

SURVEY OF USAF VEHICLE DIRECTORATE UTILIZATION AND OIL CONDITION

**INTERIM REPORT
No. 508**

**By
Douglas M. Yost**

**GVSC Fuels and Lubricants Research Facility
Southwest Research Institute® (SwRI®)
San Antonio, TX**

**For
Eric Sattler
Force Projection Technology
Warren, Michigan**

**Brandon Hammontree
U.S. Air Force
Air Logistics Center
Robins AFB, Georgia**

Contract No. W56HZV-15-C-0030 (WD029)

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November 2022

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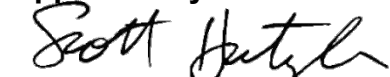
**Stephen Gibbs
U.S. Air Force
Air Logistics Center
Robins AFB, Georgia**

**Contract No. W56HZV-15-C-0030 (WD029)
SwRI® Project No. 08.24911**

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Approved by:



**Scott A. Hutzler, Director
Fuels and Lubricants Research Facility
Southwest Research Institute**

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EXECUTIVE SUMMARY

The condition of Vehicle Directorate asset lubricant conditions was investigated. The technical feasibility of using portable lubricant analyzers to monitor vehicle asset crankcase lubricant conditions for a fifteen month period was also investigated. All assets utilized the lubricant charge that existed in the vehicle

Within the limitations of the study, the following conclusions can be made from the cumulative knowledge of analyzing crankcase lubricants of diesel engine powered vehicle assets at eight U.S. Air Force locations:

- Based on information provided some assets monitored had not had their lubricant changed for years because they appear to be operating on a mileage based oil change criteria.
- A substantial number of assets revealed compromised lubricant.
- Over the course of the study the portable analyzers appeared sufficiently accurate for monitoring lubricant viscosity for degradation when compared to ASTM laboratory test results, and for monitoring fuel dilution.
- Potential readiness improvements exist, stemming from condition based monitoring of lubricant versus mileage based mandatory oil changes.

Based on the vehicle lubricant data accumulated the following recommendations can be made:

- Track engine hours AND mileage routinely so that Vehicle Directorate assets can have their oil change intervals based on utilization instead of just mileage.
- It would be recommended as a minimum to change lubricant at 200 hours operation, following industrial engine practice.

FOREWORD/ACKNOWLEDGMENTS

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The author would like to acknowledge the contribution of the GFLRF technical and administrative support staff.

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ACRONYMS AND ABBREVIATIONS

° C	degrees Centigrade
AGE	Aircraft Ground Support Equipment
ASTM	ASTM International
AW	Anti Wear
cc	Cubic Centimeter
cm	Centimeter
cSt	Centistokes
ft	Foot
GVSC	Ground Vehicle Systems Center
hr	Hour
in	Inch
JBER	Joint Base Elmendorf-Richardson
JP-8	Jet Propulsion 8
kW	Kilowatt
L	Liter
lb	Pound
m	Meter
mg	milligram
mg/L	milligrams per Liter concentration
mL	milliliter
mm	millimeter
POC	Point of Contact
ppm	parts per million
psi	pounds per square inch
QPL	Qualified Products List
RPM	rotation(s) per minute
SMPL	Single Multi-Purpose Lubricant
SwRI®	Southwest Research Institute®
SOW	Scope of Work
TACOM	Tank Automotive and Armaments Command
TAN	Total Acid Number
TARDEC	Tank Automotive RD&E Center
TBN	Total Base Number
GFLRF	GVSC Fuel and Lubricants Research Facility
WOT	Wide Open Throttle
WD	Work Directive

1.0 BACKGROUND & INTRODUCTION

1.1 Background

The Government has a requirement to study the engine oil condition on Vehicle Directorate assets with low rate usage. The assets were sampled with the lubricant currently charged, without any changes except for routine maintenance. The government has a requirement to study engine oil degradation of USAF tactical vehicles services by the Air Force. Oil samples shall be collected over a period of 15 months from eight selected bases worldwide. SwRI will analyze these oil samples to better predict oil life and provide recommendations for changing the maintenance protocol. This is an expansion of results reported in Interim Reports GFLRF No. 481 and GFLRF No.501. (1,2)

These collected oil samples will be analyzed in order to better predict oil life and provide recommendations for changing the maintenance protocol. The samples were analyzed by both standard ASTM laboratory methods and by portable lubricant analysis instruments. The portable instruments determined selected lubricant properties by FTIR, viscosity at 40 °C, and fuel dilution. A comparison of the portable instrument results and the laboratory methods will be made. At this time there is no requirement for an infield oil condition analyzer.

1.2 Purpose

The purpose of this test was to evaluate used lubricant samples from selected pieces of low use Vehicle Directorate vehicles and characterize the lubricant deterioration. Vehicles were selected based on low annual mileage accumulation by the Vehicle Directorate. For example, oil change guidelines are based on mileage, however several types of flightline vehicles may only accumulate low miles annually but have excessive idling time. For that scenario the lubricant would not get changed annually, but water can accumulate in the sump due to low temperatures and lead to sludge formation.

2.0 TESTING METHODOLOGY

2.1 Test Locations

The Air Force bases to be utilized in this study included:

Elmendorf
Al Udeid
Misawa
Robins

Macdill
Dobbins
Moody
Minot

2.2 Test Item Selection

A Point of Contact (POC) was established with the units at each of the selected sites. The Vehicle Directorate at Robins AFB selected the vehicles at each site for lubricant analysis. GFLRF coordinated with the units on the timing of the samplings.

2.3 Test Reporting

Each unit was requested to supply estimates of vehicle utilization either in hours or mileage, and an estimate of the latest oil change. The inclusion of the lubricant utilization data was sporadic from the various units.

2.4 Lubricant Sampling

Participating units performed lubricant sampling on the test assets at the appropriate sampling intervals determined by the project engineer. The sampling was to be performed 15 months apart, however COVID protocols delayed receipt of some of the samples. One 8 ounce sample of fresh lubricant utilized in the vehicle assets at each test location was also requested. Sampling supplies and shipping containers were supplied to the units by Southwest Research Institute.

