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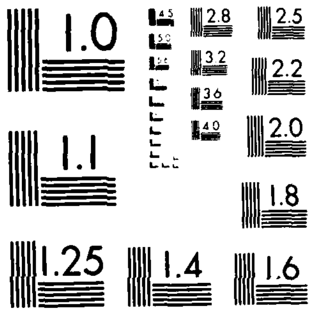

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# INSPECTION DATA FOR SPARK-IGNITION ENGINES FROM AIR FORCE NONTACTICAL VEHICLES (MEEP Project H79-1C, Synthetic Oils)

**INTERIM REPORT**
**AFLRL No. 163**

**VOLUME I – TECHNICAL REPORT**

By

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



January 1983

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Many DOD vehicles are operated under short-trip, "stop and go" conditions. Since this type of operation imposes severe requirements on the engine oil and because poor performances and failure in the engine oil increase operation and maintenance costs, the decision was made to test synthetic lubricants as a possible solution to the problem. Today's energy shortage, rising labor and material cost, and smaller budgets require exploration of

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20. ABSTRACT (Cont'd)

potential methods of cost reductions in operation of government vehicles. This MEEP project was requested by the Triservices through the Joint Deputies for Laboratory Committee (JDLC). Of approximately 450 general-purpose vehicles selected by 11 Air Force installations for this program, 29 of the vehicles were chosen for engine inspection at USAFLRL, San Antonio, TX. These 29 engines were disassembled by AFLRL personnel and inspected in accordance with CRC rating methods. Wear measurements were made of selected parts, and photographs were taken of representative parts from each engine. For various reasons the three engines from Sondrestrom Air Force Base were eliminated from the test at this point and are not included in this report. The number of engines was thus reduced to 26. A comparison was also made between the lubricants used in the test by utilizing the oil analyses data provided by the Technical Service Center, Joint Oil Analysis Program Laboratory in Pensacola, FL and copies of the individual maintenance records provided by each installation. Based solely on the results of the engine tear-down inspections and in consideration of the data developed from oil analyses and maintenance records, synthetic lubricants can be successfully used in spark ignition engines. Statistical studies revealed no significant differences could be determined which would clearly indicate if the use of any one test oil would be more advantageous than the use of any of the other test lubricants. Final conclusions, of course, reside with the Warner Robins Air Logistics Center where coordination of the compilation of a report covering all aspects of the program will be made.

## FOREWORD/ACKNOWLEDGMENTS

This report was prepared by the U.S. Army Fuels and Lubricants Research Laboratory (AFLRL) located at Southwest Research Institute, San Antonio, TX, under Contract No. DAAK70-82-C-0001. It presents the work done by AFLRL personnel for the period September 1981 through October 1982. This work was performed as part of MEEP Project H-79-1C, Synthetic Oils initiated by the U.S. Air Force at Warner Robins Air Logistics Center (AFLC), Robins Air Force Base, GA in response to a request by the Triservices through the Joint Deputies for Laboratory Committee (JDLC). The Project monitor for the Air Force was Mr. C.H. Coffey, Warner Robins Air Force Base. The Project Monitor and Contracting Officer's Representative for the Army was Mr. F.W. Schaekel, Belvoir Research and Development Center, STRBE-VF, Ft. Belvoir, VA.

The authors acknowledge with appreciation the cooperation and immediate response by MEEP and Air Force maintenance personnel, without which this report could not have been successfully concluded. Also appreciated was the help and support of Mr. Sidney J. Lestz, USAFLRL.

TABLE OF CONTENTS

## LIST OF TABLES

# I. INTRODUCTION

A multivehicle fleet test utilizing U.S. Air Force general-purpose vehicles was organized and conducted from approximately March 1980 through June 1981 at the request of the Triservices through the Joint Deputies for Laboratory Committee (JDLC).(1)* The project was conducted under the direction of the Management and Equipment Evaluation Program (MEEP) Section, Materiel Analysis Branch, Warner Robins Air Logistics Center (AFLC), Warner Robins Air Force Base, GA and was designated as MEEP Project H 79-1C, Synthetic Oils. The Project Manager, WR-ALC, was directed to coordinate with the U.S. Army to perform teardown inspections of 29 of the test engines at the conclusion of the test. This was done with the U.S. Army Belvoir Research and Development Center, Ft. Belvoir, VA which provided the funding, and designated the U.S. Army Fuels and Lubricants Research Laboratory (USAFLRL) located at Southwest Research Institute (SwRI), San Antonio, TX as the agency responsible for the after-test inspections of the 29 engines.

The objective of the test was to determine through accumulation of field data if use of synthetic engine oil would extend oil drain intervals, reduce oil filter changes, eliminate sludge buildup, prolong engine life, give advantages in fuel consumption, improve cold weather starting, and reduce operational cost. The synthetic oils chosen were of different manufacture and were assigned the color codes Yellow and Green. The baseline, or control oil was a mineral oil of normal procurement and stockage. This oil was color coded Blue.

# II. DETAILS OF TEST

## Test Procedures

Reference 1 includes guidelines for the selection and preparation of vehicles used in the test. Each designated U.S. Air Force Major Command (MAJCOM) was directed to select a minimum of 60 general-purpose, gasoline

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* Underscored numbers in parentheses indicate references at the end of this report.

engine-powered vehicles. The vehicles were selected in groups of three and were matched as nearly as possible as to make, model, age, mileage, engines, general condition, and use. Within each set, one vehicle was operated with a mineral oil, and each of the other two vehicles was operated with a synthetic oil of different manufacture. One set of three vehicles was selected from each MAJCOM for after-test disassembly and inspection. Parameters for taking oil samples and changing oil and filters were established as well as procedures for sample analysis.

- Vehicles designated to use synthetic lubricants had oil samples taken and the crankcase oil and oil filter changed at the beginning of the test.
- These vehicles were operated for 500 miles or 50 hours and again had oil samples taken and the crankcase oil and oil filter changed to ensure purging of any mineral oil that may have remained in the crankcase.
- After this second oil and filter change, oil samples were taken from all involved vehicles each 2000 miles or 600 hours of operation.
- Oil samples were forwarded to Air Force personnel at the Joint Oil Analysis Program (JOAP) Laboratory in Pensacola, FL.
- Engine oil was changed as necessary by comparing laboratory findings with parameters developed by the Air Force Systems Command (AFSC).
- Oil filters were changed each 6000 miles or when the oil was changed, whichever occurred first.
- In case of engine failure, an additional oil sample was drawn and forwarded to the USAFLRL.(2)

Some of the engines did fail, and an investigation into the cause of each was done by AFLRL personnel. A final report, AFWAL-TR-81-4153 "Field Liaison in Support of Evaluation of Synthetic Lubricants in NonTactical Vehicles", published in February 1982(2), gives the details of each failure including the probable cause. According to the report, none of the engine failures was due to oil-related causes.

