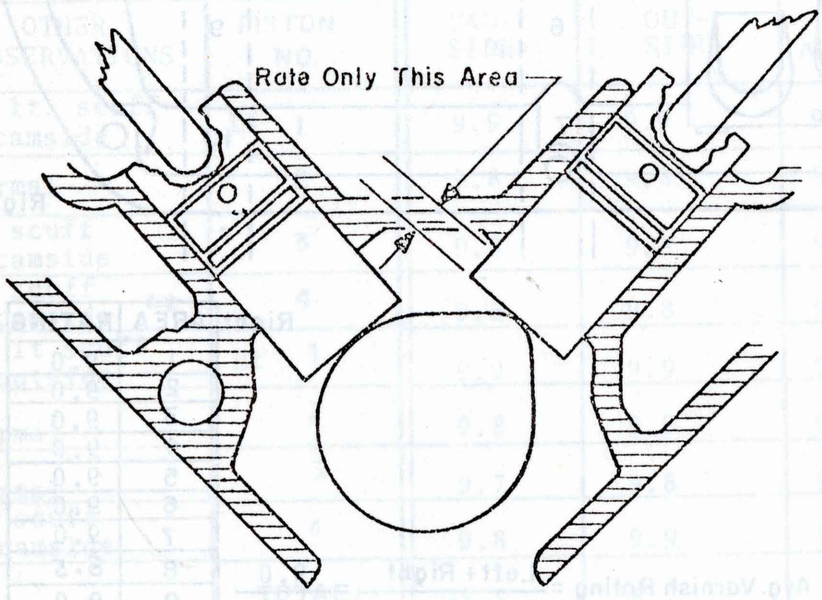
$$\text{Varnish Rating} = \frac{\text{Total}}{10} = 9.0$$

Rating Work Sheet No. 9

VARNISH RATING OF VALVE LIFTER BODIES



		RATING	VISUAL WEAR
Lt	1	7.8	Normal
	2	7.8	Normal
	3	7.8	Normal
	4	7.8	Normal
	5	7.9	Normal
	6	7.9	Normal
	7	7.9	Normal
	8	8.0	Normal
Rt	1	7.8	Normal
	2	8.0	Normal
	3	7.8	Normal
	4	8.0	Normal
	5	7.8	Normal
	6	8.0	Normal
	7	8.0	Normal
	8	8.0	Normal
TOTAL		1263	



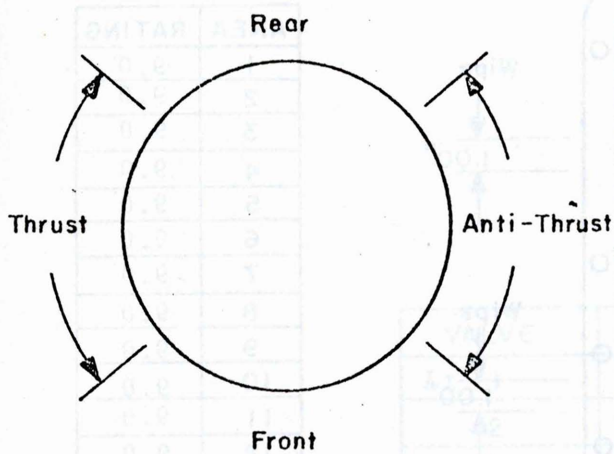
Inspector ERL

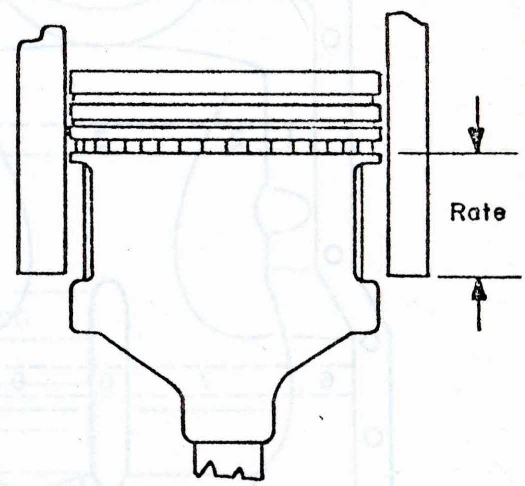
Date 5-78

Varnish Rating = $\frac{\text{Total}}{16}$ = 7.9

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.	AREA				AVERAGE
	CAM	OUTSIDE	FRONT	REAR	
Lt 1	9.5	9.5	9.5	9.5	9.5
2	9.0	9.5	9.5	9.5	9.4
3	9.5	9.5	9.5	9.5	9.5
4	9.5	9.5	9.5	9.5	9.5
Rt 1	9.0	9.5	9.5	9.5	9.4
2	9.0	9.5	9.5	9.5	9.4
3	9.0	9.5	9.5	9.5	9.4
4	9.5	9.5	9.5	9.5	9.5
				TOTAL	756

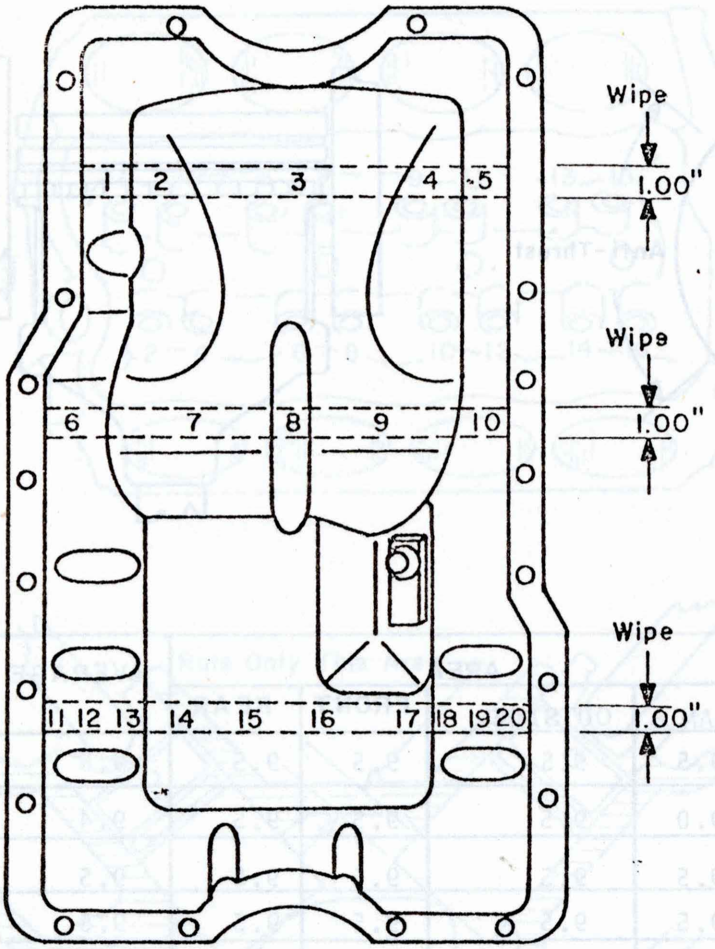
Inspector ERL

Date 5-78

Varnish Rating $= \dfrac{\text{Total}}{8} =$ 9.5

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	9.0
2	9.0
3	9.0
4	9.0
5	9.0
6	9.0
7	9.0
8	9.0
9	9.0
10	9.0
11	9.0
12	9.0
13	9.0
14	9.0
15	9.0
16	9.0
17	9.0
18	9.0
19	9.0
20	9.0
TOTAL	180

Inspector ERL

Varnish Rating = $\frac{\text{Total}}{20}$ = 9.0

Date 5-78

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

VALVE	RATING
Lt 1	8.0
2	8.5
3	5.5
4	9.0
Rt 1	8.5
2	6.5
3	7.0
4	6.0
TOTAL	590

Visual Observation of Seat, recession, or burning: All normal

Avg. Rating $= \frac{\text{total}}{8} =$ 7.4

Inspector ERL

Date 5-78

Rating Work Sheet No. 11

PAN

AREA	RATING
1	[illegible]
2	[illegible]
3	[illegible]
4	[illegible]
5	9.0
6	[illegible]
7	[illegible]
8	[illegible]
9	[illegible]
10	[illegible]
11	[illegible]
12	[illegible]
13	9.0
14	[illegible]
15	[illegible]
16	[illegible]
17	[illegible]
18	[illegible]
19	[illegible]
20	[illegible]
TOTAL	[illegible]

Inspector [illegible]

Date 5-76

Varnish Rating = $\frac{\text{Total}}{20}$ [illegible]

ENGINE INSPECTION SUMMARY

Vehicle I.D.:	A17685
Engine Type:	AMC, 360 CID
Miles:	60,174
Oil Type:	MORCO Rerefined
Oil Drain Interval:	4000 mi for 21,000 miles 8000 mi for balance

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	9.7	Piston Skirts	9.5
Intake Manifold	9.9	Rocker Arm Covers	8.5
Oil Pan	9.7	Valve Lifters	7.6
Valve Deck Area	10.0	Cylinder Wall (BRT)	8.8
Push Rod Chamber	10.0	Oil Pan	9.0
Timing Gear Cover	10.0		
AVG. SLUDGE	9.9	AVG. VARNISH	8.7

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	9.6
Stuck Compression Rings	0	Piston Varnish, Min.	9.0
Stuck Oil Rings	0	Intake Valve Deposits, Max.	8.5
		Intake Valve Deposits, Min.	1.5
		Intake Valve Deposits, Avg.	4.1

Clogging

Push Rods, No.	0
Oil Ring, %	0
Oil Screen, %	0

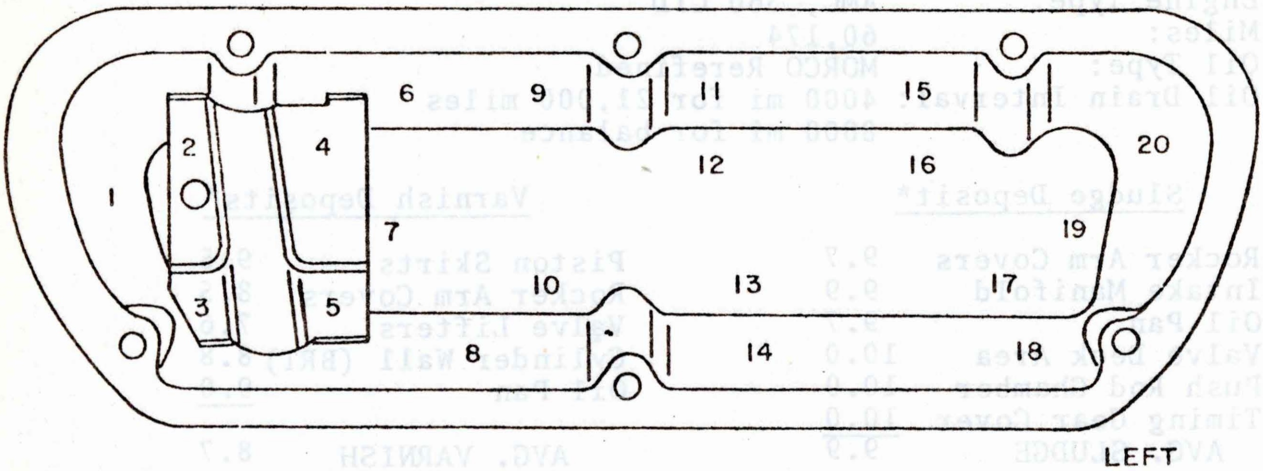
Observations, Comments

Most of the parts rated had been splattered with aluminum paint during mishap at teardown location.

Date: 5-78
Rater: E.R. Lyons

* 10=Clean

Rating Work Sheet No. 1
SLUDGE RATING OF LEFT ROCKER ARM COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.25

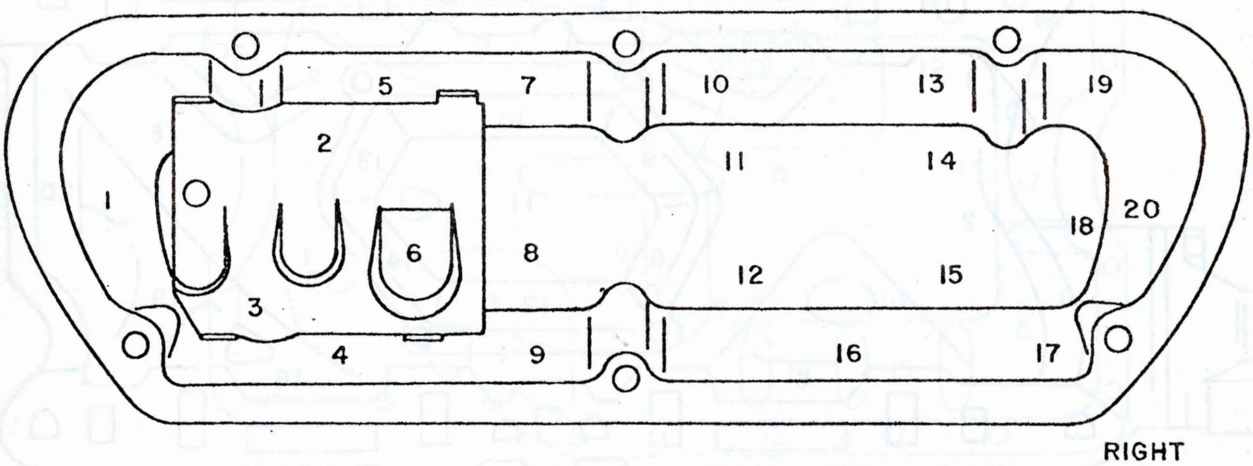
Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Rating Work Sheet No. Ia

SLUDGE RATING OF RIGHT ROCKER ARM COVER



Note Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.25

Inspector ERL

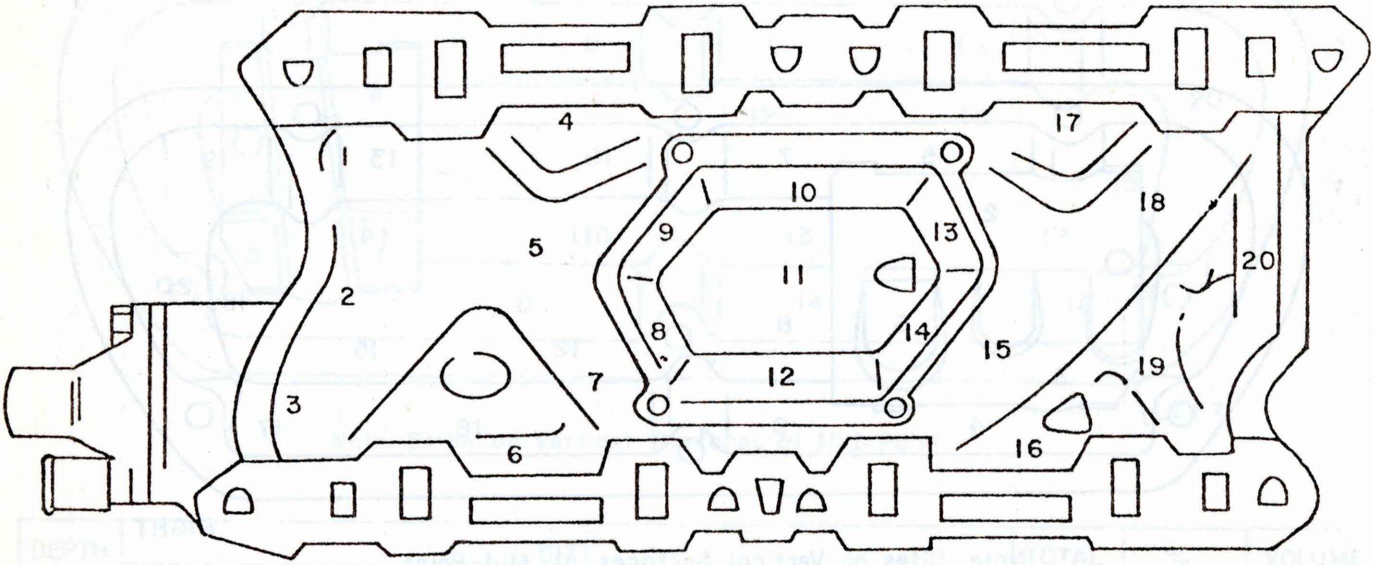
Sludge Merit Rating 9.7

Date 5-78

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 9.7

Rating Work Sheet No. 2

SLUDGE RATING OF UNDERSIDE OF INTAKE MANIFOLD



DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	x	x	x	x	x	x	x	X							x	x	x	x	x	x	14	70	
1/4A									x	x	x	x	x	x							6	30	.08
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.08

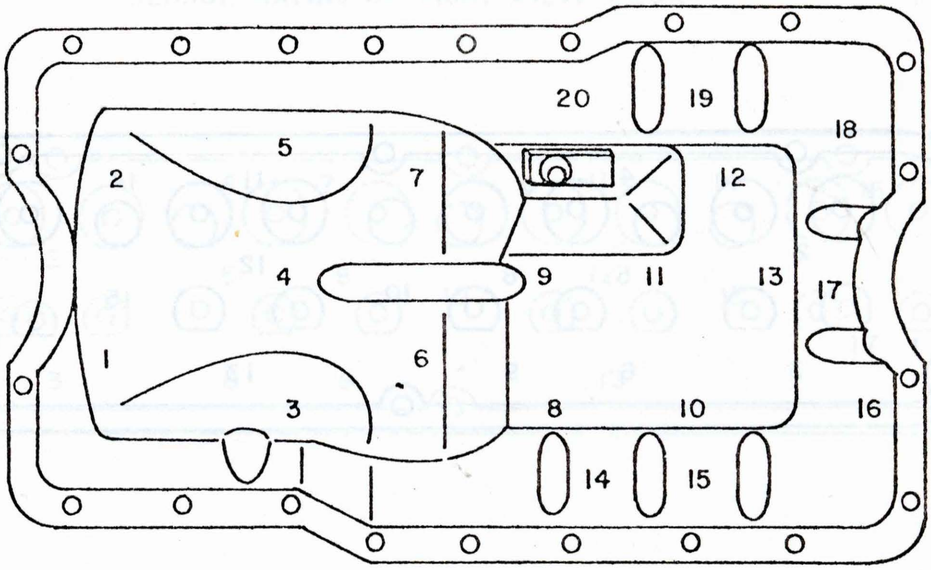
Inspector ERL

Date 5-78

Sludge Merit Rating 9.9

Rating Work Sheet No. 3

SLUDGE RATING OF OIL PAN



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOI
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

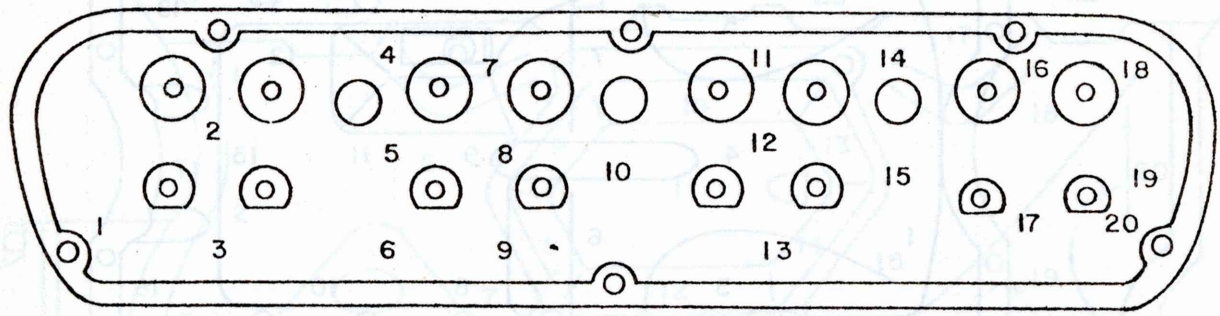
Sludge Merit Rating 9.7

Inspector ERL

Date 5-78

Rating Work Sheet No. 4

SLUDGE RATING OF LEFT VALVE DECK



Left

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTO
CLEAN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

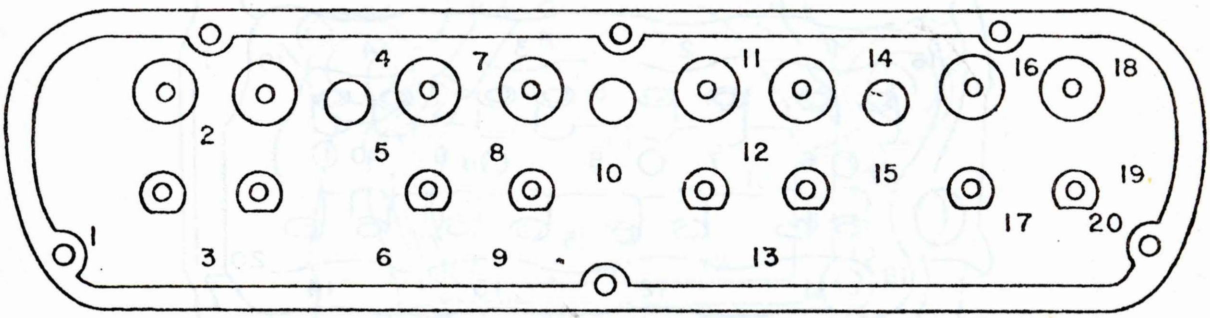
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No.4a

SLUDGE RATING OF RIGHT VALVE DECK



Right

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOR
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

Inspector ERL

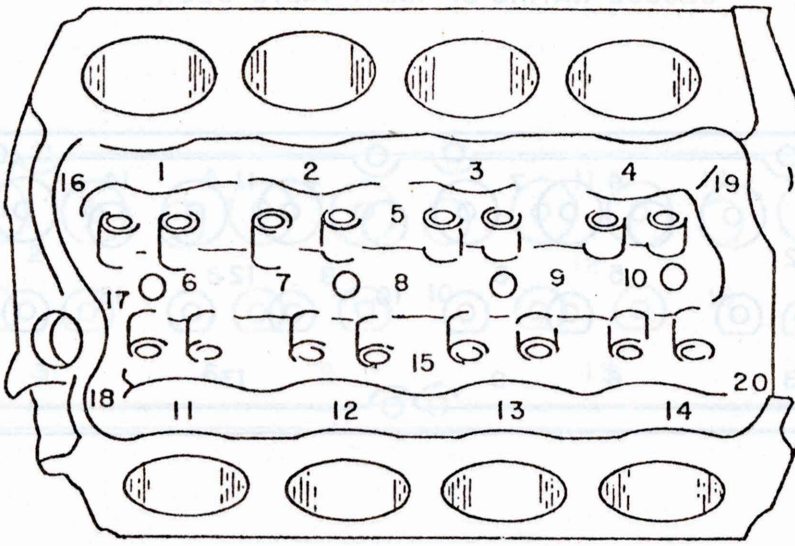
Date 5-78

Sludge Merit Rating 10.0

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 10.(

Rating Work Sheet No. 5

SLUDGE RATING OF PUSH ROD CHAMBER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
																				GRAND TOTAL			

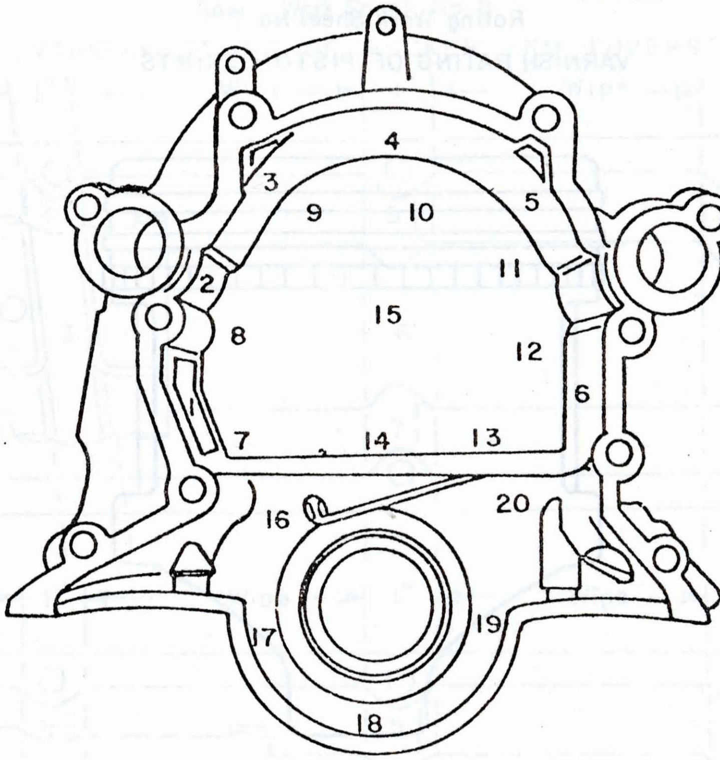
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 6

SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTC
CLEAN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							

Inspector ERL

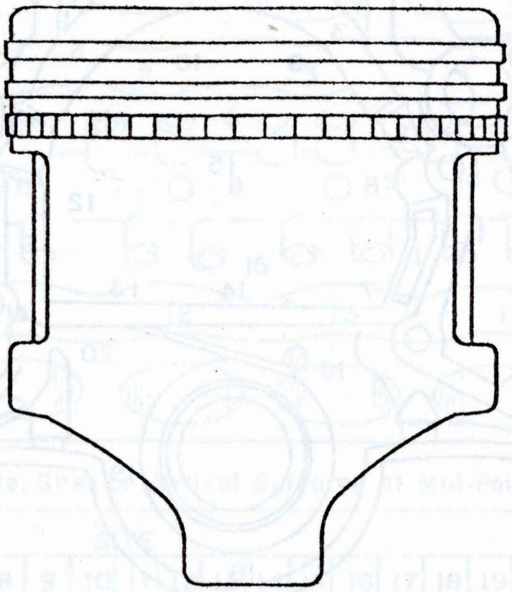
GRAND TOTAL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	CAM SIDE	OUT-SIDE	AVERAGE	CON. ROD BRGS APPEARANCE
	Lt 1	9.3	9.5	9.4	Normal
	2	9.6	9.5	9.5	Normal
	3	9.6	9.4	9.5	Normal
	4	9.5	9.3	9.4	Normal
	Rt 1	9.6	9.5	9.5	Normal
	2	9.5	9.6	9.5	Normal
	3	9.0	9.5	9.2	Normal
	4	9.3	9.3	9.3	Normal
	TOTAL	75.4	75.6		
	AVERAGE	9.4	9.5		

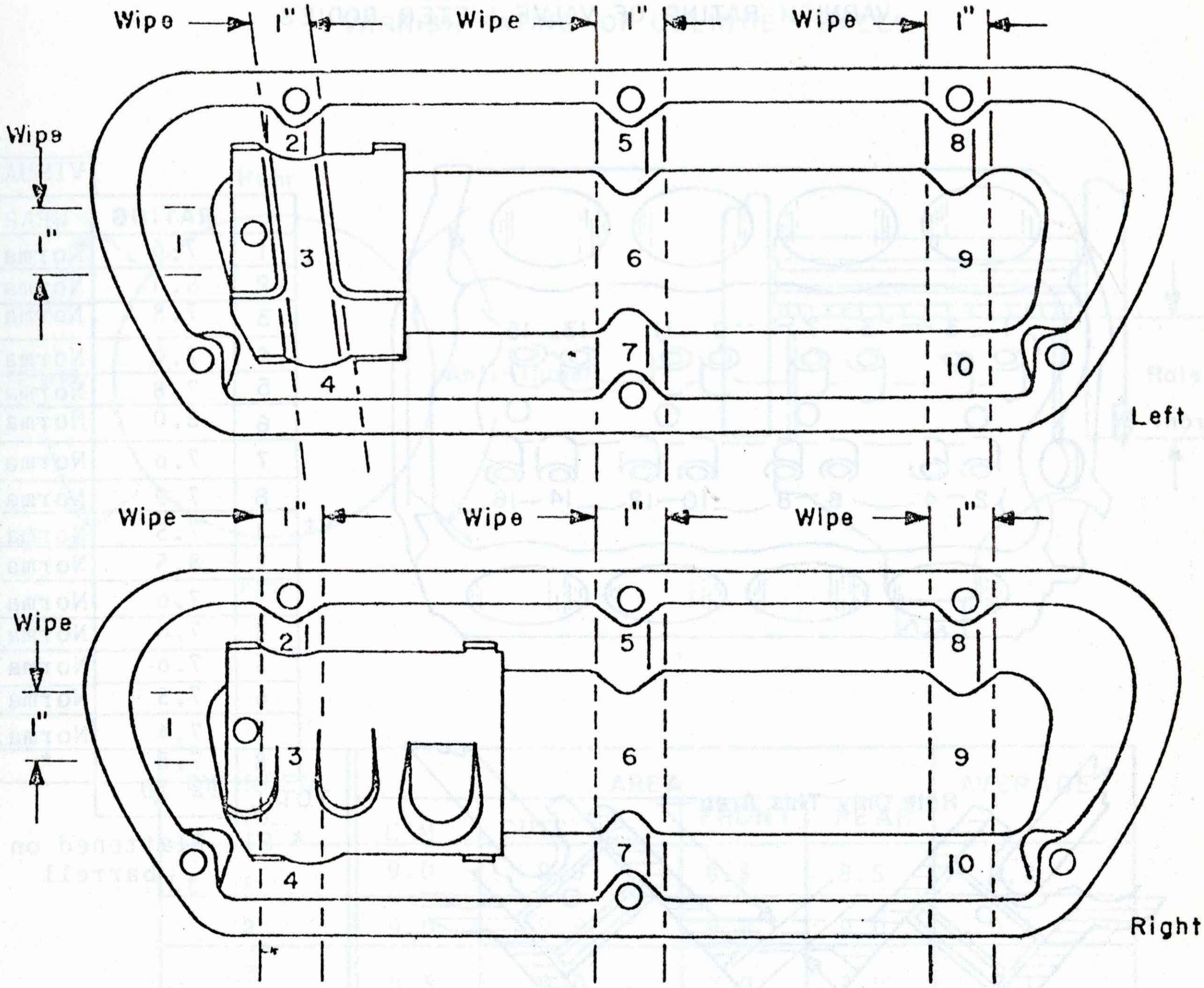
Inspector __________

Date __________

VARNISH RATING = $\frac{\text{AvgThrust + Avg Antithrust}}{2}$ = 9.5

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



Left

AREA	RATING
1	8.5
2	8.5
3	8.5
4	8.5
5	8.5
6	8.5
7	8.5
8	8.5
9	8.5
10	8.5
TOTAL	8 5

Avg. Varnish Rating = $\frac{\text{Left + Right}}{2}$ = 8.5

Right

AREA	RATING
1	8.5
2	8.5
3	8.5
4	8.5
5	8.5
6	8.5
7	8.5
8	8.5
9	8.5
10	8.5
TOTAL	8 5

Varnish Rating = $\frac{\text{Total}}{10}$ = 8.5

Inspector ERL

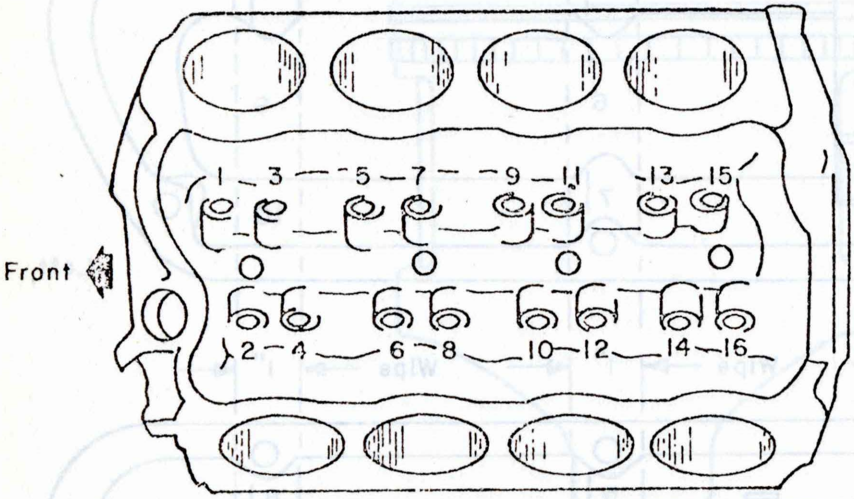
5-78

Date

Varnish Rating = $\frac{\text{Total}}{10}$ = 8.5

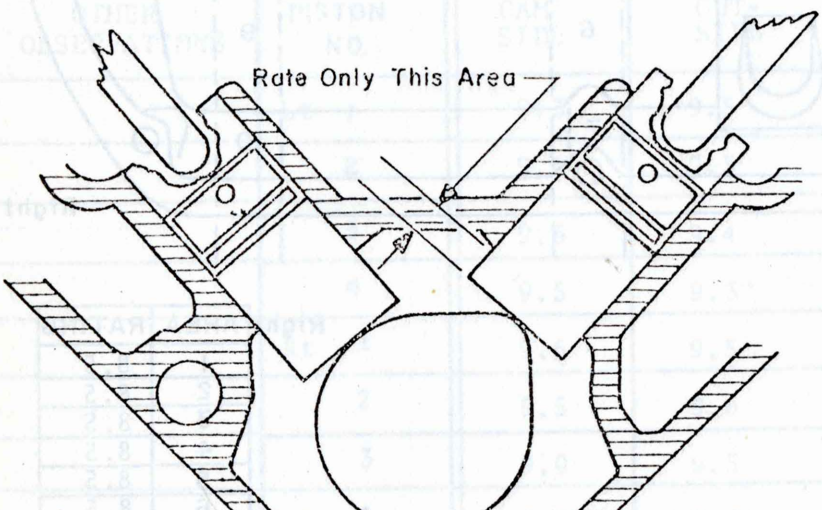
Rating Work Sheet No. 9

VARNISH RATING OF VALVE LIFTER BODIES



		RATING	VISUAL WEAR
Lt	1	7.6	Normal
	2	5.0	Normal
	3	7.8	Normal
	4	7.6	Normal
	5	7.8	Normal
	6	8.0	Normal
	7	7.6	Normal
	8	7.9	Normal
Rt	1	7.5	Normal
	2	8.5	Normal
	3	7.6	Normal
	4	7.6	Normal
	5	7.6	Normal
	6	7.5	Normal
	7	7.4	Normal
	8	7.8	*
TOTAL		12 1.0	

* Sl. Flattened on barrell



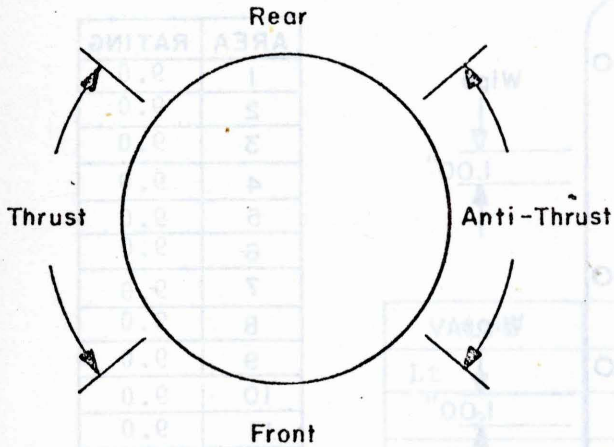
Inspector ERL

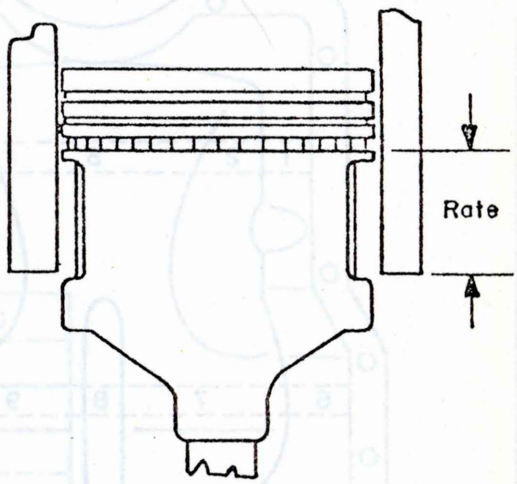
Varnish Rating = $\frac{\text{Total}}{16}$ = 7.6

Date 5-78

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.	AREA				AVERAGE
	CAM	OUTSIDE	FRONT	REAR	
Lt 1	9.0	9.0	8.5	8.5	8.8
2	9.0	9.5	9.0	9.0	9.1
3	8.5	9.0	8.0	7.0	8.1
4	9.0	9.0	8.5	9.0	8.9
Rt 1	8.5	9.0	8.5	9.0	8.8
2	9.0	9.0	9.0	9.0	9.0
3	8.5	9.0	9.0	9.0	8.9
4	9.0	9.0	9.0	9.0	9.0
				TOTAL	70.6

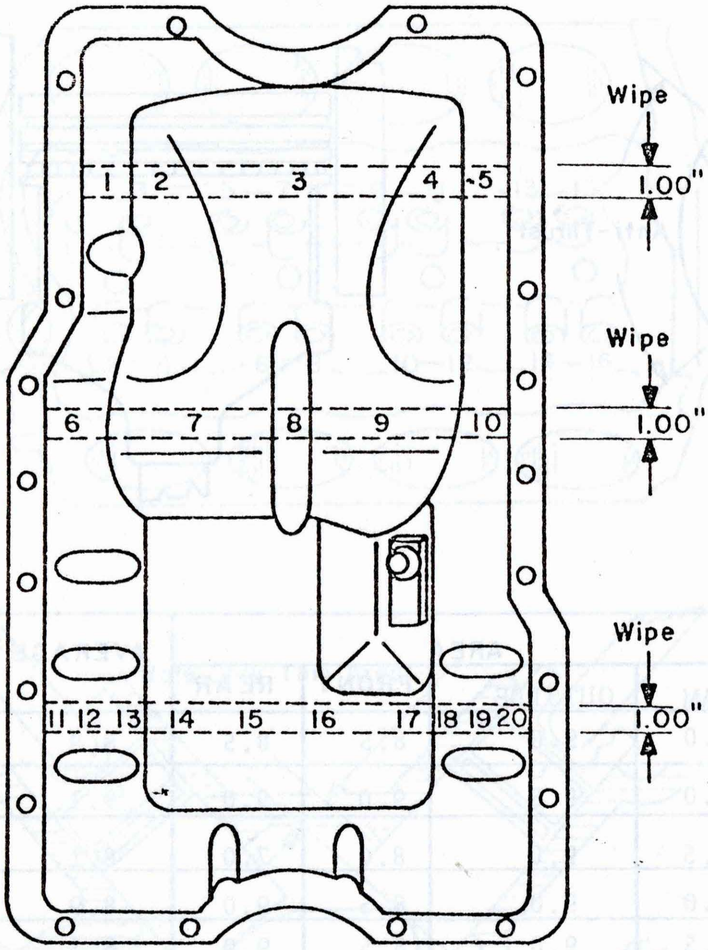
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 8.8

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	9.0
2	9.0
3	9.0
4	9.0
5	9.0
6	9.0
7	9.0
8	9.0
9	9.0
10	9.0
11	9.0
12	9.0
13	9.0
14	9.0
15	9.0
16	9.0
17	9.0
18	9.0
19	9.0
20	9.0
TOTAL	

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{20}$ = 9.0

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

VALVE	RATING
Lt 1	3.0
2	4.0
3	1.5
4	8.5
Rt 1	4.0
2	2.0
3	4.5
4	7.0
TOTAL	33.15

Visual Observation of Seat, recession, or burning: Lt 2 valve seat had very heavy deposit.