2.5 Lubricant Inspections

The following laboratory tests on all collected lubricant samples were performed at Southwest Research Institute pending receipt of samples:

ASTM D445	Kinematic Viscosity at 100 °C
ASTM D445	Kinematic Viscosity at 40 °C
ASTM D664	Total Acid Number
ASTM D4739	Total Base Number
ASTM D5185	Elementals
ASTM D6304C	Water Content, ppm
CEC Soot	Weight Percent Soot

2.6 Field Portable Instrument Correlation

A field portable infrared oil analyzer, a field portable fuel dilution meter, and a field portable viscometer were utilized for generating lubricant condition data that can be compared to the laboratory analysis data. The handheld instrumentation measurements were performed using a small portion of the received asset lubricant samples.

3.0 OBJECTIVE & APPROACH

The objective of this effort was to demonstrate the suitability/unsuitability of current vehicle engine lubricant change practices over a 15 month period with low utilization vehicles.

3.1 Measure of Performance

3.1.1 Test Methodology

Eight bases provided 5 to 15 lubricant samples that were at least 8 ounces in volume, for a period of at least 15 months. Each sample was evaluated in accordance with the seven tests listed in 3.1.2. If an unusual sample appearance was noted or a very low viscosity was measured, then additional tests were performed. These were annotated on the data sheet.

3.1.2 Laboratory Analysis of Sample Collection

Samples were collected, transported, and received at the laboratory. After receipt of the sample at Southwest Research Institute, the sample was logged into the sample tracking system with a

unique identifier number assigned to each sample. Each asset lubricant sample was tested in accordance with the following standardized laboratory procedures:

ASTM D445	Kinematic Viscosity at 100°C
ASTM D445	Kinematic Viscosity at 40°C
ASTM D664	Total Acid Number
ASTM D4739	Total Base Number
ASTM D5185	Elementals
ASTM D6304C	Water Content, ppm
CEC Soot	Weight Percent Soot

3.1.3 Evaluation Criteria

Engine lubricants were specified by the engine manufacturers based on operating temperatures and the viscosity grades defined by the Society of Automotive Engineers (SAE) specification J300. The viscosity grades have a minimum and maximum limit defined at 100 °C for each lubricant viscosity classification. In-service lubricant viscosity measurements can be utilized to determine if lubricant has thickened above the viscosity grade upper limit due to oxidation and soot levels, or below the viscosity grade lower limit due to fuel dilution or water contamination.

Besides lubricating engine components, engine lubricants act as a buffer to absorb and neutralize engine combustion byproducts that blow by the piston into the engine crankcase. Diesel engine lubricants are initially chemically basic, as measured by the Total Base Number (TBN), to have a chemical reserve available for absorbing the acids generated during combustion. The acidic level of an engine lubricant is determined by measuring the Total Acid Number (TAN). As lubricants age in an engine, the lubricant buffers the acids formed until a certain TBN level is reached, and then the TAN level will start increasing. Thus, lubricant TAN level and TBN level trends indicate lubricant service life.

Lubricant elemental determination measures the minute concentrations of metallic elements in the lubricant in order to determine engine condition. The metallic elements are classified in two groups, engine wear metals and lubricant additive metals. The in-service lubricant elemental levels can be utilized to determine if the lubricant change intervals are adequate, or if a potential engine issue is occurring. Most engine manufacturers publish acceptable ranges of lubricant wear metals and the specific critical areas that certain elements may indicate where unusual wear is occurring.

Water content in the lubricant can indicate cooling system health and head gasket integrity, along with whether the engine is adequately warmed up during operation to drive the water from the lubricant. Engines that typically idle long periods accumulate water in the lubricant, versus engines that perform at high power levels.

Soot content in the lubricant is an indicator of how long the lubricant may have been in the engine and may indicate possible fuel injection system issues. Injector deposits or retarded injection timing can lead to increased soot formation during combustion that eventually is scavenged by the lubricant.

3.1.4 Data Analysis

A Southwest Research Institute petroleum product analysis laboratory provided results for each provided in-service lubricant sample. The results for each asset in the study were recorded on a data sheet and entered into a spreadsheet.

- Based on the results of the testing, a recommendation was provided to change the service interval (increase, decrease) or remain unchanged.
- Developed recommendations regarding the inspection / maintenance practices for vehicles.

3.1.5 Anticipated Results

Successful testing and documentation of each laboratory sample provided a foundation for adjusting the maintenance interval for servicing.

3.2 Field Portable Handheld Lubricant Condition Instruments

3.2.1 Evaluations

This section was completed when the laboratory analysis results of the in-service lubricant samples were compared to the results measured with the field portable handheld instrumentation. All lubricant analyses, laboratory and field portable instrument, were performed by Southwest Research Institute.

The portable instrument test results were compared to the ASTM laboratory standardized test results for viscosity at 40 °C and TBN using laboratory ASTM method analysis. The portable instruments do not report TAN results for engine oils. The instrument libraries only have TAN values for gear oils. Thus, TAN results were not available from the portable instrument. The

portable instruments did not measure wear elements for engine oils because the libraries only contain fresh lubricant scans. Wear metal response would be very low in a fresh lubricant.

3.2.2 Anticipated Results

The field portable instrumentation are to be evaluated with respect to laboratory analytical data for the same lubricant samples. A determination of suitability of the portable instruments for measuring fielded vehicle lubricant conditions for service interval recommendations will be attempted.

4.0 DISCUSSION AND RESULTS

An agreement was obtained on the test plan with the vehicle maintenance units at the selected Air Force bases. A presentation outlining the goals of the program was generated and distributed to the bases. Subsequently, points of contact were established. Personnel were supportive of the program and were provided a detailed program statement of work outlining the unit responsibilities and a presentation on the sampling, packaging, and shipping procedures.