On completion of test, a portion of the vehicles operating on each test lubricant were designated for engine teardown inspections. Vehicle engines were removed and forwarded to the AFLRL where they were disassembled and evaluated for condition, wear and deposit formation. Table 1 identifies the vehicles selected for inspection.

Test Lubricants, Synthetic and Control

Six engine lubricants were used in testing the twenty-nine engines chosen for teardown inspections at USAFLRL. Four of the oils were MIL-L-46152 Qualified Products which met the requirements established in MIL-L-46152 "Military Specification, Lubricating Oil, Internal Combustion Engine, Administrative Service". The other two oils were certified to meet the MIL-L-46152 standards. Of the six lubricants, two were multiviscosity synthetic lubricants each manufactured by a different company. One of the lubricants was color coded Yellow, while the second synthetic lubricant was color coded Green. The other four oils were standard issue mineral oils and were color coded Blue. To differentiate one Blue oil from another of different manufacture, they were further designated as Blue(A), Blue(B), Blue(C), and Blue(D). Thus, comparisons are possible between mineral oils as well as a collective comparison against the synthetic lubricants used in the test.

As stated in Reference 1, sampling of new synthetic lubricants was not required to establish a baseline because this had already been done by the JOAP laboratory and the organization procuring the oil. Therefore, baseline data on the lubricants used in the synlube test were requested from the JOAP Laboratory in Pensacola, FL. These data were provided and form the basis for the values shown for the synthetic lubricants in Table 2, "Physical Properties of Test Lubricants". The values in the table pertaining to the Blue oils were determined by USAFLRL using approved ASTM methods.

TABLE 1. DESCRIPTION OF VEHICLES IDENTIFIED FOR TEARDOWN

| MAJCOMS | Installation | Test Lubricant | Vehicle Reg. No. | Make & Type Vehicle | Engine & Disp. |
|---|---|---|---|---|---|
| | USAFA, CO | Green | 79B5659 | Ford Sedan, Compact | 6 cyl, 200 CID |
| | | Yellow | 79B5660 | Ford Sedan, Compact | 6 cyl, 200 CID |
| | | Blue(C) | 79B5668 | Ford Sedan, Compact | 6 cyl, 200 CID |
| TAC | GAFB, CA | Green | 79B2533 | Dodge Panel Truck | V-8, 318 ICD |
| | | Yellow | 79B2534 | Dodge Panel Truck | V-8, 318 CID |
| | | Blue(C) | 79B2539 | Dodge Panel Truck | V-8, 318 CID |
| SAC | GFAFB, ND | Blue(B) | 79B1735 | Chevrolet Truck, Carryall | V-8, 350 CID |
| | | Yellow | 79B1734 | Chevrolet Truck, Carryall | V-8, 350 CID |
| ADCOM | HAFB, NY | Green | 78B5038 | Plymouth, St. Wagon, Compact | 6 cyl, 225 CID |
| | | Yellow | 78B5646 | Ford, Truck, Stake body | 6 cyl, 300 CID |
| ATC | LAFB, TX | Yellow | 79B2270 | Ford Truck, 1 1/2 T, 4x2 | 6 cyl, 300 CID |
| | | Green | 79B2271 | Ford Truck, 1 1/2 T, 4x2 | 6 cyl, 300 CID |
| | | Blue(A) | 79B2272 | Ford Truck, 1 1/2 T, 4x2 | 6 cyl, 300 CID |
| SAC | MAFB, ND | Green | 79B1736 | Chevrolet Truck, Carryall | V-8, 350 CID |
| | | Blue(C) | 79B1759 | Chevrolet Truck, Carryall | V-8, 350 CID |
| TAC | MBAFB, SC | Green | 79B5212 | Plymouth Sedan | 6 cyl, 225 CID |
| | | Yellow | 79B9187 | Plymouth Sedan | 6 cyl, 225 CID |
| | | Blue(D) | 79B9188 | Plymouth Sedan | 6 cyl, 225 CID |
| SAC | OAFB, NE | Green | 78B4766 | Chevrolet Truck, Delivery | 6 cyl, 292 CID |
| | | Blue(C) | 78B4768 | Chevrolet Truck, Delivery | 6 cyl, 292 CID |
| ADCOM | PAFB, CO | Yellow | 78B4571 | Chevrolet Truck, Multistop, 7K# | 6 cyl, 292 CID |
| | | Green | 78B4569 | Chevrolet Truck, Multistop, 7K# | 6 cyl, 292 CID |
| | | Blue(C) | 78B8831 | Chevrolet Truck, Multistop, 7K# | 6 cyl, 292 CID |
| ATC | RAFB, TX | Yellow | 79B5719 | Ford Sedan, Compact | 4 cyl, 140 CID |
| | | Blue(A) | 79B5720 | Ford Sedan, Compact | 4 cyl, 140 CID |
| | | Green | 79B5721 | Ford Sedan, Compact | 4 cyl, 140 CID |

TABLE 2. PHYSICAL PROPERTIES OF TEST LUBRICANTS

| | MIL-L-46152 Qualified* | | Certified to meet MIL-L-46152 Specifications | | MIL-L-46152 Qualified | |
|---|---|---|---|---|---|---|
| Lubricant Color Code | Green | Yellow | Blue(A)a/ | Blue(B) | Blue(C) | Blue(D)b/ |
| Lubricant Type | Synthetic | Synthetic | Mineral | Mineral | Mineral | Mineral |
| Description: | | | | | | |
| API Service Classification | SE/CC | SE/CC | SE/CC | SE/CC | SE/CC | SE/CC |
| Viscosity Classification | 10W-30 | 10W-40 | 10W-30 | 10W-40 | 10W-30 | 10W-40 |
| Properties* | | | | | | |
| Kvis. @ 100°C, cSt | 10.20 | 13.8 | 11.06 | 13.17 | 10.29 | 13.65 |
| Kvis. @ 40°C, cSt | 52.2 | 78.4 | ND | ND | ND | ND |
| Viscosity Index | 180 | 182 | ND | ND | ND | ND |
| TAN | 2.6 | 2.96 | 1.69 | 2.55 | 2.38 | 3.41 |
| TBN | 6.9 | 6.3 | ND | ND | ND | ND |
| Flash Point, °C | 204 | 232 | ND | ND | ND | ND |
| Pour Point, °C | -48 | -43 | ND | ND | ND | ND |

* - Data provided JOAP Laboratory by the company supplying the synthetic lubricants

ND - Not determined

a/ - Oil sample received at AFLRL was labeled as a 10W-40 grade oil. However, subsequent testing proved it to be a 10W-30 grade oil.

b/ - Oil sample received at AFLRL was labeled as a 10W-30 grade oil. However, subsequent testing proved it to be a 10W-40 grade oil.