Avg. Rating = $\frac{\text{total}}{8}$ = 4.1

Inspector ERL

Date 5-78

Observations: oil seal umbrellas appeared slightly out-of-round to mechanic. Intake ports look washed.

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN

AREA	RATING
1	[illegible]
2	[illegible]
3	[illegible]
4	[illegible]
5	[illegible]
6	9.0
7	9.0
8	9.0
9	[illegible]
10	9.0
11	9.0
12	[illegible]
13	[illegible]
14	9.0
15	[illegible]
16	[illegible]
17	9.0
18	9.0
19	9.0
20	[illegible]
TOTAL	

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{20}$ = [illegible]

ENGINE INSPECTION SUMMARY

Vehicle I.D.:	A17683
Engine Type:	AMC, 360 CID
Miles:	49,503
Oil Type:	Virgin Base Stock
Oil Drain Interval:	4000 mi for 23,000 miles 8000 mi for balance

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	9.9	Piston Skirts	7.9
Intake Manifold	9.8	Rocker Arm Covers	8.7
Oil Pan	9.8	Valve Lifters	7.3
Valve Deck Area	10.0	Cylinder Wall (BRT)	8.8
Push Rod Chamber	10.0	Oil Pan	9.0
Timing Gear Cover	9.7		
AVG. SLUDGE	9.9	AVG. VARNISH	8.3

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	9.1
Stuck Compression Rings	0	Piston Varnish, Min.	6.6
Stuck Oil Rings	0	Intake Valve Deposits, Max.	8.0
		Intake Valve Deposits, Min.	1.5
		Intake Valve Deposits, Avg.	4.9

Clogging

Push Rods, No.	0
Oil Ring, %	0
Oil Screen, %	0

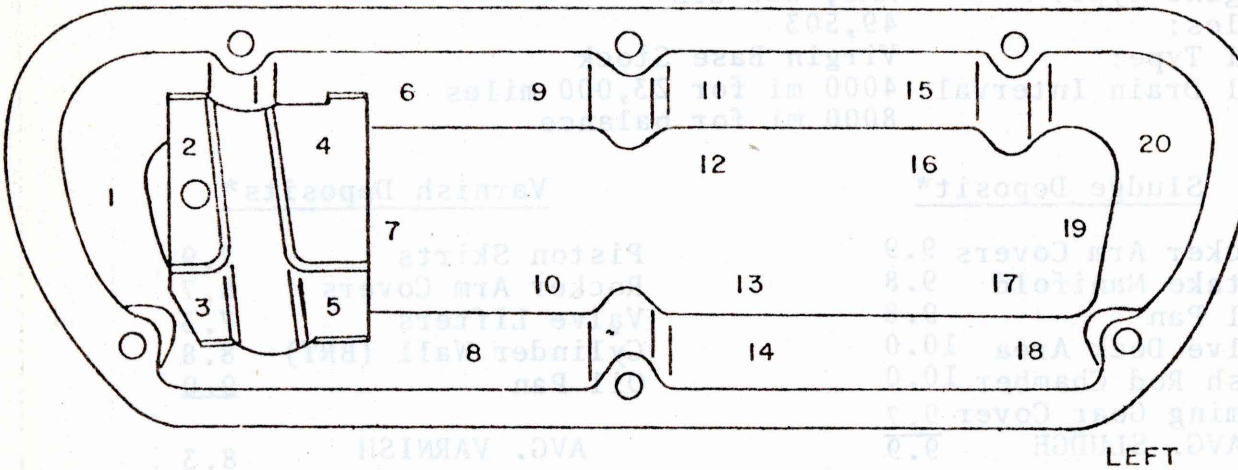
Observations, Comments

Date: 5-78
Rater: E.R. Lyons

* 10=Clean

Rating Work Sheet No. I

SLUDGE RATING OF LEFT ROCKER ARM COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN							x			x		x	x			x	x		x		7	35	
1/4A	x	x	x	x	x	x		x	x		x			x	x			x		x	13	65	.16
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	

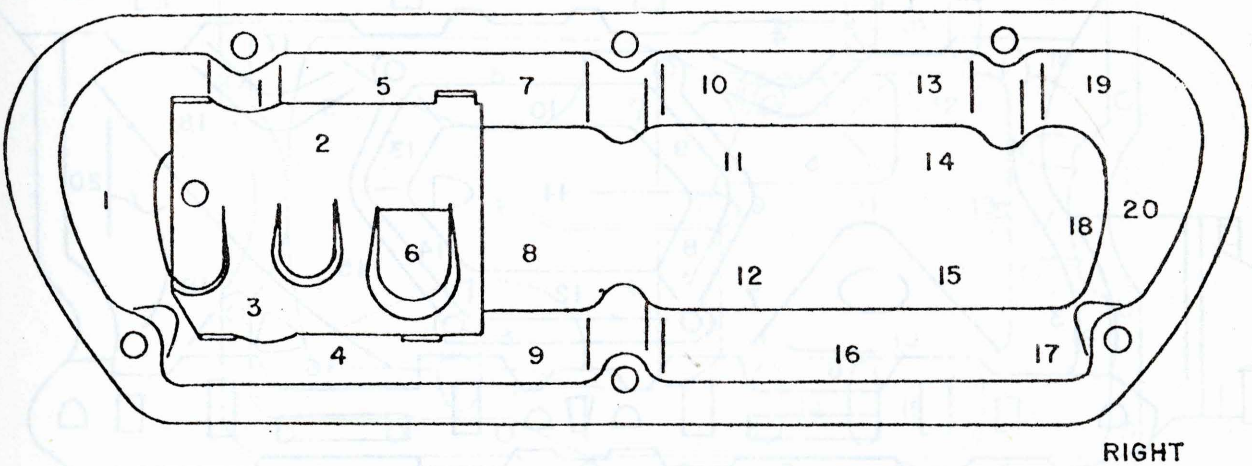
Inspector ERL

Sludge Merit Rating 9.8

Date 5-78

Rating Work Sheet No. Ia

SLUDGE RATING OF RIGHT ROCKER ARM COVER



Note Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN		x	x			x		x			x	x		x	x			x			9	45	
1/4A				x	x		x		x	x			x			x	x		x	x	10	50	.12
1/2A	x																				1	5	.02
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.14

Inspector ERL

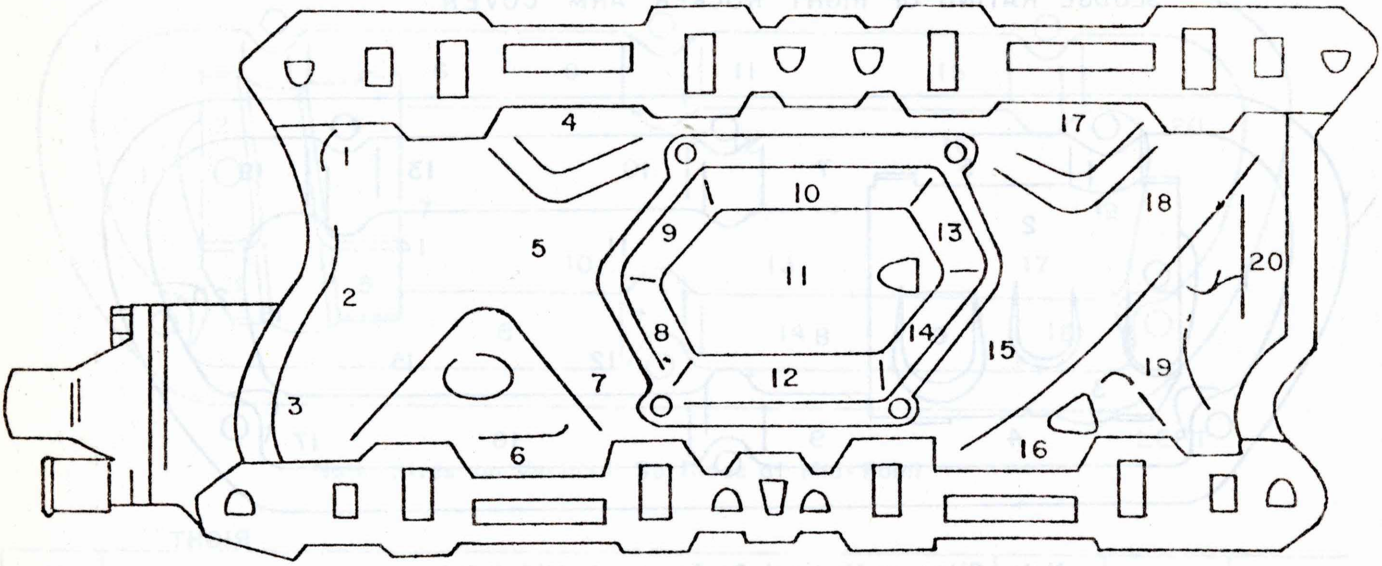
Sludge Merit Rating 9.9

Date 5-78

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 9.9

Rating Work Sheet No. 2

SLUDGE RATING OF UNDERSIDE OF INTAKE MANIFOLD



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	X	X	X	X	X	X	X														7	35	
1/4A								X	X	X	X	X	X	X	X	X	X	X	X	X	13	65	.16
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.16

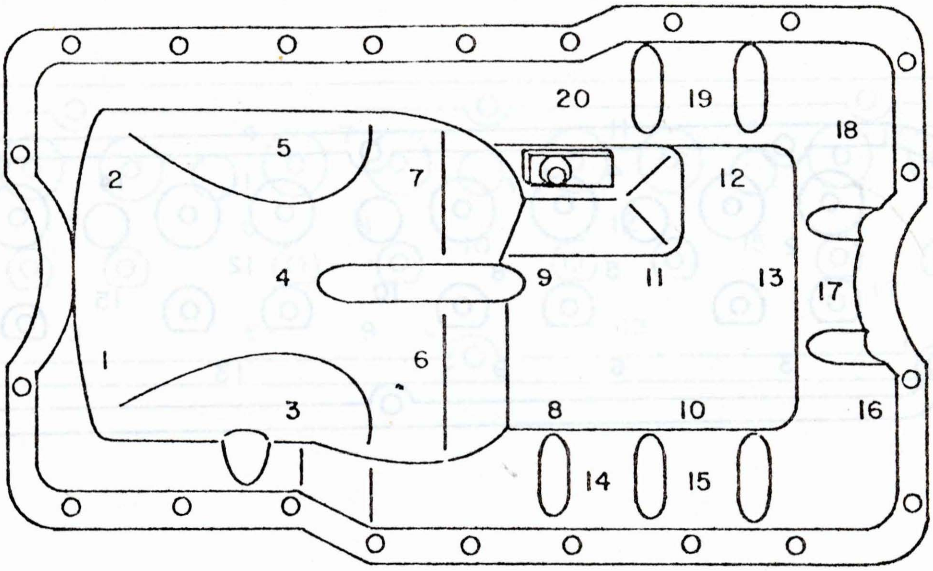
Inspector ERL

Date 5-78

Sludge Merit Rating 9.8

Rating Work Sheet No. 3

SLUDGE RATING OF OIL PAN



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOF
CLEAN	x	x																			2	10	
1/4A			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	18	90	.22
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	

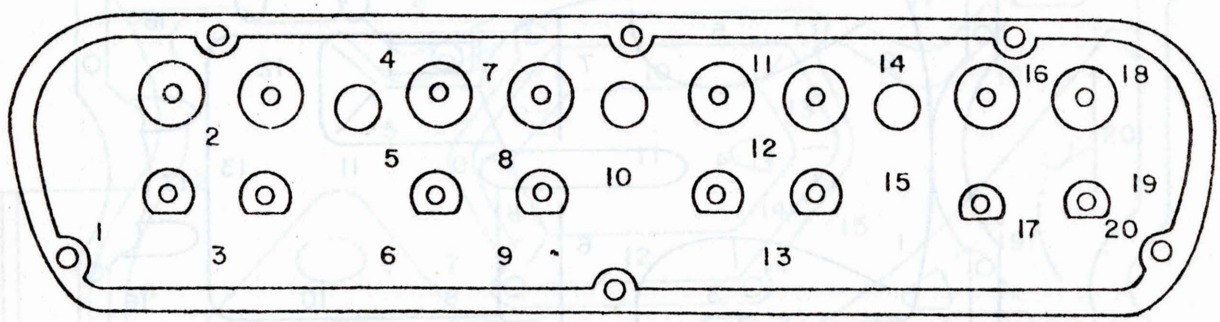
Inspector ERL

Date 5-78

Sludge Merit Rating 9.8

Rating Work Sheet No. 4

SLUDGE RATING OF LEFT VALVE DECK



Left

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTO
CLEAN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

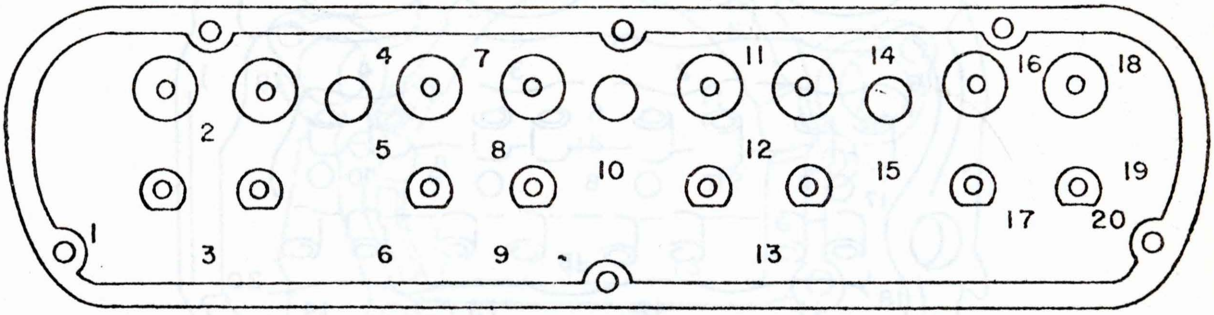
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 4a

SLUDGE RATING OF RIGHT VALVE DECK



Right

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
																	GRAND TOTAL						

Inspector ERL

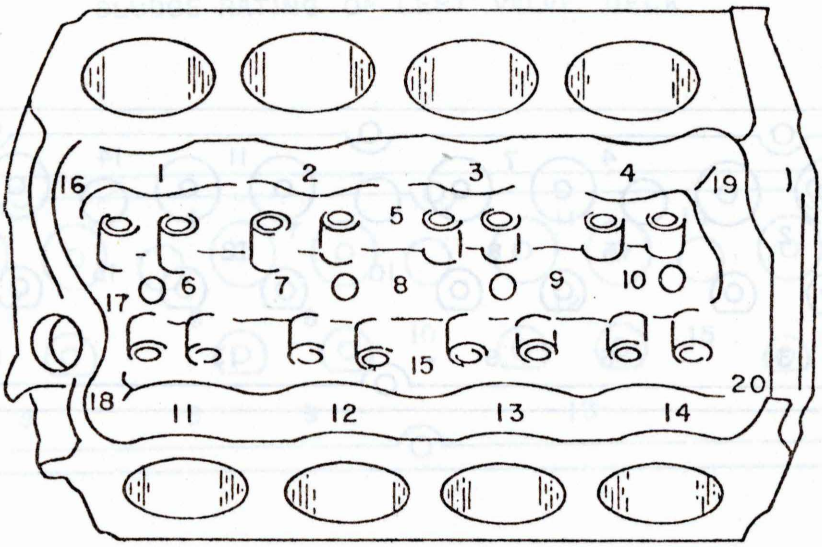
Date 5-78

Sludge Merit Rating 10.0

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 10.

Rating Work Sheet No. 5

SLUDGE RATING OF PUSH ROD CHAMBER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
																				GRAND TOTAL			

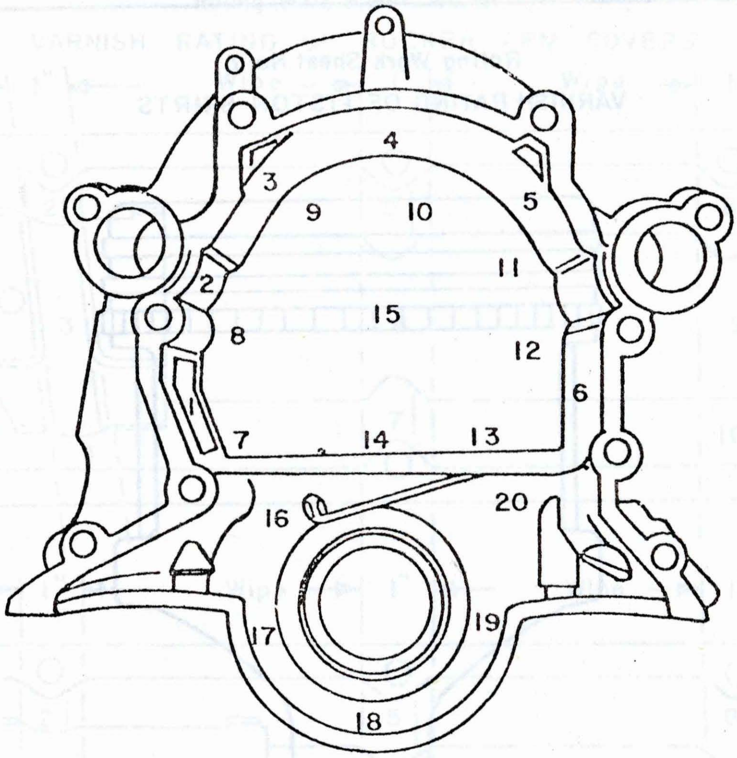
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 6

SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU[…] FACTO[…]
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							

Inspector ERL

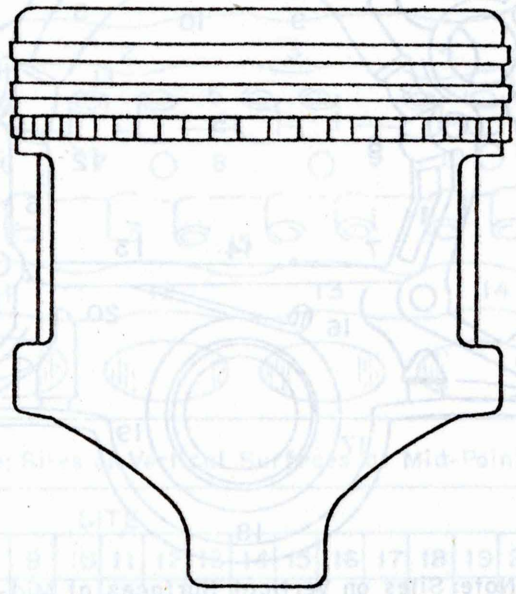
GRAND TOTAL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	CAM SIDE	OUT-SIDE	AVERAGE	CON. ROD BRGS APPEARANCE
Normal	Lt 1	8.0	8.6	8.3	Normal
Normal	2	7.7	9.0	8.4	Normal
Normal	3	6.6	7.5	7.1	Lt wiping
Normal	4	6.9	7.5	7.2	Normal
Normal	Rt 1	9.1	8.5	8.8	Normal
Normal	2	8.0	7.7	7.9	Normal
Normal	3	7.8	7.4	7.6	Normal
Lt scuff camside	4	7.9	7.0	7.5	Normal
	TOTAL	62.0	63.2		
	AVERAGE	7.8	7.9		

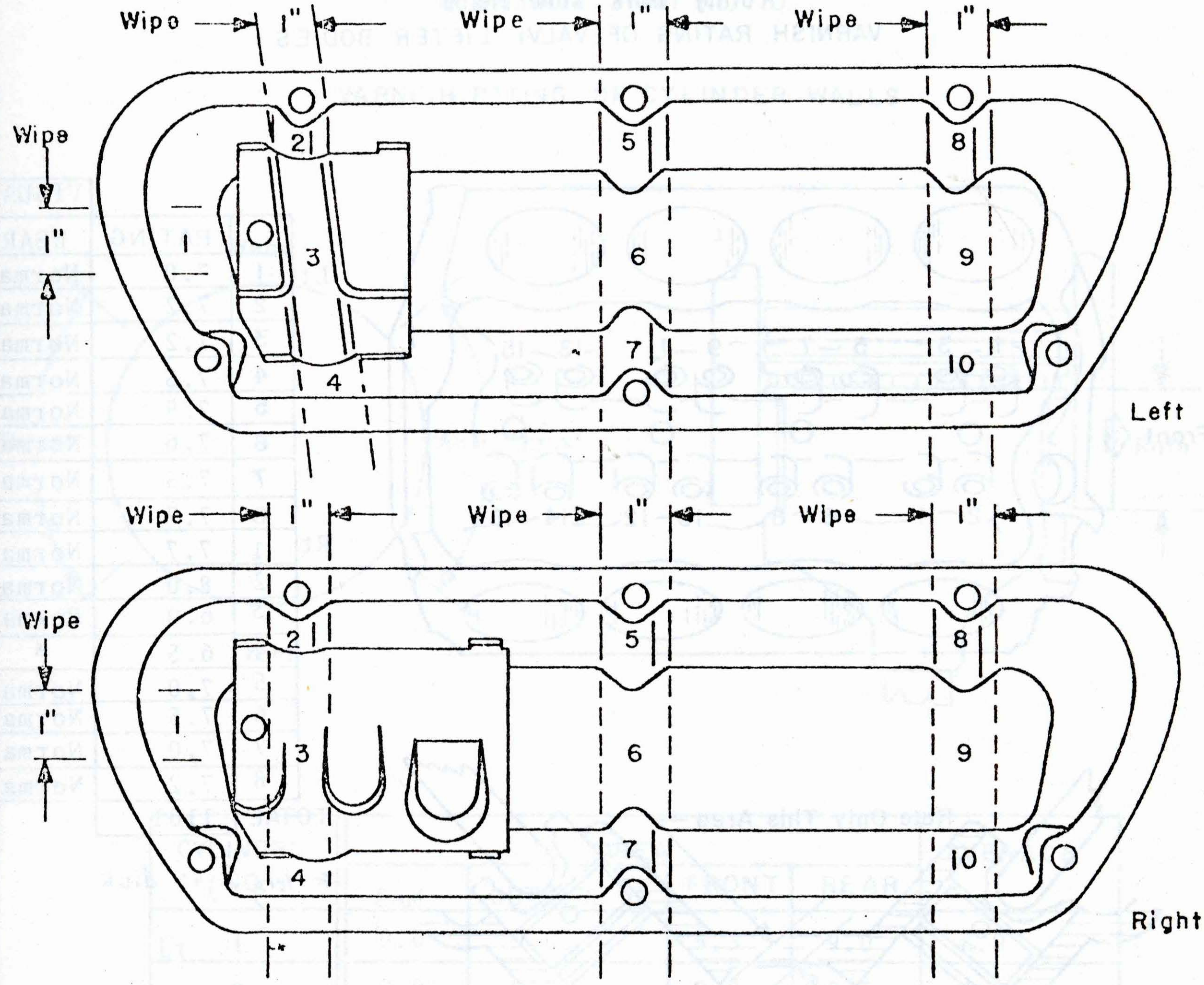
Inspector ________

Date ________

VARNISH RATING = $\frac{\text{AvgThrust + Avg Antithrust}}{2}$ = 7.9

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



Left

AREA	RATING
1	9.0
2	9.0
3	9.0
4	9.0
5	9.0
6	9.0
7	9.0
8	8.8
9	9.0
10	9.0
TOTAL	

Avg. Varnish Rating = $\frac{\text{Left} + \text{Right}}{2}$ = 8.7

Right

AREA	RATING
1	7.8
2	8.0
3	8.0
4	8.0
5	9.0
6	8.5
7	8.0
8	9.0
9	8.5
10	9.0
TOTAL	

Varnish Rating = $\frac{\text{Total}}{10}$ = 9.0

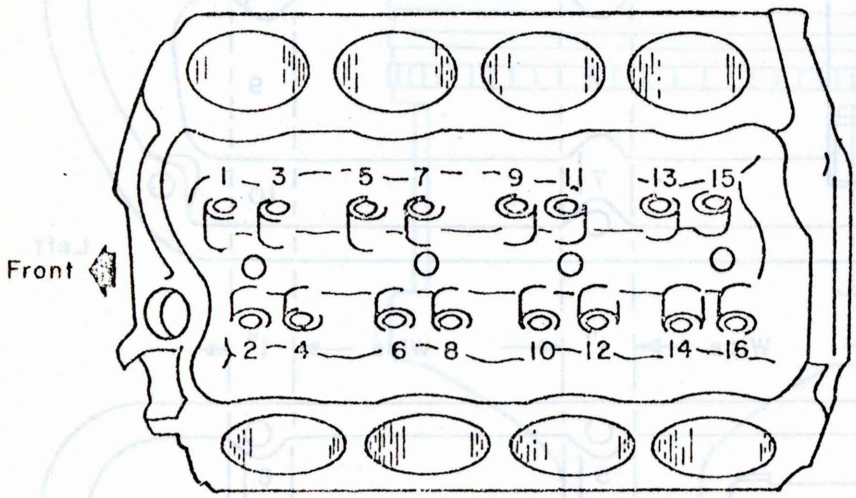
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{10}$ = 8.4

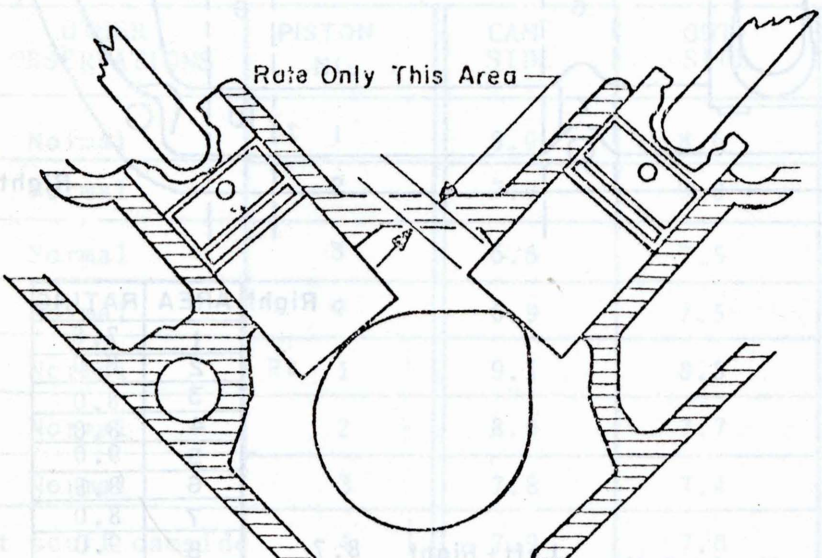
Rating Work Sheet No. 9

VARNISH RATING OF VALVE LIFTER BODIES



		RATING	VISUAL WEAR
Lt	1	7.0	Normal
	2	7.2	Normal
	3	7.2	Normal
	4	7.5	Normal
	5	7.5	Normal
	6	7.6	Normal
	7	7.5	Normal
	8	7.7	Normal
Rt	1	7.7	Normal
	2	8.0	Normal
	3	6.0	Normal
	4	6.5	*
	5	7.0	Normal
	6	7.5	Normal
	7	7.0	Normal
	8	7.2	Normal
TOTAL		1161	

* Very light dish



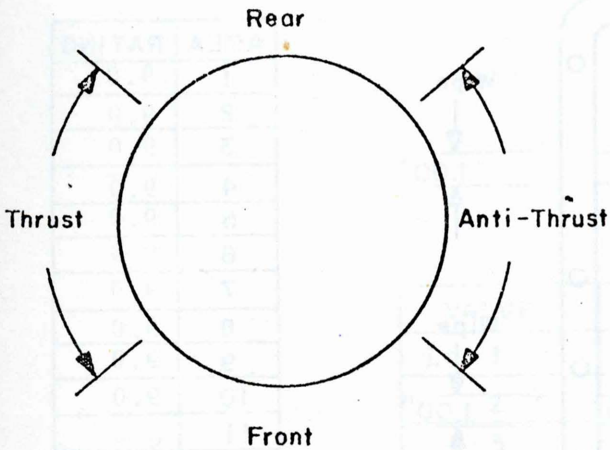
Inspector ERL

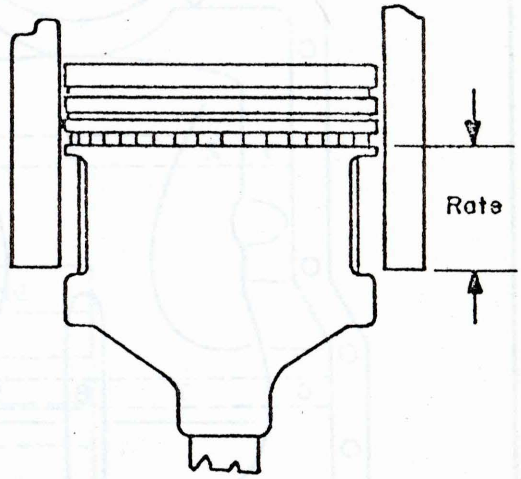
Varnish Rating = $\frac{\text{Total}}{16}$ = 7.3

Date 5-78

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.		AREA				AVERAGE
		CAM	OUTSIDE	FRONT	REAR	
Lt	1	9.0	9.0	8.5	9.0	8.9
	2	9.0	9.0	9.0	8.5	8.9
	3	9.0	8.5	8.5	9.0	8.8
	4	9.0	9.0	9.0	9.0	9.0
Rt	1	9.0	9.0	7.5	7.5	8.3
	2	9.0	9.0	8.5	8.5	8.8
	3	9.0	9.0	9.0	8.5	8.9
	4	9.0	9.0	8.0	8.0	8.5
					TOTAL	

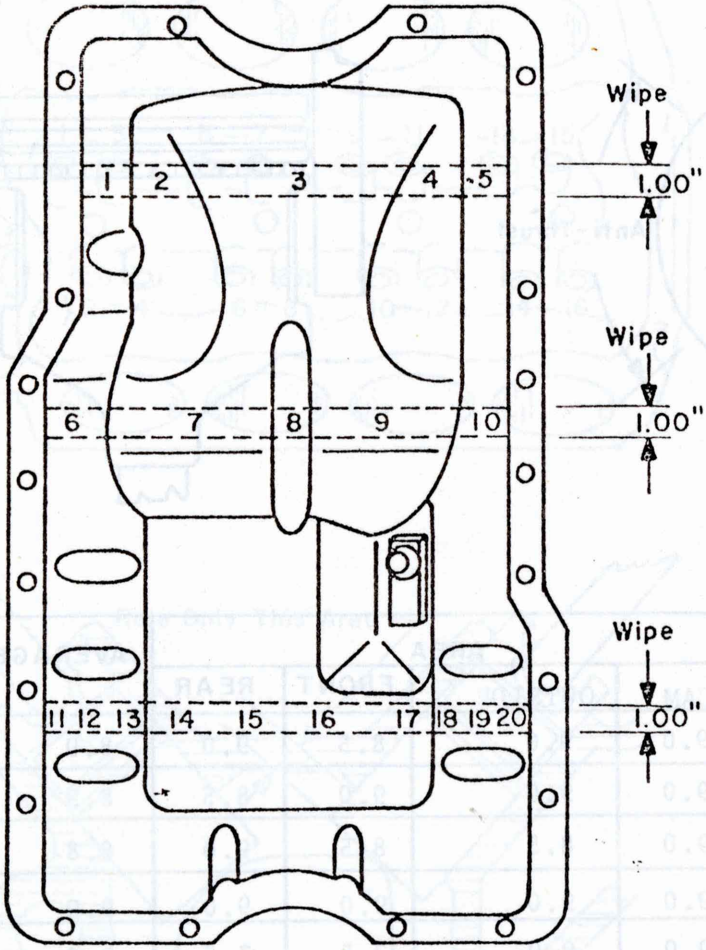
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 8.8

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	9.0
2	9.0
3	9.0
4	9.0
5	9.0
6	9.0
7	9.0
8	9.0
9	9.0
10	9.0
11	9.0
12	9.0
13	9.0
14	9.0
15	9.0
16	9.0
17	9.0
18	9.0
19	9.0
20	9.0
TOTAL	180

Inspector ERL

Varnish Rating = $\frac{\text{Total}}{20}$ = 9.0

Date 5-78

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

VALVE		RATING
Lt	1	5.0
	2	2.5
	3	7.5
	4	3.0
Rt	1	1.5
	2	7.5
	3	4.5
	4	8.0
TOTAL		39.5

Visual Observation of Seat, recession, or burning: All Normal

Avg. Rating = $\frac{\text{total}}{8}$ = 4.9

Inspector ERL

Date 5-78

Work Sheet No. 11

VISUAL RATING OF OIL PAN

AREA	RATING
1	9.0
2	9.0
3	9.0
4	9.0
5	9.0
6	9.0
7	9.0
8	9.0
9	9.0
10	9.0
11	9.0
12	9.0
13	9.0
14	9.0
15	9.0
16	9.0
17	9.0
18	9.0
19	9.0
20	9.0
TOTAL	180

Inspector ERL

Date 5-78

Merit Rating = $\frac{\text{Total}}{20}$ = 9.0

ENGINE INSPECTION SUMMARY

Vehicle I.D.: A17688
Engine Type: AMC, 360 CID
Miles: 54,477
Oil Type: Virgin Base Stock
Oil Drain Interval: 4000 miles for 22,000 mi
8000 miles for balance

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	9.6	Piston Skirts	6.0
Intake Manifold	9.7	Rocker Arm Covers	6.2
Oil Pan	9.8	Valve Lifters	5.0
Valve Deck Area	10.0	Cylinder Wall (BRT)	6.1
Push Rod Chamber	9.9	Oil Pan	8.1
Timing Gear Cover	10.0		
AVG. SLUDGE	9.8	AVG. VARNISH	6.4

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	6.5
Stuck Compression Rings	0	Piston Varnish, Min.	5.5
Stuck Oil Rings	0	Intake Valve Deposits, Max.	8.0
		Intake Valve Deposits, Min.	5.0
		Intake Valve Deposits, Avg.	6.6

Clogging

Push Rods, No.	0
Oil Ring, %	0
Oil Screen, %	0

Observations, Comments

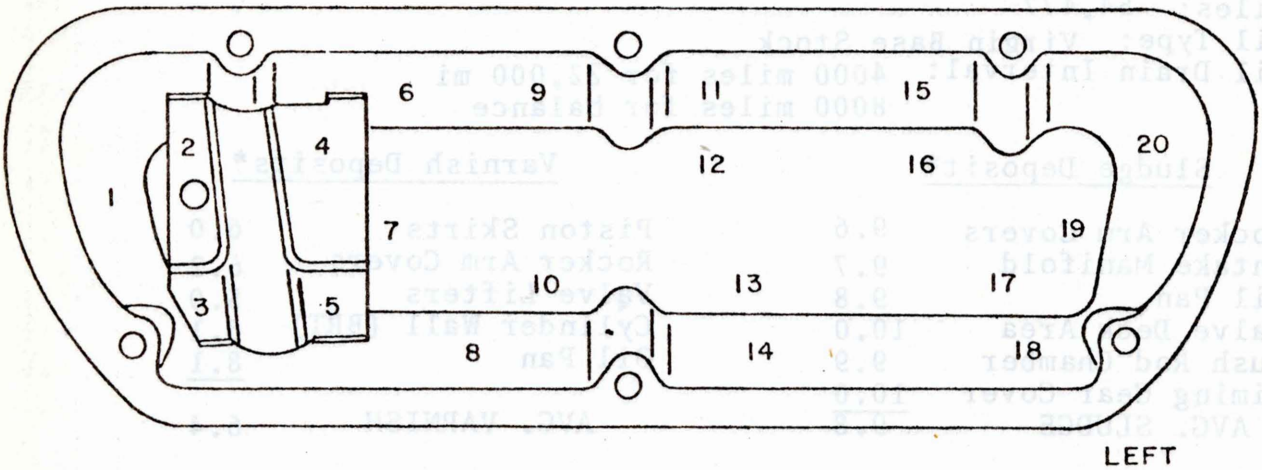
Some light rust on valve lifters.