4.1 Vehicle Directorate

The Vehicle Directorate at the U.S. Air Force Air Logistics Center, Robins AFB, selected all assets and arranged for Points of Contact at each site. The following sections discuss the vehicles sampled and reviews the results.

4.2 Laboratory analysis of Macdill AFB Vehicle Lubricant Samples

The vehicles selected for evaluation at Macdill AFB are shown in Table 1 along with the information requested about maintenance and vehicle utilization for the initial sampling. Of the fifteen vehicles selected, only nine were sampled at the start of the program. For some reason extra samples of the fresh oil were returned, using up the sample bottles that could have been used for the other unsampled vehicles. In the future it should be explicitly stated that only one sample of the fresh oil would be needed.

The vehicles samples for lubricant evaluation after 15 months of operation at Macdill AFB are shown in Table 2. Of the fifteen vehicles selected, only four were sampled at the 15 month interval of the program. Of the four that were sampled, three were at least the same vehicles sampled at the start of the program. The fourth vehicle sampled was a replacement vehicle that did not have an initial sample. The utilization information was recorded from the sample bottles and the units were not always noted. The range of utilization for the repeat vehicles was a low of 38 hours to a high of 363 hours for the 15 month interval.

The ASTM laboratory analysis of the selected lubricant properties for the Macdill AFB vehicles and fresh oil are included in Table 3. The elemental analysis suggests most of the vehicles were using a lubricant different from the fresh oil sample supplied. The wear elements for the vehicles sampled looked normal. The TBN for all vehicles showed reserve alkalinity and the TAN values were low. One vehicle, 97L00170, showed a low viscosity. Vehicles 02L00233 and 03C00016 revealed a viscosity increase from the second sampling, which could suggest an oil change of substantial makeup oil was added. There were not any maintenance notes on those vehicles. Vehicle 11L00086 showed a slight viscosity degradation after 15 months along with an increase in lubricant water content. Also noted was a slight Sodium bump, Na, possibly due to humid salt air.

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Table 1. MacDill AFB Vehicle Directorate Initial Lubricant Samples

BASE NAME	MGMT Code	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Miles / Hours	Recent Major Engine Maintenance	ARMY Lab Code	ASSET Description
MACDILL (JCSE)	K461	12K00046		M1078A1P2 2.5T Trk w/ Winch							12K00046
MACDILL (JCSE)	L542	12L00364		M1165A1B3AFC HMMWV							12L00364
MACDILL (JCSE)	L542	12L00385		M1165A1B3AFC HMMWV							12L00385
MACDILL (JCSE)	D630	23D08059		LODR SCP PT 1 CY / UNDER							23D08059
MACDILL (JCSE)	E958	05E00654		TRK FL 10K 463L							05E00654
MACDILL (MOB)	L350	02L00223		TRAC ACFT TWG MB-2				1596h		CL20-5256	02L00223
MACDILL (MOB)	C122	03C00016		TRK FFGT MRT P-30				4701h		CL20-5257	03C00016
MACDILL (MOB)	C355	06C00645		TRAC TOW SUPPORT EQP				24554h		CL20-5254	06C00645
MACDILL (MOB)	C603	06C01061		LAVATORY SERVICE TRUCK							06C01061
MACDILL (MOB)	L351	08L00527		TRAC ACFT TWG MB-4				240h		CL20-5251	08L00527
MACDILL (MOB)	E829	09E80007		TRK FL 15K				757h		CL20-5253	09E80007
MACDILL (MOB)	C604	11C00011		STAIRCASE TRUCK				618m		CL20-5249	11C00011
MACDILL (MOB)	L541	12L01087		M1152A1 HMMWV				943h		CL20-5250	12L01087
MACDILL (MOB)	L130	14L00028	11L00086	TRK FIRE PUMPER P-24				4922h		CL20-5247	11L00086
MACDILL (MOB)	L275	97L00355	97L00170	TRK TK 6000 GAL R11				81h		CL20-5258	97L00170
										CL20-5248	New Oil

Table 2. MacDill AFB Vehicle Directorate 15 Month Lubricant Samples

BASE NAME	MGMT Code	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Miles / Hours	Recent Major Engine Maintenance	ARMY Lab Code	ASSET Description
MACDILL (JCSE)	K461	12K00046		M1078A1P2 2.5T Trk w/ Winch							12K00046
MACDILL (JCSE)	L542	12L00364		M1165A1B3AFC HMMWV							12L00364
MACDILL (JCSE)	L542	12L00385		M1165A1B3AFC HMMWV							12L00385
MACDILL (JCSE)	D630	23D08059		LODR SCP PT 1 CY / UNDER							23D08059
MACDILL (JCSE)	E958	05E00654		TRK FL 10K 463L							05E00654
MACDILL (MOB)	L350	02L00223		TRAC ACFT TWG MB-2				1775h		CL21-6373	02L00223
MACDILL (MOB)	C122	03C00016		TRK FFGT MRT P-30				4739h		CL21-6375	03C00016
MACDILL (MOB)	C355	06C00645		TRAC TOW SUPPORT EQP							06C00645
MACDILL (MOB)	C603	06C01061		LAVATORY SERVICE TRUCK							06C01061
MACDILL (MOB)	L351	08L00527		TRAC ACFT TWG MB-4							08L00527
MACDILL (MOB)	E829	09E80007		TRK FL 15K							09E80007
MACDILL (MOB)	C604	11C00011		STAIRCASE TRUCK							11C00011
MACDILL (MOB)	L541	12L01087		M1152A1 HMMWV							12L01087
MACDILL (MOB)	L130	14L00028	11L00086	TRK FIRE PUMPER P-24				5285h		CL21-6376	11L00086
MACDILL (MOB)	L275	97L00355	96L00204	TRK TK 6000 GAL R11				95h		CL21-6377	96L00204

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Table 3. Vehicle Lubricant Analysis from MacDill AFB