## III. RESULTS OF TEST

Lubricant performance was evaluated by two methods:

(1) analysis of the data provided by the JOAP laboratory, and

(2) after-test inspections of engines selected by each designated MAJCOM and the USAF Academy.

### Used Oil Analyses

All the lubricants used in the 26 engines inspected at AFLRL appeared to have performed satisfactorily. Some oil distress occurred as shown by high viscosity values for some engines. Table 3 shows the average viscosity density product (VDP) for test oils used at each Air Force installation and identifies those oils that were outside the parameters establishing the acceptable range for each oil at a given temperature.(3) The TSC, JOAP determined the VDP for new test lubricants for each deg F for a range of ambient temperatures. These VDPs were labeled "True Values" which is the basis for the term's use in this report. Each True Value VDP was then multiplied by 0.25, and the result was added to and substracted from its respective True Value VDP to establish parameters for VDP acceptability. Appendix D, Volume II, shows the average for each wear metal, additive element, particulate content, and VDP of each test oil for each test engine. These averages were used to establish a mean and standard deviation for each of the data categories for each group of test oil, (i.e., Yellow, Green and Blue). A statistical analysis then established the range of predicted difference between the means for the test oils.

By comparing the means for each variable of one oil with the means for each respective variable of a second oil, it was determined that there were no statistical differences between the means for any variable listed except one. There was a statistical difference between the means for the variable, VDP, for the Blue and the Green lubricants. This does not mean that one oil is better than the other, only that the difference between VDPs for each oil at the beginning of the test was still present at the end of the test. Appendix E, Volume II, contains an explanation of the statistical tests used. Table 4 illustrates the True Value VDPs for each test oil at 74°F at

TABLE 3. COMPARISON OF TRUE VALUE (T.V.) VDP* (Baseline) WITH USED TEST OIL VDP

| Installation | Blue Oil Code | New Oil VDP Temp, °F | New Oil VDP Low Limit | New Oil VDP TV | New Oil VDP High Limit | Used Oil Average VDP Temp, °F | Used Oil Average VDP VDP |
|---|---|---|---|---|---|---|---|
| USAF Academy | C | 75 | 84 | 112 | 140 | 74.5 | 95.93 |
| George AFB | C | 74 | 87 | 116 | 145 | 73.5 | 154.04 a/ |
| Grand Forks AFB | B | 74 | 95 | 126 | 158 | 73.7 | 161.14 a/ |
| Hancock AFB b/ | | | | | | | |
| Lackland AFB | A | 74 | 72 | 96 | 120 | 73.9 | 111.57 |
| Minot AFB | C | 73 | 89 | 119 | 132 | 73.2 | 130.28 |
| Myrtle Beach AFB | D | 74 | 76 | 101 | 126 | 74 | 98.85 |
| Offutt AFB | C | 74 | 87 | 116 | 145 | 74 | 124.92 |
| Peterson AFB | C | 74 | 87 | 116 | 145 | 73.8 | 112.67 |
| Randolph AFB | A | 75 | 76 | 101 | 126 | 74.5 | 121.83 |

*VDP = Viscosity Density Product (Centipoise x $g/cm^3$)
a/ = VDP value outside of range established by True Value ± 25 percent.
b/ = Hancock AFB did not ship any test engines that had used a Blue oil.

TABLE 3. COMPARISON OF TRUE VALUE (TV) VDP* (Baseline) WITH USED TEST OIL VDP (CONT'D)

| | Yellow Oils | | | | | | Green Oils | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | New Oil VDP | | | | Used Oil Average VDP | | New Oil VDP | | | | Used Oil Average VDP | |
| Installation | Temp, °F | Low Limit | TV | High Limit | Temp, °F | VDP | Temp, °F | Low Limit | TV | High Limit | Temp, °F | VDP |
| USAF Academy | 74 | 81 | 108 | 134 | 74 | 113.80 | 74 | 65 | 87 | 109 | 74.1 | 89.70 |
| George AFB | 73 | 83 | 110 | 138 | 73 | 154.14 a/ | 73 | 67 | 89 | 112 | 73.2 | 116.40 a/ |
| Grand Forks AFB | 73 | 83 | 110 | 138 | 73.5 | 175.60 a/ | -+ | - | - | - | - | - |
| Hancock AFB b/ | 75 | 79 | 105 | 131 | 74.8 | 102.00 | 74 | 65 | 87 | 109 | 73.5 | 92.17 |
| Lackland AFB | 73 | 83 | 110 | 138 | 73.5 | 101.60 | 74 | 65 | 87 | 109 | 73.8 | 93.00 |
| Minot AFB | - b/ | - | - | - | - | - | 73 | 67 | 89 | 112 | 73.2 | 119.05 a/ |
| Myrtle Beach AFB | 74 | 81 | 108 | 134 | 74 | 108.22 | 74 | 65 | 87 | 109 | 73.5 | 96.68 |
| Offutt AFB | - b/ | - | - | - | - | - | 74 | 65 | 87 | 109 | 73.8 | 113.08 a/ |
| Peterson AFB | 74 | 81 | 108 | 134 | 73.6 | 119.14 | 74 | 65 | 87 | 109 | 73.8 | 87.80 |
| Randolph AFB | 73 | 83 | 110 | 138 | 73.5 | 134.00 | 73 | 67 | 89 | 112 | 73.4 | 85.08 |

*VDP= Viscosity Density Product (Centipoise x $g/cm^3$)
a/ = VDP values outside of range established by the True Value ± 25 percent.
b/ = No test engines were received that had used Yellow oil during the test.
+No engine utilizing Green oil was shipped from Grand Forks AFB.

the beginning of the test and the average VDPs for each test oil at the end of the test at an average 74°F. Also shown is the average percent increase in VDP for each test oil.

TABLE 4. PERCENT INCREASE IN VDPs*

| Color Code | Average True Value VDP Beginning of Test | Average VDP At End of Test | Average Percent Increase |
|---|---|---|---|
| Green | 88 | 100 | 13.64 |
| Blue(Avg.) | 111 | 123 | 10.81 |
| Yellow | 109 | 126 | 15.60 |

*Average temperature for determining VDP before and after the field test was 74°F.