Date: 5-78
Rater: E.R. Lyons

* 10=Clean

Rating Work Sheet No. I

SLUDGE RATING OF LEFT ROCKER ARM COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A						x		x	x	x	x	x	x	x	x	x					10	50	.12
1/2A		x		x	x		x										x	x	x	x	8	40	.20
3/4A			x																		1	5	.04
A	x																				1	5	.05
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.41

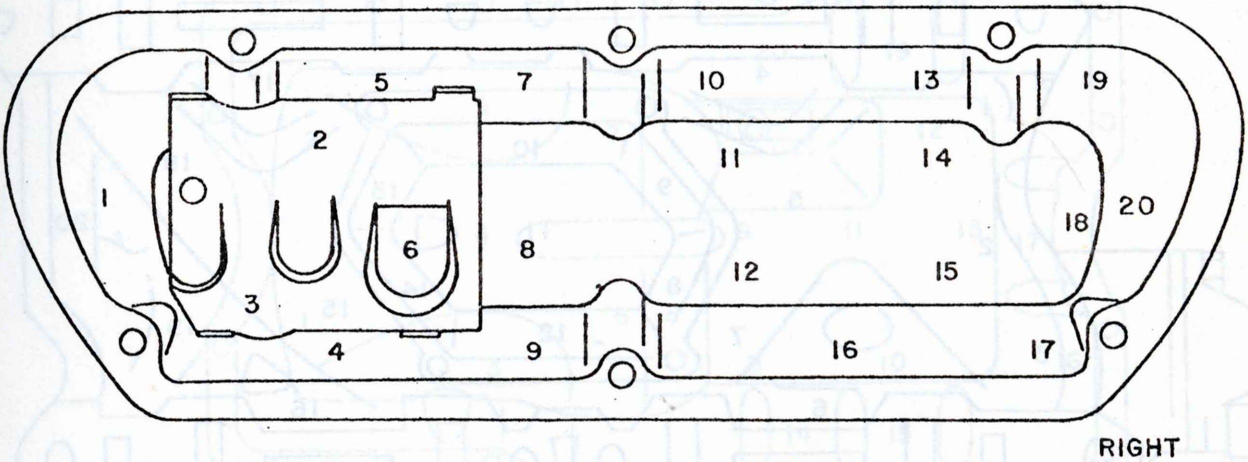
Inspector ERL

Sludge Merit Rating 9.6

Date 5-78

Rating Work Sheet No. Ia

SLUDGE RATING OF RIGHT ROCKER ARM COVER



Note Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x		x	x		x	x	x	x			x	x	x	x			x	x	x	14	70	.18
1/2A		x			x					x	x					x	x				6	30	.15
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.33

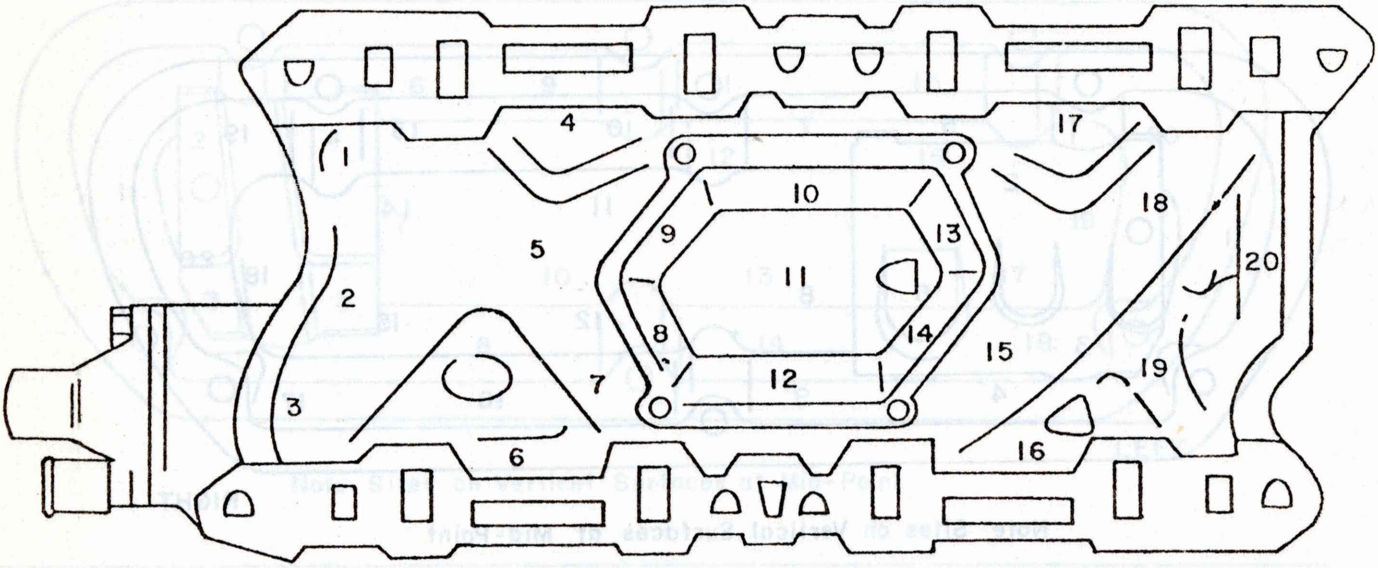
Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 9.6

Rating Work Sheet No. 2
SLUDGE RATING OF UNDERSIDE OF INTAKE MANIFOLD



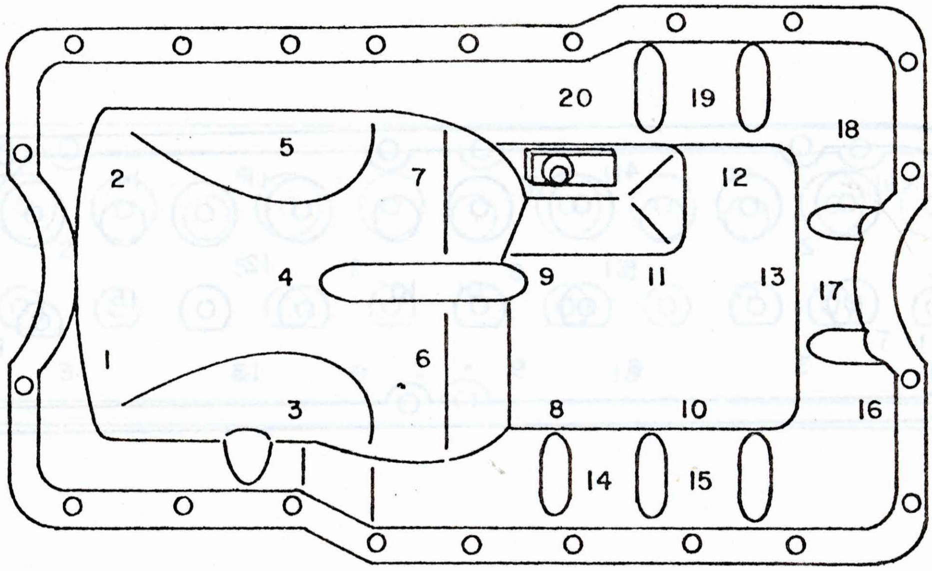
DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		19	95	.24
1/2A																							
3/4A																							
A																				x	1	5	.05
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.29

Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 3
SLUDGE RATING OF OIL PAN



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN			X	X	X																3	15	
1/4A	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	17	85	.21
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.21

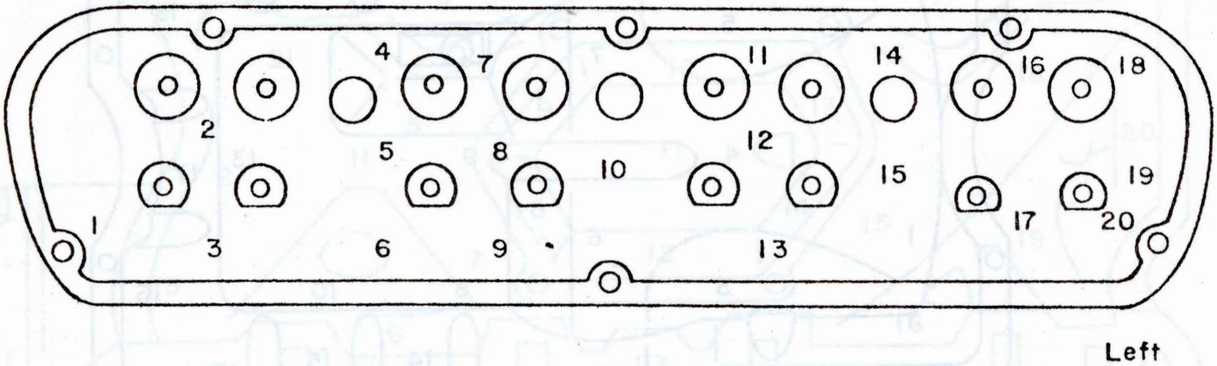
Sludge Merit Rating 9.8

Inspector ERL

Date 5-78

Rating Work Sheet No. 4

SLUDGE RATING OF LEFT VALVE DECK



Left

DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
																				GRAND TOTAL			

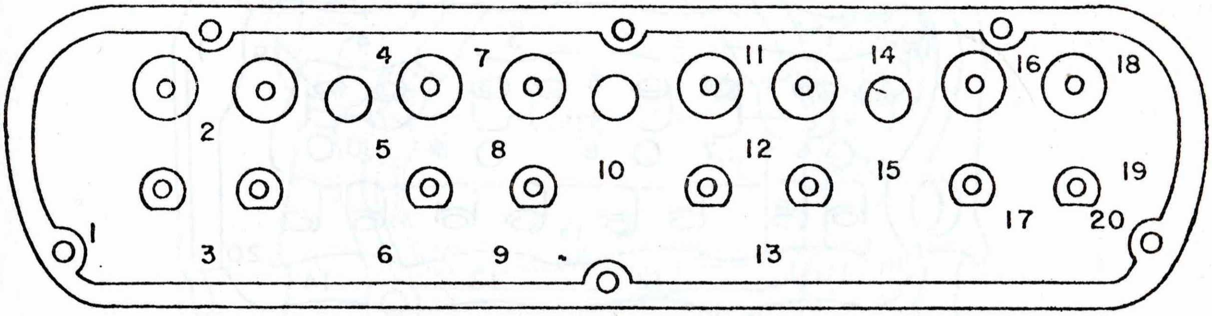
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 4a

SLUDGE RATING OF RIGHT VALVE DECK



Right

DEPTH SCALE	SITE																				TOTAL CHECKS	% COVERED	VOLUM FACTOR
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20			
CLEAN	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

Inspector ERL

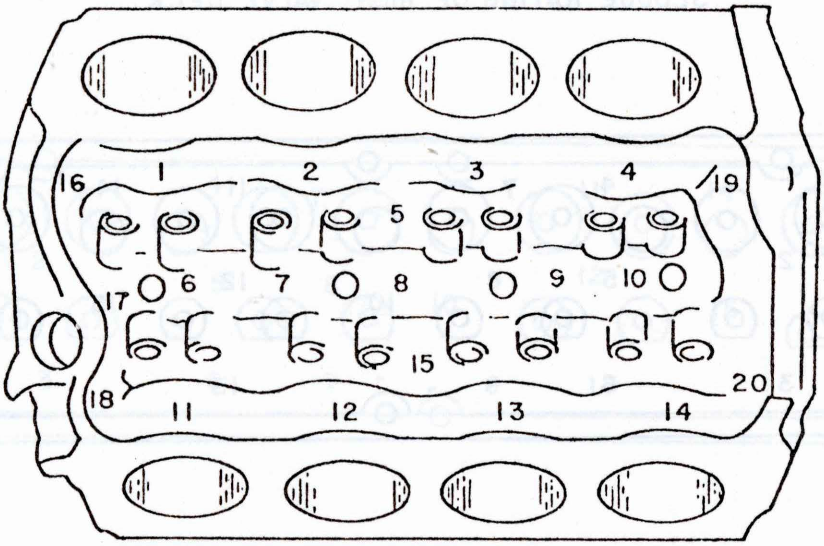
Date 5-78

Sludge Merit Rating 10.0

Avg. Sludge Merit Rating = $\frac{\text{Left+Right}}{2}$ = 10.

Rating Work Sheet No. 5

SLUDGE RATING OF PUSH ROD CHAMBER



Note: Sites on Vertical Surfaces at Mid-Point

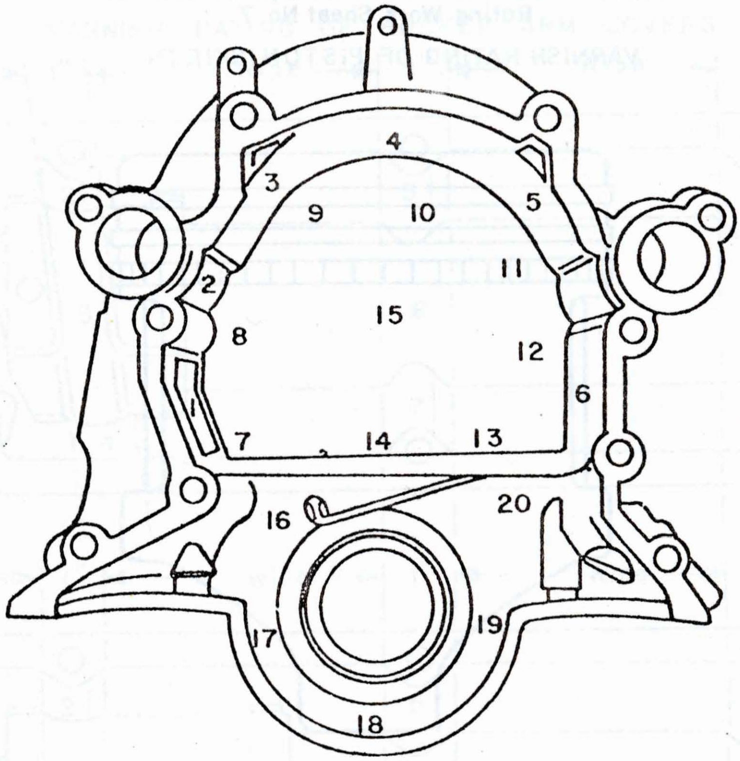
DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			18	90	
1/4A																							
1/2A																							
3/4A																							
A																			x	x	2	10	.08
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	

Inspector ERL

Date 5-78

Sludge Merit Rating 9.9

Rating Work Sheet No. 6
SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTO
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

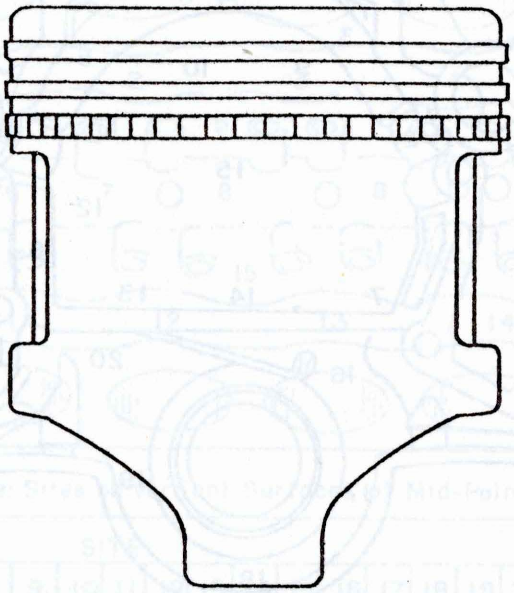
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	CAM SIDE	OUT-SIDE	AVERAGE	CON. ROD BRGS APPEARANCE
	Lt 1	5.7	6.5	6.1	ALL NORMAL
	2	6.1	6.5	6.3	
Sl. Tight Pin	3	6.0	5.9	5.9	
	4	5.9	6.0	5.9	
	Rt 1	6.0	6.5	6.2	
	2	6.0	6.0	6.0	
Tight Pin	3	5.7	6.4	6.0	
	4	5.5	6.5	6.0	
	TOTAL	50.3	46.9		
	AVERAGE	5.7	6.3		

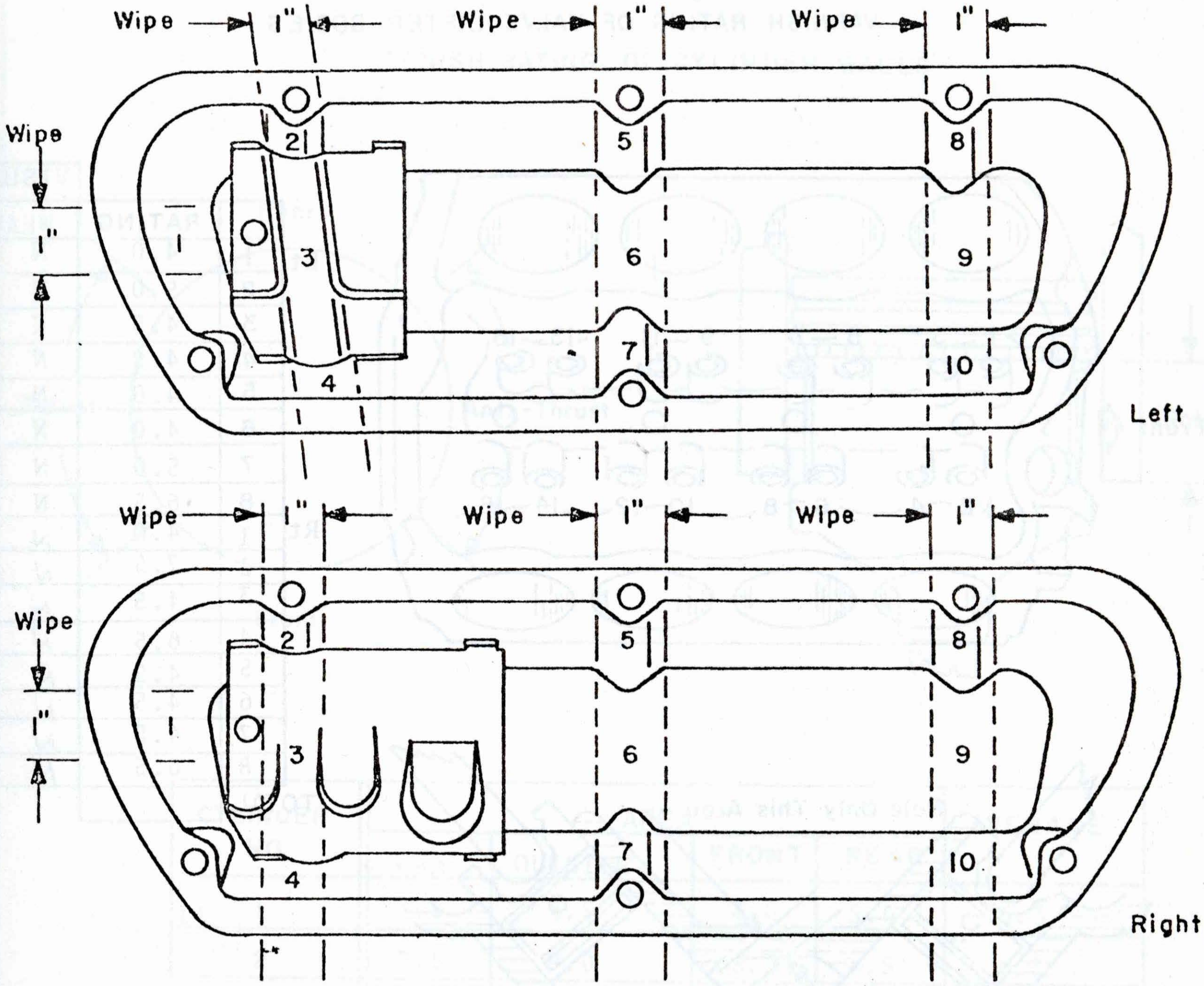
Inspector ______

Date ______

$$\text{VARNISH RATING} = \frac{\text{AvgThrust} + \text{Avg Antithrust}}{2} = 6.0$$

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



Left

AREA	RATING
1	8.0
2	5.0
3	6.0
4	7.0
5	4.0
6	4.0
7	6.0
8	4.0
9	4.0
10	5.0
TOTAL	

Right

AREA	RATING
1	8.5
2	8.0
3	8.0
4	8.0
5	7.0
6	5.0
7	4.0
8	8.5
9	5.0
10	8.0
TOTAL	

Avg. Varnish Rating = $\frac{\text{Left+ Right}}{2}$ = 6.2

Varnish Rating = $\frac{\text{Total}}{10}$ = 5.3

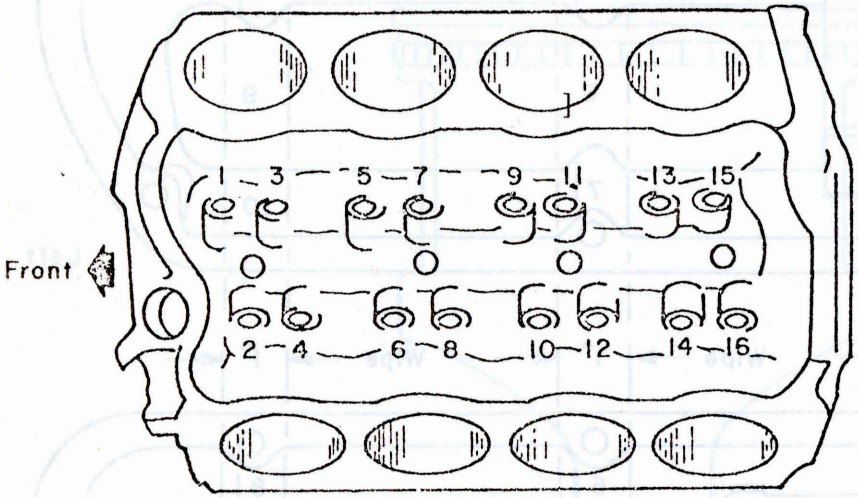
Inspector ERL

Date 5-78

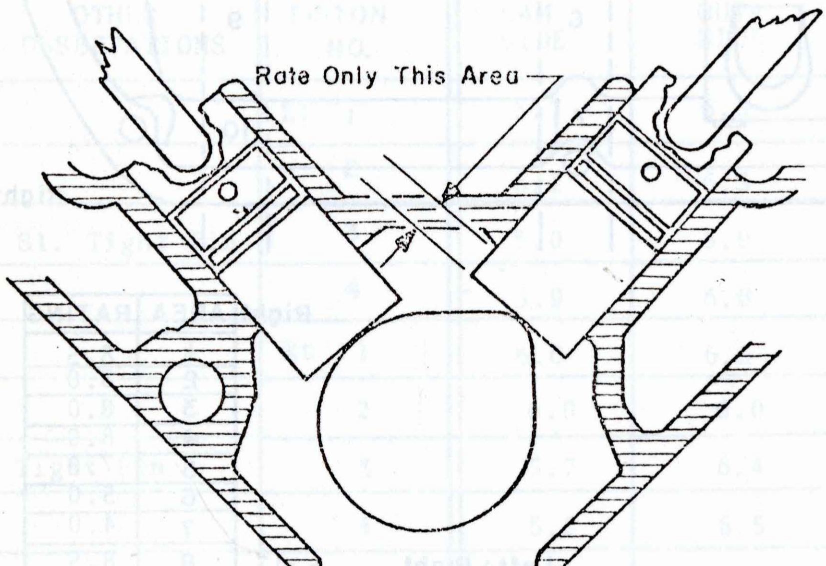
Varnish Rating = $\frac{\text{Total}}{10}$ = 7.0

Rating Work Sheet No. 9

VARNISH RATING OF VALVE LIFTER BODIES



		RATING	VISUAL WEAR
Lt	1	4.0	N
	2	5.0	N
	3	4.5	N
	4	4.0	N
	5	4.0	N
	6	4.0	N
	7	5.0	N
	8	6.5	N
Rt	1	4.0	N
	2	7.5	N
	3	4.5	N
	4	6.5	N
	5	4.5	N
	6	4.5	N
	7	4.5	N
	8	6.5	N
TOTAL			



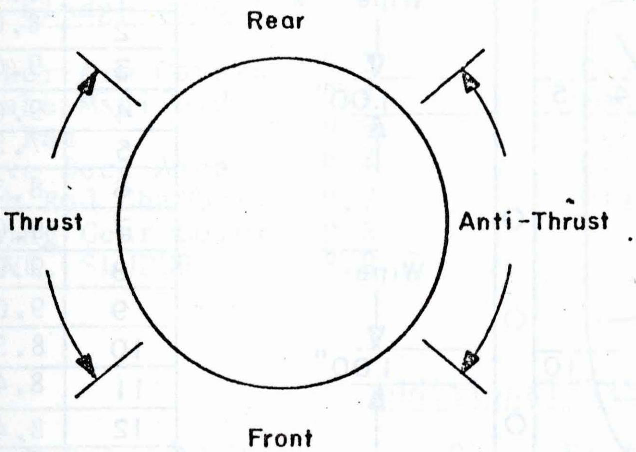
Inspector ERL

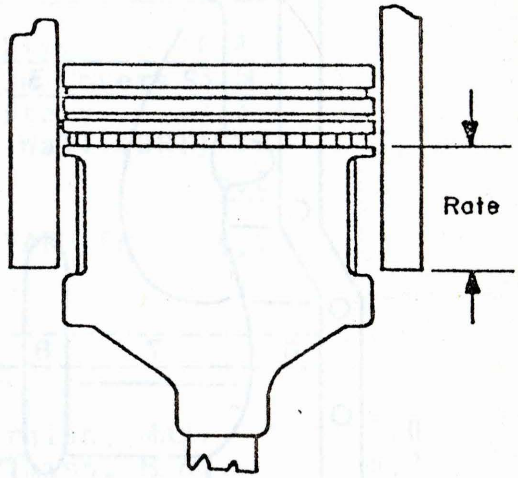
Varnish Rating = $\frac{\text{Total}}{16}$ = 5.0

Date 5-78

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.	AREA				AVERAGE
	CAM	OUTSIDE	FRONT	REAR	
Lt 1	7.5	8.5	4.0	5.0	6.3
2	7.5	9.0	3.5	4.5	6.2
3	7.5	8.5	5.0	5.5	6.6
4	7.5	8.0	6.0	6.0	6.9
Rt 1	5.5	6.0	4.5	5.0	5.3
2	7.5	8.0	4.5	4.5	6.1
3	6.5	7.5	5.0	4.5	5.9
4	6.0	6.0	5.0	4.5	5.4
				TOTAL	48.7

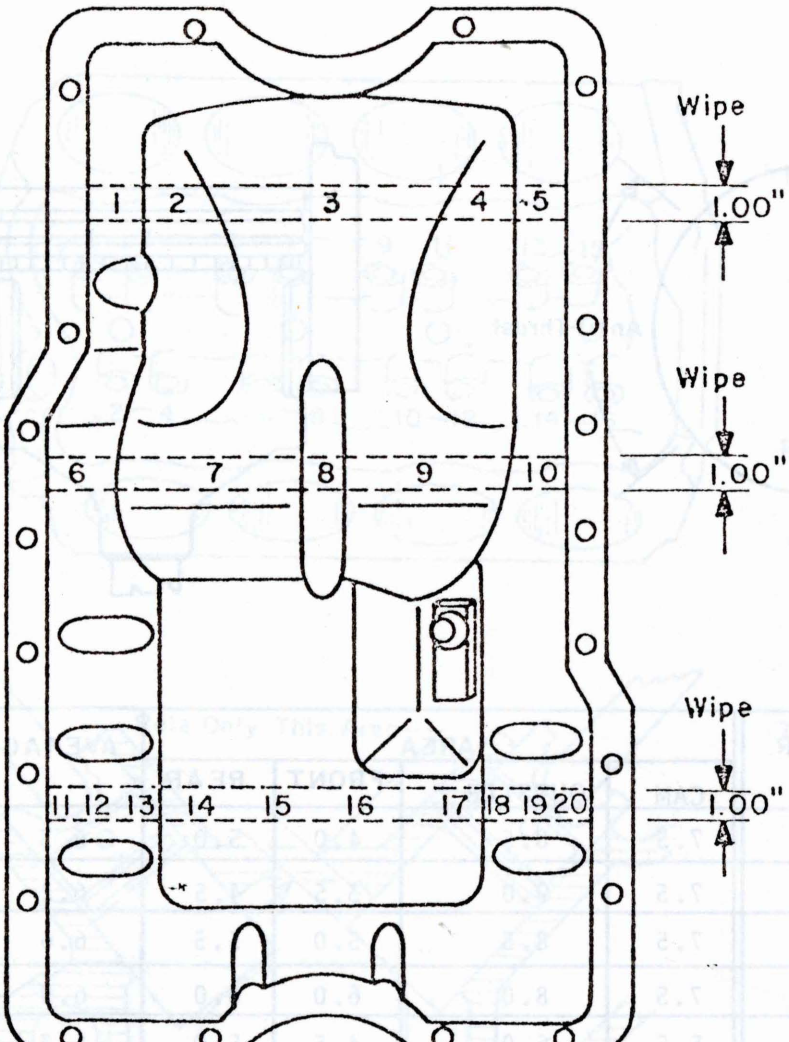
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 6.1

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	8.5
2	8.0
3	9.0
4	9.0
5	7.5
6	8.5
7	9.0
8	9.0
9	9.0
10	8.5
11	8.4
12	8.4
13	8.4
14	8.9
15	8.9
16	8.9
17	8.9
18	8.5
19	8.5
20	8.5
TOTAL	1723

Inspector ERL

Varnish Rating = Total / 20 = 8.6

Date 5-78

ENGINE INSPECTION SUMMARY

Vehicle I.D.:	A20371
Engine Type:	Ford F-750, 361 CID
Miles:	27,207
Oil Type:	Virgin Base Stock
Oil Drain Interval:	4000 mi

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	9.3	Piston Skirts	6.4
Intake Manifold	9.4	Rocker Arm Covers	3.6
Oil Pan	9.5	Valve Lifters	7.3
Valve Deck Area	6.2	Cylinder Wall (BRT)	7.0
Push Rod Chamber	9.7	Oil Pan	6.2
Timing Gear Cover	9.5		
AVG. SLUDGE	8.9	AVG. VARNISH	6.1

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	7.0
Stuck Compression Rings	0	Piston Varnish, Min.	5.7
Stuck Oil Rings	0	Intake Valve Deposits, Max.	8.0
		Intake Valve Deposits, Min.	6.0
		Intake Valve Deposits, Avg.	7.1

Clogging

Push Rods, No.	ND (solid design)
Oil Ring, %	0
Oil Screen, %	0

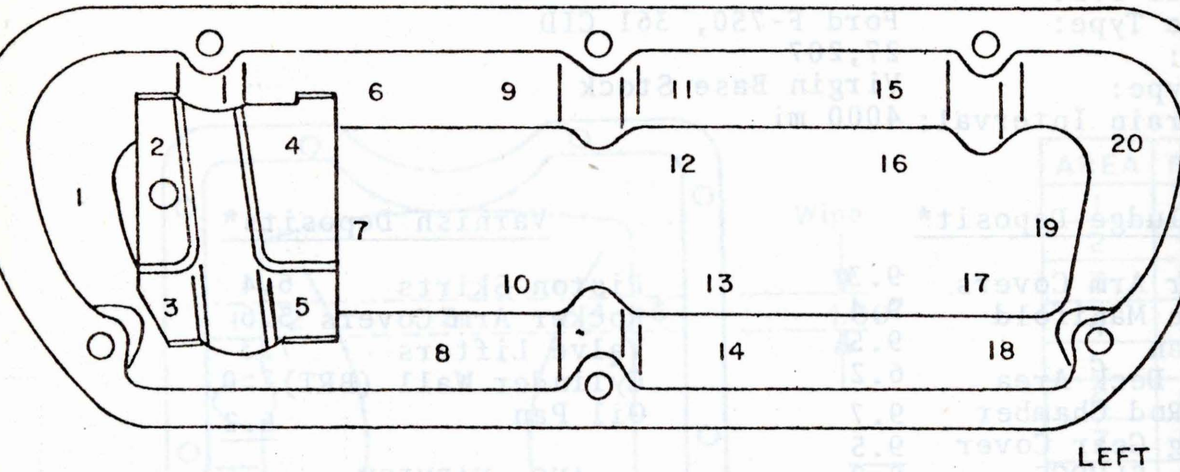
Observations, Comments

Virtually no rust on lifters despite use of leaded gasoline. Some dished valve lifters. V. slight corrosion on some compression rings.

Date: 5-78
Rater: E.R. Lyons

* 10=Clean

Rating Work Sheet No. I
SLUDGE RATING OF LEFT ROCKER ARM COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A														x							1	5	.01
1/2A					x		x	x									x	x	x	x	7	35	.18
3/4A																							
A	x	x	x	x		x			x	x	x	x	x		x	x					12	60	.60
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.79

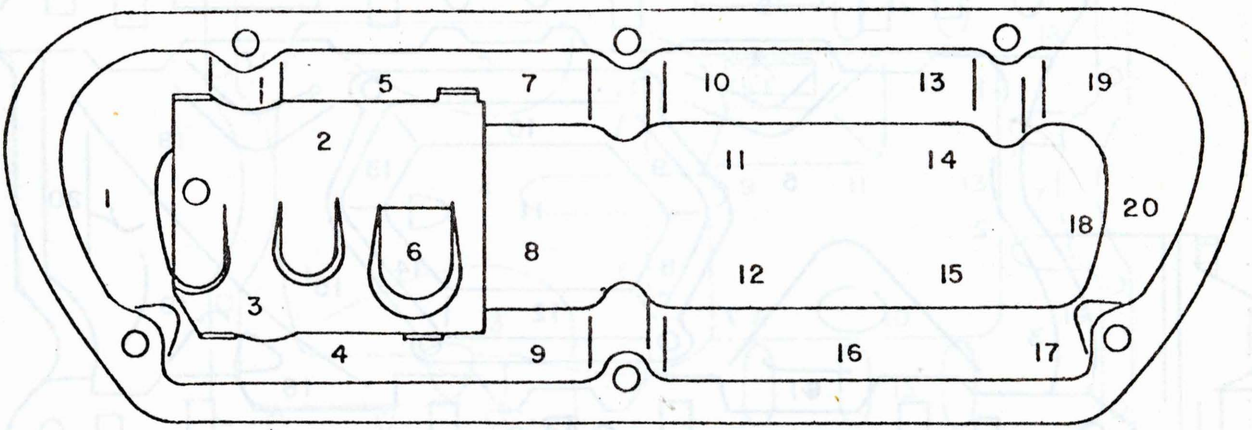
Inspector ERL

Sludge Merit Rating 9.2

Date 5-78

Rating Work Sheet No. Ia

SLUDGE RATING OF RIGHT ROCKER ARM COVER



Note Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A						x	x			x	x		x				x		x		7	35	.09
1/2A	x	x			x			x	x			x		x	x			x		x	10	50	.25
3/4A																							
A			x	x												x					3	15	.15
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.49

Inspector ERL

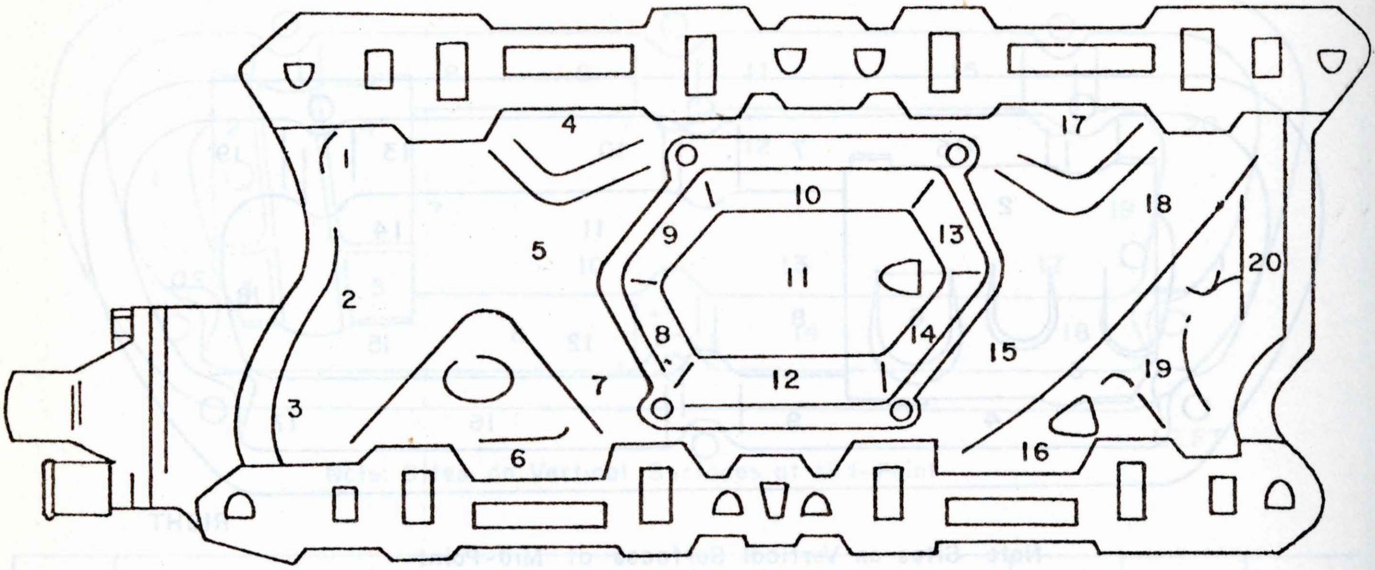
Sludge Merit Rating 9.5

Date 5-78

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 9.3

Rating Work Sheet No. 2

SLUDGE RATING OF UNDERSIDE OF INTAKE MANIFOLD



DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x				x	x										8	40	.10
1/2A								x	x			x	x								4	20	.10
3/4A																							
A							x							x	x	x	x	x	x	x	8	40	.40
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.60

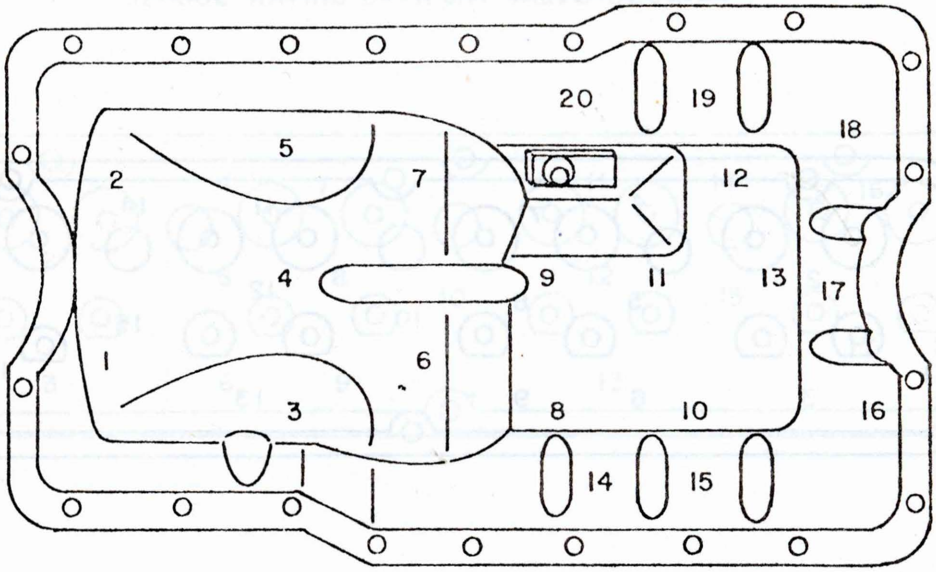
Inspector ERL

Date 5-78

Sludge Merit Rating 9.4

Rating Work Sheet No. 3

SLUDGE RATING OF OIL PAN



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTO
CLEAN																							
1/4A	X	X				X	X														4	20	.05
1/2A			X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	16	80	.40
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.45

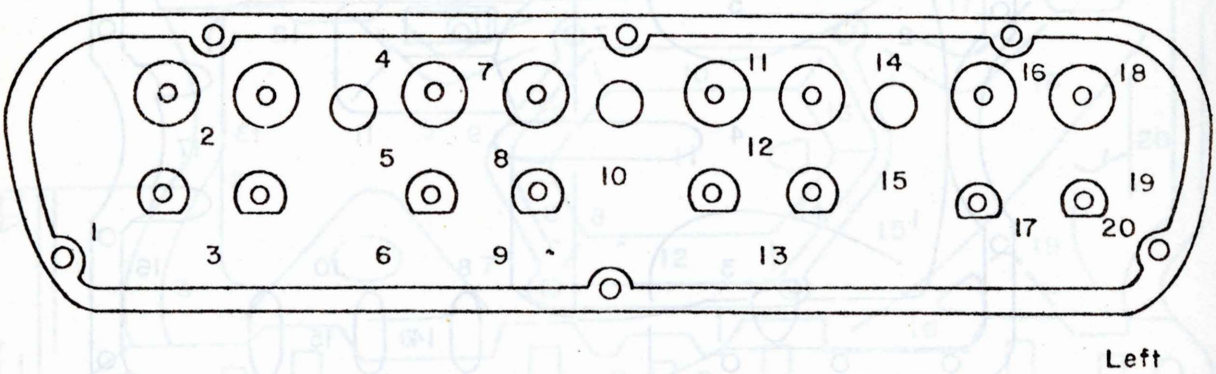
Inspector ERL

Date 5-78

Sludge Merit Rating 9.5

Rating Work Sheet No. 4

SLUDGE RATING OF LEFT VALVE DECK



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU… FACTO…
CLEAN																							
1/4A																							
1/2A		x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x			17	85	.42
3/4A																							
A	x																				1	5	.05
AB																							
B													x								1	5	.10
BC																							
C																				x	1	5	.05
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							.77