Lab Code	ASSET	TestInfo		CEC Soot	D445 100c	D445 40c	TBN D4739		D5185 - Elementals, ppm																						3304C Oils		TAN D664			
		Hours	Miles	Soot	Viscosity	Viscosity	Inflect	Buffer	Al	Sb	Ba	B	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Ag	Na	Sn	Zn	K	Sr	V	Ti	Cd	Water	Inflect	Buffer	
	12K00046																																			
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	23D08059																																			
	05E00654																																			
CL20-5256	02L00223	1596		0.5	12.035	84.711	6.26	4.65	1	<1	<1	2	1877	2	3	23	4	285	<1	41	<1	992	5	<1	<5	1	1111	<5	<1	<1	<1	<1	<1	566	1.44	3.19
CL21-6373		1775		0.2	14.026	101.316	7.34	6.81	<1	<1	<1	9	1216	<1	1	10	1	751	<1	62	<1	1021	9	<1	<5	<1	1132	<5	<1	<1	<1	<1	<1	507	1.62	1.98
CL20-5257	03C00016	4701		0.05	12.25	87.83	8.11	6.82	<1	<1	<1	1	1,615	<1	4	7	3	652	<1	32	<1	1,157	4	<1	<5	<1	1,293	<5	<1	<1	<1	<1	<1	992	1.57	2.30
CL21-6375		4739		0.02	13.817	103.477	8.6	8.18	<1	<1	<1	3	1602	<1	<1	3	<1	540	<1	62	<1	1107	4	<1	10	<1	1211	<5	<1	<1	<1	<1	<1	675	1.44	1.76
CL20-5254	06C00645	24554		0.07	13.041	94.192	6.84	5.88	2	<1	<1	4	1689	1	1	28	10	448	<1	50	<1	1080	6	<1	5	1	1191	<5	<1	<1	<1	<1	<1	763	0.11	2.45
	06C01061																																			
CL20-5251	08L00527	240		0.11	13.328	98.278	8.44	6.69	1	<1	<1	3	1627	1	8	12	2	627	<1	42	<1	1164	4	<1	6	1	1281	<5	<1	<1	<1	<1	<1	921	1.73	2.31
CL20-5253	09E80007	757		0.09	14.561	108.201	6.44	6.30	<1	<1	<1	3	2412	<1	7	7	<1	31	<1	2	<1	975	6	<1	<5	<1	1037	<5	<1	<1	<1	<1	<1	533	1.90	1.93
CL20-5249	11C00011		618.0	0.02	14.440	104.715	6.52	6.29	2	<1	<1	1	2265	<1	<1	19	<1	63	<1	4	<1	978	6	<1	<5	<1	1046	<5	<1	<1	<1	<1	<1	611	2.23	2.24
CL20-5250	12L01087	943		0.10	14.087	105.437	8.86	6.98	2	<1	<1	16	1935	4	18	73	19	572	3	46	2	1140	58	<1	<5	9	1324	<5	<1	<1	<1	<1	<1	772	1.72	1.94
CL20-5247	11L00086	4922		0.11	13.161	92.217	6.97	6.32	3	<1	<1	<1	1002	<1	<1	8	<1	842	<1	58	<1	1018	3	<1	5	<1	1124	<5	<1	<1	<1	<1	<1	448	1.15	3.54
CL21-6376		5285		0.18	11.752	80.254	7.04	6.16	3	<1	<1	8	1076	<1	3	27	1	785	<1	60	4	1001	8	<1	87	<1	1115	12	<1	<1	<1	<1	<1	1044	1.54	1.8
CL20-5258	97L00170	81		0.02	9.969	62.533	6.54	5.44	2	<1	<1	2	1442	<1	1	15	1	482	<1	56	<1	988	4	<1	8	<1	1113	<5	<1	<1	<1	<1	<1	785	1.3	3.09
CL21-6377	96L00204	95		0.07	14.03	105.09	6.62	5.82	<1	<1	<1	75	2,148	2	<1	7	1	129	<1	91	<1	1,077	7.00	<1	<5	<1	1,180	<5	<1	<1	<1	<1	<1	227	1.94	2.02
CL20-5248	Fresh	0		0.01	15.15	112.05	6.36	6.31	<1	<1	<1	1	2397	<1	<1	2	<1	9	<1	<1	<1	979	5	<1	<5	<1	1034	<5	<1	<1	<1	<1	<1	312	2.33	2.37

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4.3 Laboratory analysis of Elmendorf AFB Vehicle Lubricant Samples

The vehicles selected for evaluation at Elmendorf AFB are shown in Table 4 along with the information requested about maintenance and vehicle utilization for the initial sampling. Of the fifteen vehicles selected, only eleven were sampled at the start of the program. It was noted that several of the vehicles selected were assigned to temporary duty and not available for sampling.

The vehicles samples for lubricant evaluation after 15 months of operation at Elmendorf AFB are shown in Table 5. Of the fifteen vehicles selected, only eleven were sampled at the 15 month interval of the program. Of the eleven that were sampled, three were vehicles that were not sampled at the start of the program. There were eight vehicles that had an initial and a 15 month sample. The utilization information was recorded from the sample bottles and the units were not always noted. The range of utilization for the repeat vehicles was a low of 15 hours to a high of 719 hours for the 15 month interval. The mileage reported ranged from a low of 0 miles to a high of 600 miles for the 15 month period.

The ASTM laboratory analysis of the selected lubricant properties for the Elmendorf AFB vehicles and fresh oil are included in Table 6. The elemental analysis suggests most of the vehicles were using a lubricant different from the fresh oil sample supplied, although some were close in formulation. The wear elements for the vehicles sampled looked normal except for asset 11C00008 which had high Iron (Fe), copper (Cu), aluminum (Al), tin (Sn), and chromium (Cr). The TBN for vehicle 11C00008 was exhausted and the TAN was high, and the viscosity was low. After 15 months the viscosity for 11C00008 was even lower but the TBN and wear metal seem to indicate either an oil change or substantial oil addition. Vehicle 10C00131 showed elevated aluminum (Al) wear metals at both samplings. With the exception of vehicles 06B01312, 04C00436, and 10C00131 the TBN for all vehicles showed reserve alkalinity and the TAN values were low. Vehicles 04C00436 and 13K00053 showed low viscosities at both sampling intervals.