Unfortunately, total acid numbers (TANs) and total base numbers (TBNs) were not determined at JOAP laboratories. Oil alkalinity reserve capacity and other oil properties and conditions were shown in subjective terms as follows:

Oil alkalinity reserve capacity.......Good or bad

Oil dispersive properties.............Good, fair or poor

Particulate contaminants..............Light, medium or heavy

Coolant contamination.................Not present or present

These properties and conditions were determined by blotter tests and included in the oil analyses computer printouts from the JOAP laboratories. A summary of these oil properties and conditions is given in Table 5.

Reference 3 also gave the baseline data for additives for each of the test lubricants. The quantities given in the oil analysis computer printouts for used oil samples were averaged for each test lubricant. Table 6 compares the used oil sample additive quantity averages with the values shown in Reference 3. Calcium was not included in the computer printouts; therefore, no comparisons for that element could be made. It should also be noted that the value of 998 is the highest value in parts per million (ppm) that is

TABLE 5. LUBRICANT ANALYSIS DATA SUMMARY

| Installation | Vehicle Number | Lubricant Code | Average VDP[a/] | Average Particulate, mL of Solids | Particulate Range, mL of Solids | Total Particulate Contaminants[b/] | Coolant Contamination In Oil | Alkalinity Reserve Capacity | Oil Dispersive Properties |
|---|---|---|---|---|---|---|---|---|---|
| USAF Academy | 79B5659 | Green | 89.70 | 0.15 | 0.06–0.25 | Medium | Not present | Good | Fair |
| | 79B5660 | Yellow | 113.80 | 0.14 | 0.01–0.30 | Med to hvy | Not present | Good | Fair |
| | 79B5668 | Blue (C) | 95.93 | 0.07 | 0.05–0.10 | Medium | Not present | Good | Good to fair |
| George AFB | 79B2533 | Green | 116.40 | 0.11 | 0.01–0.20 | Lt to med | Not present | Good | Fair |
| | 79B2534 | Yellow | 154.14 | 0.08 | 0.01–0.40 | Medium | Not present | Good | Fair |
| | 79B2539 | Blue (C) | 146.83 | 0.19 | 0.01–0.57 | Med to hvy | Not present | Bad | Fair |
| Grand Forks AFB | 79B1734 | Yellow | 171.12 | 0.02 | 0.01–0.06 | Lt | Present | Good | Fair |
| | 79B1735 | Blue (B) | 161.14 | 0.08 | 0.01–0.40 | Lt to med | Not present | Good | Good to fair |
| Hancock AFB | 78B5038 | Green | 94.72 | 0.18 | 0.01–0.31 | Medium | Not present | Good | Fair |
| | 78B5646 | Yellow | 111.80 | 0.23 | 0.01–0.71 | Medium | Not present | Good | Fair |
| Lackland AFB | 79B2270 | Yellow | 101.60 | 0.13 | 0.01–0.20 | Medium | Not present | Good | Fair |
| | 79B2271 | Green | 93.00 | 0.22 | 0.18–0.32 | Med to hvy | Not present | Good | Fair to poor |
| | 79B2272 | Blue (A) | 111.57 | 0.15 | 0.08–0.25 | Lt to med | Not present | Bad | Fair |
| Minot AFB | 79B1736 | Green | 119.05 | 0.14 | 0.01–0.28 | Medium | Not present | Good | Fair |
| | 79B1759 | Blue (C) | 130.28 | 0.14 | 0.01–0.40 | Medium | Not present | Good | Fair |
| Myrtle Beach, SC | 79B5212 | Green | 96.68 | 0.15 | 0.01–0.22 | Medium | Not present | Good | Fair |
| | 78B9187 | Yellow | 108.22 | 0.25 | 0.06–0.60 | Med to hvy | Not present | Good | Fair to poor |
| | 78B9188 | Blue (D) | 98.85 | 0.11 | 0.02–0.30 | Lt to med | Not present | Good | Good to fair |
| Offutt AFB | 78B4766 | Green | 113.08 | 0.18 | 0.01–0.30 | Med to hvy | Not present | Bad | Fair |
| | 78B4768 | Blue (C) | 124.92 | 0.25 | 0.12–0.50 | Med to hvy | Not present | Bad | Fair |
| Peterson AFB | 78B4571 | Yellow | 119.14 | 0.32 | 0.15–0.60 | Medium | Not present | Bad | Fair to poor |
| | 78B4569 | Green | 87.80 | 0.13 | 0.06–0.17 | Medium | Not present | Good | Good to fair |
| | 78B8831 | Blue (C) | 112.67 | 0.23 | 0.10–0.30 | Med to hvy | Not present | Good | Fair |
| Randolph AFB | 79B5719 | Yellow | 134.00 | 0.04 | 0.01–0.08 | Medium | Not present | Good | Fair |
| | 79B5720 | Blue (A) | 121.83 | 0.06 | 0.02–0.10 | Lt to med | Not present | Bad | Fair |
| | 79B5721 | Green | 85.08 | 0.11 | 0.08–0.12 | Lt to med | Not present | Good | Good |

a/ = Viscosity Density Product (Centipoise x $g/cm^3$)
b/ = Light; Med = Medium; Hvy = Heavy

TABLE 6. AVERAGE ADDITIVE QUANTITIES FROM USED OIL SAMPLES COMPARED TO NEW OIL ADDITIVE QUANTITIES*

| Additives | Blue A | | Blue B | | Blue C | | Blue D | | Yellow | | Green | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (PPM) | New | Used | New | Used | New | Used | New | Used | New | Used | New | Used |
| B | 1 | 5 | 0 | 61 | 184 | 86 | 0 | 2 | 11 | 33 | 3 | 20 |
| Ba | 0 | 8 | 0 | 7 | 3 | 81 | 80 | 65 | 118 | 123 | 998 | 985 |
| Mg | 8 | 69 | 538 | 350 | 532 | 685 | 450 | 433 | 15 | 124 | 538 | 694 |
| Zn | 469 | 770 | 740 | 956 | 941 | 985 | 844 | 958 | 998 | 991 | 663 | 903 |

* Information provided by the JOAP Laboratory, Pensacola, FL.

determined in oil analyses by the TSC, JOAP laboratories. The actual ppm for any given element may be much higher than the value 998 but measurement limitations prohibit the determination of the exact values. Overall this means that a significant part of oil analyses data essential to decision-making as to whether or not an engine is jeopardized may not be available.