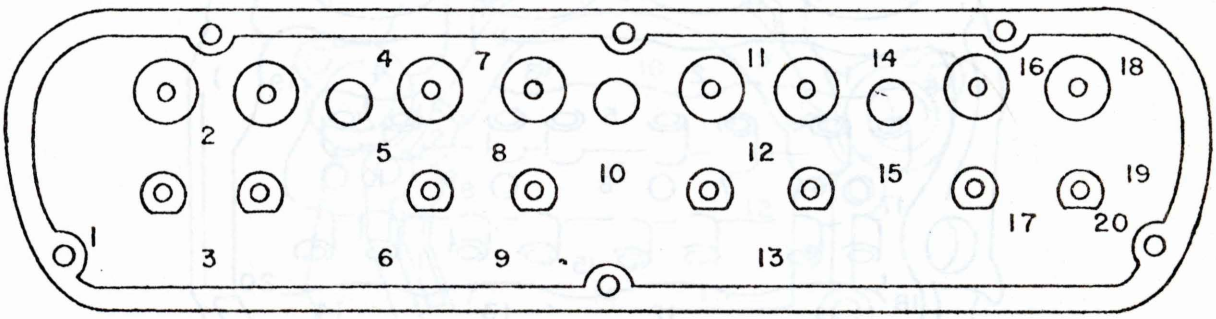
Inspector ERL

Date 5-78

Sludge Merit Rating 9.2

Rating Work Sheet No.4a

SLUDGE RATING OF RIGHT VALVE DECK



Right

LEAD paint "C" Depth AREA-1

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A																							
1/2A			x	x	x	x	x	x	x	x	x	x		x	x		x	x	x	x	16	80	.40
3/4A																							
A																							
AB																							
B													x								1	5	.10
BC																							
C	x																				1	5	.20
D																							
E																							
F																							
G																							
H		x														x					2	10	12.30
I																							
															GRAND TOTAL								13.00

Inspector ERL

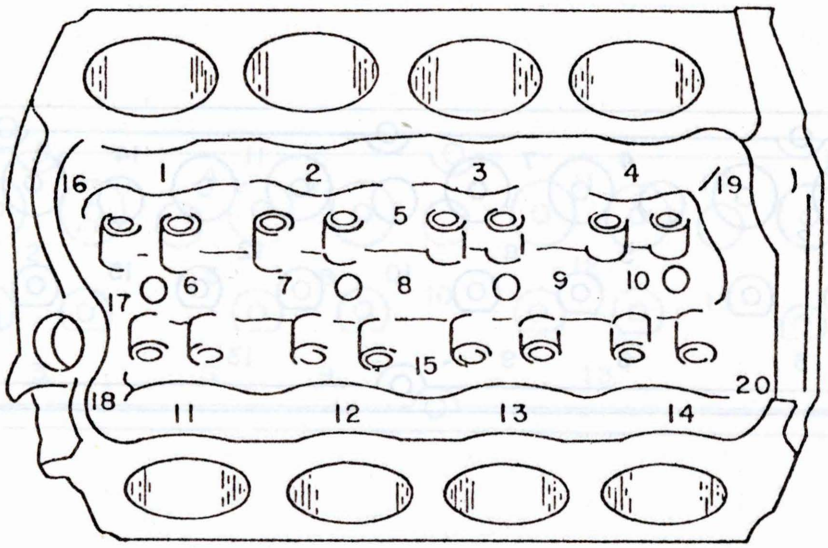
Date 5-78

Sludge Merit Rating 3.5

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ 6.2

Rating Work Sheet No. 5

SLUDGE RATING OF PUSH ROD CHAMBER



Note: Sites on Vertical Surfaces at Mid-Point

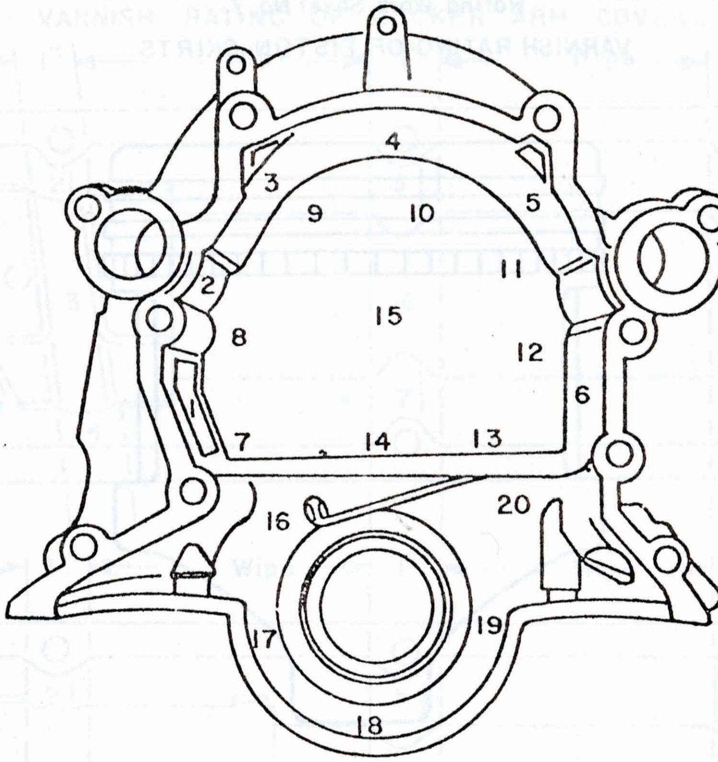
DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							.25

Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 6
SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTO
CLEAN																							
1/4A																							
1/2A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.50
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

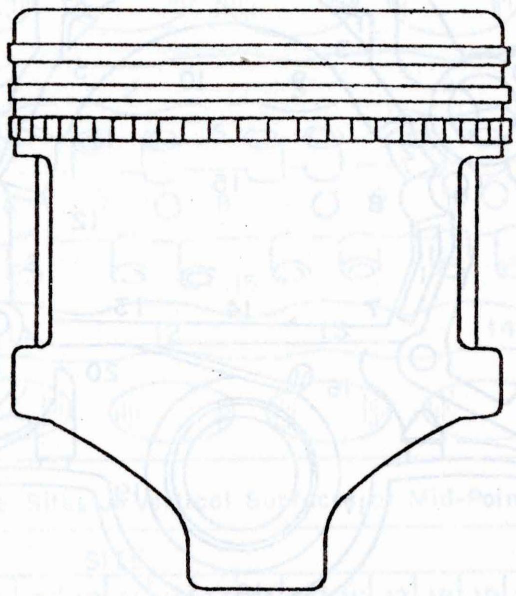
Inspector ERL

Date 5-78.

Sludge Merit Rating 9.5

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	CAM SIDE	OUT-SIDE	AVERAGE	CON. ROD BRGS APPEARANCE
Normal	Lt 1	6.5	5.8	6.2	2-scratches
#1 1% corr. #2 < 1% corr.	2	6.4	6.0	6.2	Normal
Normal	3	6.5	6.0	6.3	Normal
#1 CR 2% corr #2 CR < 1% corr.	4	7.0	6.8	6.9	1-scratch
#1 2% corr. #2 < 1% corr.	Rt 1	5.9	6.0	6.0	1-scratch
#2 1% corr.	2	6.6	6.4	6.5	Normal
Normal	3	6.5	6.5	6.5	Normal
Normal	4	6.3	6.3	6.3	1-scratch
	TOTAL	51.7	59.8		
	AVERAGE	6.5	6.2		

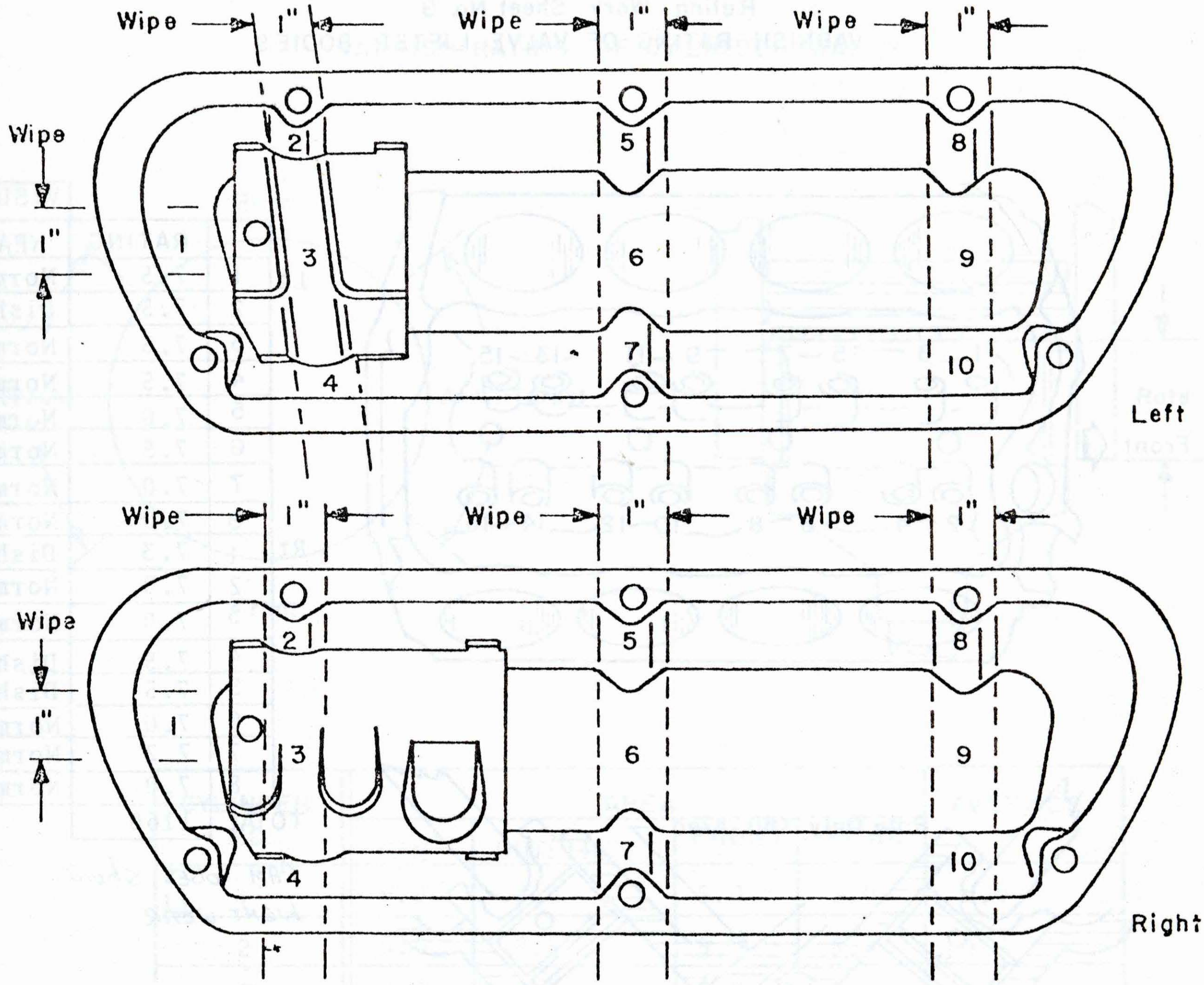
Inspector ____________

Date ____________

VARNISH RATING = $\frac{\text{AvgThrust + Avg Antithrust}}{2}$ = 6.4

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



Left

AREA	RATING
1	3.0
2	3.5
3	3.5
4	4.5
5	4.0
6	4.0
7	6.0
8	4.5
9	4.5
10	4.5
TOTAL	410

Right

AREA	RATING
1	3.5
2	2.5
3	3.0
4	3.0
5	2.0
6	2.5
7	3.5
8	4.0
9	3.5
10	3.5
TOTAL	310

$$\text{Avg. Varnish Rating} = \frac{\text{Left} + \text{Right}}{2} = 3.6$$

$$\text{Varnish Rating} = \frac{\text{Total}}{10} = 4.1$$

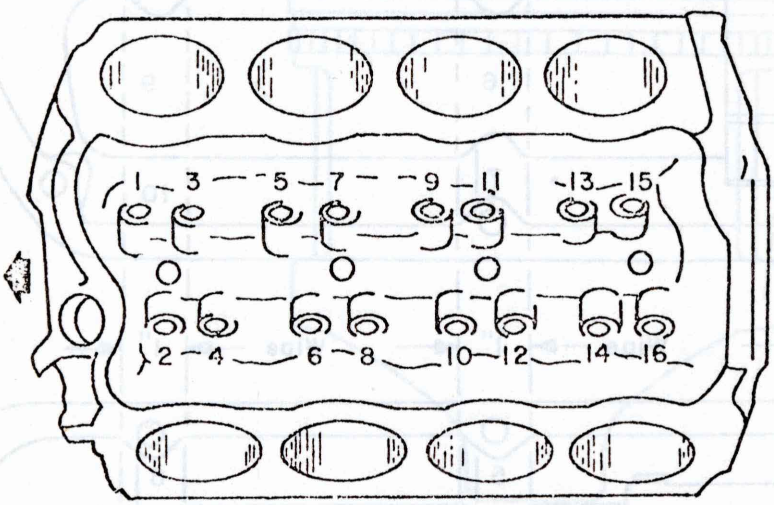
Inspector ERL

Date 5-78

$$\text{Varnish Rating} = \frac{\text{Total}}{10} = 3.1$$

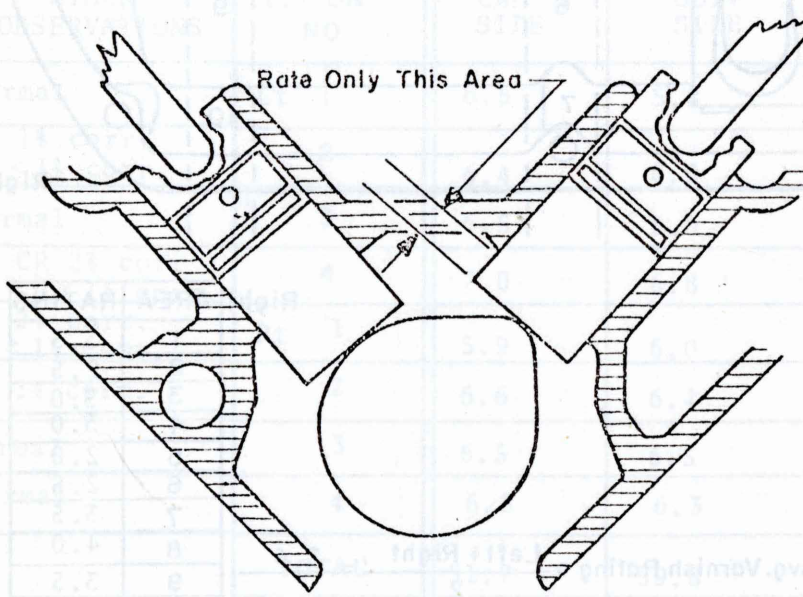
Rating Work Sheet No. 9

VARNISH RATING OF VALVE LIFTER BODIES



		RATING	VISUAL WEAR
Lt	1	7.5	Normal
	2	7.5	Dished
	3	7.5	Normal
	4	7.5	Normal
	5	7.0	Normal
	6	7.5	Normal
	7	7.0	Normal
	8	7.0	Normal
Rt	1	7.3	Dished
	2	7.0	Normal
	3	7.0	Normal
	4	7.5	Dished
	5	7.5	Dished
	6	7.0	Normal
	7	7.2	Normal
	8	7.0	Normal
TOTAL		1160	

CAM LOBES show LIGHT WEAR



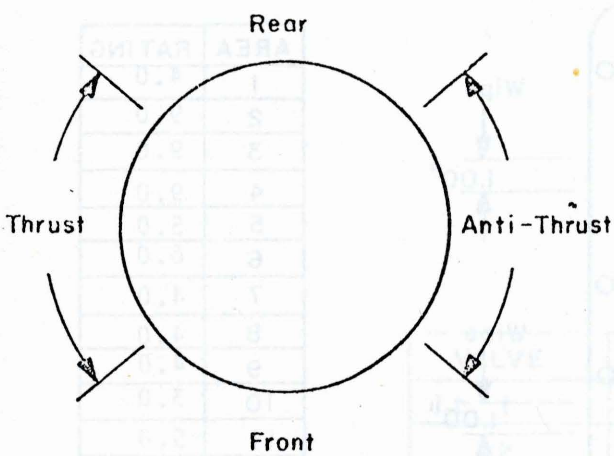
Inspector ERL

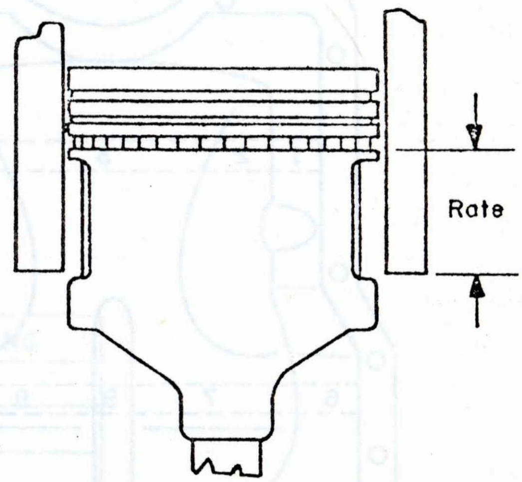
Date 5-78

Varnish Rating = $\frac{\text{Total}}{16}$ = 7.3

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





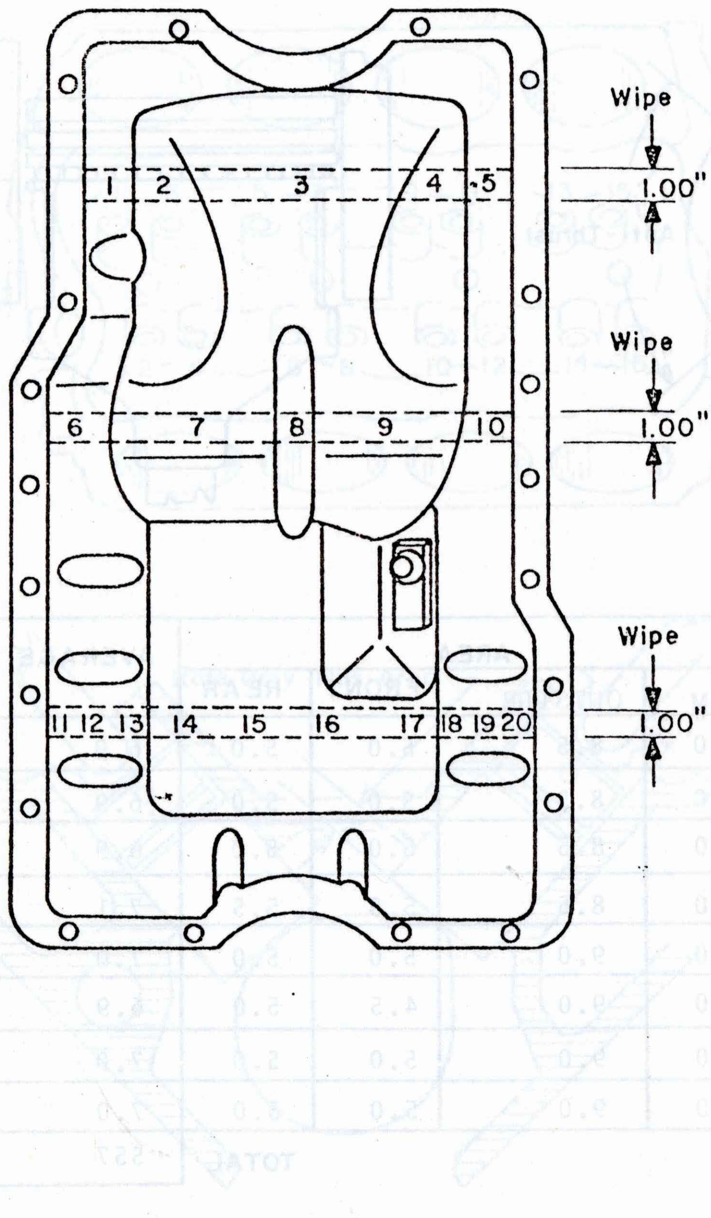
CYLINDER NO.		AREA				AVERAGE
		CAM	OUTSIDE	FRONT	REAR	
Lt	1	9.0	8.5	5.0	5.0	6.9
	2	9.0	8.5	5.0	5.0	6.9
	3	9.0	8.5	5.0	5.0	6.9
	4	9.0	8.5	5.5	5.5	7.1
Rt	1	9.0	9.0	5.0	5.0	7.0
	2	9.0	9.0	4.5	5.0	6.9
	3	9.0	9.0	5.0	5.0	7.0
	4	9.0	9.0	5.0	5.0	7.0
					TOTAL	557

Inspector ERL

Date 5-78

Varnish Rating $= \frac{\text{Total}}{8} =$ 7.0

Rating Work Sheet No. 11
VARNISH RATING OF OIL PAN



AREA	RATING
1	4.0
2	9.0
3	9.0
4	9.0
5	5.0
6	6.0
7	4.0
8	4.0
9	4.0
10	3.0
11	5.0
12	5.0
13	7.0
14	9.0
15	9.0
16	9.0
17	9.0
18	7.0
19	4.0
20	3.0
TOTAL	1240

Inspector ERL

Varnish Rating = $\frac{\text{Total}}{20}$ = 6.2

Date 5-78

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

VALVE	RATING
Lt 1	7.0
2	8.0
3	6.0
4	7.0
Rt 1	6.5
2	7.5
3	7.0
4	7.5
TOTAL	56.5

Visual Observation of Seat, recession, or burning: All normal

Avg. Rating = $\frac{\text{total}}{8}$ = 7.1

Inspector ERL

Date 5-78

Rating Work Sheet No. 11

VARNISH RATINGS OF OIL PAN

AREA	RATING
1	9.0
2	9.0
3	9.0
4	9.0
5	5.0
6	6.0
7	4.0
8	4.0
9	4.0
10	3.0
11	5.0
12	3.0
13	7.0
14	9.0
15	[illegible]
16	[illegible]
17	[illegible]
18	7.0
19	4.0
20	[illegible]
TOTAL	[illegible]

Inspector ERL

Varnish Rating = $\frac{\text{Total}}{20}$ = [illegible]

Date [illegible]-28

ENGINE INSPECTION SUMMARY

Vehicle I.D.:	A20369
Engine Type:	Ford F-750, 361 CID
Miles:	31,576
Oil Type:	MORCO Rerefined
Oil Drain Interval:	4000 mi

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	9.4	Piston Skirts	9.0
Intake Manifold	9.6	Rocker Arm Covers	5.3
Oil Pan	9.2	Valve Lifters	8.1
Valve Deck Area	9.4	Cylinder Wall (BRT)	9.5
Push Rod Chamber	9.7	Oil Pan	7.4
Timing Gear Cover	9.7		
AVG. SLUDGE	9.5	AVG. VARNISH	7.9

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	9.5
Stuck Compression Rings	0	Piston Varnish, Min.	8.6
Stuck Oil Rings	0	Intake Valve Deposits, Max.	8.0
		Intake Valve Deposits, Min.	5.5
		Intake Valve Deposits, Avg.	6.9

Clogging

Push Rods, No.	ND (solid design)
Oil Ring, %	< 1
Oil Screen, %	< 1

Observations, Comments

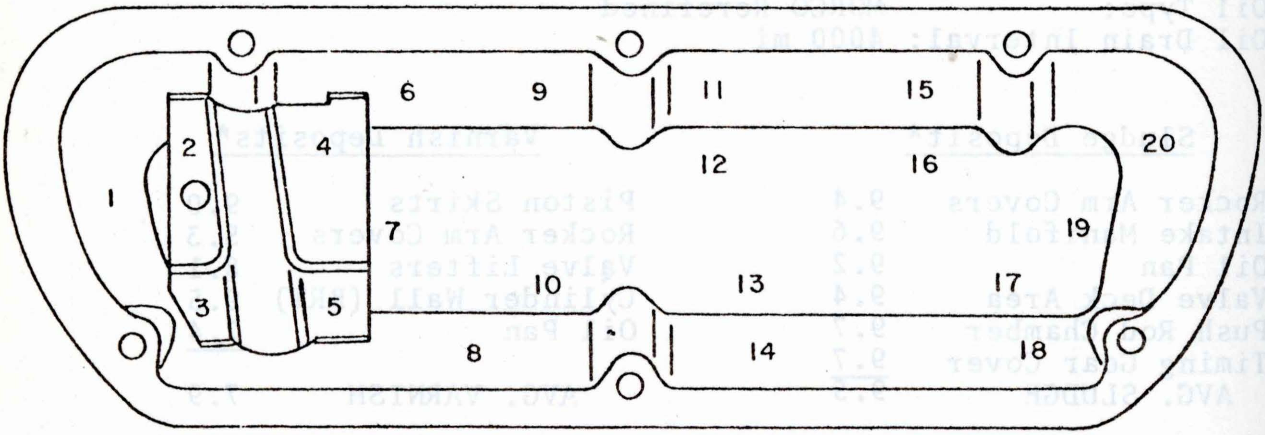
Virtually no rust on lifters, despite use of leaded gasoline.
Some dished valve lifters.
Very slight corrosion on 2 compression rings

Date: 5-78
Rater: E.R. Lyons

* 10=Clean
ND = Not determined

Rating Work Sheet No. I

SLUDGE RATING OF LEFT ROCKER ARM COVER



LEFT

Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A			x						x		x	x	x						x	x	7	35	.09
1/2A	x	x		x	x	x	x	x		x				x	x	x	x	x			13	65	.32
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.41

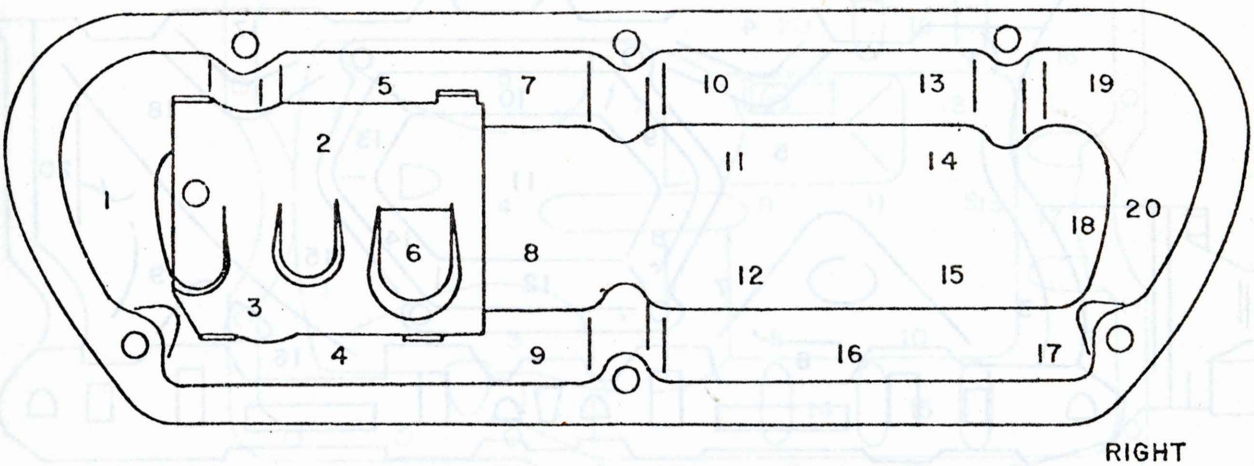
Inspector ERL

Sludge Merit Rating 9.6

Date 5-78

Rating Work Sheet No. Ia

SLUDGE RATING OF RIGHT ROCKER ARM COVER



Note Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x																				1	5	.01
1/2A			x			x			x		x	x		x	x		x	x		x	10	50	.25
3/4A																							
A		x		x	x		x	x		x			x			x			x		9	45	.45
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20		.71

Inspector ERL

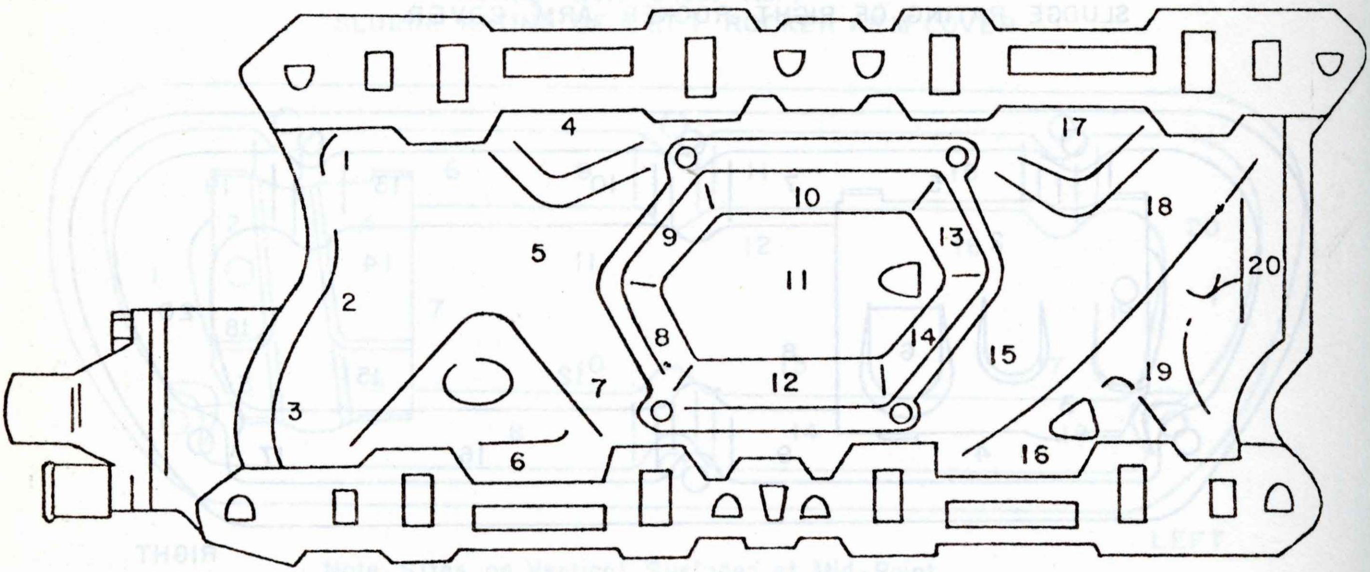
Date 5-78

Sludge Merit Rating 9.3

Avg. Sludge Merit Rating= $\frac{\text{Left+Right}}{2}$ = 9.4

Rating Work Sheet No. 2

SLUDGE RATING OF UNDERSIDE OF INTAKE MANIFOLD



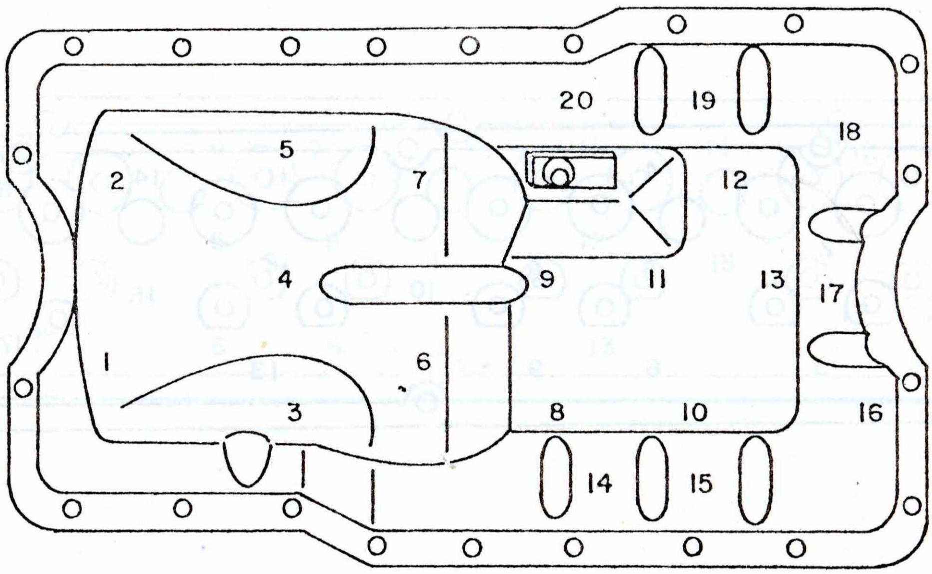
DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	16	80	.20
1/2A													x								1	5	.02
3/4A																							
A														x	x						2	10	.10
AB																							
B																x					1	5	.10
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.42

Inspector ERL

Date 5-78

Sludge Merit Rating 9.6

Rating Work Sheet No. 3
SLUDGE RATING OF OIL PAN



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTO
CLEAN																							
1/4A					x			x	x	x	x			x	x						7	35	.09
1/2A	x	x				x	x					x	x			x	x	x	x	x	11	55	.28
3/4A																							
A																							
AB																							
B				x																	1	5	.10
BC																							
C			x																		1	5	.20
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							.67

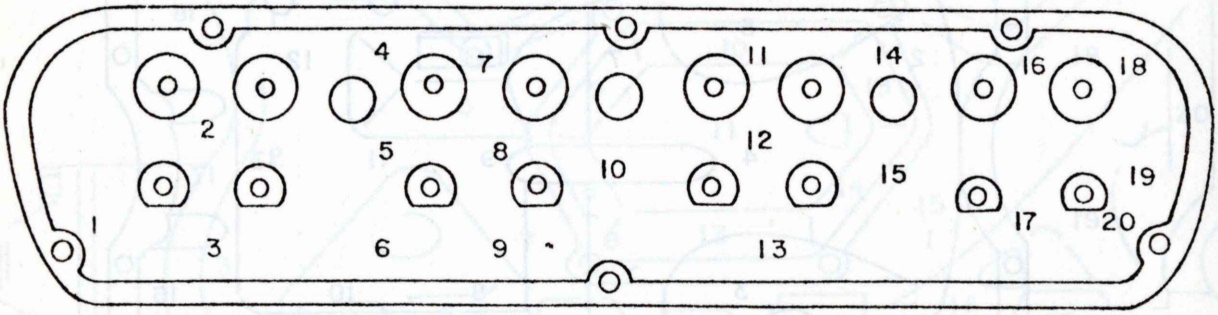
Inspector ERL

Sludge Merit Rating 9.2

Date 5-78

Rating Work Sheet No. 4

SLUDGE RATING OF LEFT VALVE DECK



Left

DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTO
CLEAN																							
1/4A		X			x		x	x		x	x	x		x	x	x		x	x		12	60	.15
1/2A																							
3/4A																							
A	x		x	x		x			x				x				x			x	8	40	.40
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.55

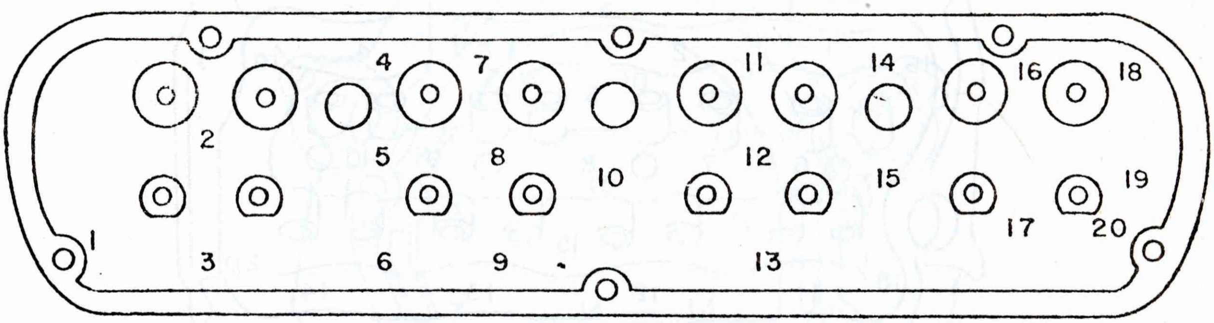
Inspector ERL

Date 5-78

Sludge Merit Rating 9.4

Rating Work Sheet No. 4a

SLUDGE RATING OF RIGHT VALVE DECK



Right

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A		x	x	x	x	x	x	x		x	x	x		x	x	x	x	x	x		16	80	.20
1/2A																							
3/4A																							
A									x				x							x	3	15	.15
AB																							
B	x																				1	5	.10
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.45

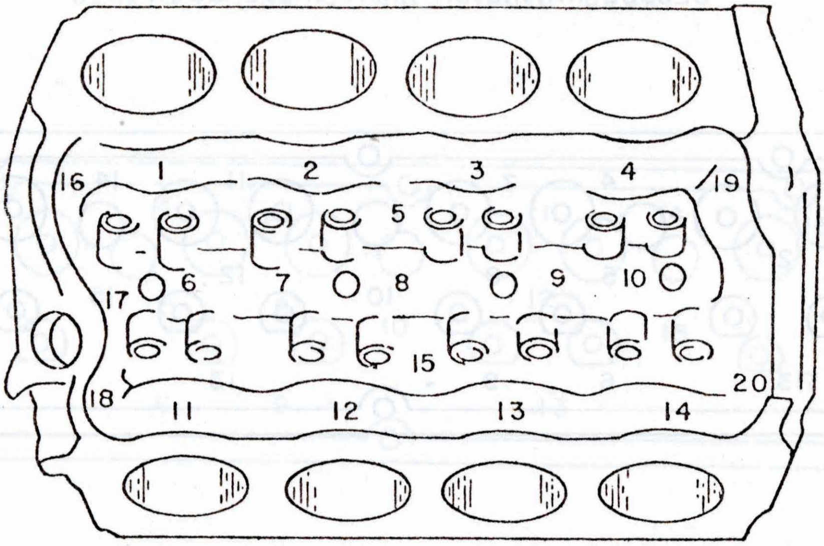
Inspector ERL

Date 5-78

Sludge Merit Rating 9.5

Avg. Sludge Merit Rating = $\frac{\text{Left+Right}}{2}$ 9.4

Rating Work Sheet No.5
SLUDGE RATING OF PUSH ROD CHAMBER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	19	95	.24
1/2A																							
3/4A																							
A										x											1	5	.05
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
																				GRAND TOTAL	20	100	.29