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Table 4. Elmendorf Initial Vehicle Lubricant Samples

BASE NAME	MGMT Code	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Oil Change	Hours at last	cent Miles / H	Recent Major Engine	ARMY Lab Code	ASSET Description
ELMENDORF (MOB)	B222	06B01312		TRK 3/4T CREW CAB 4X4 PU	15W-40	22-Apr-16	9639	13935		CL20-4739	06B01312
ELMENDORF (MOB)	C355	01C00241		TRAC TOW SUPPORT EQP	15W-40	18-Dec-15	6505	6914		CL20-4742	01C00241
ELMENDORF (MOB)	L530	03L00274		M1097A2 HMMWV Utility	TDY	TDY	TDY	TDY	TDY		03L00274
ELMENDORF (MOB)	C316	04C00436		EOD VEHICLE	15W-40	25-Apr-12	7170	9504		CL20-4735	04C00436
ELMENDORF (MOB)	L351	07L00190		TRAC ACFT TWG MB-4	15W-40	26-Jun-17	406	856		CL20-4744	07L00190
ELMENDORF (MOB)	L350	07L00325		TRAC ACFT TWG MB-2	15W-40	12-Mar-13	103	227		CL20-4741	07L00325
ELMENDORF (MOB)	C122	10C00131		TRK FFGT MRT P-30	15W-40	16-Nov-16	3018	3203		CL20-4743	10C00131
ELMENDORF (MOB)	E829	10E01058		TRK FL 15K	15W-40	25-Jul-12	15	374		CL20-4734	10E01058
ELMENDORF (MOB)	C604	11C00008		STAIRCASE TRUCK	15W-40	16-Dec-11	1	147		CL20-4736	11C00008
ELMENDORF (MOB)	L542	12L00939		M1165A1B3AFC HMMWV	TDY	TDY	TDY	TDY	TDY		12L00939
ELMENDORF (MOB)	L541	12L01095		M1152A1 HMMWV	TDY	TDY	TDY	TDY	TDY		12L01095
ELMENDORF (MOB)	K461	13K00053		M1078A1P2 2.5T Trk w/ Winch	15W-40	3-Jun-13	702	1599		CL20-4738	13K00053
ELMENDORF (MOB)	D630	23D08482		LODR SCP PT 1 CY / UNDER	15W-40	28-Nov-12	345	674		CL20-4737	23D08482
ELMENDORF (MOB)	L130	10L00894		TRK FIRE PUMPER P-24	15W-40	7-Oct-19	4039	4166		CL20-4740	10L00894
ELMENDORF (MOB)	L275	05L00030		TRK TK 6000 GAL R11 DED	DEPOT MX	DEPOT MX	DEPOT MX	DEPOT MX	DEPOT MX		05L00030
										CL20-4770	New Oil

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Table 5. Elmendorf 15 Month Vehicle Lubricant Samples

BASE NAME	MGMT Code	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil	Current Miles / Hours	Recent Major Engine	ARMY Lab Code	ASSET Description
ELMENDORF (MOB)	B222	06B01312		TRK 3/4T CREW CAB 4X4 PU	15W-40	22-Apr-16	9639	13935			06B01312
ELMENDORF (MOB)	C355	01C00241		TRAC TOW SUPPORT EQP	15W-40	18-Dec-15	6505	6914			01C00241
ELMENDORF (MOB)	L530	03L00274		M1097A2 HMMWV Utility	15W-41			11434m		CL21-6380	03L00274
ELMENDORF (MOB)	C316	04C00436		EOD VEHICLE	15W-40	25-Apr-12	7170	10104m		CL21-6381	04C00436
ELMENDORF (MOB)	L351	07L00190		TRAC ACFT TWG MB-4	15W-40	26-Jun-17	406	1406		CL21-6382	07L00190
ELMENDORF (MOB)	L350	07L00325		TRAC ACFT TWG MB-2	15W-40	12-Mar-13	103	242		CL21-6386	07L00325
ELMENDORF (MOB)	C122	10C00131		TRK FFGT MRT P-30	15W-40	16-Nov-16	3018	3430		CL21-6383	10C00131
ELMENDORF (MOB)	E829	10E01058		TRK FL 15K	15W-40	25-Jul-12	15	374			10E01058
ELMENDORF (MOB)	C604	11C00008		STAIRCASE TRUCK	15W-40	16-Dec-11	1	866		CL21-6387	11C00008
ELMENDORF (MOB)	L542	12L00939		M1165A1B3AFC HMMWV	15W-41			3535m		CL21-6378	12L00939
ELMENDORF (MOB)	L541	12L01095		M1152A1 HMMWV	15W-42			3026m		CL21-6379	12L01095
ELMENDORF (MOB)	K461	13K00053		M1078A1P2 2.5T Trk w/ Winch	15W-40	3-Jun-13	702	1885m		CL21-6385	13K00053
ELMENDORF (MOB)	D630	23D08482		LODR SCP PT 1 CY / UNDER	15W-40	28-Nov-12	345	674		CL21-6388	23D08482
ELMENDORF (MOB)	L130	10L00894		TRK FIRE PUMPER P-24	15W-40	7-Oct-19	4039	4672		CL21-6384	10L00894
ELMENDORF (MOB)	L275	05L00030		TRK TK 6000 GAL R11 DED	DEPOT MX	DEPOT MX	DEPOT MX	DEPOT MX	DEPOT MX		05L00030

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Table 6. Elmendorf Vehicle Lubricant Sample Analysis