After-Test Engine Inspections

Ratings for the 26 engines inspected by USAFLRL are contained in Appendix A, Volume II, "Engine Inspection Data-Ratings". Sludge ratings were not made for the two engines shipped from Hancock Air Force Base, New York because the parts normally rated for sludge deposits were not shipped with the engines.

The inspection results showed that Chevrolet engines, both the V-8, 350 CID and the six cylinder, 292 CID, appeared to have fared the worst according to the ratings. They appeared to have been particularly susceptible to lifter body wear and piston scuffing with all lubricants in the program. A comparison of these engines to the total test mileages driven shows that six of them were among the highest mileage engines in the test. However, the three 292 CID engines from Peterson AFB which were among the lowest in total test miles still showed abnormal wear to lifter bodies. Again, it should also be noted that the lifter and piston wear occurred whether a green, yellow or blue test lubricant was used. However, a study of the maintenance history of each of these engines reveals that normal maintenance procedures were followed for three of the four engines operated with Blue oils and one of the three engines operated with a Green lubricant. Two of the engines operated with Yellow lubricants had extensive maintenance problems for the test period. Tables 7 and 8 contain the Sludge and Varnish Ratings Summaries, respectively. An examination of the data in Tables 7 and 8 reveals that all the test lubricants performed satisfactorily. Those sludge and varnish ratings that averaged below a rating of 8 were still average or above as compared to ratings normally achieved by other oils in fleet tests. The results averaging 8 or higher are considered to be indicative of very good performances by the test oils. Table 9 gives a brief summary of the maintenance histories for each test engine. Normal maintenance consisted of routine scheduled maintenance and replacement or repairs due to normal wear and tear. Specific maintenance actions were noted where the problems could possibly have been oil related. However, no positive conclusions can be made about the actual impact any given test oil had on any given engine.

TABLE 7. SLUDGE RATINGS SUMMARY FOR TEARDOWN ENGINES
(10 = Clean)

| | Type Oil | | | | | |
|---|---|---|---|---|---|---|
| Installations | Green | Yellow | Blue | | | |
| | | | A | B | C | D |
| AF Academy | 9.6 | 9.7 | | | 9.6 | |
| George* | 9.8 | 9.8 | | | 9.8 | |
| Grand Forks, ND | | 9.6 | | 9.5 | | |
| Hancock** | No sludge ratings | | | | | |
| Lackland | 9.4 | 9.6 | 9.7 | | | |
| Minot | 9.7 | | | | 9.6 | |
| Myrtle Beach | 9.3 | 9.2 | | | | 9.5 |
| Offutt | 8.4 | | | 6.7 | | |
| Peterson | 9.7 | 8.6 | | | 9.6 | |
| Randolph | 9.7 | 9.6 | 9.4 | | | |
| Average | 9.5 | 9.4 | 9.6 | 8.1 | 9.7 | 9.5 |

* These ratings are for the left and right valve decks and pushrod chamber only; the rocker arm covers, oil pan and intake manifolds were missing from the engines when received at AFLRL.

**The parts that are rated for sludge deposits were missing from the engines when received at AFLRL.

TABLE 8. VARNISH RATINGS SUMMARY FOR TEARDOWN ENGINES
(10 = Clean)

| Installations | Type Oil | | | | | |
|---|---|---|---|---|---|---|
| | Green | Yellow | Blue | | | |
| | | | A | B | C | D |
| AF Academy | 7.3 | 7.5 | | | 8.7 | |
| George | 7.0 | 7.8 | | | 7.4 | |
| Grand Forks, ND | | 9.6 | | 9.5 | | |
| Hancock | 6.0 | 9.95 | | | | |
| Lackland | 8.8 | 8.2 | 7.4 | | | |
| Minot | 7.8 | | | | 8.6 | |
| Myrtle Beach | 6.0 | 5.8 | | | | 5.7 |
| Offutt | 6.1 | | | 5.8 | | |
| Peterson | 8.8 | 7.7 | | | 6.7 | |
| Randolph | 8.9 | 9.6 | 9.4 | | | |
| Average | 7.4 | 8.3 | 8.4 | 7.7 | 7.9 | 5.7 |

TABLE 9. MAINTENANCE HISTORY FOR TEARDOWN ENGINES

| MAJCOM | Installation | Vehicle No. | Color Code | Maintenance Actions |
|---|---|---|---|---|
| | USAFA, CO | 79B5659 | Green | Normal maintenance |
| | | 79B5660 | Yellow | Normal maintenance |
| | | 79B5668 | Green | Normal maintenance |
| TAC | GAFB, CA | 79B2533 | Green | Normal maintenance |
| | | 79B2534 | Yellow | Normal maintenance |
| | | 79B2539 | Blue(C) | Normal maintenance |
| SAC | GFAFB, ND | 79B1734 | Yellow | Right valve cover gasket leaking. Left valve cover leaking. Constant system problems. |
| | | 79B1735 | Blue(B) | Oil leaks top and bottom of engine valve job rod bearings. Replaced #8 piston. |
| | HAFB, NY | 78B5038 | Green | Normal maintenance |
| | | 78B5646 | Yellow | Replaced head and head gasket (added 1 qt. Quaker State by mistake @ 12,206 mi. Head gasket blew @ 12,218 mi.) |
| ATC | LAFB, TX | 79B2270 | Yellow | Normal maintenance |
| | | 79B2271 | Green | JOAP remarked that this engine "was one of the worst vehicles in the Synlube program with respect to wear" |
| | | 79B2272 | Blue(C) | Normal maintenance |
| | MAFB, ND | 79B1736 | Green | Engine had quit at end of test and had been partially dismantled. |
| | | 79B1759 | Blue(C) | Normal maintenance |
| | MBAFB, SC | 79B5212 | Green | Normal maintenance |
| | | 79B9187 | Yellow | Valve cover leak @ about 49,000 mi. |
| | | 79B9188 | Blue(D) | Normal maintenance |
| SAC | OAFB, NE | 78B4766 | Green | Valve noise @ 30,753 mi. Knock in engine @ 44,168 mi. Engine cuts out and stalls @ 49,194 mi. Oil leak at valve @ 51,042 mi. |
| | | 78B4768 | Blue(C) | Normal maintenance |
| ADCOM | PAFB, CO | 78B4569 | Green | Normal maintenance |
| | | 78B4571* | Yellow | Push rods, valves, lifters, camshaft and eventually, the entire engine was replaced(4). |
| | | 78B8831 | Blue(C) | Normal maintenance |

*A study of this engine was made by Air Force personnel and the conclusion was reached that the problems were attributable to a faulty air induction system (4)