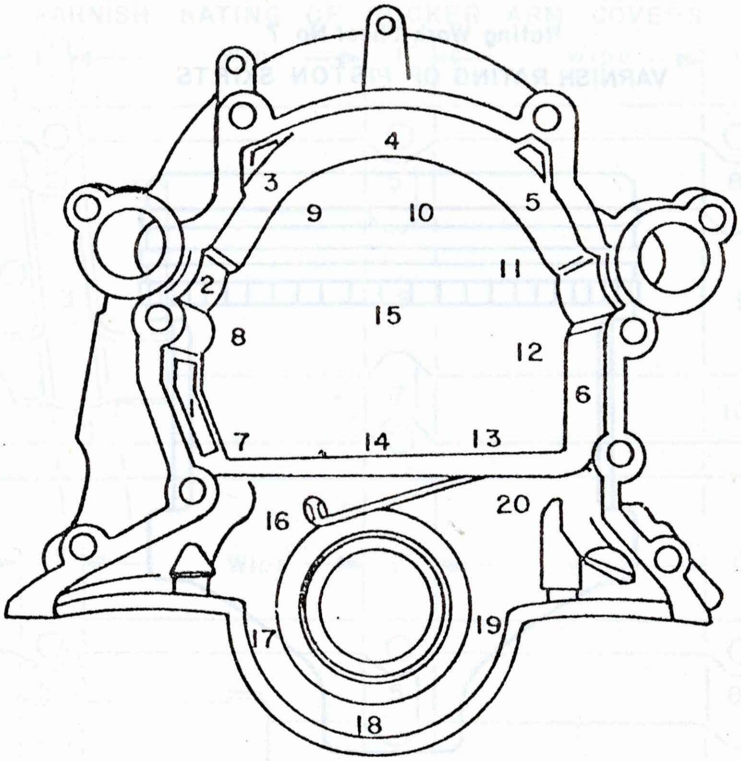
Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 6

SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTO
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

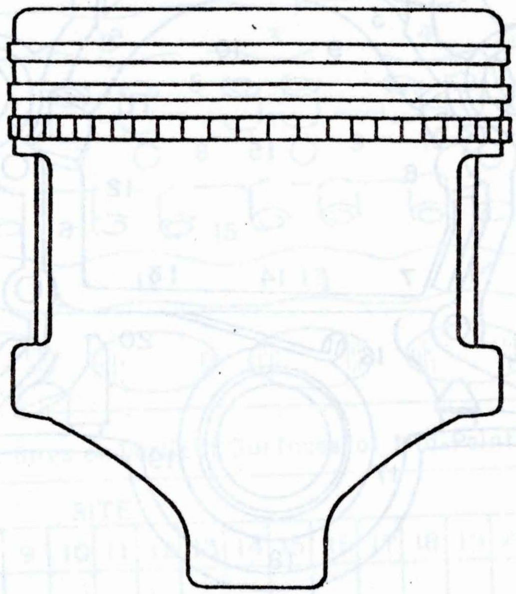
Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	CAM SIDE	OUT-SIDE	AVERAGE	CON. ROD BRGS APPEARANCE
OK	Lt 1	8.8	8.5	8.7	Normal
#1,2 CR < 1%corr	2	8.6	9.2	8.9	Normal
OK	3	8.8	9.0	8.9	Normal
OK	4	9.0	9.5	9.3	Normal
OK	Rt 1	9.5	9.0	9.3	Normal
OK	2	9.5	8.8	9.2	Normal
OK	3	9.4	8.8	9.1	Normal
OK	4	9.0	9.0	9.0	Normal
	TOTAL	72.6	71.8		
	AVERAGE	9.1	9.0		

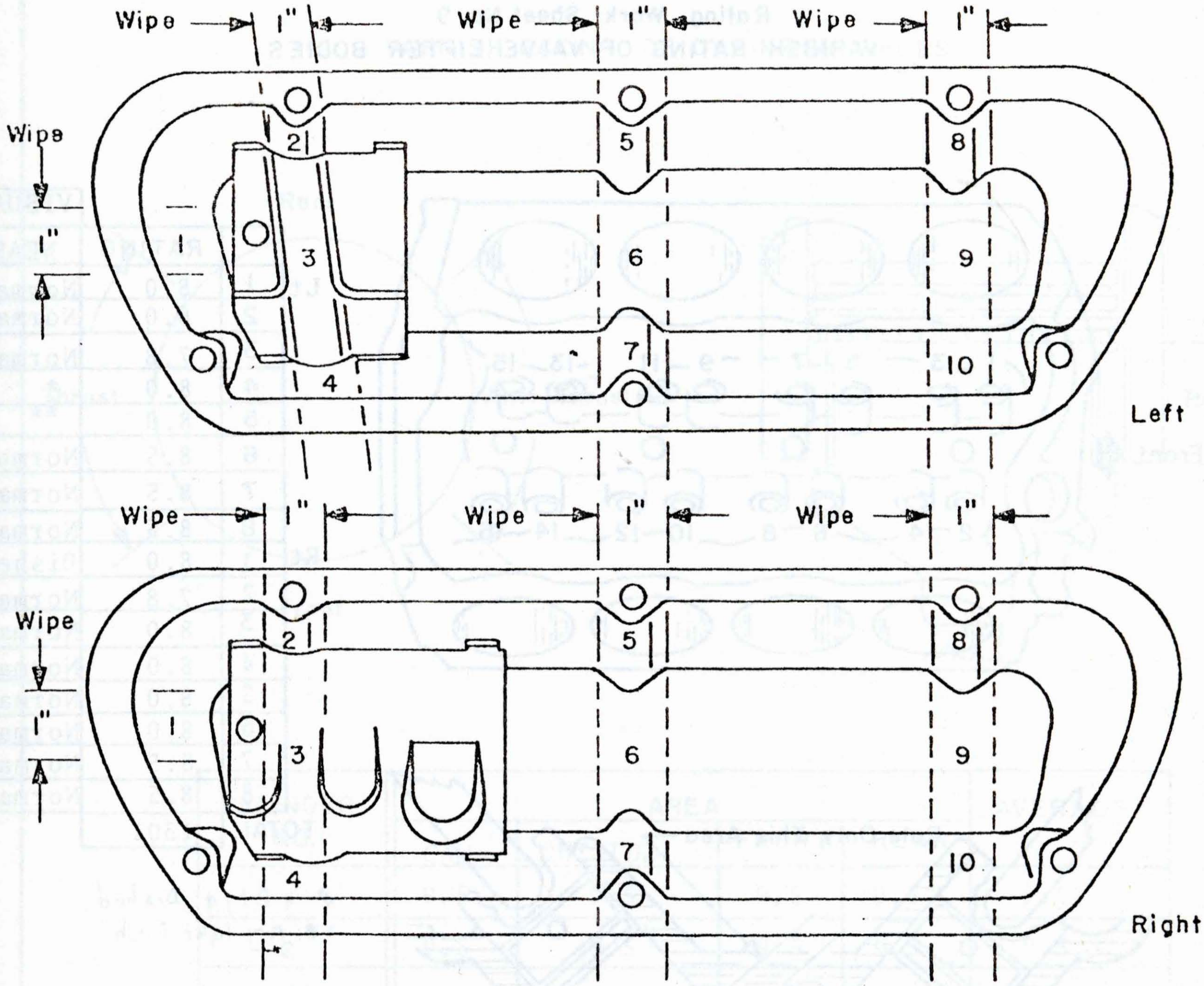
Inspector ____________

Date ____________

$$\text{VARNISH RATING} = \frac{\text{AvgThrust} + \text{Avg Antithrust}}{2} = 9.0$$

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



Left

AREA	RATING
1	6.0
2	5.5
3	7.0
4	6.0
5	2.5
6	5.0
7	6.5
8	6.5
9	6.0
10	6.0
TOTAL	57.0

Avg. Varnish Rating = $\frac{\text{Left + Right}}{2}$ = 5.3

Right

AREA	RATING
1	6.0
2	2.0
3	6.0
4	7.0
5	2.5
6	4.5
7	5.0
8	5.0
9	4.5
10	5.0
TOTAL	47.5

Varnish Rating = $\frac{\text{Total}}{10}$ = 5.7

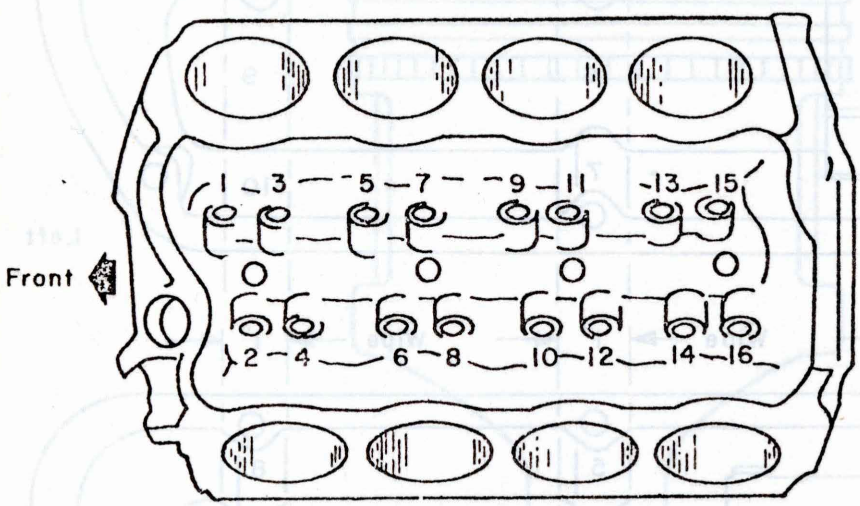
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{10}$ = 4.8

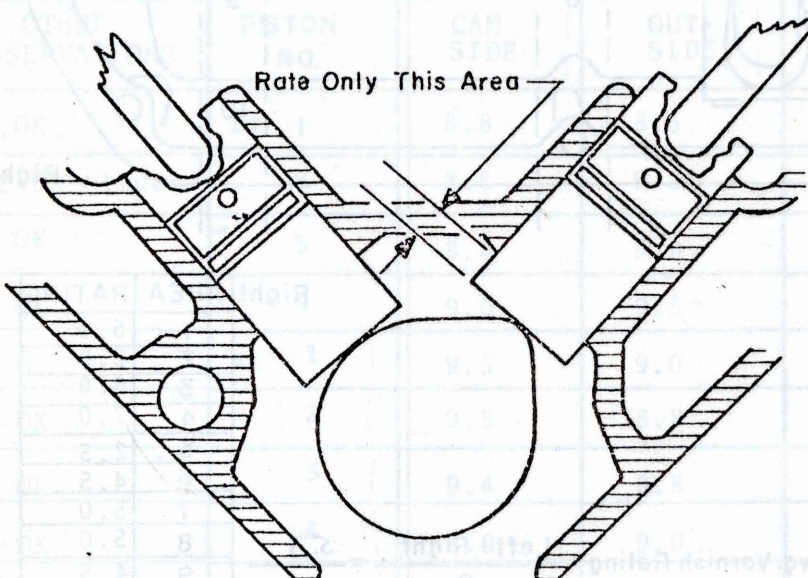
Rating Work Sheet No. 9

VARNISH RATING OF VALVE LIFTER BODIES



		RATING	VISUAL WEAR
Lt	1	8.0	Normal
	2	8.0	Normal
	3	7.8	Normal
	4	8.0	*
	5	8.0	**
	6	8.5	Normal
	7	8.5	Normal
	8	8.5	Normal
Rt	1	8.0	Dished
	2	7.8	Normal
	3	8.0	Normal
	4	8.0	Normal
	5	8.0	Normal
	6	8.0	Normal
	7	8.5	Normal
	8	8.5	Normal
TOTAL		1301	

* 1 Pit & Dished
** very light Dish



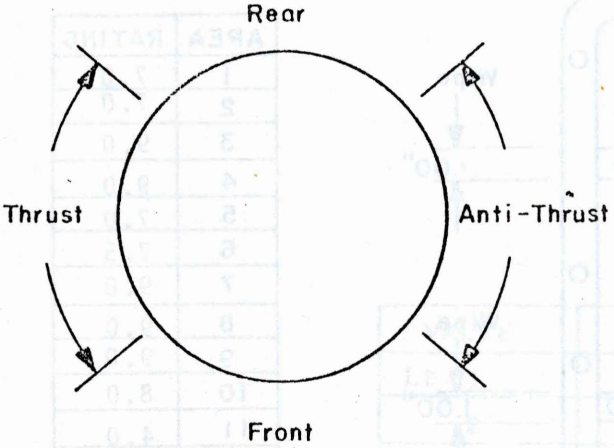
Inspector ERL

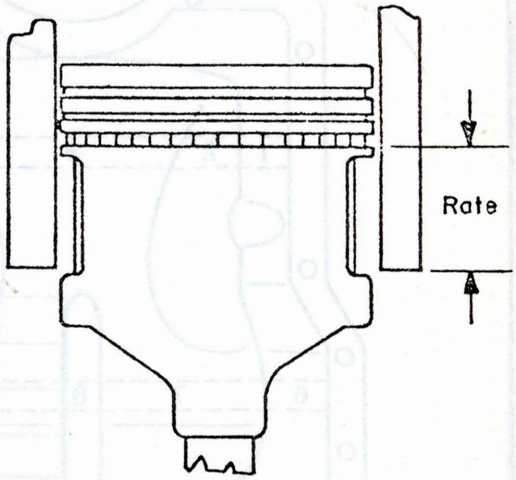
Varnish Rating = $\frac{\text{Total}}{16}$ = 8.1

Date 5-78

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.	AREA				AVERAGE
	CAM	OUTSIDE	FRONT	REAR	
Lt 1	9.5	9.5	9.5	9.5	9.5
2	9.5	9.5	9.5	9.5	9.5
3	9.5	9.5	9.5	9.5	9.5
/ SCOPE MARK → 4	9.5	9.5	9.5	9.5	9.5
Rt 1	9.5	9.5	8.5	9.5	9.3
2	9.5	9.5	9.5	9.5	9.5
3	9.5	9.5	9.5	9.5	9.5
4	9.5	9.5	9.5	9.5	9.5
				TOTAL	9.5

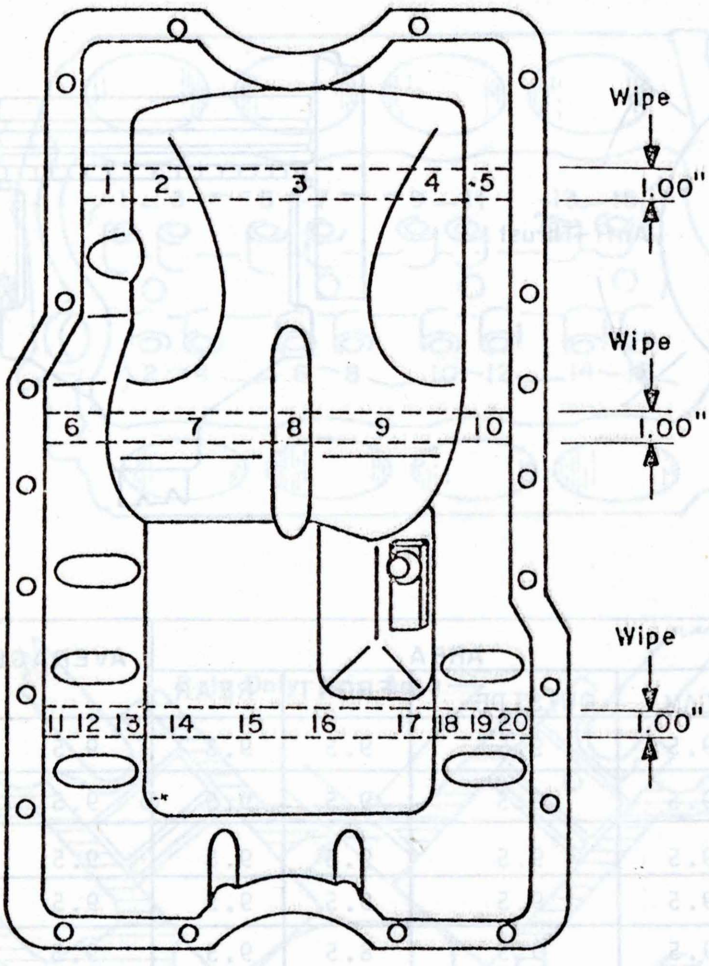
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 9.5

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	7.0
2	7.0
3	9.0
4	9.0
5	7.0
6	7.5
7	9.0
8	9.0
9	9.0
10	8.0
11	4.0
12	6.0
13	8.0
14	9.0
15	9.0
16	9.0
17	8.0
18	4.0
19	4.0
20	4.0
TOTAL	1475

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{20}$ = 7.4

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

VALVE	RATING
Lt 1	7.0
2	6.0
3	8.0
4	8.0
Rt 1	8.0
2	5.5
3	6.0
4	6.5
TOTAL	550

Visual Observation of Seat, recession, or burning: All OK

Avg. Rating = $\frac{\text{total}}{8}$ = 6.9

Inspector ERL

Date 5-78

ENGINE INSPECTION SUMMARY

Vehicle I.D.: A 18716
Engine Type: Dodge, 225 CID
Miles: 63,910
Oil Type: Virgin Base Stock
Oil Drain Interval: 10,000 mi

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	8.3	Piston Skirts	5.7
Intake Manifold	NA	Rocker Arm Covers	4.8
Oil Pan	9.1	Valve Lifters	7.6
Valve Deck Area	9.7	Cylinder Wall (BRT)	5.1
Push Rod Chamber	NA	Oil Pan	5.1
Timing Gear Cover	8.6		
AVG. SLUDGE	8.9	AVG. VARNISH	5.7

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	6.2
Stuck Compression Rings	0	Piston Varnish, Min.	5.0
Stuck Oil Rings	0	Intake Valve Deposits, Max.	8.0
		Intake Valve Deposits, Min.	6.0
		Intake Valve Deposits, Avg.	6.5

Clogging

Push Rods, No. NA (Solid Design)
Oil Ring, % 0
Oil Screen, % 0

Observations, Comments

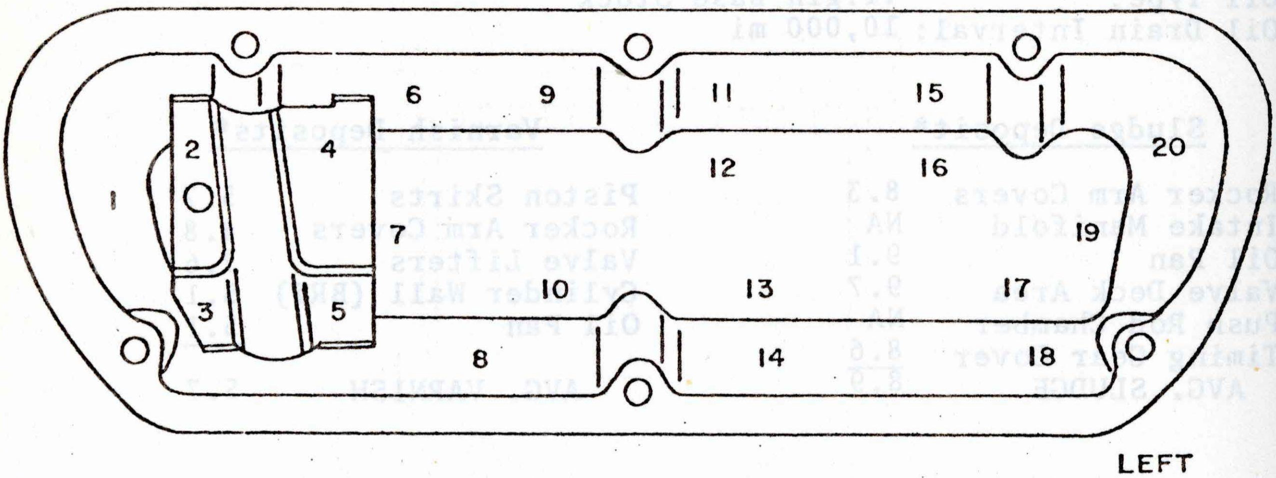
Light to medium scuffing, left side all pistons v.v. slight corrosion on 2 compression rings

Date: 5-78
Rater: E.R. Lyons

* 10=Clean
NA = Not applicable

Rating Work Sheet No. 1

SLUDGE RATING OF ROCKER ARM COVER



Note: Sites on Vertical Surfaces at Mid-Point

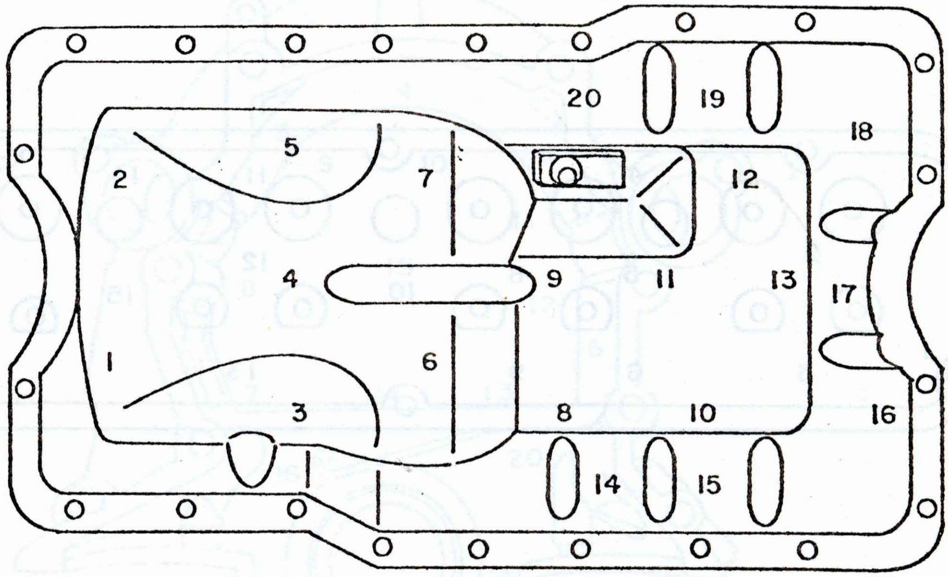
DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A											x										1	5	.01
1/2A				x		x			x												3	15	.08
3/4A																							
A		x			x			x				x		x	x	x		x	x	x	10	50	.50
AB																							
B			x							x			x				x				4	20	.40
BC																							
C	x						x														2	10	.40
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20		1.39

Sludge Merit Rating 8.3

Inspector ERL

Date 5-78

Rating Work Sheet No. 3
SLUDGE RATING OF OIL PAN



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACT
CLEAN																							
1/4A													x								1	5	.01
1/2A												x						x	x	x	4	20	.10
3/4A																							
A	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x				15	75	.75
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							.86

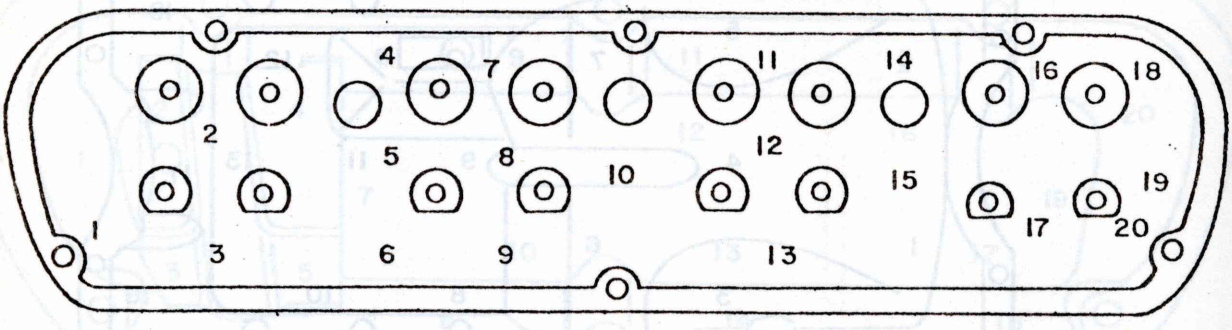
Inspector ERL

Date 5-78

Sludge Merit Rating 9.1

Rating Work Sheet No. 4

SLUDGE RATING OF VALVE DECK



Left

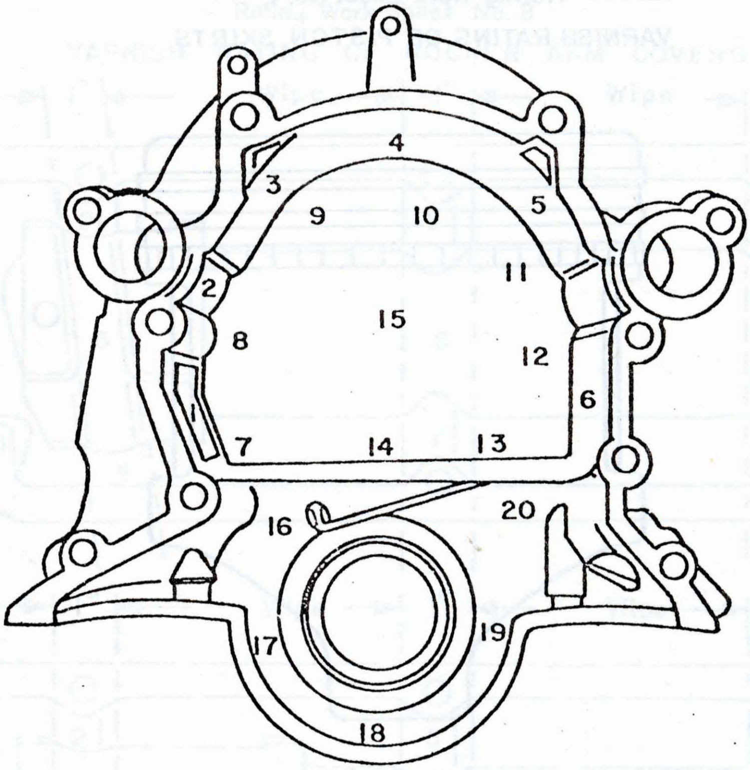
DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOR
CLEAN																							
1/4A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No.6
SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOR
CLEAN																							
1/4A																							
1/2A																							
3/4A																							
A					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16	80	.80
AB																							
B	x	x	x	x																	4	20	.40
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	1.20

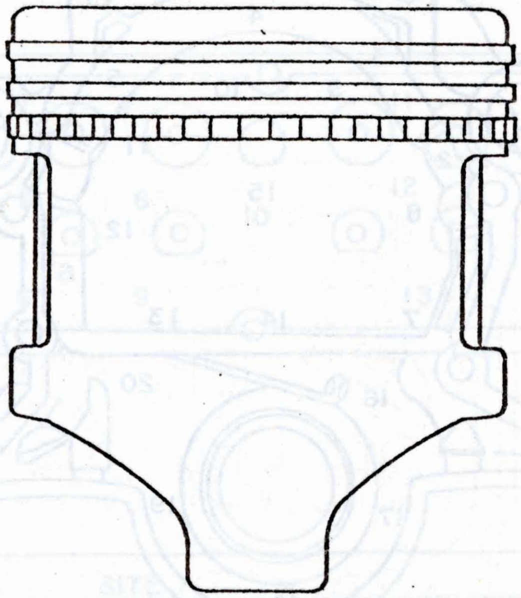
Inspector ERL

Date 5-78.

Sludge Merit Rating 8.6

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	LEFT	RIGHT	AVERAGE	CON. ROD BRGS APPEARANCE
#2CR< 1% corr, Lt scuff (left)	1	6.0	6.0	6.0	Normal
#2CR< 1% corr-Lt scuff left side	2	5.4	6.2	5.8	Normal
Lt scuff left side	3	5.2	5.6	5.4	Normal
Lt scuff left side	4	5.0	5.6	5.3	Normal
Med scuff left side	5	5.2	5.6	5.4	Normal
Lt scuff left side	6	5.8	6.2	6.0	Normal
	TOTAL	32.6	35.2		
	AVERAGE	5.4	5.9		

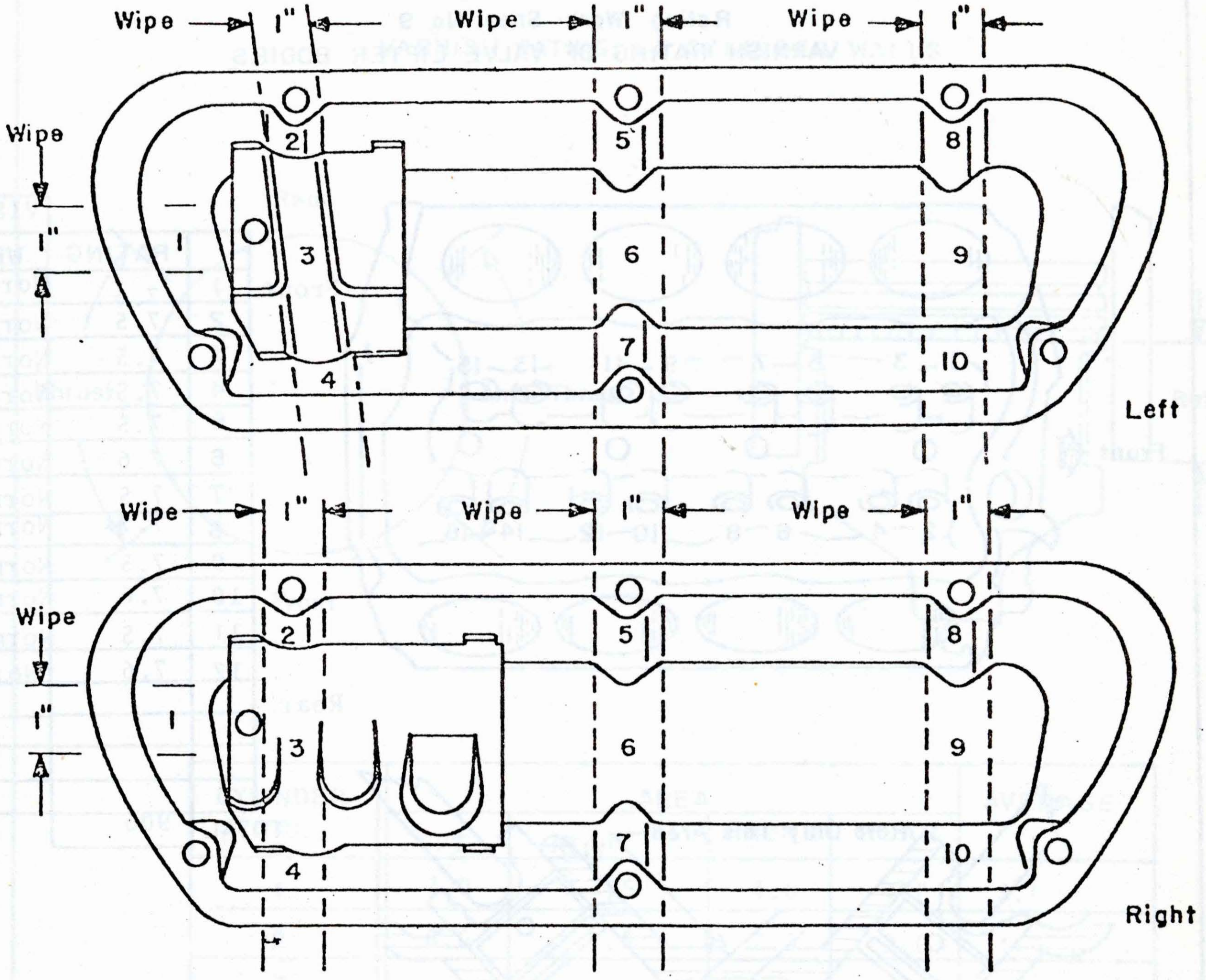
Inspector ______________

Date ______________

VARNISH RATING = $\frac{\text{Avg Thrust} + \text{Avg Antithrust}}{2}$ = 5.7

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



AREA	RATING
1	3.5
2	6.0
3	7.0
4	3.0
5	4.0
6	3.0
7	3.0
8	6.0
9	8.0
10	4.5
TOTAL	

Avg. Varnish Rating = $\frac{\text{Left + Right}}{2}$ = ______

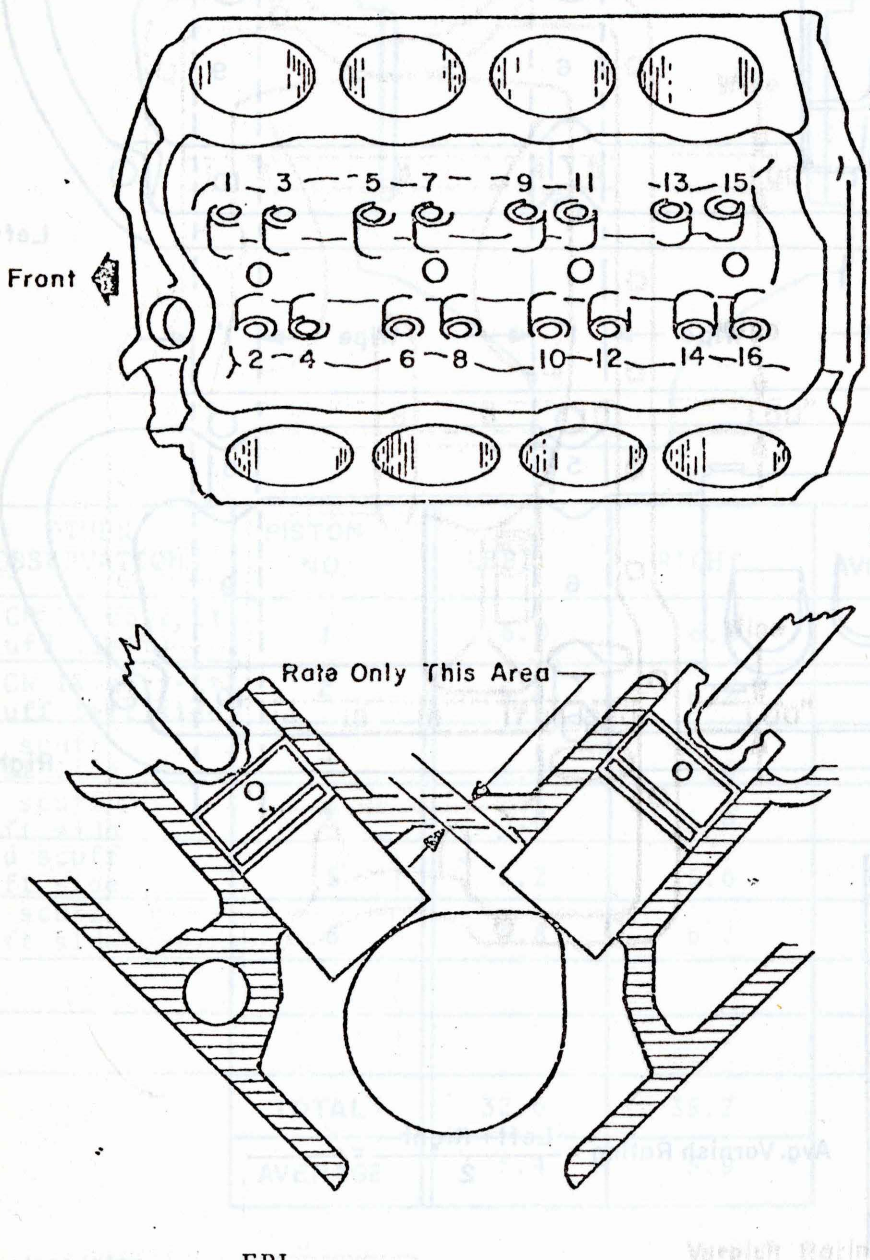
Varnish Rating = $\frac{\text{Total}}{10}$ = 4.8

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{10}$ = ______

Rating Work Sheet No. 9
VARNISH RATING OF VALVE LIFTER BODIES



	RATING	VISUAL WEAR
Front: 1	7.6	Normal
2	7.5	Normal
3	7.5	Normal
4	7.5	Normal
5	7.5	Normal
6	7.6	Normal
7	7.5	Normal
8	7.7	Normal
9	7.5	Normal
10	7.6	Normal
11	7.5	Normal
12	7.6	Norma
Rear		
TOTAL	906	

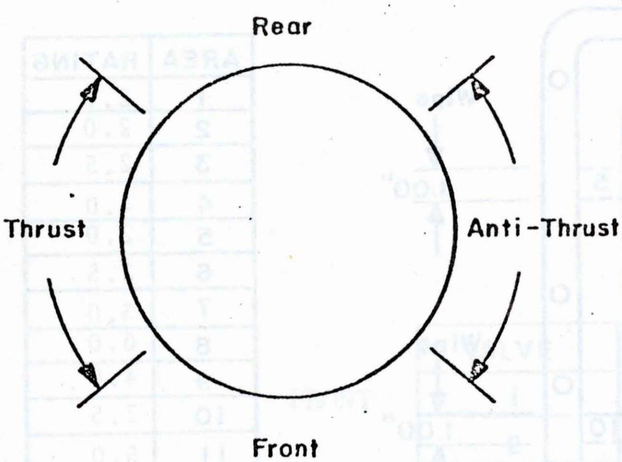
Inspector ERL

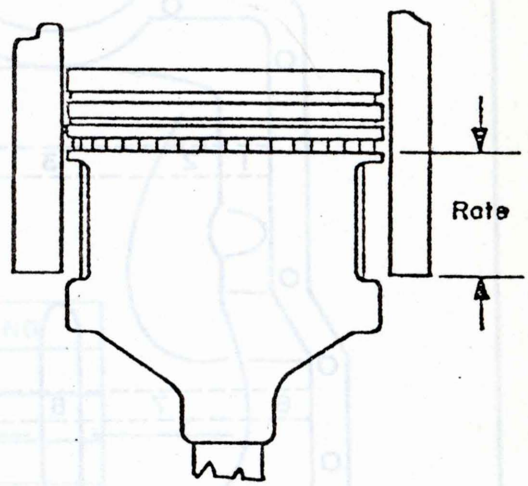
Date 5-78

Varnish Rating = $\frac{\text{Total}}{16}$ = 7.6

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.	AREA				AVERAGE
	LEFT	RIGHT	FRONT	REAR	
1	7.0	7.5	4.0	4.0	5.6
2	8.0	7.5	2.0	2.0	4.9
3	8.0	8.0	2.0	2.0	5.0
4	7.5	7.5	2.0	2.0	4.8
5	8.0	7.5	2.0	2.0	4.9
6	8.0	8.0	2.5	2.5	5.3
				TOTAL	305

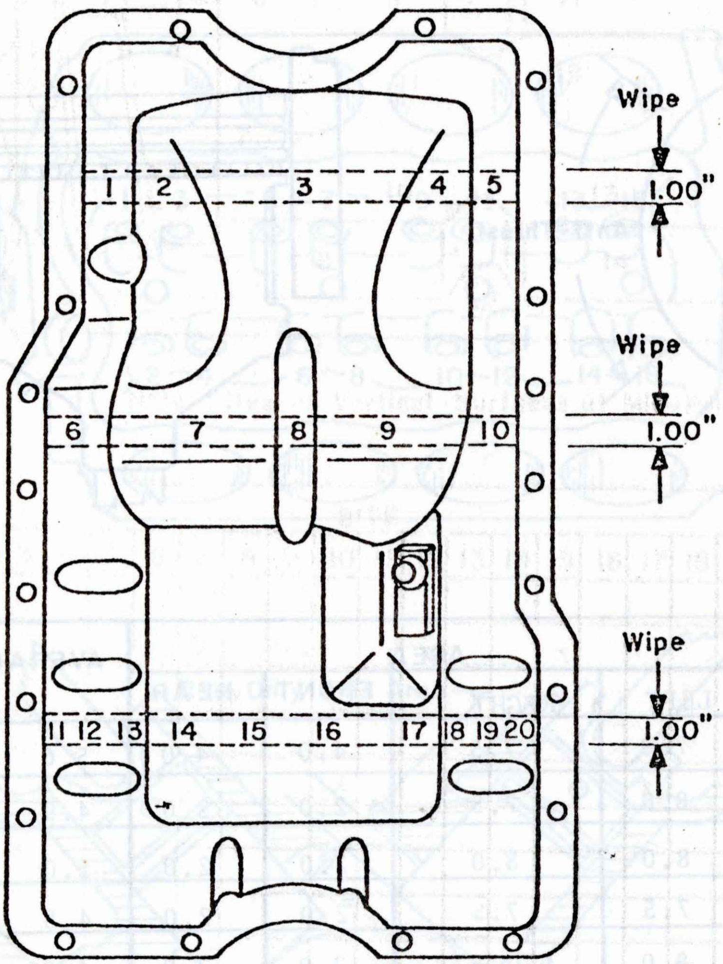
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 5.1

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	2.0
2	2.0
3	2.5
4	4.0
5	2.0
6	2.5
7	3.0
8	6.0
9	4.0
10	2.5
11	5.0
12	5.0
13	5.0
14	9.0
15	9.0
16	9.0
17	9.0
18	8.5
19	8.5
20	4.0
TOTAL	1025

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{20}$ = 5.1

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

	VALVE	RATING
FRONT	1	8.0
	2	6.5
	3	6.0
	4	6.0
	5	6.0
	6	6.5
REAR		
	TOTAL	390

Visual Observation of Seat, recession, or burning; ALL OK

Avg. Rating $= \frac{\text{total}}{8} = 6.5$

Inspector ERL

Date 5-78

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN

AREA	RATING
1	2.0
2	2.0
3	2.5
4	4.0
5	2.0
6	2.5
7	3.0
8	6.0
9	4.0
10	2.5
11	5.0
12	5.0
13	5.0
14	9.0
15	9.0
16	9.0
17	9.0
18	8.5
19	8.5
20	4.0
TOTAL	1025

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{20}$ = 5.1

ENGINE INSPECTION SUMMARY

Vehicle I.D.:	A18710
Engine Type:	Dodge 225 CID
Miles:	25,617
Oil Type:	MORCO Rerefined
Oil Drain Interval:	10,000 mi.