Lab Code	Asset	Hours	Miles	CEC Soot	D445 100c Viscosity	D445 40c Viscosity	TBN Inflect	TBN Buffer	D5185 Elementals																				D6304C Water	TAN Inflect	TAN Buffer				
									Al	Sb	Ba	B	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Ag	Na	Sn	Zn	K				Sr	V	Ti	Cd
CL20-4739	06B01312	13935		0.13	12.318	88.411	2.15	1.62	8	<1	<1	3	1211	4	6	66	3	760	2	54	2	916	36	<1	12	2	1100	8	<1	<1	<1	<1	884	6.42	6.36
CL20-4742	01C00241	6914		0.06	13.392	96.173	7.69	6.24	2	<1	<1	<1	1117	4	2	22	2	817	<1	50	2	1050	9	<1	7	2	1223	<5	<1	<1	<1	<1	498	1.80	2.32
CL21-6380	03L00274		11434	0.01	15.113	115.233	8.14	7.86	<1	<1	<1	3	991	2	3	44	2	897	<1	60	<1	1047	17	<1	<5	1	1154	<5	<1	<1	<1	<1	229	1.94	2.05
CL20-4735	04C00436		9504	0.05	10.872	70.361	5.64	5.05	3	<1	<1	<1	1083	<1	2	27	1	713	<1	41	<1	934	3	<1	7	<1	1107	<5	<1	<1	<1	<1	404	2.02	3.03
CL21-6381			10104	0.09	10.633	69.165	4.54	4.05	1	<1	<1	<1	1125	<1	3	26	2	698	<1	42	<1	882	4	<1	<5	<1	1044	<5	<1	<1	<1	<1	586	0.77	3.32
CL20-4744	07L00190	856		0.05	13.689	98.235	5.50	4.78	2	<1	<1	<1	1102	<1	1	15	2	782	<1	48	<1	937	3	<1	6	<1	1155	<5	<1	<1	<1	<1	451	1.67	3.18
CL21-6382		1406		0.06	14.904	108.722	6.96	5.74	<1	<1	<1	1	1010	<1	<1	13	2	910	<1	64	<1	1028	4	<1	<5	<1	1148	<5	<1	<1	<1	<1	181	2.72	4.12
CL20-4741	07L00325	227		0.08	13.081	92.731	8.60	7.02	2	<1	<1	2	2350	<1	4	14	2	298	<1	3	<1	1232	9	<1	<5	1	1414	<5	<1	<1	<1	<1	497	2.16	2.52
CL21-6386		1242		0.02	12.964	92.543	8.6	6.5	<1	<1	<1	3	2491	1	4	17	2	296	<1	3	<1	1259	14	<1	<5	2	1399	<5	<1	<1	<1	<1	424	2.1	2.29
CL20-4743	10C00131	3203		0.18	13.759	84.261	7.70	5.72	162	<1	<1	57	989	4	4	83	2	965	1	62	2	1117	13	<1	8	1	1301	<5	<1	<1	<1	<1	432	1.25	3.45
CL21-6383		3430		0.17	13.318	83.647	5.42	4.23	181	<1	<1	35	1058	7	6	127	3	941	2	66	3	986	14	<1	<5	3	1202	<5	<1	<1	<1	<1	697	4.51	4.48
CL20-4734	10E01058	374		0.18	10.244	53.234	7.02	6.35	3	<1	2	159	2837	3	19	34	16	95	2	19	<1	1097	103	<1	9	4	1311	<5	1	<1	<1	<1	156	2.50	3.21
CL20-4736	11C00008	147		0.91	10.945	71.344		0.08	585	<1	3	2	1976	66	94	1894	3	131	28	11	21	966	53	19	16	29	1105	31	6	<1	1	<1	944	N/A	5.65
CL21-6387		866		0.12	9.254	58.748	5.73	4.67	49	<1	<1	73	2176	8	6	142	<1	109	2	67	2	797	9	<1	<5	3	856	<5	1	<1	<1	<1	727	0.13	1.76
CL21-6378	12L00939		3535	0.23	14.441	104.902	7.08	6.25	4	<1	<1	6	1449	7	10	176	16	828	3	62	3	1080	46	<1	<5	9	1265	<5	<1	<1	<1	<1	782	1.79	2.72
CL21-6379	12L01095		3026	0.2	16.058	110.601	8.2	6.79	4	<1	<1	33	2512	6	27	215	26	518	7	48	3	1195	109	<1	<5	14	1447	9	<1	<1	<1	<1	184	2.15	8.34
CL20-4738	13K00053	1599		0.32	10.828	70.596	7.27	5.93	10	<1	7	54	1244	6	18	59	4	797	3	48	<1	926	18	<1	12	3	1068	<5	<1	<1	<1	<1	662	1.83	2.38
CL21-6385		702	1885	0.38	10.767	70.212	7.3	5.33	8	<1	8	52	1323	7	20	67	3	795	3	49	<1	948	18	<1	7	4	1071	<5	<1	<1	<1	<1	927	2.05	3.61
CL20-4737	23D08482	674		0.41	14.610	112.386	7.14	4.25	4	<1	<1	237	1580	2	12	27	<1	702	<1	190	<1	1009	9	<1	6	<1	1204	<5	<1	<1	<1	<1	431	2.29	3.14
CL21-6388		345	674	0.47	14.693	114.512	6.75	3.56	2	<1	<1	229	1700	2	32	34	<1	720	<1	195	<1	1019	7	<1	<5	<1	1210	<5	<1	<1	<1	<1	214	1.15	3.78
CL20-4740	10L00894	4166		0.08	14.205	104.427	8.00	7.04	<1	<1	<1	4	1267	<1	<1	5	<1	802	<1	47	<1	1108	3	<1	6	<1	1279	<5	<1	<1	<1	<1	277	1.46	3.16
CL21-6384		4672		0.18	14.345	104.937	7.4	6.42	2	<1	<1	3	1006	1	8	25	5	862	<1	88	<1	1007	7	<1	75	<1	1131	220	<1	<1	<1	<1	562	1.2	3.12
CL20-4770	Fresh			0.00	15.453	111.895		8.65	<1	<1	<1	<1	1023	<1	<1	<1	<1	973	<1	64	<1	1083	4	<1	<5	<1	1225	<5	<1	<1	<1	<1	194	2.54	2.50

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4.4 Laboratory analysis of Al Udeid AFB Vehicle Lubricant Samples

The vehicles selected for evaluation at Al Udeid AFB are shown in Table 7 along with the information requested about maintenance and vehicle utilization for the initial sampling. Of the fifteen vehicles selected, all fifteen were sampled at the start of the program. A fresh oil sample was not included with the shipment from Al Udeid AFB.