TABLE 9. MAINTENANCE HISTORY FOR TEARDOWN ENGINES
(Cont'd)

| MAJCOM | Installation | Vehicle No. | Color Code | Maintenance Actions |
|---|---|---|---|---|
| | RAFB, TX | 79B5719 | Yellow | Normal maintenance |
| | | 79B5720 | Blue(A) | Normal maintenance |
| | | 79B5721 | Green | Normal maintenance |

Examinations of the engines after being disassembled did not reveal any significant differences between the problem engines and the others in the test. The difficulties could well have been attributed to maintenance practices and procedures. Appendix B, Volume II, shows the wear measurements for each of the test engines while Table 10 gives a summary of the wear measurements data for each engine and indicates those components worn beyond the manufacturer's specifications. A tabulation of the results reveal that of 79 wear measurements outside of manufacturer's specified wear limits, 27 percent of them were from engines operated on a Blue oil, 35 percent of them were from engines operated with the Green lubricant and 38 percent of them were from engines operated with the Yellow lubricant. This indicates that the engines operated with the synthetic oils experienced a higher wear rate than those operated with the normal issue mineral oils. The largest single category of wear measurements outside of specifications for all of the teardown engines was compression ring gaps, top and bottom. Other wear measurements outside of manufacturer's specifications appeared to be normal for the mileage and usage of each engine. With the exception of Hancock AFB which showed a significant difference in the average oil change mileage between its two engines, the average oil change interval in miles for each set of engines tended to group by installation. Assuming the information valid and the maintenance data for each vehicle seems to confirm it solidly, this would indicate a difference primarily in the basic maintenance procedures and practices at each installation. It should be noted that there were no oil changes at all for the three engines from Randolph AFB, nor the engine operated with Green oil at the USAF Academy which ended up with a total of 28,409 test miles. Table 11 shows the average oil change intervals for all test engines at each installation. Nine of the ten installations shown

TABLE 10. ENGINE INSPECTION DATA-WEAR MEASUREMENTS SUMMARY*

| Type Engine | Ford, 6 cyl, 200 CID | | | Dodge V-8, 318 CID | | |
|---|---|---|---|---|---|---|
| Installation | US Air Force Academy | | | George AFB | | |
| Vehicle No. | 79B5659 | 79B5660 | 79B5668 | 79B2533 | 79B2534 | 79B2539 |
| Type Oil | Green | Yellow | Blue (C) | Green | Yellow | Blue (C) |
| Overall Average Measurements | | | | | | |
| Compression Ring Gaps | | | | | | |
| Top | 0.029 a/(0.74) | 0.027 a/(0.69) | 0.028 a/(0.71) | 0.028 a/(0.64) | 0.026 a/(0.66) | 0.025 a/(0.64) |
| Bottom | 0.027 a/(0.69) | 0.026 a/(0.66) | 0.026 a/(0.66) | 0.027 a/(0.69) | 0.026 a/(0.66) | 0.026 a/(0.66) |
| Cylinder Bore to Piston Clearances | 0.0016 (0.041) | 0.0023 a/(0.058) | 0.0024 a/(0.061) | 0.0012 (0.030) | 0.0003 a/(0.008) | 0.0011 (0.028) |
| Main Bearing Journal to Bearing Shell Clearances | 0.0202 a/(0.513) | 0.0022 (0.056) | 0.0201 a/(0.511) | 0.0012 (0.030) | 0.007 a/(0.178) | 0.0021 (0.053) |
| Connecting Rod Journal to Bearing Shell Clearances | 0.0034 a/(0.086) | 0.0037 a/(0.094) | 0.0026 (0.066) | 0.0018 (0.046) | 0.0021 (0.053) | 0.0026 a/(0.066) |
| Valve Stem to Guide Clearances | 0.0014 (0.036) | 0.0019 (0.048) | 0.0015 (0.038) | 0.0017 (0.043) | 0.0014 (0.036) | 0.0020 (0.51) |
| Valve Spring Compression, psi (N-m) | 54.4 (242) | 54.9 (244) | 54.8 (244) | 84.4 (375) | 84.6 (376) | 84.4 (375) |
| Camshaft Lobe Lift | 0.229 a/(5.82) | 0.242 (6.15) | 0.244 (6.20) | 0.246 a/(6.25) | 0.244 a/(6.20) | 0.243 a/(6.17) |

* = Average wear measurements for each component are in inches and (mm) except valve spring compression.
a/ = Outside manufacturer's specifications for maximum wear limits.

## TABLE 10. ENGINE INSPECTION DATA-WEAR MEASUREMENTS SUMMARY (CONT'D)

| Type Engine | Chevrolet V-8, 350 CID | | | | Ford, 6 cyl, 300 CID | | | |
|---|---|---|---|---|---|---|---|---|
| Installation | Grand Forks AFB | | Minot AFB | | Lackland AFB | | | Rancock AFB |
| Vehicle No. | 79B1734 | 79B1735 | 79B1736 | 79B1759 | 79B2271 | 79B2270 | 79B2272 | 79B5646 |
| Type Oil | Yellow | Blue (B) | Green | Blue (C) | Green | Yellow | Blue (A) | Yellow |
| Overall Average Measurements | | | | | | | | |
| Compression Ring Gaps | | | | | | | | |
| Top | 0.025 (0.64) | 0.024 (0.61) | 0.023 b/ (0.58) | 0.030 (0.76) | 0.067 a/ (1.70) | 0.044 a/ (1.12) | 0.031 a/ (0.79) | 0.026 a/ (0.66) |
| Bottom | 0.024 (0.61) | 0.026 (0.66) | 0.024 (0.61) | 0.027 (0.69) | 0.064 a/ (1.63) | 0.041 a/ (1.04) | 0.031 a/ (0.79) | 0.026 a/ (0.66) |
| Cylinder Bore to Piston Clearances | 0.0023 (0.058) | 0.0025 (0.064) | 0.0020 (0.051) | 0.0021 (0.053) | 0.0030 a/ (0.076) | 0.0022 (0.056) | 0.0028 a/ (0.071) | 0.0024 a/ (0.061) |
| Main Bearing Journal to Bearing Shell Clearances | 0.0036 a/ (0.091) | 0.0018 (0.046) | 0.0027 (0.069) | 0.0031 (0.079) | 0.0023 (0.058) | 0.0023 (0.058) | 0.0024 (0.061) | 0.0034 a/ (0.086) |
| Connecting Rod Journal to Bearing Shell Clearances | 0.0030 (0.076) | 0.0029 (0.074) | 0.0033 a/ (0.084) | 0.0024 (0.061) | 0.0029 a/ (0.074) | 0.0026 a/ (0.066) | 0.0023 (0.058) | 0.0045 a/ (0.114) |
| Valve Stem to Guide Clearances | 0.0015 (0.038) | 0.0015 (0.038) | 0.0014 (0.036) | 0.0018 (0.046) | 0.0021 (0.053) | 0.0017 (0.043) | 0.0015 (0.038) | d/ |
| Valve Spring Compression, psi (N-m) | 76.9 (342) | 75.4 (335) | 75.1 (334) | 72.4 (322) | 79.5 (354) | 79.4 (353) | 79.5 (354) | d/ |
| Camshaft Lobe Lift | 0.265 a/ (6.73) | 0.265 a/ (6.73) | 0.265 a/ (6.73) | 0.253 a/ (6.43) | 0.245 (6.22) | 0.247 (6.27) | c/ | 0.233 a/ (5.91) |