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	9.5	Piston Skirts	9.0
Intake Manifold	NA	Rocker Arm Covers	7.0
Oil Pan	9.7	Valve Lifters	9.5
Valve Deck Area	9.7	Cylinder Wall (BRT)	9.1
Push Rod Chamber	NA	Oil Pan	7.6
Timing Gear Cover	9.3		
AVG. SLUDGE	9.6	AVG. VARNISH	8.4

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	9.8
Stuck Compression Rings	0	Piston Varnish, Min.	7.9
Stuck Oil Rings	0	Intake Valve Deposits, Max.	9.0
		Intake Valve Deposits, Min.	6.0
		Intake Valve Deposits, Avg.	7.7

Clogging

Push Rods, No.	NA (solid design)
Oil Ring, %	< 1
Oil Screen, %	< 1

Observations, Comments

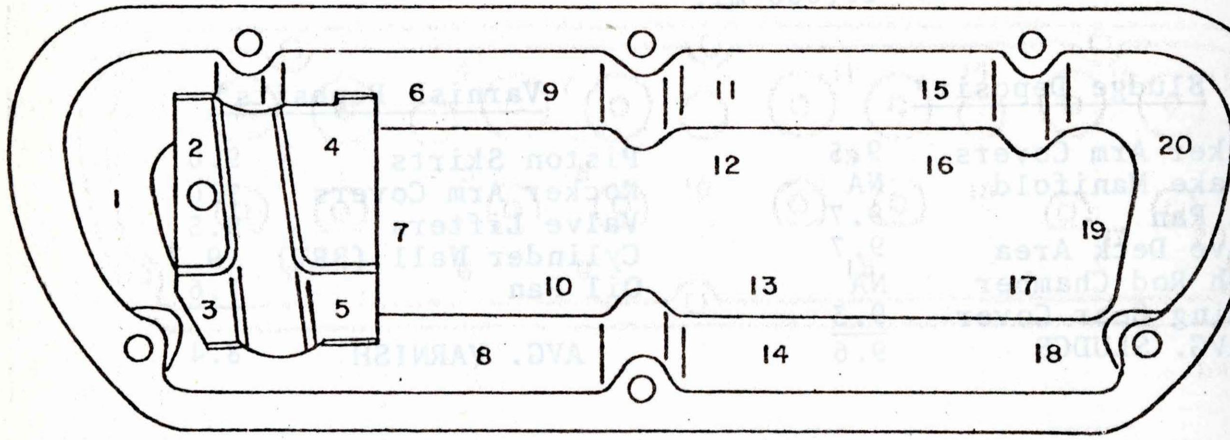
Light to medium scuffing all pistons, left side
Several compression rings with very slight corrosion

Date: 5-78
Rater: E.R. Lyons

* 10=Clean
NA = Not Applicable

Rating Work Sheet No. 1

SLUDGE RATING OF ROCKER ARM COVER



LEFT

Note: Sites on Vertical Surfaces at Mid-Point

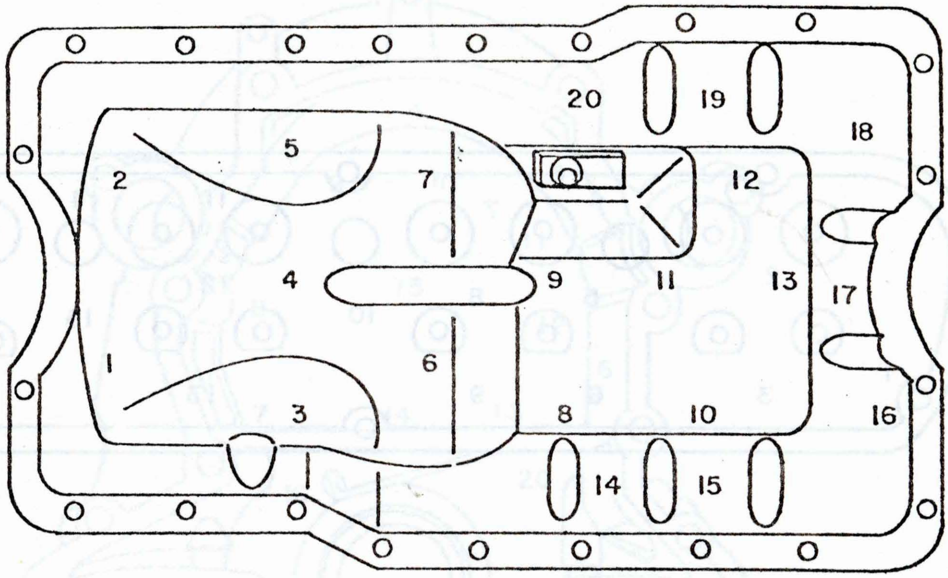
DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A				x		x	x		x		x	x			x						7	35	.09
1/2A			x		x			x					x	x		x		x		x	8	40	.20
3/4A																							
A	x	x								x							x		x		5	25	.25
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.54

Inspector ERL

Sludge Merit Rating 9.5

Date 5-78

Rating Work Sheet No. 3
SLUDGE RATING OF OIL PAN



DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACTO
CLEAN																							
1/4A		x		x	x		x	x	x	x	x	x	x					x	x	x	13	65	.16
1/2A	x		x			x								x	x	x	x				7	35	.18
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.34

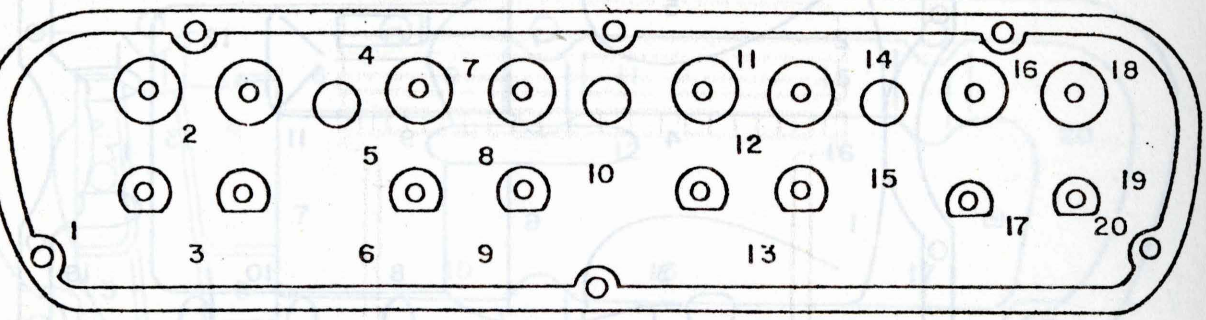
Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Rating Work Sheet No. 4

SLUDGE RATING OF VALVE DECK



Left

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTO
CLEAN																							
1/4A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

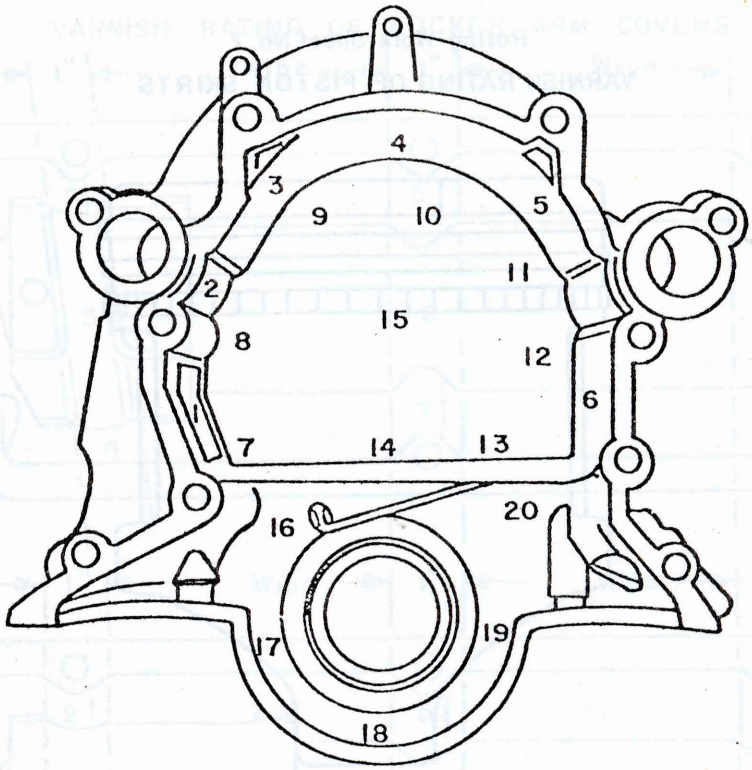
Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 6

SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOR
CLEAN																							
1/4A													x	x		x	x	x	x	x	7	35	.09
1/2A																							
3/4A																							
A	x	x	x	x	x	x	x	x	x	x	x	x			x						13	65	.65
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20		.74

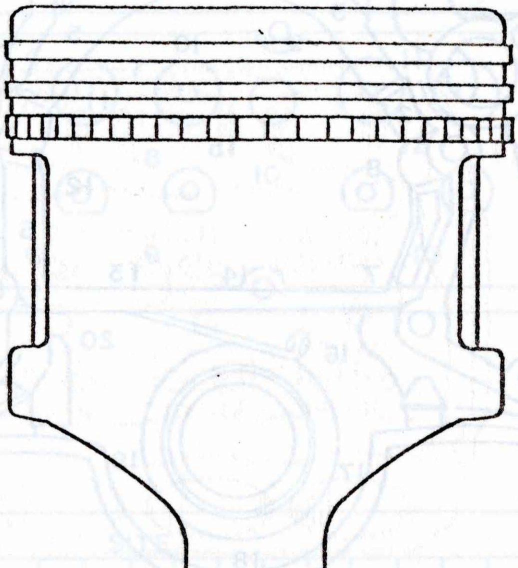
Inspector ERL

Date 5-78

Sludge Merit Rating 9.3

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	LEFT	RIGHT	AVERAGE	CON. ROD BRGS APPEARANCE
Lt Scuff-Left	1	9.8	9.8	9.8	Normal
Med. to Hvy Scuff Left	2	9.0	8.3	8.7	Normal
#2CR 1%Corr 1 cut mark *	3	8.7	7.9	8.3	Lt Scratch
Lt to Med scuff 1 cut mark	4	9.0	8.8	8.9	Lt scratch
#2CR 1%corr Med scuff-L	5	9.3	9.0	9.2	Scratches
#2CR < 1% corr Lt scuff-L	6	9.0	8.9	9.0	Normal
	TOTAL	54.8	52.7		
	AVERAGE	9.1	8.8		

* Med to Lt Scuff - L

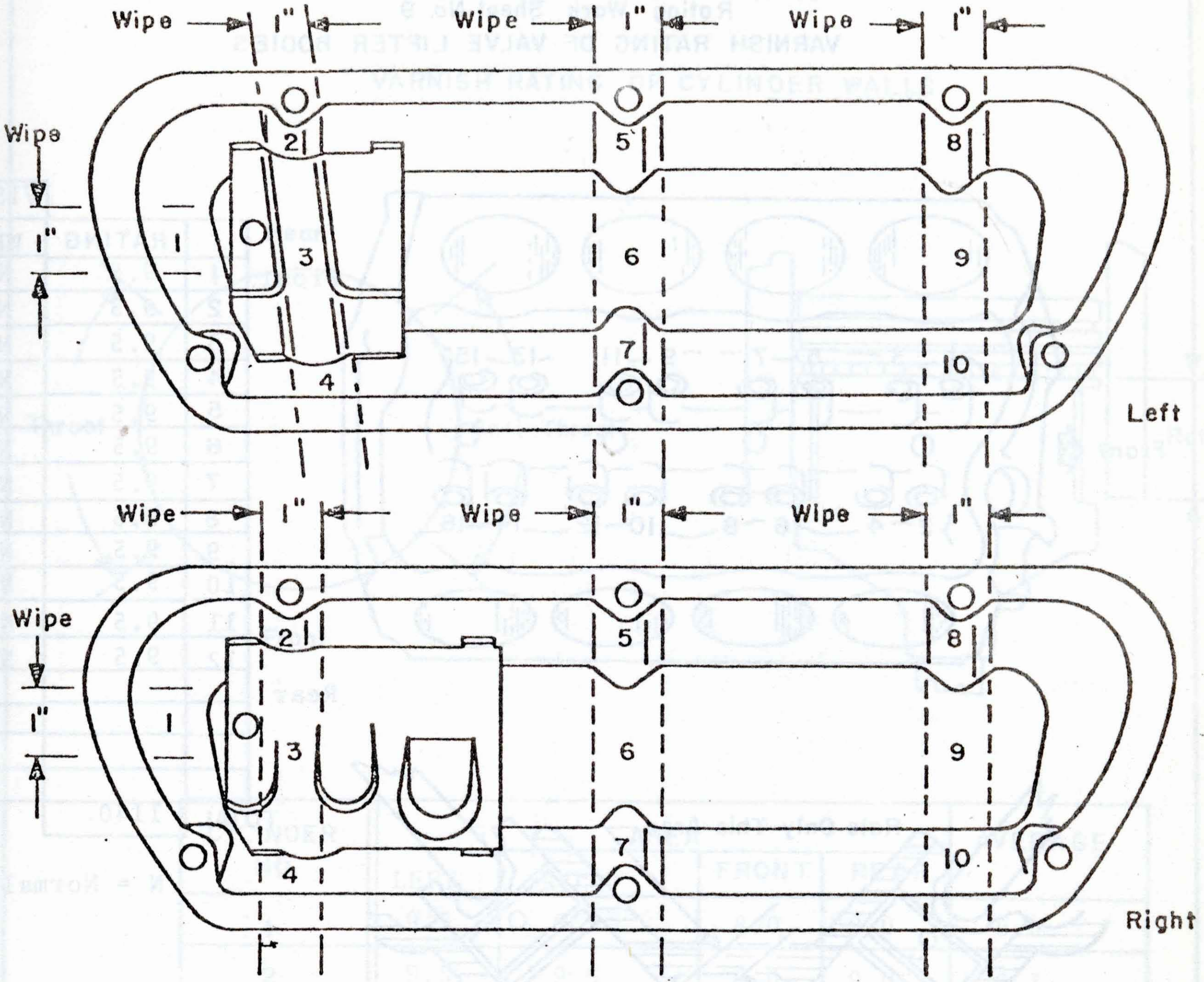
Inspector ____________

Date ____________

$$\text{VARNISH RATING} = \frac{\text{AvgThrust} + \text{Avg Antithrust}}{2} = 9.0$$

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



AREA	RATING
1	7.0
2	8.0
3	8.0
4	7.0
5	7.0
6	5.0
7	6.0
8	7.0
9	8.0
10	7.0
TOTAL	700

Avg. Varnish Rating = $\frac{\text{Left} + \text{Right}}{2}$ = ______

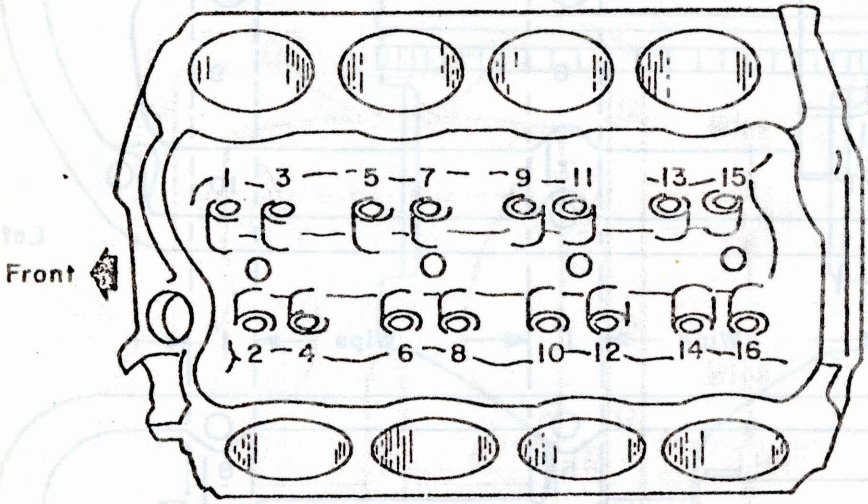
Varnish Rating = $\frac{\text{Total}}{10}$ = 7.0

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{10}$ = ______

Rating Work Sheet No. 9
VARNISH RATING OF VALVE LIFTER BODIES

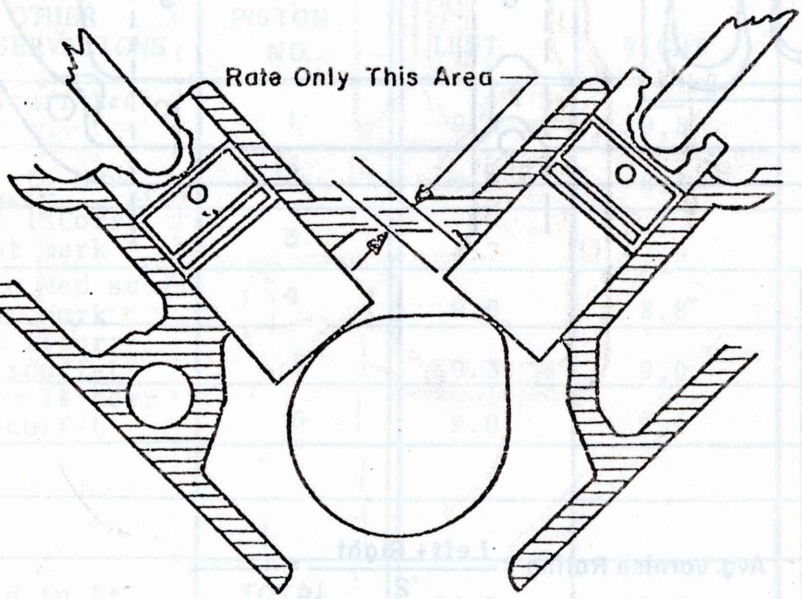


Front:

	RATING	VISUAL WEAR
1	9.5	N
2	9.5	N
3	9.5	N
4	9.5	N
5	9.5	N
6	9.5	N
7	9.5	N
8	9.5	N
9	9.5	N
10	9.5	N
11	9.5	N
12	9.5	N
TOTAL	1140	

Rear

N = Normal



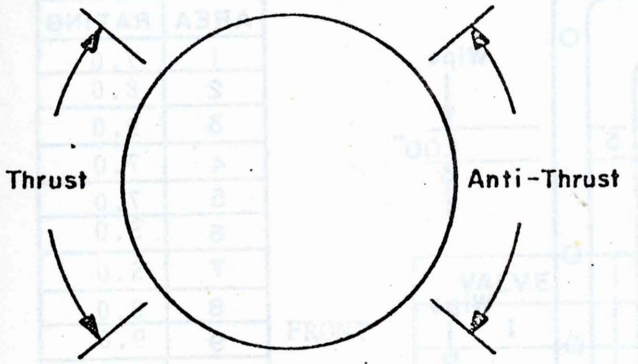
Inspector ERL

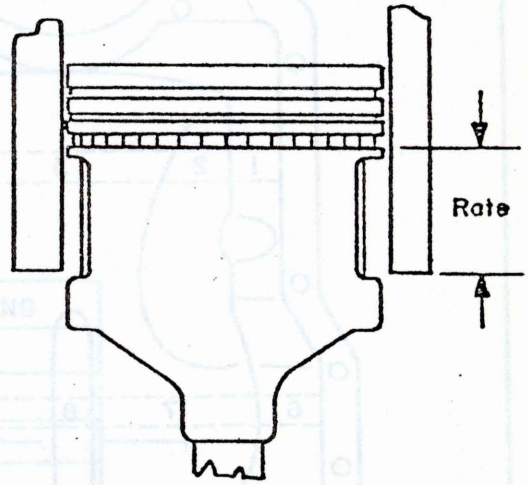
Date 5-78

Varnish Rating = $\frac{\text{Total}}{16}$ = 9.5

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.	AREA				AVERAGE
	LEFT	RIGHT	FRONT	REAR	
1	9.5	9.5	8.0	9.0	9.0
2	9.5	9.5	9.0	9.0	9.3
3	9.5	9.5	8.0	9.0	9.0
4	9.5	9.5	8.5	9.0	9.1
5	9.5	9.5	8.5	8.5	9.0
6	9.5	9.5	9.0	9.0	9.3
				TOTAL	547

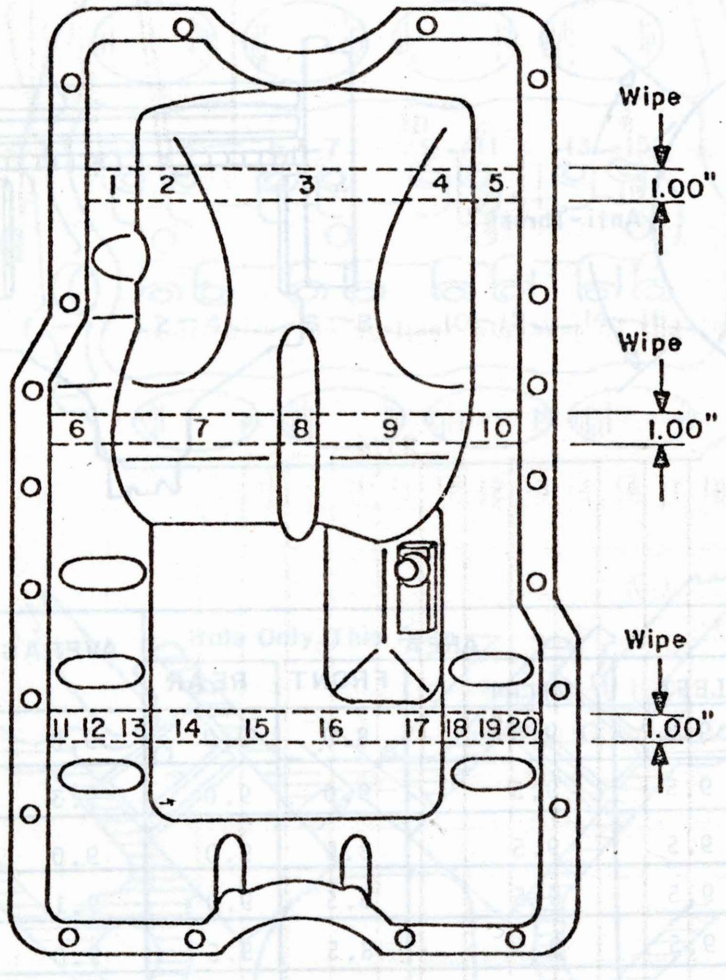
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 9.1

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	7.0
2	8.0
3	9.0
4	7.0
5	7.0
6	5.0
7	5.0
8	8.0
9	9.0
10	5.0
11	7.0
12	8.0
13	8.0
14	9.0
15	9.0
16	9.0
17	9.0
18	8.0
19	7.0
20	7.0
TOTAL	1510

Inspector ERL

Varnish Rating = $\frac{\text{Total}}{20}$ = 7.6

Date 5-78

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

	VALVE	RATING
FRONT	1	9.0
	2	7.5
	3	8.0
	4	8.0
	5	6.0
	6	7.5
REAR		
	TOTAL	460

Visual Observation of Seat, recession, or burning; All ok

Avg. Rating= $\frac{\text{total}}{8}$ = 7.7

Inspector ERL

Date 5-78

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN

AREA	RATING
1	[illegible]
2	[illegible]
3	[illegible]
4	[illegible]
5	[illegible]
6	[illegible]
7	[illegible]
8	[illegible]
9	[illegible]
10	[illegible]
11	[illegible]
12	[illegible]
13	[illegible]
14	[illegible]
15	[illegible]
16	[illegible]
17	[illegible]
18	[illegible]
19	[illegible]
20	[illegible]
TOTAL	[illegible]

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{20}$ = 7.0

ENGINE INSPECTION SUMMARY

Vehicle I.D.:	A18729
Engine Type:	Dodge 225 CID
Miles:	31,950
Oil Type:	Virgin Base Stock
Oil Drain Interval:	8.000 miles

Sludge Deposit*

Rocker Arm Covers	9.2
Intake Manifold	NA
Oil Pan	9.2
Valve Deck Area	9.7
Push Rod Chamber	NA
Timing Gear Cover	9.1
AVG. SLUDGE	9.3

Varnish Deposits*

Piston Skirts	6.1
Rocker Arm Covers	5.0
Valve Lifters	8.9
Cylinder Wall (BRT)	6.7
Oil Pan	5.5
AVG. VARNISH	6.4

Additional Ratings*

Stuck Valve Lifters	0
Stuck Compression Rings	0
Stuck Oil Rings	0
Piston Varnish, Max.	6.5
Piston Varnish, Min.	5.5
Intake Valve Deposits, Max.	8.0
Intake Valve Deposits, Min.	7.0
Intake Valve Deposits, Avg.	7.4

Clogging

Push Rods, No. NA (solid design)
Oil Ring, % 0
Oil Screen, % 0

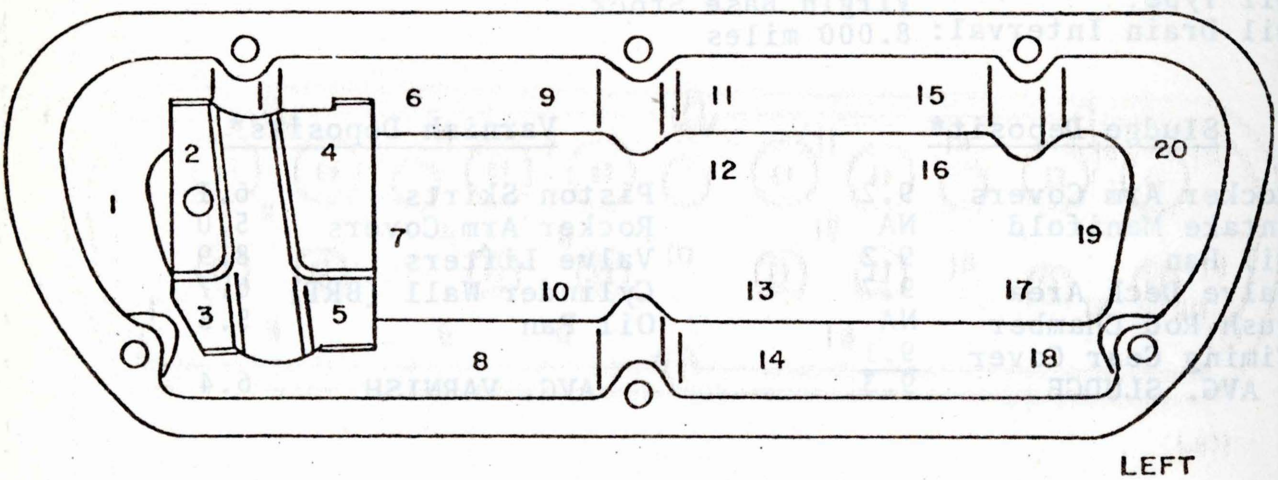
Observations, Comments

Very light scuff on several pistons - left side

Date: 5-78
Rater: E.R. Lyons

* 10=Clean
NA = Not Applicable

Rating Work Sheet No. 1
SLUDGE RATING OF ROCKER ARM COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN																							
1/4A																x	x				2	10	0.02
1/2A				x	x	x	x				x				x			x		x	8	40	.20
3/4A																							
A		x						x	x	x		x	x	x					x		8	40	.40
AB																							
B	x		x																		2	10	.20
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							.82

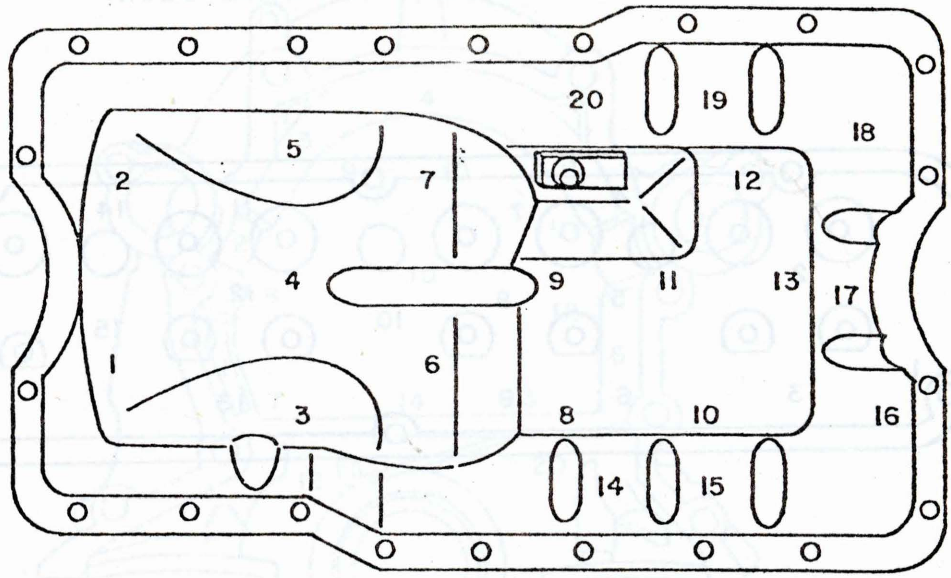
Sludge Merit Rating 9.2

Inspector ERL

Date 5-78

Rating Work Sheet No. 3

SLUDGE RATING OF OIL PAN



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACT
CLEAN																							
1/4A																		x			1	5	.01
1/2A				x												x	x		x	x	5	25	.12
3/4A																							
A	x	x	x			x	x	x	x	x	x	x	x	x	x						14	70	.70
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.83

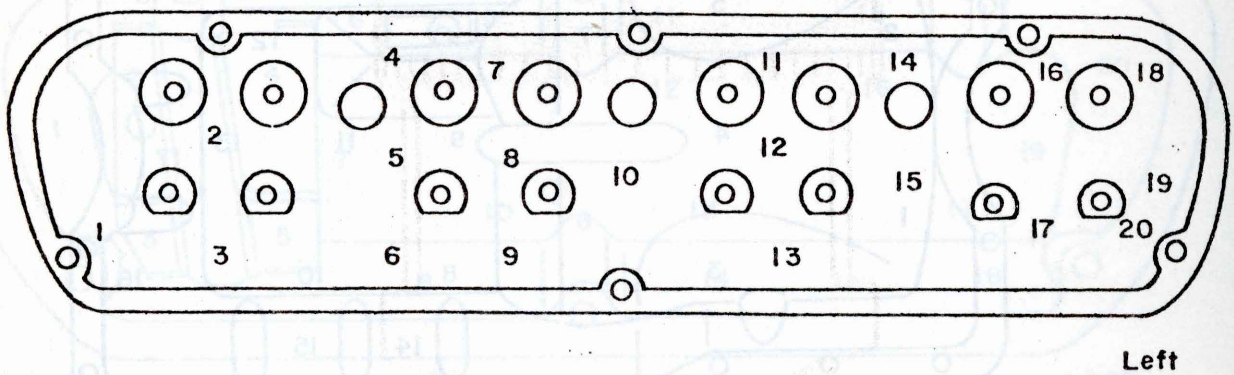
Inspector ERL

Sludge Merit Rating 9.2

Date 5-78

Rating Work Sheet No. 4

SLUDGE RATING OF VALVE DECK



DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOF
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

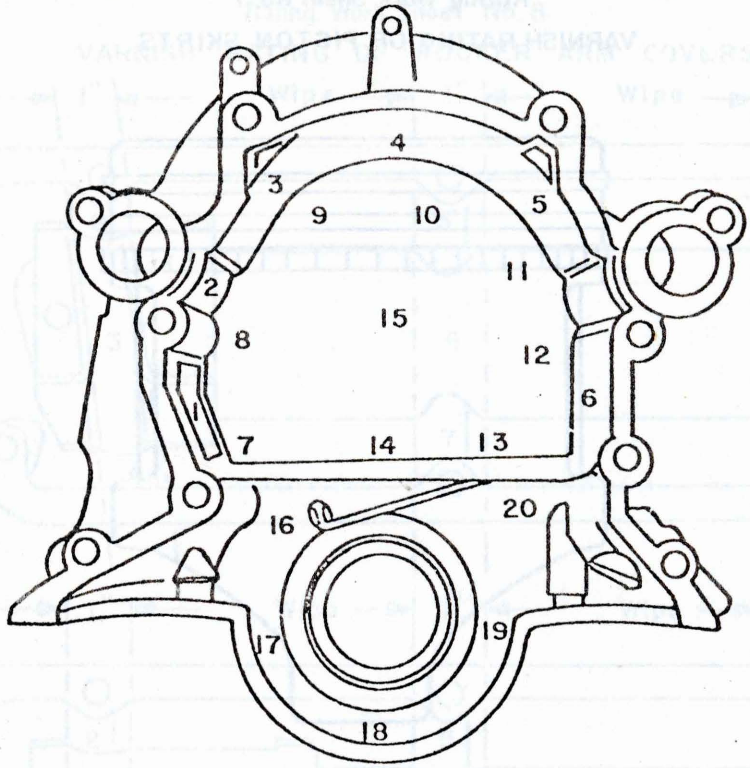
Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 6

SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOF
CLEAN																							
1/4A																							
1/2A													x			x	x	x	x	x	6	30	.15
3/4A																							
A	x	x	x	x	x	x	x	x	x	x	x	x		x	x						14	70	.70
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.85

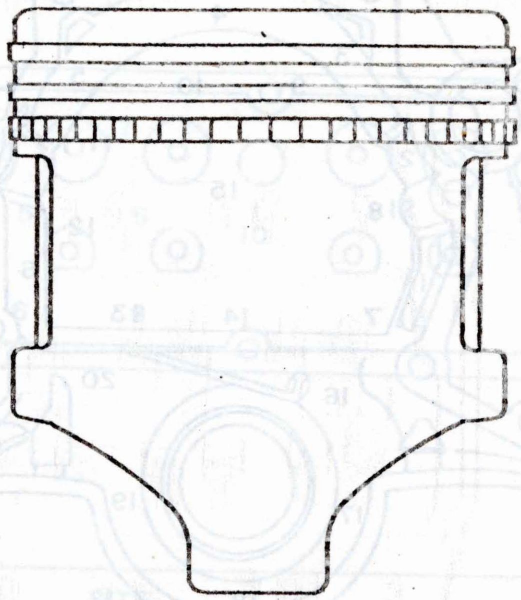
Inspector ERL

Date 5-78

Sludge Merit Rating 9.1

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	LEFT	RIGHT	AVERAGE	CON. ROD BRGS APPEARANCE
Lt scuff+scratch -L, Scratch-R	1	6.0	6.4	6.2	2-scratches
OK	2	5.7	6.5	6.1	Normal
V lt scuff-L	3	5.9	6.0	6.0	Normal
OK	4	5.7	6.0	5.9	1-Scratch
V lt scuff-L	5	5.5	6.3	5.9	Normal
V lt scuff-L	6	5.8	6.4	6.1	Normal
	TOTAL	34.6	37.6		
	AVERAGE	5.8	6.3		