The vehicles samples for lubricant evaluation after 15 months of operation were never supplied from Al Udeid AFB. An extra set of sampling supplies was sent due to a change of the POC, but samples were never received. The utilization information was recorded from the sample bottles and the units were not always noted. Because there was not a second sample set, the vehicle utilization could not be estimated.

The ASTM laboratory analysis of the selected lubricant properties for the Al Udeid AFB vehicles are included in Table 8. The elemental analysis suggest most of the vehicles were using a variety of different lubricants. The wear elements for the vehicles sampled looked normal except for asset 18D00234 and 18B00386 which had high copper (Cu). The TBN for vehicle 06C00774 was exhausted and the TAN was high, and the viscosity was low. Vehicles 04E00036 and 11B02867 revealed TAN values near the high limit, typically accepted as a value around 4. Vehicle 04E00036 also showed a strangely high TBN, that was rerun and repeated. Vehicles 18D00136 and 10D00355 showed low viscosities.

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Table 7. AI Udeid Selected Vehicles Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Miles / Hours	Recent Major Engine Maintenance	ARMY Lab Code	ASSET Description
AL UDEID (MOB)	B363	00B00277	12C00219	Bobtail	15W-40		7160.6m	8805.6m		CL20-5293	12C00219
AL UDEID (MOB)	C355	00C00144	18D00234	Sweeper	15W-40		778	778		CL20-5279	18D00234
AL UDEID (MOB)	D594	00D00046	06C00774	Bobtail	15W-40		109.3	4436		CL20-5280	06C00774
AL UDEID (MOB)	E831	00E00168	17D00412	Dump Truck	15W-40		125.2	125.2		CL20-5281	17D00412
AL UDEID (MOB)	C211	01C00400	17B00298	Bus	15W-40		231.6	4140.5		CL20-5282	17B00298
AL UDEID (MOB)	B163	02B01179	18D00136	Sweeper	15W-40		734	734		CL20-5284	18D00136
AL UDEID (MOB)	D525	03D00103	04E00036	60K Loader	15W-40		211.3	211.3		CL20-5285	04E00036
AL UDEID (MOB)	L535	03L00038	18B00386	Bus	15W-40		952.9	952.9		CL20-5288	18B00386
AL UDEID (MOB)	C603	05C00411	18D00269	Tractor Trailer	15W-40		465	465		CL20-5289	18D00269
AL UDEID (MOB)	B222	06B02509	11B02867	Bus	15W-40		4961.5	5487.4		CL20-5290	11B02867
AL UDEID (MOB)	C508	07C00664	17D00410	Dump Truck	15W-40		26.7	26.7		CL20-5291	17D00410
AL UDEID (MOB)	B220	08B01429	06C00773	Bobtail	15W-40		150.7	4168.8		CL20-5292	06C00773
AL UDEID (MOB)	L532	07L00166		XM1116 HMMWV Up-armored	15W-40		322.2m	13224.2m		CL20-5287	07L00166
AL UDEID (MOB)	D752	10D00355		EXCAV CRAW MTD	15W-40		271.8	1571.9		CL20-5283	10D00355
AL UDEID (MOB)	C604	11C00015		STAIRCASE TRUCK	15W-40		57	1757		CL20-5286	11C00015