b/ = No Rings on Pistons 6 and 8
c/ = Camshaft lobe diameters were measured instead of lobe lift; measurements were within manufacturer's specifications
d/ = No head with engine when uncrated

TABLE 10. ENGINE INSPECTION DATA-WEAR MEASUREMENTS SUMMARY (CONT'D)

| Type Engine | Dodge, 6-Cyl, 225 CID | | | |
|---|---|---|---|---|
| Installation | Hancock AFB | Myrtle Beach S.C. | | |
| Vehicle No. | 79B5038 | 79B5212 | 78B9187 | 78B9188 |
| Type Oil | Green | Green | Yellow | Blue (D) |
| Overall Average Measurements | | | | |
| Compression Ring Gaps | | | | |
| Top | 0.046 (1.17) | 0.097 a/ (2.46) | 0.10 a/ (2.54) | 0.029 (0.74) |
| Bottom | 0.034 (0.86) | 0.065 a/ (1.65) | 0.078 a/ (1.98) | 0.028 (0.71) |
| Cylinder Bore to Piston Clearances | 0.0017 a/ (0.043) | 0.0028 a/ (0.071) | 0.0026 a/ (0.066) | 0.0015 (0.038) |
| Main Bearing Journal Bearing Shell Clearances | 0.0016 (0.041) | 0.0030 a/ (0.076) | 0.0029 a/ (0.074) | 0.0016 (0.041) |
| Connecting Rod Journal to Bearing Shell Clearances | 0.0105 a/ (0.267) | 0.0037 a/ (0.094) | 0.0040 a/ (0.102) | 0.0262 a/ (0.665) |
| Valve Stem to Guide Clearances | d/ | 0.0020 (0.051) | 0.0032 (0.081) | 0.0021 (0.053) |
| Valve Spring Compression, psi (N-m) | d/ | 51.2 (228) | 51.2 (228) | 140.3 (624) |
| Camshaft Lobe Lift | 0.264 a/ (6.71) | 0.270 a/ (6.81) | 0.268 a/ (6.93) | 0.273 a/ (6.83) |

## TABLE 10. ENGINE INSPECTION DATA-WEAR MEASUREMENTS SUMMARY (CONT'D)

| Type Engine | Chevrolet, 6 Cyl, 292 CID | | | | | Ford, 4 Cyl, 140 CID | | |
|---|---|---|---|---|---|---|---|---|
| Installation | Offutt AFB | | Peterson Field | | | Randolph AFB | | |
| Vehicle No. | 78B4766 | 78B4768 | 78B4569 | 78B4571 | 78B8831 | 79B5721 | 79B5719 | 79B5720 |
| Type Oil | Green | Blue (B) | Green | Yellow | Blue (C) | Green | Yellow | Blue (A) |
| Measurements | | | | | | | | |
| Compression Ring Gaps | | | | | | | | |
| Top | 0.030 (0.76) | 0.029 (0.74) | 0.023 (0.58) | 0.024 (0.61) | 0.025 (0.64) | 0.026 a/(0.66) | 0.029 a/(0.74) | 0.025 a/(0.64) |
| Bottom | 0.029 (0.74) | 0.031 (0.79) | 0.026 (0.66) | 0.030 (0.76) | 0.026 (0.66) | 0.029 a/(0.74) | 0.029 a/(0.74) | 0.025 a/(0.64) |
| Cylinder Bore to Piston Clearances | 0.0041 a/(0.104) | 0.0039 a/(0.99) | 0.0038 a/(0.097) | 0.0043 a/(0.109) | 0.0040 a/(0.102) | 0.0015 (0.030) | 0.0017 (0.041) | 0.0011 (0.023) |
| Main Bearing Journal to Bearing Shell Clearances | 0.0032 (0.081) | 0.0029 (0.074) | 0.0024 (0.061) | 0.0022 (0.056) | 0.0029 (0.074) | e/ | e/ | e/ |
| Connecting Rod Journal to Bearing Shell Clearances | 0.0027 (0.069) | 0.0087 a/(0.221) | 0.0041 a/(0.104) | 0.0108 a/(0.274) | 0.0037 a/(0.094) | e/ | e/ | e/ |
| Valve Stem to Guide Clearances | 0.0014 (0.036) | 0.0016 (0.041) | 0.0029 (0.074) | 0.0015 (0.038) | 0.0028 (0.071) | e/ | e/ | e/ |
| Valve Spring Compression, psi (N-m) | 172.3 (766) | 170.3 (758) | 81.3 (362) | 171.3 (762) | 80.3 (357) | e/ | e/ | e/ |
| Camshaft Lobe Lift | 0.220 (5.59) | 0.218 (5.54) | e/ | 0.224 (5.69) | 0.221 (5.61) | 0.242 (6.15) | 0.242 (6.15) | 0.243 (6.17) |

e/ = Only representative measurements made when visual inspection revealed no abnormal appearances; representative measurements within manufacturer's specifications for new engine.

TABLE 11. AVERAGE OIL CHANGE INTERVALS AT EACH INSTALLATION

| Installation | Average Oil Change Intervals, miles |
|---|---|
| USAD Academy | 16,040.8 |
| George AFB | 4,161.9 |
| Grand Forks AFB | 4,212.9 |
| Hancock AFB | 5,773.2 |
| Lackland AFB | 2,923.1 |
| Minot AFB | 7,535.1 |
| Myrtle Beach AFB | 11,185.9 |
| Offutt AFB | 6,874.5 |
| Peterson AFB | 4,380.9 |
| Randolph AFB | 10,052.7 |

average over 4,000 miles between oil changes, and six of those nine average above 5,000 miles between oil changes, while three of the nine average over 10,000 miles between oil changes. Photographs of selected engine components are exhibited in Appendix C, Volume II. Although no conclusive inferences may be made from the appearance of photographed components, the components from engines operated with the Yellow lubricants appeared slightly cleaner, overall, than the components from engines operated with the Blue and Green lubricants.