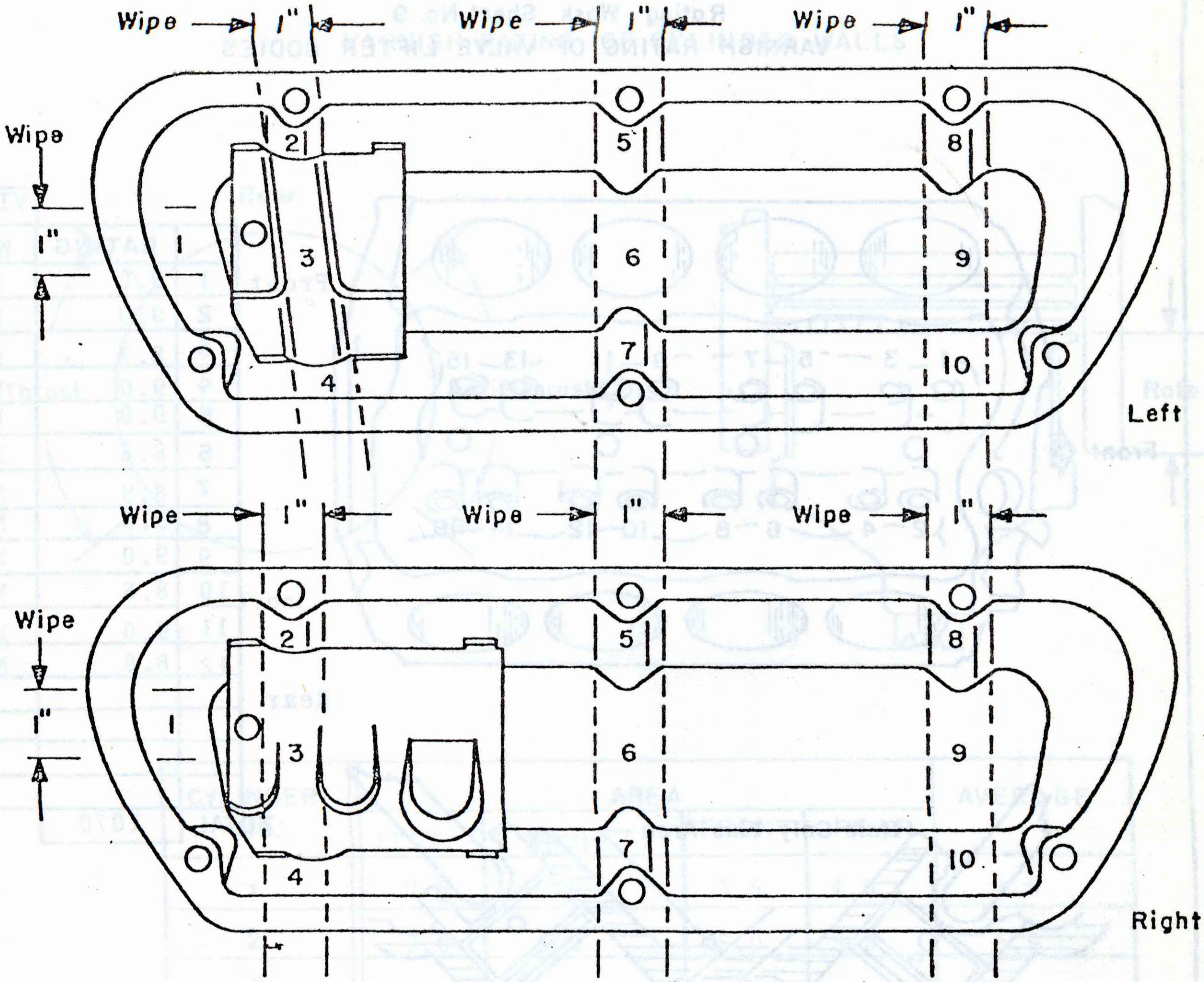
Inspector ______________

Date ______________

$$\text{VARNISH RATING} = \frac{\text{Avg Thrust} + \text{Avg Antithrust}}{2} = 6.1$$

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



AREA	RATING
1	5.0
2	4.0
3	5.0
4	6.0
5	5.0
6	4.0
7	4.5
8	5.0
9	6.0
10	5.0
TOTAL	495

Avg. Varnish Rating $= \frac{\text{Left} + \text{Right}}{2} =$ ____

Varnish Rating $= \frac{\text{Total}}{10} = \underline{5.0}$

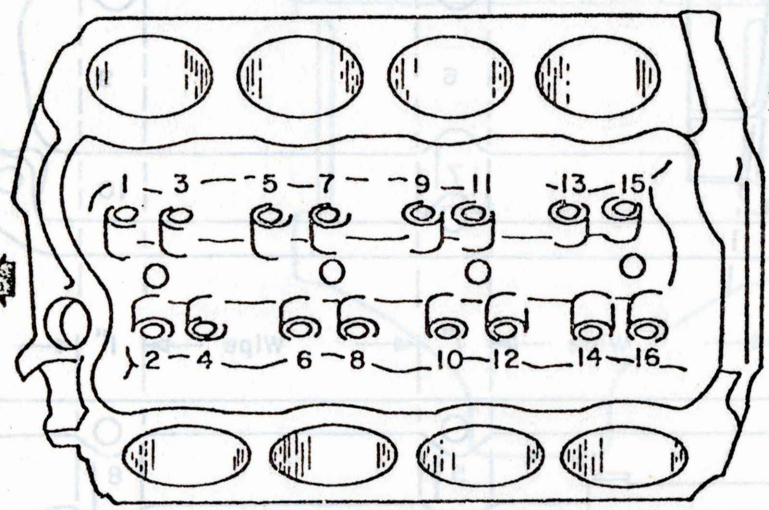
Inspector ERL

Date 5-78

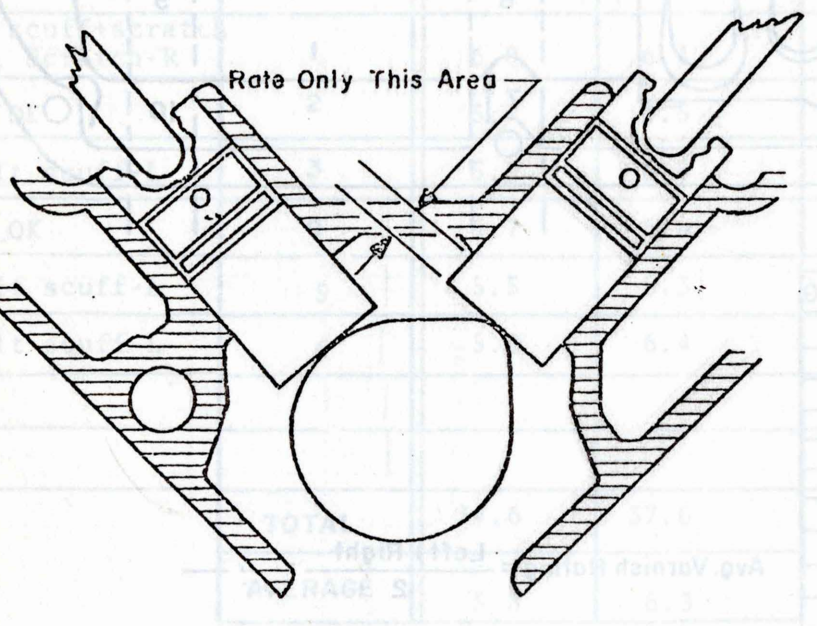
Varnish Rating $= \frac{\text{Total}}{10} =$ ____

Rating Work Sheet No. 9

VARNISH RATING OF VALVE LIFTER BODIES



		RATING	VISUAL WEAR
Front:	1	9.0	N
	2	9.0	N
	3	8.7	N
	4	9.0	N
	5	9.0	N
	6	8.8	N
	7	8.9	N
	8	9.0	N
	9	9.0	N
	10	8.8	N
	11	9.0	N
	12	8.8	N
Rear			
	TOTAL	1070	



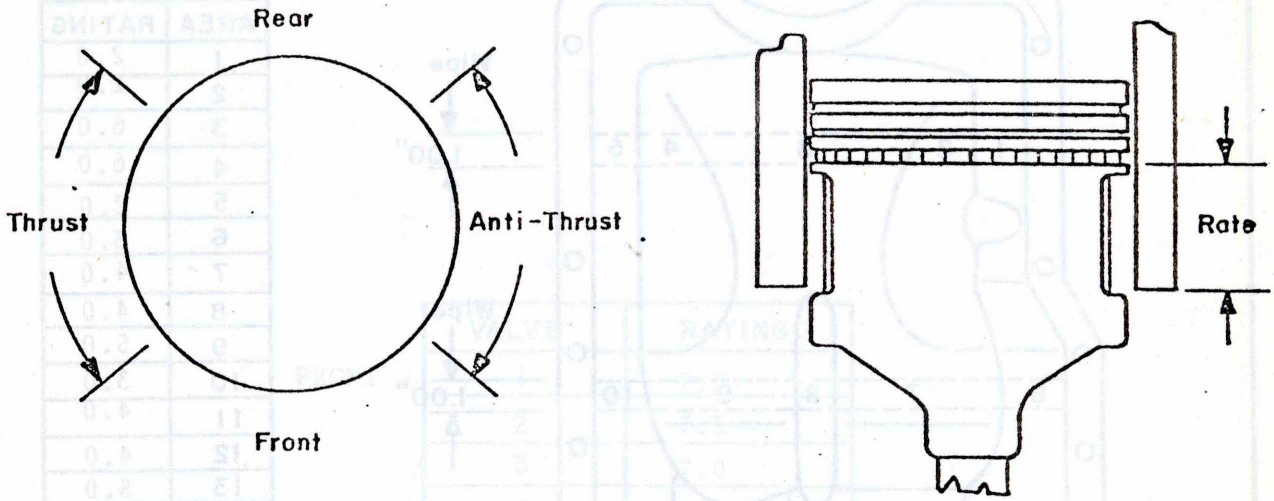
Inspector ERL

Date 5-78

Varnish Rating = Total / 16 = 8.9

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS



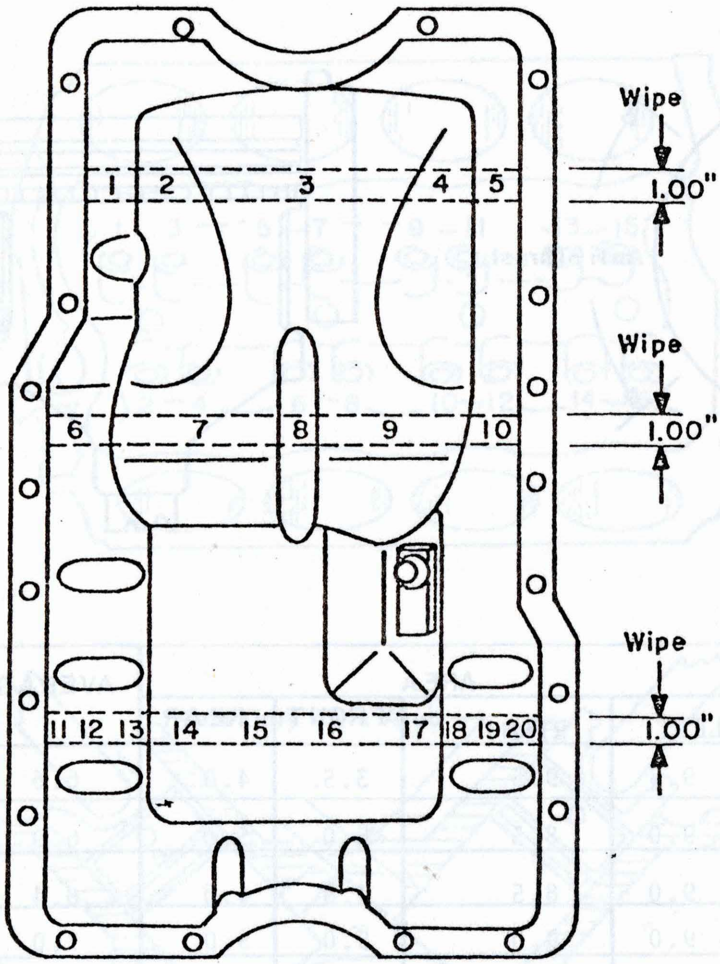
CYLINDER NO.	AREA				AVERAGE
	LEFT	RIGHT	FRONT	REAR	
1	9.5	9.5	3.5.	4.0	6.6
2	9.0	8.5	5.0	5.0	6.9
3	9.0	8.5	4.0	4.0	6.4
4	9.0	9.0	5.0	5.0	7.0
5	9.5	8.5	4.0	4.0	6.5
6	9.5	8.5	5.0	5.0	7.0
				TOTAL	404

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 6.7

Rating Work Sheet No. 11
VARNISH RATING OF OIL PAN



AREA	RATING
1	2.0
2	2.0
3	6.0
4	6.0
5	2.0
6	3.0
7	4.0
8	4.0
9	5.0
10	3.0
11	4.0
12	4.0
13	5.0
14	9.0
15	9.0
16	9.0
17	9.0
18	9.0
19	9.0
20	5.0
TOTAL	1090

Inspector ERL

Varnish Rating = $\frac{\text{Total}}{20}$ = 5.5

Date 5-78

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

	VALVE	RATING
FRONT	1	7.5
	2	7.5
	3	7.0
	4	7.0
	5	7.5
	6	8.0
REAR		
	TOTAL	445

Visual Observation of Seat, recession, or burning: ALL OK EXCEPT NO.5 EXH. VALVE Appeared to have very slight leak

Avg. Rating = $\frac{\textbf{total}}{\textbf{8}}$ = 7.4

Inspector ERL

Date 5-78

Rating Work Sheet No 11

OIL PAN

AREA	RATING
1	2.0
2	2.0
3	6.[illegible]
4	6.0
5	2.0
6	3.0
7	4.0
8	4.[illegible]
9	5.0
10	3.5
11	[illegible]
12	4.0
13	5.0
14	[illegible]
15	[illegible]
16	9.[illegible]
17	9.0
18	9.0
19	9.0
20	5.0
TOTAL	[illegible]

Inspector EPL

Varnish Rating = $\frac{\text{Total}}{20}$ = 5.5

Date 5-78

ENGINE INSPECTION SUMMARY

Vehicle I.D.: A18731
Engine Type: Dodge, 225 CID
Miles: 45,091
Oil Type: MORCO Rerefined
Oil Drain Interval: 8,000 mi.

Sludge Deposit*		Varnish Deposits*	
Rocker Arm Covers	9.7	Piston Skirts	7.4
Intake Manifold	NA	Rocker Arm Covers	8.7
Oil Pan	9.7	Valve Lifters	9.0
Valve Deck Area	10.0	Cylinder Wall (BRT)	9.5
Push Rod Chamber	NA	Oil Pan	7.5
Timing Gear Cover	9.8		
AVG. SLUDGE	9.8	AVG. VARNISH	8.4

Additional Ratings*

Stuck Valve Lifters	0	Piston Varnish, Max.	9.0
Stuck Compression Rings	0	Piston Varnish, Min.	5.8
Stuck Oil Rings	0	Intake Valve Deposits, Max.	7.0
		Intake Valve Deposits, Min.	5.0
		Intake Valve Deposits, Avg.	6.2

Clogging

Push Rods, No. NA (solid design)
Oil Ring, % 0
Oil Screen, % 0

Observations, Comments

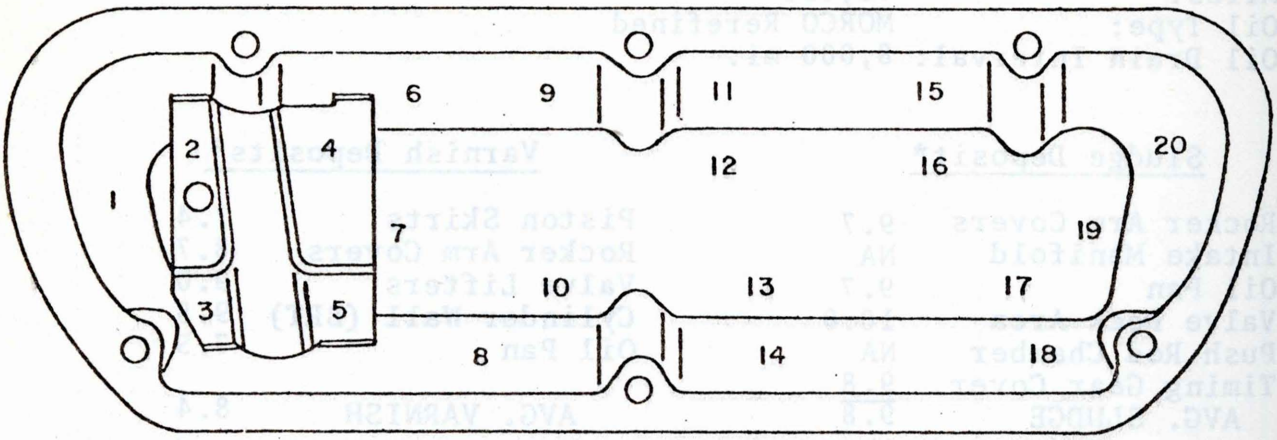
Very light to medium scuffing on left side all pistons
V. Very slight corrosion on one compression ring

Date: 5-78
Rater: E.R. Lyons

* 10=Clean
NA = Not Applicable

Rating Work Sheet No. 1

SLUDGE RATING OF ROCKER ARM COVER



LEFT

Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUME FACTOR
CLEAN				x	x	x	x	x	x		x				x						8	40	
1/4A												x		x		x	x	x		x	6	30	.08
1/2A		x								x			x						x		4	20	.10
3/4A																							
A	x		x																		2	10	.10
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																					20	100	.28

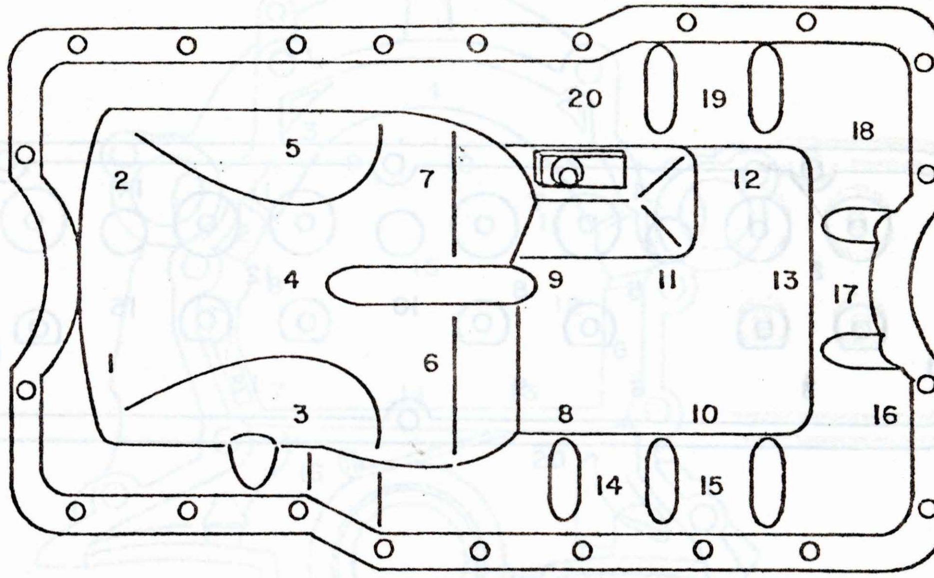
Inspector ERL

Sludge Merit Rating 9.7

Date 5-78

Rating Work Sheet No. 3

SLUDGE RATING OF OIL PAN



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLU FACT
CLEAN																							
1/4A	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	20	100	.25
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

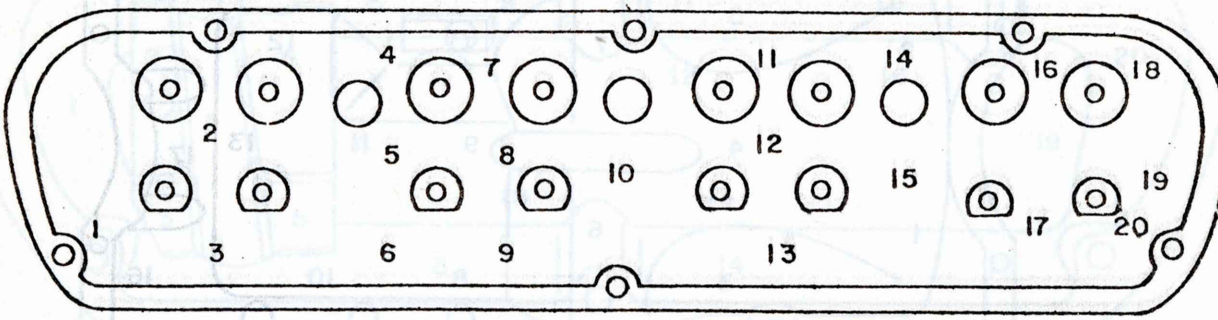
Inspector ERL

Date 5-78

Sludge Merit Rating 9.7

Rating Work Sheet No. 4

SLUDGE RATING OF VALVE DECK



DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOF
CLEAN	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
1/4A																							
1/2A																							
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

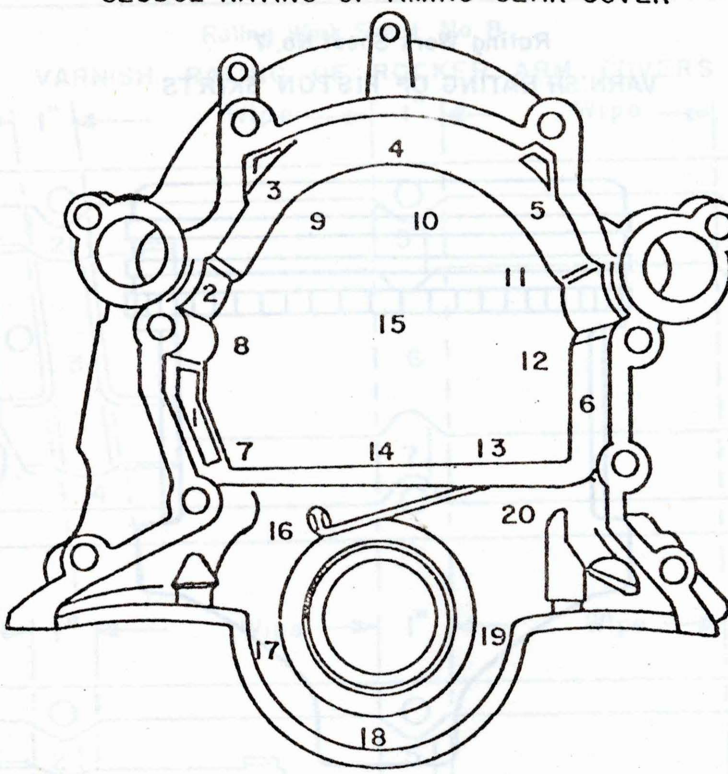
Inspector ERL

Date 5-78

Sludge Merit Rating 10.0

Rating Work Sheet No.6

SLUDGE RATING OF TIMING GEAR COVER



Note: Sites on Vertical Surfaces at Mid-Point

DEPTH SCALE	SITE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL CHECKS	% COVERED	VOLUM FACTOR
CLEAN	x	x	x	x	x	x										x	x	x	x	x	11		
1/4A																							
1/2A							x	x	x	x	x	x	x	x	x						9	45	.22
3/4A																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
H																							
I																							
GRAND TOTAL																							

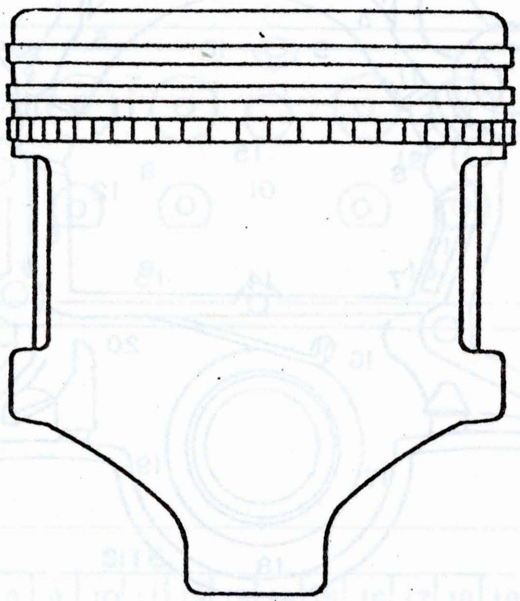
Inspector ERL

Date 5-78

Sludge Merit Rating 9.8

Rating Work Sheet No. 7

VARNISH RATING OF PISTON SKIRTS



OTHER OBSERVATIONS	PISTON NO.	LEFT	RIGHT	AVERAGE	CON. ROD BRGS APPEARANCE
v. lt scuff-L	1	9.0	7.4	8.2	Lt scratches
#2CR < 1% corr Lt scuff-L	2	8.0	7.4	7.7	Normal
Lt scuff-L	3	7.8	5.8	6.8	Normal
V. lt scuff-L	4	7.4	7.0	7.2	Normal
V. lt scuff-L	5	7.8	6.5	7.2	Normal
Med Scuff-L	6	7.5	6.5	7.0	Normal
	TOTAL	47.5	40.6		
	AVERAGE	7.9	6.8		

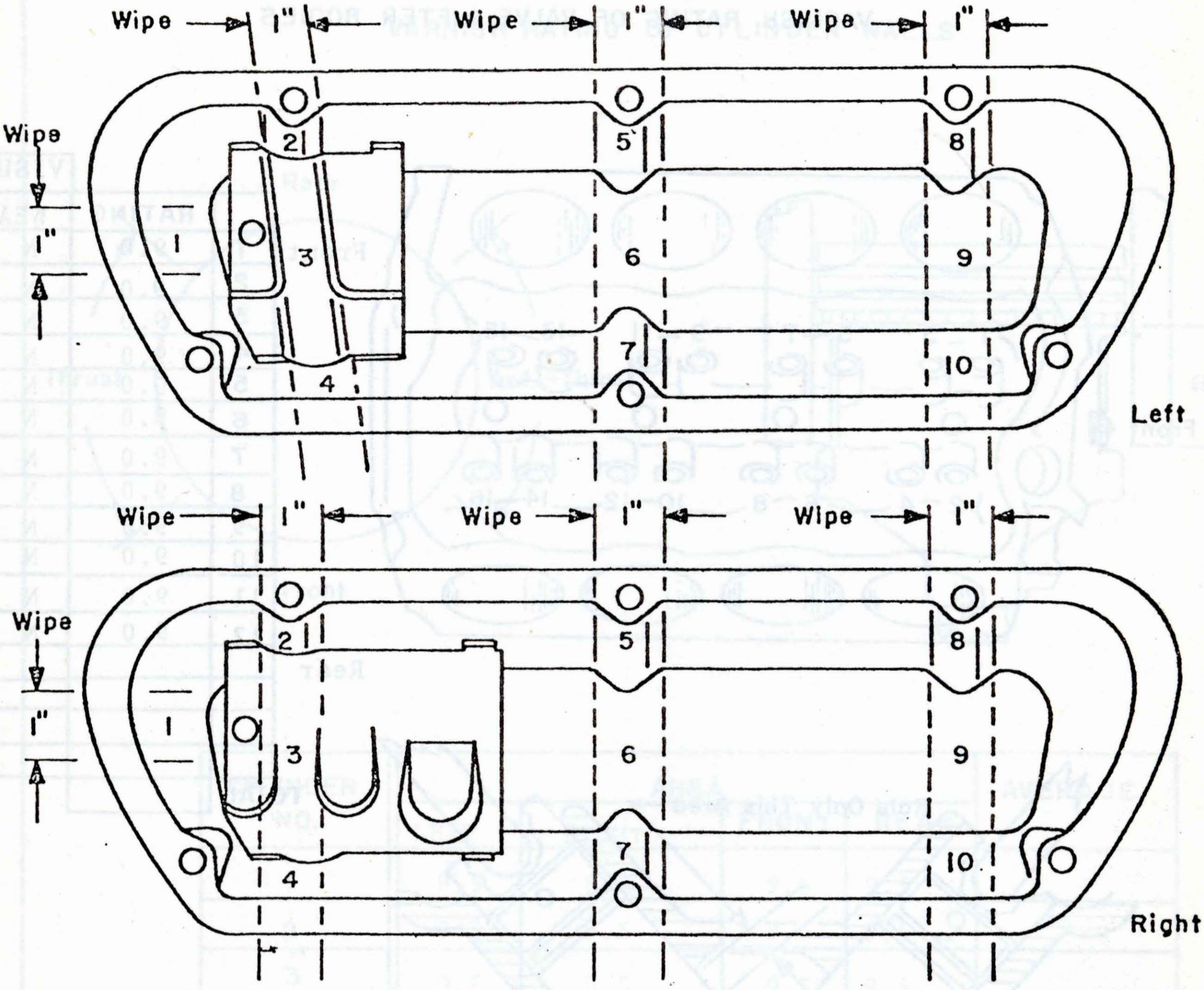
Inspector ____________

Date ____________

$$\text{VARNISH RATING} = \frac{\text{AvgThrust + Avg Antithrust}}{2} = 7.4$$

Rating Work Sheet No. 8

VARNISH RATING OF ROCKER ARM COVERS



AREA	RATING
1	8.5
2	9.5
3	9.0
4	9.0
5	8.0
6	7.5
7	8.0
8	9.0
9	9.0
10	9.0
TOTAL	865

Avg. Varnish Rating = $\frac{\text{Left} + \text{Right}}{2}$ = ______

Varnish Rating = $\frac{\text{Total}}{10}$ = 8.7

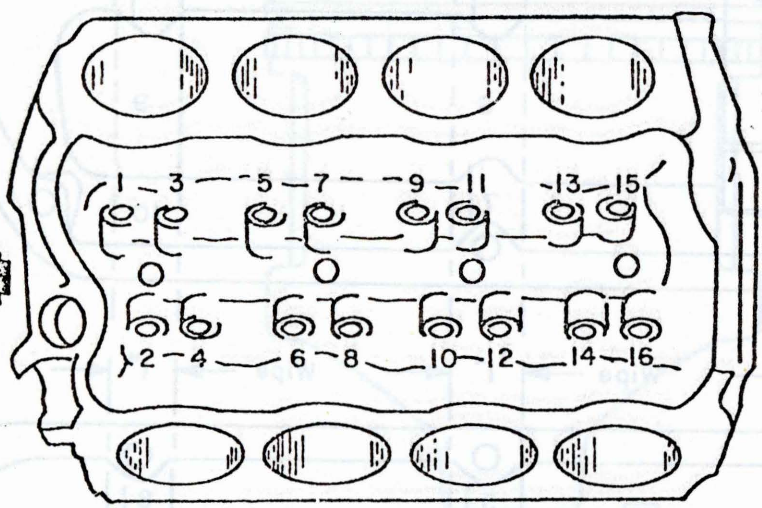
Inspector ERL

Date 5-78

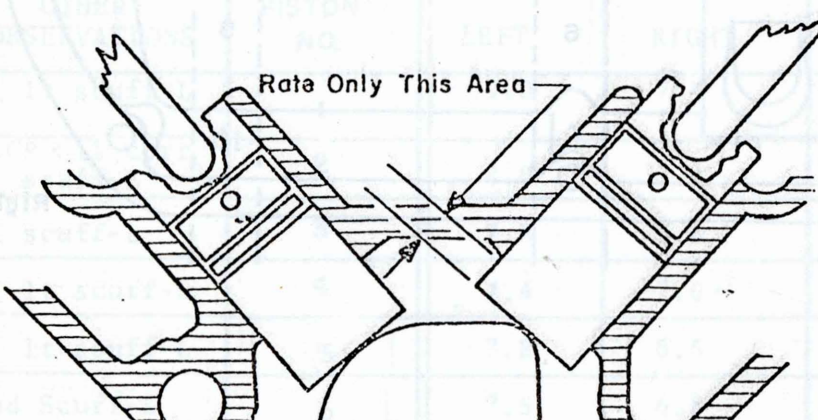
Varnish Rating = $\frac{\text{Total}}{10}$ = ______

Rating Work Sheet No. 9
VARNISH RATING OF VALVE LIFTER BODIES

Front



	RATING	VISUAL WEAR
Front: 1	9.0	N
2	9.0	N
3	9.0	N
4	9.0	N
5	9.0	N
6	9.0	N
7	9.0	N
8	9.0	N
9	9.0	N
10	9.0	N
11	9.0	N
12	9.0	N
Rear		
TOTAL		



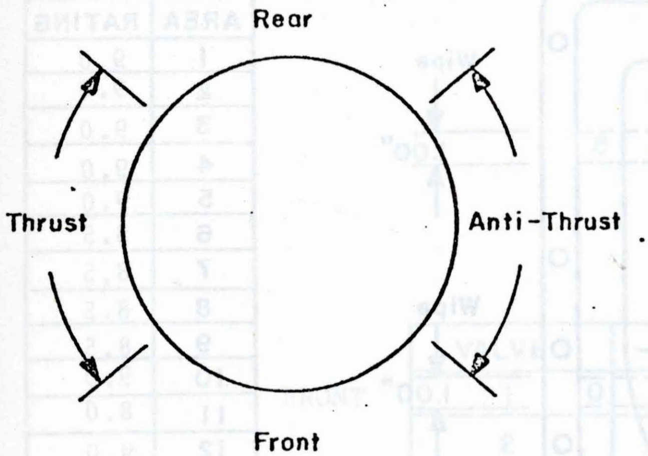
Inspector ERL

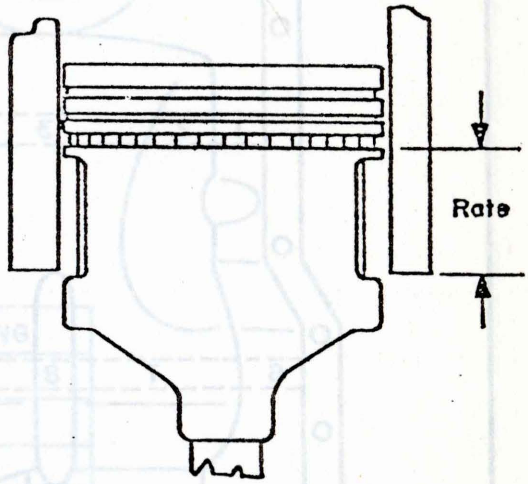
Date 5-78

Varnish Rating = $\frac{\text{Total}}{16}$ = 9.0

Rating Work Sheet No. 10

VARNISH RATING OF CYLINDER WALLS





CYLINDER NO.	AREA				AVERAGE
	LEFT	RIGHT	FRONT	REAR	
1	9.5	9.5	9.5	9.5	
2	9.5	9.5	9.5	9.5	
3	9.5	9.5	9.5	9.5	
4	9.5	9.5	9.5	9.5	
5	9.5	9.5	9.5	9.5	
6	9.5	9.5	9.5	9.5	
				TOTAL	

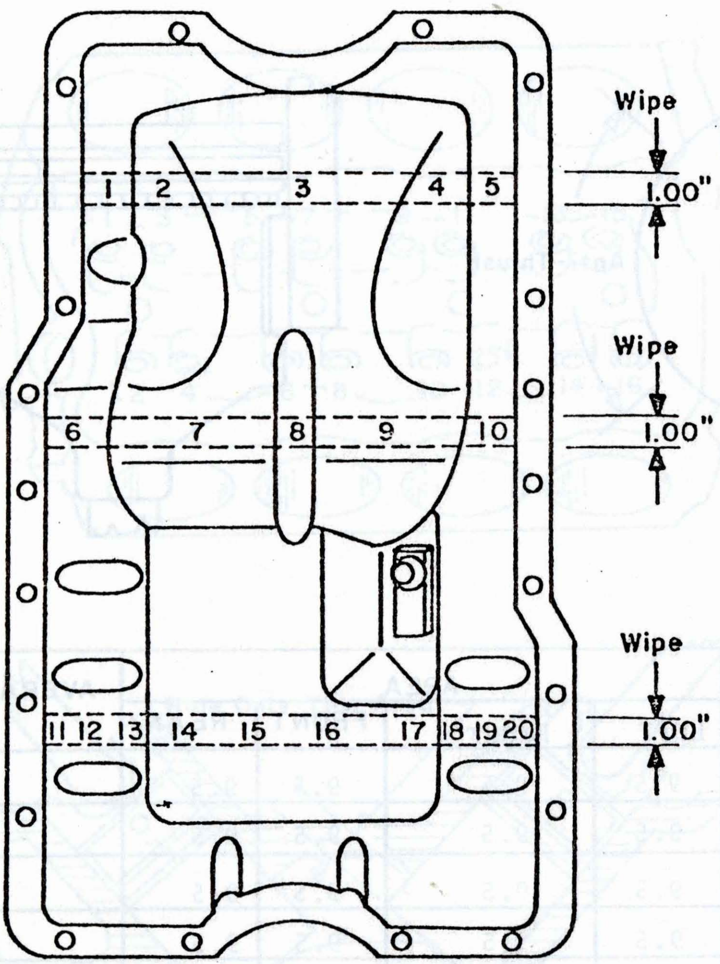
Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{8}$ = 9.5

Rating Work Sheet No. 11

VARNISH RATING OF OIL PAN



AREA	RATING
1	9.0
2	9.0
3	9.0
4	9.0
5	9.0
6	8.5
7	8,5
8	8.5
9	8.5
10	9.0
11	8.0
12	9.0
13	9.0
14	9.0
15	9.0
16	9.0
17	9.0
18	9.0
19	9.0
20	7.0
TOTAL	1750

Inspector ERL

Date 5-78

Varnish Rating = $\frac{\text{Total}}{20}$ = 7.5

Rating Work Sheet No. 12

INTAKE VALVE DEPOSITS

	VALVE	RATING
FRONT	1	7.0
	2	6.5
	3	6.0
	4	6.0
	5	5.0
	6	6.5
REAR		
	TOTAL	370

Visual Observation of Seat, recession, or burning: All ok

Avg. Rating = $\frac{\text{total}}{8}$ = 6.2

Inspector ERL

Date 5-78

APPENDIX C

PICTORIAL DOCUMENTATION OF DEPOSIT RATINGS

Table 1. Piston skirt picture documentation.

Vehicle Number	Engine Location*	Test Oil	Final Mileage	Varnish Rating	Engine Rating
17680	Rt #2 - Outside	BERC	45667	5.4	5.8
17687	Lt #3 - Outside	MORCO	48285	9.8	9.8
17683	Rt #3 - Cam Side	VIRGIN	49503	7.8	7.9
18731	#4 - Outside	MORCO	48091	7.4	7.4
18716	#4 - Cam Side	VIRGIN	63910	5.6	5.7
18729	#5 - Cam Side	VIRGIN	31940	6.3	6.1
18710	#1 - Cam Side	MORCO	25617	7.8	9.8
20369	Lt #3 - Outside	MORCO	31576	9.0	9.0
20371	Lt #2 - Outside	VIRGIN	27207	6.0	6.4

*Cylinders are numbered from front to back (1,2,3,4). Left (Lt) and Right (Rt) sides of the engine are located while viewing from back to front.

Table 2. Intake valve picture documentation.

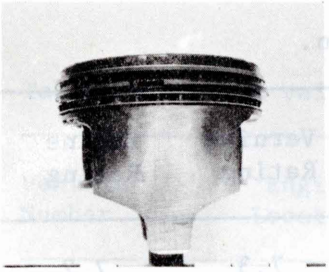
Vehicle Number	Engine Location*	Test Oil	Final Mileage	Varnish Rating	Engine Rating
17680	Lt # 1, 2 / 4, 3	BERC	45667	7.5, 7.0 / 6.0, 5.5	7.0
17687	Lt # 1, 3 / 2, 4	MORCO	48285	8.0, 5.5 / 8.5, 9.0	7.4
17683	Lt # 1, 3 / 2, 4	VIRGIN	49503	1.5, 4.5 / 7.5, 8.0	4.9
17685	Lt # 1, 4 / 2, 3	MORCO	60174	3.0, 8.5 / 4.0, 1.5	4.1
18731	#3	MORCO	45091	6.0	6.2
18716	#4	VIRGIN	63910	6.0	6.5
18729	#2	VIRGIN	31940	7.5	7.4
20369	Lt #2, 3	MORCO	31576	6.0, 8.0	6.9
20371	Lt #3, 2	VIRGIN	27207	8.0, 6.0	7.1

*Cylinders are numbered from front to back (1,2,3,4). Left (Lt) and Right (Rt) sides of the engine are located while viewing from back to front.

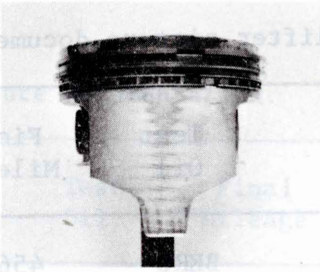
Table 3. Intake valve lifter picture documentation.

Vehicle Number	Engine Location*	Test Oil	Final Mileage	Varnish Rating	Engine Rating
17680	Rt #1	BERC	45667	7.3	7.2
17687	Rt #1	MORCO	48285	7.8	7.9
17683	Lt #4	VIRGIN	49503	7.5	7.3
18731	#3	MORCO	45091	9.0	9.0
18716	#3	VIRGIN	63910	7.5	7.6
20369	Rt #1	MORCO	31576	8.0 (Dished)	8.1
20371	Rt #4	VIRGIN	27207	7.5 (Dished)	7.3

*Cylinders are numbered from front to back (1,2,3,4). Left (Lt) and Right (Rt) sides of the engine are located while viewing from back to front.

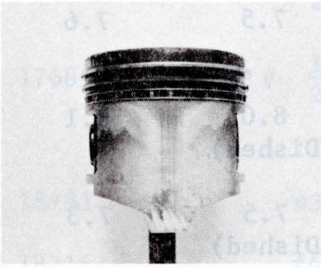


VEH. 17680, BERC
MILEAGE = 45,667
VARNISH RATING = 5.4

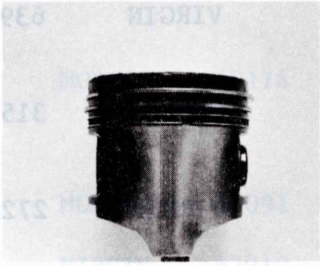


VEH. 17687, MORCO
MILEAGE = 48,285
VARNISH RATING = 9.8

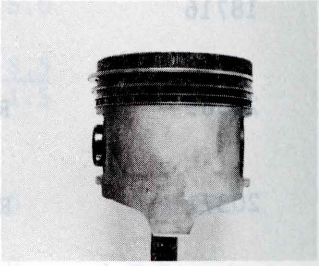
VEH. 17683, VIRGIN
MILEAGE = 49,503
VARNISH RATING = 7.8



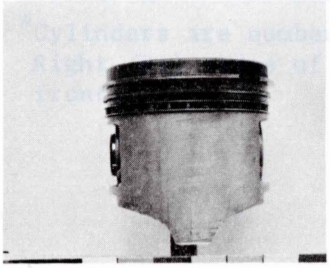
VEH. 18731, MORCO
MILEAGE = 45,091
VARNISH RATING = 7.4



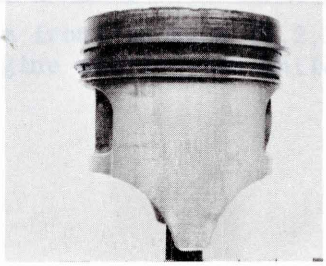
VEH. 18716, VIRGIN
MILEAGE = 63,910
VARNISH RATING = 5.6



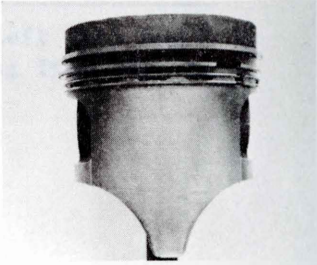
VEH. 18729, VIRGIN
MILEAGE = 31,940
VARNISH RATING = 6.3



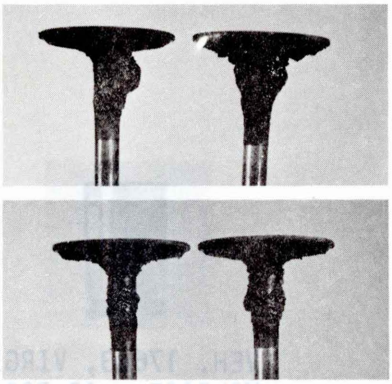
VEH. 18710, MORCO
MILEAGE = 25,617
VARNISH RATING = 9.8



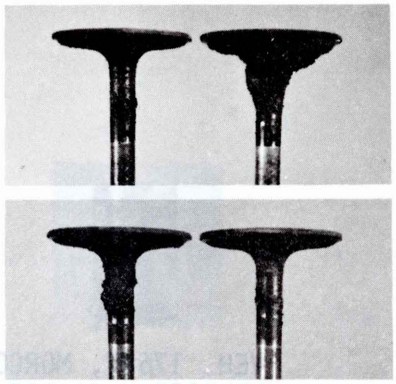
VEH. 20369, MORCO
MILEAGE = 31,576
VARNISH RATING = 9.0



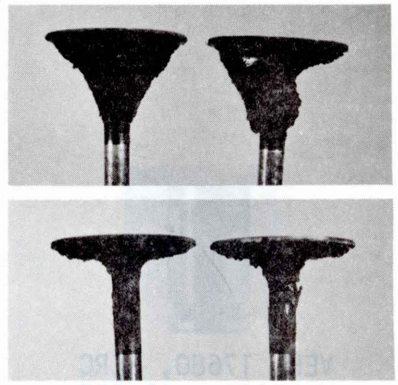
VEH. 20371, VIRGIN
MILEAGE = 27,207
VARNISH RATING = 6.0



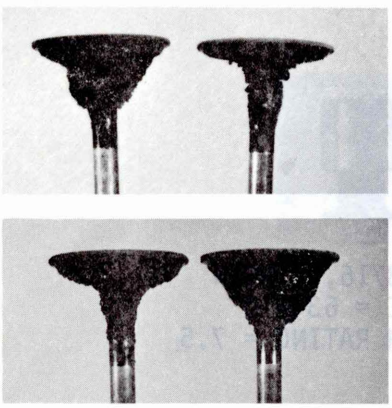
VEH. 17680, BERC
MILEAGE = 45,667
DEPOSIT RATING = $\frac{7.5,\ 7.0}{6.0,\ 5.5}$



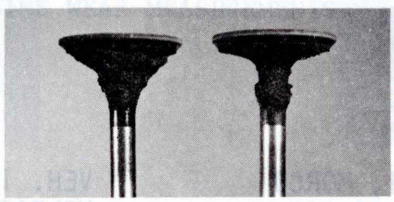
VEH. 17687, MORCO
MILEAGE = 48,285
DEPOSIT RATING = $\frac{8.0,\ 5.5}{8.5,\ 9.0}$



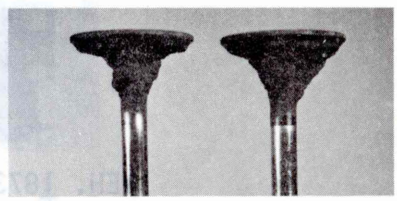
VEH. 17683, VIRGIN
MILEAGE = 49,503
DEPOSIT RATING = $\frac{1.5,\ 4.5}{7.5,\ 8.0}$



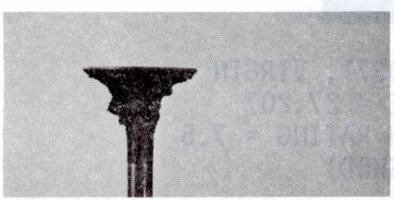
VEH. 17685, MORCO
MILEAGE = 60,174
DEPOSIT RATING = $\frac{3.0,\ 8.5}{4.0,\ 1.5}$



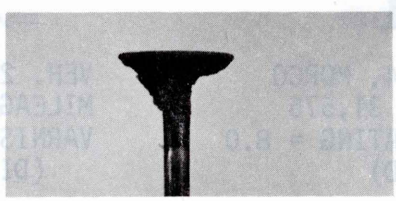
VEH. 20369, MORCO
MILEAGE = 31,576
DEPOSIT RATING = 6.0, 8.0



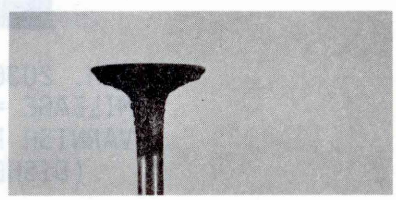
VEH. 20371, VIRGIN
MILEAGE = 27,207
DEPOSIT RATING = 8.0, 6.0



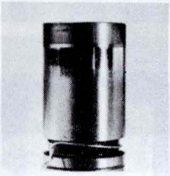
VEH. 18781, MORCO
MILEAGE = 45,091
DEPOSIT RATING = 6.0



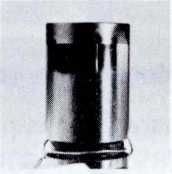
VEH. 18716, VIRGIN
MILEAGE = 63,910
DEPOSIT RATING = 6.0



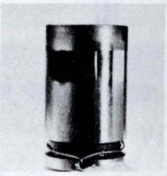
VEH. 18729, VIRGIN
MILEAGE = 31,940
DEPOSIT RATING = 7.5



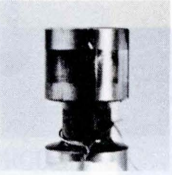
VEH. 17680, BERC
MILEAGE = 45,667
VARNISH RATINGS = 7.2



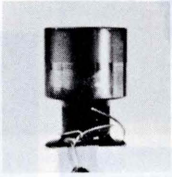
VEH. 17687, MORCO
MILEAGE = 48,285
VARNISH RATING = 7.9



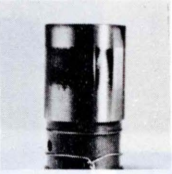
VEH. 17683, VIRGIN
MILEAGE = 49,503
VARNISH RATING = 7.3



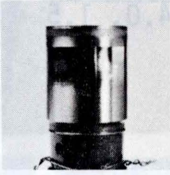
VEH. 18731, MORCO
MILEAGE = 45,049
VARNISH RATING = 9.0



VEH. 18716, VIRGIN
MILEAGE = 63,910
VARNISH RATING = 7.5



VEH. 20364, MORCO
MILEAGE = 31,576
VARNISH RATING = 8.0
(DISHED)



VEH. 20371, VIRGIN
MILEAGE = 27,207
VARNISH RATING = 7.5
(DISHED)

APPENDIX D

ENGINE WEAR MEASUREMENTS

VEH. 17680, BERC
MILEAGE = 45,667
VARNISH RATINGS = 7.2

VEH. 17687, MORCO
MILEAGE = 48,285
VARNISH RATING = 7.9

VEH. 17683, VIRGIN
MILEAGE = 49,503
VARNISH RATING = 7.3

VEH. 18731, MORCO
MILEAGE = 45,049
VARNISH RATING = 9.0

VEH. 18716, VIRGIN
MILEAGE = 53,910
VARNISH RATING = 7.5

VEH. 20364, MORCO
MILEAGE = 31,576
VARNISH RATING = 8.0
(DISHED)

VEH. 20371, VIRGIN
MILEAGE = 27,207
VARNISH RATING = 7.5
(DISHED)

The engine measurements presented in this appendix were performed by the Iowa Department of Transportation. Ring gap measurements were made while the original compression ring was placed into its operating position (near the top of the cylinder). In this way ring wear and cylinder wear were measured. All data are reported in inches.

The cylinders are numbered from front to back and the left and right sides of the engine are located while viewing from back to front.

VEHICLE NUMBER A17680/BERC OIL

	Right Side 1	2	3	4	Left Side 1	2	3	4
Cylinder Diameters:[a]								
Top (Approx. 1/2 in. down)	4.0835	4.0835	4.0835	4.0825	4.084	4.083	4.083	4.0825
Bottom	4.0800	4.0800	4.0800	4.0800	4.0800	4.0800	4.0800	4.0800
Wear (Difference)	0.0035	0.0035	0.0035	0.0025	0.004	0.003	0.003	0.0025
Avg. = 0.00281								
Piston Diameter:[a]								
Bottom of Skirt	4.079	4.078	4.080	4.079	4.079	4.0815	4.079	4.080
Just Below Rings	4.078	4.0775	4.0775	4.0775	4.0775	4.078	4.075	4.078
Wear (Difference)	0.001	0.0005	0.0025	0.0015	0.0015	0.0035	0.004	0.002
Avg. = 0.00206								
Ring Gap:[a]	0.025	0.025	0.025	0.025	0.025	0.025	0.028	0.025
Avg. = 0.025								
Valve Guide:[a]								
Intake	Standard							
Exhaust	Standard							
Main Bearings:	Standard							
Rod Bearings:	Standard							

[a] All dimensions are given in inches.

VEHICLE NUMBER A17683/VIRGIN OIL

	Right Side				Left Side			
	1	2	3	4	1	2	3	4
Cylinder Diameter:[a]								
Top (Approx. 1/2" down)	4.0833	4.083	4.0833	4.083	4.083	4.083	4.083	4.083
Bottom	4.082	4.082	4.082	4.082	4.082	4.082	4.082	4.082
Wear (Difference)	0.0013	0.001	0.0013	0.001	0.001	0.001	0.001	0.001
Avg. = 0.00108								
Piston Diameter:[a]								
Bottom of Skirt	4.080	4.080	4.080	4.080	4.080	4.080	4.080	4.080
Just Below Rings	4.078	4.078	4.0785	4.078	4.0785	4.079	4.079	4.078
Wear (Difference)	0.0015	0.002	0.0015	0.002	0.0015	0.001	0.001	0.002
Avg. = 0.00119								
Ring Gap:[a]	0.026	0.028	0.028	0.023	0.022	0.030	0.026	0.025
Avg. = 0.026								
Valve Guide:[a]								
Intake	Avg. wear = 0.0005							
Exhaust	Avg. wear = 0.002							
Main Bearings:	Avg. wear = 0.001							
Rod Bearings:	Avg. wear = 0.001							

[a] All dimensions are given in inches.

VEHICLE NUMBER A17685/MORCO OIL

	Right Side				Left Side			
	1	2	3	4	1	2	3	4
Cylinder Diameter:[a]								
Top (Approx. 1/2" down)	4.0835	4.0835	4.0835	4.0835	4.0835	4.083	4.083	4.082
Bottom	4.082	4.082	4.083	4.082	4.082	4.083	4.082	4.082
Wear (Difference)	0.0015	0.0015	0.0015	0.0015	0.0015	0.00	0.001	0.00
Avg. = 0.00125								
Piston Diameter:[a]								
Bottom of Skirt	4.080	4.084	4.080	4.080	4.080	4.0795	4.0805	4.080
Just Below Rings	4.078	4.078	4.079	4.078	4.078	4.0795	4.0795	4.078
Wear (Difference)	0.002	0.006	0.001	0.002	0.002	0.00	0.001	0.002
Avg. = 0.002								
Ring Gap:[a]	0.024	0.023	0.035	0.023	0.026	0.032	0.032	0.024
Avg. = 0.0274								
Valve Guide:[a]								
Intake	Avg. wear = 0.001							
Exhaust	Avg. wear = 0.001							
Main Bearings:	Avg. wear = 0.0005							
Rod Bearings:	Avg. wear = 0.0013							

[a] All dimensions are given in inches.

VEHICLE NUMBER A17686/BERC OIL

	Right Side				Left Side			
	1	2	3	4	1	2	3	4
Cylinder Diameter:[a]								
Top (Approx. 1/2" down)	4.082	4.084	4.083	4.083	4.083	4.083	4.083	4.0835
Bottom	4.082	4.082	4.082	4.082	4.082	4.082	4.082	4.082
Wear (Difference)	0.00	0.002	0.001	0.001	0.001	0.001	0.001	0.0015
Avg. = 0.00106								
Piston Diameter:[a]								
Bottom of Skirt	4.079	4.080	4.079	4.082	4.080	4.080	4.081	4.080
Just Below Rings	4.078	4.078	4.078	4.079	4.078	4.0785	4.0785	4.078
Wear (Difference)	0.001	0.002	0.001	0.003	0.002	0.0015	0.0025	0.002
Avg. = 0.00188								
Ring Gap:[a]	0.022	0.025	0.025	0.025	0.025	0.025	0.025	0.028
Avg. = 0.025								
Valve Guide:[a]								
Intake — Avg. wear = 0.001								
Exhaust — Avg. wear = 0.002								
Main Bearings — Avg. wear = 0.001								
Rod Bearings — Avg. wear = 0.001								

[a] All dimensions are given in inches.

VEHICLE NUMBER A17687/MORCO OIL

	Right Side				Left Side			
	1	2	3	4	1	2	3	4
Cylinder Diameter:[a]								
Top (Approx. 1/2" down)	4.083	4.0825	4.083	4.083	4.083	4.083	4.084	4.083
Bottom	4.0825	4.082	4.082	4.082	4.081	4.081	4.0825	4.082
Wear (Difference)	0.0005	0.0005	0.001	0.001	0.002	0.002	0.0015	0.001
Avg. = 0.00119								
Piston Diameter:[a]								
Bottom of Skirt	4.082	4.080	4.084	4.081	4.079	4.081	4.081	4.081
Just Below Rings	4.078	4.078	4.078	4.078	4.0775	4.078	4.099	4.079
Wear (Difference)	0.004	0.002	0.006	0.003	0.0015	0.003	0.002	0.002
Avg. = 0.00294								
Ring Gap:[a]	0.028	0.025	0.025	0.028	0.027	0.025	0.038	0.025
Avg. = 0.0276								
Valve Guide:[a]								
Intake	Avg. wear = None							
Exhaust	Avg. wear = 0.0025							
Main Bearings:	Avg. wear = 0.001							
Rod Bearings:	Avg. wear = 0.0008							

[a] All dimensions are given in inches.

VEHICLE NUMBER A17688/VIRGIN OIL

	Right Side				Left Side			
	1	2	3	4	1	2	3	4
Cylinder Diameter:[a]								
Top (Appox. 1/2" down)	4.0835	4.084	4.0835	4.082	4.084	4.084	4.0825	4.082
Bottom	4.082	4.082	4.082	4.081	4.082	4.082	4.082	4.081
Wear (Difference)	0.001	0.002	0.0013	0.001	0.002	0.002	0.0005	0.001
Avg. = 0.00135								
Piston Diameter:[a]								
Bottom of Skirt	4.080	4.082	4.080	4.083	4.082	4.081	4.080	4.078
Just Below Rings	4.078	4.0985	4.078	4.078	4.078	4.079	4.078	4.078
Wear (Difference)	0.002	0.0035	0.002	0.005	0.004	0.002	0.002	0.00
Avg. = 0.00206								
Ring Gap:[a]	0.027	0.027	0.022	0.020	0.024	0.028	0.020	0.020
Avg. = 0.0235								
Valve Guide:[a]								
Intake — Avg. wear = 0.0005								
Exhaust — Avg. wear = 0.002								
Main Bearings: — Avg. wear = 0.001								
Rod Bearings: — Avg. wear = 0.0013								

[a] All dimensions are given in inches.

VEHICLE NUMBER A18710/MORCO OIL

	1	2	3	4	5	6
Cylinder Diameter:[a]						
Top (Approx. 1/2" down)	3.402	3.402	3.402	3.402	3.402	3.402
Bottom	3.401	3.401	3.401	3.401	3.401	3.401
Wear (Difference)	0.001	0.001	0.001	0.001	0.001	0.001
Avg. = 0.001						
Piston Diameter:[a]						
Bottom of Skirt	3.400	3.401	3.394	3.401	3.400	3.401
Just Below Rings	3.399	3.399	3.399	3.400	3.399	3.399
Wear (Difference)	0.001	0.001	0.001	0.001	0.001	0.001
Avg. = 0.001						
Ring Gap:[a]	0.025	0.025	0.025	0.025	0.025	0.025
Avg. = 0.025						
Valve Guide:[a]						
Intake	Avg. wear = 0.001					
Exhaust	Avg. wear = 0.0035					
Main Bearings:	No wear.					
Rod Bearings:	No wear.					

[a] All dimensions are given in inches.

VEHICLE NUMBER A18716/VIRGIN OIL

	1	2	3	4	5	6
Cylinder Diameter:[a]						
Top (Approx. 1/2" down)	3.402	3.403	3.403	3.4025	3.4025	3.4025
Bottom	3.400	3.400	3.400	3.401	3.400	3.400
Wear (Difference)	0.0025	0.003	0.003	0.0015	0.0025	0.0025
Avg. = 0.0025						
Piston Diameter:[a]						
Bottom of Skirt	3.400	3.400	3.400	3.400	3.399	3.399
Just Below Rings	3.399	3.3985	3.3985	3.398	3.398	3.399
Wear (Difference)	0.001	0.0015	0.0005	0.001	0.001	0.001
Avg. = 0.0011						
Ring Gap:[a]	0.023	0.023	0.023	0.023	0.023	0.023
Avg. = 0.023						
Valve Guide:[a]						
Intake	Avg. wear = 0.001					
Exhaust	Avg. wear = 0.005					
Main Bearings:	No wear.					
Rod Bearings:	No wear.					

[a] All dimensions are given in inches.

VEHICLE NUMBER A18729/VIRGIN OIL

		1	2	3	4	5	6
Cylinder Diameter:[a]							
Top (Approx. 1/2" down)		3.403	3.403	3.403	3.402	3.4025	3.402
Bottom		3.401	3.401	3.401	3.401	3.401	3.401
Wear (Difference)		0.002	0.002	0.002	0.001	0.0015	0.001
	Avg. = 0.00158						
Piston Diameter:[a]							
Bottom of Skirt		3.400	3.3995	3.4005	3.401	3.401	3.401
Just Below Rings		3.399	3.3995	3.4005	3.4005	3.400	3.4005
Wear (Difference)		0.001	0.00	0.00	0.0005	0.001	0.0005
	Avg. = 0.0005						
Ring Gap:[a]		0.025	0.025	0.025	0.025	0.025	0.025
	Avg. = 0.025						
Valve Guide:[a]							
Intake	Avg. wear = 0.001						
Exhaust	Avg. wear = 0.001		Avg. wear #3 = 0.006				
Main Bearings:	No wear.						
Rod Bearings:	No wear.						

[a] All dimensions are given in inches.

VEHICLE NUMBER A18731/MORCO OIL

		1	2	3	4	5	6
Cylinder Diameter:[a]							
Top (Approx. 1/2" down)		3.402	3.402	3.402	3.403	3.402	3.403
Bottom		3.401	3.401	3.401	3.4025	3.401	3.401
Wear (Difference)		0.001	0.001	0.001	0.0015	0.001	0.001
	Avg. = 0.00108						
Piston Diameter:[a]							
Bottom of Skirt		3.400	3.401	3.3995	3.400	3.4005	3.400
Just Below Rings		3.3995	3.400	3.3995	3.400	3.4005	3.400
Wear (Difference)		0.0005	0.001	0.00	0.00	0.00	0.00
	Avg. = 0.00025						
Ring Gap:[a]		0.025	0.025	0.025	0.025	0.025	0.025
	Avg. = 0.025						
Valve Guide:[a]							
Intake	Avg. wear = 0.001						
Exhaust		0.005	0.001	0.001	0.001	0.005	0.001
Main Bearings:	No wear.						
Rod Bearings:	No wear.						

[a] All dimensions are given in inches.

VEHICLE NUMBER A20369/MORCO OIL

	Right Side 1	Right Side 2	Right Side 3	Right Side 4	Left Side 1	Left Side 2	Left Side 3	Left Side 4
Cylinder Diameter:[a]								
Top (Approx. 1/2" down)	4.059	4.056	4.056	4.058	4.0615	4.054	4.055	4.057
Bottom	4.052	4.052	4.052	4.052	4.052	4.052	4.052	4.052
Wear (Difference)	0.005	0.004	0.004	0.006	0.0085	0.002	0.003	0.005
Avg. = 0.00469								
Piston Diameter:[a]								
Bottom of Skirt	4.050	4.0485	4.048	4.048	4.0485	4.051	4.049	4.049
Just Below Rings	4.0475	4.048	4.048	4.047	4.0475	4.048	4.047	4.0475
Wear (Difference)	0.0025	0.0005	0.00	0.001	0.001	0.003	0.002	0.0025
Avg. = 0.00175								
Ring Gap:[a]	0.077	0.122	0.103	0.075	0.125	0.043	0.052	0.042
Avg. = 0.0799								
Valve Guide:[a]								
Intake	Avg. wear = 0.002							
Exhaust	Avg. wear = 0.003							
Main Bearings:	Avg. wear = 0.0005							
Rod Bearings:	Avg. wear = 0.0005							

[a] All dimensions are given in inches.

VEHICLE NUMBER A20371/VIRGIN OIL

	Right Side				Left Side			
	1	2	3	4	1	2	3	4
Cylinder Diameter:[a]								
Top (Approx. 1/2" down)	4.062	4.061	4.060	4.0595	4.061	4.061	4.057	4.061
Bottom	4.052	4.052	4.051	4.051	4.051	4.052	4.051	4.052
Wear (Difference)	0.010	0.009	0.009	0.0085	0.010	0.009	0.006	0.009
Avg. = 0.0088								
Piston Diameter:[a]								
Bottom of Skirt	4.047	4.0475	4.047	4.047	4.047	4.048	4.049	4.048
Just Below Rings	4.047	4.0475	4.047	4.047	4.047	4.048	4.0475	4.048
Wear (Difference)	0.00	0.00	0.00	0.00	0.00	0.00	0.0015	0.00
Avg. = 0.00								
Ring Gap:[a]	0.078	0.078	0.078	0.078	0.075	0.075	0.075	0.078
Avg. = 0.758								
Valve Guide:[a]								
Intake	Avg. wear = 0.0015							
Exhaust	Avg. wear = 0.003							
Main Bearings:	Avg. wear = 0.0005							
Rod Bearings:	Avg. wear = 0.0005							

[a] All dimensions are given in inches.

APPENDIX E

COLLECTION OF WASTE OIL FROM FARMS

COLLECTION OF WASTE OIL FROM FARMS

There have been several studies concerning the amount of used oil available from service stations and manufacturing firms and the feasibility of collecting and recycling such oil. However, the quantity of oil available and the difficulty of collecting oil from farm populations have never been assessed. The purpose of this study was to consider the economics and feasibility of collecting oil from farms in Iowa.

Nationwide, the agricultural industry consumes more petroleum than any other single industry [1]. In Iowa, 19.2% of the population lives on farms and operates 32% of the internal combustion engines. Although these engines probably average fewer hours than highway vehicles, they generally consume more oil per hour and have hydraulic systems and gear boxes associated with them. Beyond that, little is known about agricultural consumption patterns.

A questionnaire was developed to survey agricultural oil consumption patterns and attitudes toward using re-refined oil. This questionnaire was mailed to 400 farm owner-operators in each of four counties (Butler, Guthrie, Keokuk and Wayne). The mailing lists were developed randomly from county directories [2-5]. Of the 400 questionnaires mailed, 113 were returned and 69 (19.4%) were considered valid. The age distribution, acres of land farmed and number and type of vehicles corresponded well with other statistical data for Iowa. This suggests a valid sample population.

RESULTS

The age and farm size distribution of the respondents are shown in Tables 1 and 2.

Question 3 asked farmers to provide information about oil use in all engines of various pieces of equipment. The detailed breakdowns obtained are presented in Table 3. The average farmer operates approximately three tractors, one car and either a pickup or a truck. With the exception of the cars, the majority change their own oil. The type of oil used, change frequency and other factors are about as expected.

About 45% of the farmers purchase their oil in drums or 5-gallon cans, and 23% purchase oil exclusively in cases of quart cans. The average quantity of oil purchased is 50.9 gallons per year, with the distribution shown in Fig. 1.

Farmers dispose of used oil in a variety of ways, as shown in Table 4. The most common use is for rust prevention (oil plowshares, etc.), with dust control second. A rather large fraction (11%) simply dump their oil on the ground. Only two respondents indicate that they return at least a portion of the waste oil to a service station or landfill. About 7% use the oil as an aid in burning brush, lumber or weeds.

Only two of the respondents felt their method of disposal might be harmful to the environment. The majority apparently felt they made good use of the waste oil and that the quantity dumped was insignificant.

The factors which influence a farmer in purchasing oil are listed in Table 5. Farmers have a large investment in equipment which they

Table 1. Iowa farm size distribution.

Acres	Percent
0-160	25.0
160-320	41.17
320-640	26.47
Other	7.36

Table 2. Age profile of Iowa farmers.

Age	Percent
18-24	0.0
25-29	1.45
30-50	23.19
Over 50	75.36

Table 3. Oil used on Iowa farms in Butler, Guthrie, Keokuk and Wayne Counties.

Vehicle		Type Oil Used				Change Frequency	Filter Change Frequency		Quantity Per Change	Oil Added Between Changes	Changed By	
Type	No.	10W-30	10W-40	30	Other	Hrs/Miles	Every Time	Alternate	Quarts	Quarts	Self	Station
Tractors												
Butler	46	13	0	28	5	108.8	34	10	7.65	1.28	All	
Guthrie	37	3	2	27	5	104.7	30	7	8.43	0.95		
Keokuk	65	8	9	41	7	125.4	54	10	8.84	2.26		
Wayne	43	6	5	31	1	102.2	33	10	8.49	1.65		
Total	191	30	16	127	18	112.2[a]	151	37	8.40[a]	1.63[a]		
Percent		15.7	8.4	66.5	9.4		80.3	19.7				
Cars												
Butler	18	13	4	1	0	3111.0	12	6	5.22	1.00	9.0	9.0
Guthrie	12	1	6	1	4	3041.7	12	0	5.08	0.66	4.5	7.5
Keokuk	29	13	5	3	8	3224.1	21	8	5.14	0.75	14.0	15.0
Wayne	16	9	6	0	1	3281.2	14	2	5.13	0.50	7.5	8.5
Total	75	36	21	5	13	3180.0[a]	59	16	5.15[a]	0.74[a]	35.0	40.0
Percent		48	28	6.7	17.3		78.7	21.3			46.0	53.0
Pickups												
Butler	14	8	4	1	1	2500.0	12	2	5.36	0.64	5.0	9.0
Guthrie	12	3	3	2	4	2541.7	11	1	5.33	0.83	6.5	5.5
Keokuk	17	8	2	4	3	3058.8	10	7	5.35	1.76	8.5	8.5
Wayne	13	4	4	3	2	3000.0	12	1	5.23	1.38	8.0	5.0
Total	56	23	13	10	10	2794.6[a]	46	11	5.32[a]	1.19[a]	28.0	28.0
Percent		41.1	23.2	17.8	17.8		80.4	19.6			50.0	50.0
Trucks												
Butler	2	1	0	0	1	1750.0	2	0	5.50	0.50	2.0	0.0
Guthrie	6	0	1	4	1	2666.7	6	0	6.83	1.83	3.0	3.0
Keokuk	6	1	2	2	1	2083.0	3	3	7.00	1.66	6.0	0.0
Wayne	4	3	0	0	1	2500.0	3	1	6.00	2.00	2.5	1.5
Total	18	5	3	6	4	2333.3[a]	14	4	6.55[a]	1.66[a]	13.5	4.5
Percent		27.8	16.7	33.3	22.2		77.8	22.2			75.0	25.0

[a] Average

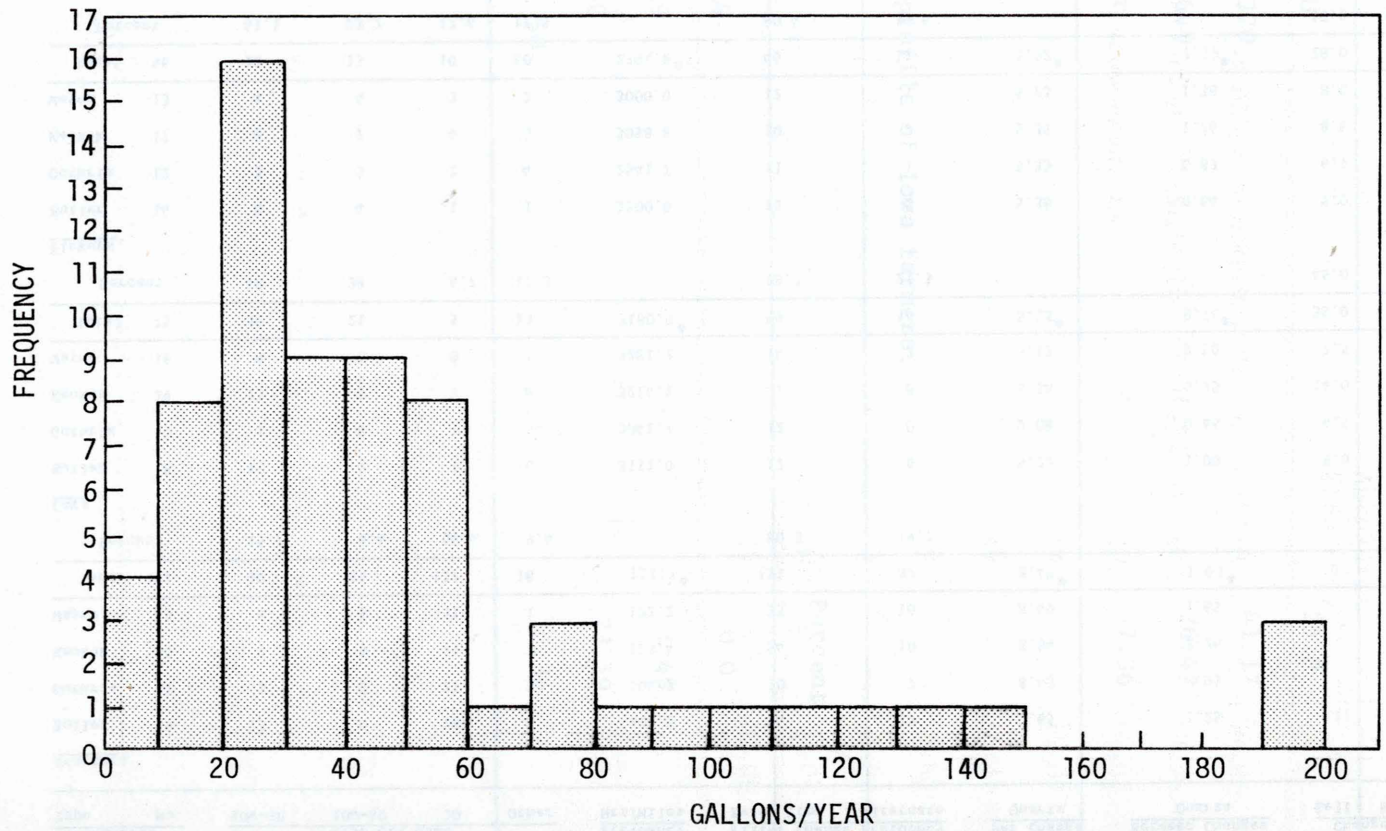


Fig. 1. Distribution of oil consumption on Iowa farms.

Table 4. Used oil disposal techniques.

	Absolute Frequency	%
Oil cultivator shovels & plowshares	55	27.64
Service station changes oil	32	16.08
Use for dust control	28	14.07
Other	25	12.56
Dump on ground	22	11.06
Use for weed control	17	8.54
Burn it	14	7.04
Insect control stagnant pools	4	2.01
Take to dump or landfill	1	0.50
Take to service station	1	0.50
Sell it	-	0.00
Total	199	100.00

Table 5. Factors in decision to purchase a particular type of oil, based on response from 69 questionnaires.

	Absolute Frequency	%
Highest quality (by SAE designation, etc.)	46	34.07
Dealer (recommendation, friendship, reputation)	26	19.26
Manufacturer's recommendation	20	14.82
Brand name	19	14.07
Viscosity	15	11.11
Other	6	4.45
Lowest price	3	2.22
Labelling	0	0.00
Total	135	100.00

protect by selecting what they feel is a high quality oil. The first five factors listed might all be interpreted as efforts to obtain high quality oil. Price is obviously a low-level criterion.

Only two of the respondents indicated that re-refined oil was available in their area, while 70% didn't know whether it was or not. About 27% didn't think it was available and no one had purchased any. Table 6 indicates the relative willingness to purchase re-refined oil of the same price and quality as virgin oil. The comments associated with the 'yes' and 'probably would' answers indicate a rather high energy resource conservation awareness. The negative responses (58%) were explained by skepticism about the quality of re-refined oil. Generally, the respondents wanted proof of quality before trying re-refined oil, and they also felt that "used" oil should be cheaper than "new."

Table 7 lists the results of an attempt to assess the willingness of farmers to participate in a recycling program. The interpretation of this question by the respondents is not really clear. Less than 25% appear to be willing to participate in a recycling program even if everything were provided, although the ratio of 'yes' to 'no' answers is 3 to 1. It also seems likely that a large fraction of farmers would continue to use oil on the farm but would contribute the excess to recycling. These results suggest that a recycling program would have to bear the cost of a container on each farm and the cost of removal from the farm in order to achieve significant participation. Even this kind of a program is unlikely to collect more than 50% of the available used oil.

The economics of such a recycling program are not likely to attract a large number of investors. There are a total of 131,000 farms in Iowa.

Table 6. Willingness to purchase re-refined oil.

	Absolute Frequency	%
Yes	6	9.38
Probably would	21	32.81
Probably would not	21	32.81
No	15	25.00
Total	64	100.00

Table 7. Willingness to participate in a recycling program, based on 65 responses to this question.

	Absolute Frequency Yes	Absolute Frequency No	% Yes	% No
1. A drum was provided for you to collect waste oil in and someone emptied it for you.	33	11	22.00	7.33
2. You were asked to provide the drum and someone would empty it out regularly for you.	19	14	12.67	9.33
3. You were asked to provide a drum and asked to haul it to a collection site where it would be dumped for you.	7	20	4.67	13.33
4. You would continue to use the oil on the farm.	35*	11	23.33	7.33
Total	150		100.00	

*Twelve respondents indicated they would continue to use some oil on the farm but would be willing to participate in a recycling program with the remainder.

With half of the farmers participating and 40% of their purchased oil available for recycling, there would be 1,330,000 gal/yr of oil recycled. This is based on the 50.9 gal/farm/year averaged cited above. A lower bound on the collection cost might be obtained by assuming 20 gallons per collection site to be picked up annually. This would require each of five trucks to make 45 stops per day and collect about 890 gallons. This leaves about 11 minutes per stop and may require 100 miles of traveling. An updated operating cost of $1.86/mile [6] then gives a transportation cost of $0.31/gal collected. An additional cost of about $0.05/gal would be required for purchase of storage facilities. A cost of $0.36/gal seems prohibitively high at today's oil prices.

A more promising alternative would be to have service station trucks collect the oil on their regular farm stops. A local Iowa collector indicates a cost of $0.10 to $0.12 per gallon to collect oil from service stations.

Considering the difficulties that urban areas have experienced in collecting waste oil, it seems clear that a strong public commitment or government support will be required to effectively recycle waste oil from rural areas.

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