## Performance Summary

As stated earlier, all the test oils appeared to have performed satisfactorily. Table 12 assigns a subjective performance rating in each of the categories listed for each oil with respect to used oil condition and the engine inspection data.

Combining these ratings, the test oils are ranked in the following order of overall performance:

TABLE 12. OVERALL PERFORMANCE RATINGS*

| | Blue | Green | Yellow |
|---|---|---|---|
| Sludge Ratings | Good | Best | Better |
| Varnish Ratings | Better | Good | Best |
| Other Ratings | Best | Good | Better |
| Wear Measurements | Best | Better | Good |
| Total Particulate Contaminants | Best | Better | Good |
| Average VDP vs. True Value VDP | Best | Good | Better |
| Oil Dispersive Properties | Best | Better | Good |

1. Blue - The normally issued mineral oils (collectively) performed in a satisfactory manner and although between the Green and Yellow oils in sludge, varnish and other ratings were judged to be demonstrably better than the two multiviscosity synthetic oils in wear measurements, particulate contaminants, viscosity increase, and dispersive properties.

2. Green and Yellow - Both multiviscosity synthetic oils performed satisfactorily and equally well overall with respect to each other. The Yellow oil performed better than the Green and Blue oils in the ratings, but not as well as the other two with respect to wear measurements, particulate contaminants, viscosity increase, and dispersive properties.

## IV. CONCLUSIONS

- The Blue lubricants (collectively) demonstrated the best overall performance of the test oils used.
- The Green and Yellow lubricants performed equally well overall and can be satisfactorily used in spark ignition engines of the type tested.
- Engine distress evidenced by light to severe piston scuffing and cracked, chipped, scuffed, and worn lifter bodies for the Chevrolet 350 V8 engines and cracked, chipped, and worn lifter bodies for the

Chevrolet 6-cylinder 292 engines cannot be attributed exclusively to the lubricants used since the distress occurred in the engines regardless of the type test oil used.

- Components of the engines operated with the Green and Yellow lubricants exceeded manufacturer's wear limit specifications more frequently than those from engines operated with the Blue oils.

## V. RECOMMENDATIONS

Based on the observations and conclusions drawn from the teardown inspections and analysis of information provided for the twenty-six engines only, the following recommendations are made:

- Conduct a test at the following bases to determine the contribution of climatic and environmental conditions to the engine distress exhibited by the Chevrolet engines utilized:

  Minot Air Force Base, ND
  Grand Forks Air Force Base, ND
  Offutt Air Force Base, NE
  Peterson Field, CO

- Consideration be given to future cooperative tests of this type for obtaining lubricant field data.

## VI. REFERENCES

1. Letter, Department of the Air Force, Headquarters Warner Robins Air Logistics Center (AFLC), Robins Air Force Base, Georgia 31098, Attn: MMEAP (Mr. Coffey/2711) to U.S. Army Fuels & Lubricants Research Laboratory, San Antonio, TX 78284, Subject: MEEP Project H79-1C, Synthetic Oils, dated 22 January 1979.

2. Final Report on Field Liaison in Support of Evaluation of Synthetic Lubricants in Nontactical Vehicles, Contract No. F33615-79-C-5159 by Anna F. Stulsas and John D. Tosh, Energy Systems Research Division, Southwest Research Institute, San Antonio, TX 78284, dated February 1982.

3. Note, Technical Support Center, Joint Oil Analysis Program, Building 780, Naval Air Station, Pensacola, Florida 32508, Attn: SMS Ed Stembler, to Walt Butler (USAFLRL), Subject: Baseline Data for Lubricants Used in the SYNLUBE project, dated 25 January 1982.

4. Letter, Technical Support Center Joint Oil Analysis Program, Building 780, Naval Air Station, Pensacola, Florida 32508, Attn: JOAP-TSC, to Southwest Research Institute, Mobile Energy Division, Attn: Mr. John D. Tosh, 6220 Culebra Road, San Antonio, TX 78284, Subject: SYNLUBE Data Format w/Enclosure (1), dated 25 September 1981.

5. Maintenance Record accompanying Engine 78B4571.

6. Military Specification, MIL-L-46152, "Lubricating Oil, Internal Combustion Engine, Administrative Service," dated 20 November 1970.

7. CRC Manual No. 8, "CRC Varnish Rating Manual for Non-Rubbing Parts," dated March 1964.

8. CRC Manual No. 9, "CRC Varnish Rating Manual," dated June 1971.

9. CRC Manual No. 10, "Sludge Rating Manual," dated May 1966, revised January 1969.

10. CRC Manual No. 4, " Techniques for Valve Rating," Table 12, dated January 1958, revised July 1969.

## LIST OF ACRONYMS

| | | |
|---|---|---|
| ADCOM | - | Aerospace Defense Command |
| AFLC | - | Warner Robins Air Logistic's Center |
| AFSC | - | Air Force Systems Command |
| ATC | - | Air Training Command |
| CID | - | Cubic Inch Displacement |
| CRC | - | Coordinating Research Council |
| DOD | - | Department of Defense |
| GAFB | - | Georgia Air Force Base |
| GFAFB | - | Grand Forks Air Force Base |
| HAFB | - | Hancock Air Force Base |
| JDLC | - | Joint Deputies for Laboratory Committee |
| JOAP | - | Joint Oil Analysis Program |
| LAFB | - | Lackland Air Force Base |
| MAFB | - | Minot Air Force Base |
| MAJCOM | - | Major Command |
| MBAFB | - | Myrtle Beach Air Force Base |
| MEEP | - | Management Equipment Evaluation Program |
| OAFB | - | Offutt Air Force Base |
| PAFB | - | Peterson Air Force Base |
| RAFB | - | Randolph Air Force Base |
| SAC | - | Strategic Air Command |
| SwRI | - | Southwest Research Institute |
| Synlube | - | Synthetic Lubricant |
| TAC | - | Tactical Air Command |
| TAN | - | Total Acid Number |
| TBN | - | Total Base Number |
| TSC | - | Technical Support Center |
| USAFA | - | United States Air Force Academy |
| USAFLRL | - | United States Army Fuels & Lubricants Research Laboratory |
| Belvoir R&D Center | - | U.S. Army Belvoir Research & Development Center |
| VDP | - | Viscosity Density Product |

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