Table 8. AI Udeid Vehicle Lubricant Analysis

Lab Code	Asset	TestInfo		CEC Soot	D445 100c	D445 40c	TBN D4739		D5185 - Elementals, ppm																												D6304C Oils		TAN D664	
		Hours	Miles	Soot	Viscosity	Viscosity	Infect	Buffer	Al	Sb	Ba	B	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Ag	Na	Sn	Zn	K	Sr	V	Ti	Cd	Water	Infect	Buffer					
CL20-5293	12C00219		8805.6	0.02	15.197	112.731	9.36	8.66	1	<1	<1	4	1227	<1	<1	8	<1	1036	<1	66	<1	1230	7	<1	<5	1	1354	<5	<1	<1	<1	<1	<1	370	1.70	2.66				
CL20-5279	18D00234	778		0.12	9.507	58.711	4.76	4.03	6	<1	<1	81	1312	<1	228	15	2	569	1	<1	<1	640	7	<1	5	1	697	<5	<1	<1	<1	<1	<1	275	0.17	2.55				
CL20-5280	06C00774	4436		0.37	8.841	52.681	1.98	1.91	4	<1	<1	3	1044	3	5	70	6	702	1	44	<1	819	20	<1	34	3	999	<5	<1	<1	<1	<1	<1	624	5.51	4.65				
CL20-5281	17D00412	125.2		0.25	13.857	103.770	6.79	5.93	5	<1	9	106	2119	<1	40	29	1	116	3	10	<1	1020	26	<1	<5	<1	1147	9	<1	<1	<1	<1	<1	365	1.70	2.28				
CL20-5282	17B00298	4140.5		0.01	13.424	96.371	8.75	8.16	<1	<1	<1	2	1140	<1	1	2	<1	1004	<1	65	<1	1172	4	<1	<5	1	1331	<5	<1	<1	<1	<1	<1	479	1.43	3.27				
CL20-5284	18D00136	734		0.02	8.522	49.826	6.15	5.55	3	<1	<1	269	1411	<1	12	10	2	514	<1	89	<1	613	7	<1	<5	2	703	<5	<1	<1	<1	<1	<1	238	1.49	1.82				
CL20-5285	04E00036	211.3		0.28	12.966	83.662	14.44	13.95	2	<1	<1	274	4809	1	17	20	5	43	1	1	<1	1157	8	<1	<5	2	1290	<5	2	<1	<1	<1	244	3.44	4.10					
CL20-5288	18B00386	952.9		0.28	13.908	103.780	6.24	4.95	5	<1	13	25	1536	1	400	42	2	652	3	52	<1	1030	25	<1	5	2	1219	13	<1	<1	<1	<1	<1	238	3.63	3.22				
CL20-5289	18D00269	465		0.65	13.435	97.860	9.41	7.39	5	<1	11	11	3285	2	23	38	5	99	4	10	<1	1147	20	<1	7	3	1323	5	1	<1	<1	<1	<1	270	2.26	3.85				
CL20-5290	11B02867	5487.4		0.16	12.899	94.253	5.47	2.81	7	<1	<1	209	3034	6	3	49	<1	290	1	52	<1	982	16	<1	10	3	1195	<5	1	<1	<1	<1	<1	420	3.51	4.45				
CL20-5291	17D00410	26.7		0.10	13.942	104.213	6.84	6.66	3	<1	8	120	2081	<1	42	13	<1	129	2	11	<1	1044	24	<1	<5	<1	1150	<5	<1	<1	<1	<1	<1	509	1.73	1.87				
CL20-5292	06C00773	4168.8		0.05	12.945	89.271	8.32	7.08	<1	<1	<1	59	1559	<1	2	7	1	779	<1	62	<1	1109	8	<1	<5	1	1239	<5	<1	<1	<1	<1	<1	322	1.86	2.84				
CL20-5287	07L00166		13224.2	0.07	15.438	114.090	8.34	7.97	3	<1	<1	10	1139	1	5	46	6	1022	<1	69	<1	1136	27	<1	<5	2	1262	<5	<1	<1	<1	<1	1	492	2.40	3.31				
CL20-5283	10D00355	1571.9		0.07	9.767	62.060	9.11	5.91	2	<1	2	263	1380	<1	61	14	5	786	1	261	<1	942	8	<1	11	3	1064	10	<1	<1	<1	<1	<1	254	1.95	1.95				
CL20-5286	11C00015	1757		0.00	13.958	101.206	8.40	8.16	<1	<1	<1	59	1424	<1	<1	4	<1	692	<1	47	<1	1122	6	<1	<5	<1	1242	<5	<1	<1	<1	<1	<1	420	1.90	2.79				

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4.5 Laboratory analysis of Dobbins AFB Vehicle Lubricant Samples

The vehicles selected for evaluation at Dobbins AFB are shown in Table 9 along with the information requested about maintenance and vehicle utilization for the initial sampling. Of the fifteen vehicles selected, all fifteen were sampled at the start of the program.

The vehicles samples for lubricant evaluation after 15 months of operation at Dobbins AFB are shown in Table 10. All fifteen vehicles selected were sampled at the 15 month interval of the program. The utilization information was recorded from the sample bottles and the units were noted fairly well. The range of utilization for the repeat vehicles was a low of 0 hours to a high of 448 hours for the 15 month interval. The mileage reported ranged from a low of 0 miles to a high of 9578 miles for the 15 month period.

The ASTM laboratory analysis of the selected lubricant properties for the Dobbins AFB vehicles and the fresh oil are included in Table 11. The elemental analysis suggest most of the vehicles were using a lubricant different from the fresh oil sample supplied, although some were close in formulation. The wear elements for the vehicles sampled looked normal except for asset 16E00041, 06B00061, and 06L00352 which had high copper (Cu) responses at both sample intervals. Vehicle 06L00352 also revealed low viscosities, exhausted TBN, and elevated water content at both sample intervals. Vehicle 06L00431 had elevated water initially that reduced at 15 months, while vehicle 05L00198 initially had low water that increased in 15 months. Vehicle 08C00017 seemed to undergo an oil change, as the viscosity improved and the additive element ratios seemed to change.

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Table 9. Dobbins AFB Initial Vehicle Lubricant Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Oil Change Date	Miles / Hours at last oil change	Current Miles / Hours	Recent Major Engine Maintenance	ARMY Lab Code	ASSET Description
DOBBINS	L275	07L00003	07L00003	TRK CNTRN-MAINT 4X2 SZ 5	15w-40	3/5/2016	4748	4851 h	4910h/40269m	CL20-4817	07L00003
DOBBINS	B180	01B01486	01B01517	Maint Utility Del Van	15w-40	11/9/2017	43895	47335 m	49624m	CL20-4811	01B01517
DOBBINS	B130	02B01782		BUS SCH 42-45 PAX 4X2 DE	15w-40	2/2/2017	23662	23843 m		CL20-4818	02B01782
DOBBINS	D560	03D00112	03D00157	TRAC WHLD IW70	15w-40	2/1/2019	4391	4626 h		CL20-4814	03D00157
DOBBINS	L530	04L00429	06L00431	M1097A2 HMMWV Utility	15w-40	11/18/2016	3227	6225 m	rebuilt radiator, m	CL20-4807	06L00431
DOBBINS	E801	05E00546	16E00041	TUG WHSE 4K	15w-40	never-factor	0	351 m	300.7h	CL20-4816	16E00041
DOBBINS	L548	05L00475	12L00853	XM1116 HMMWV Up-armored	15w-40	never- factor	0	1736 m	268h	CL20-4812	12L00853
DOBBINS	B361	06B00061		TRK TRAC 6X4 44.5K-46K GV	15w-40	10/27/2017	64069	65310 m	268h	CL20-4808	06B00061
DOBBINS	L145	06L00352		TRK FIRE CRS RESCUE P-19	15w-40	7/10/2013	1405	2192 h	2235h	CL20-4813	06L00352
DOBBINS	L275	92C00166	05L00198	TRK CNTRN-MAINT 4X2 SZ 5	15w-40	5/4/2018	3806	4096 h		CL20-4806	05L00198
DOBBINS	D633	07D00460		LODR SCP PT 4CY	15w-40	2/24/2013	775	775 h	883h	CL20-4804	07D00460
DOBBINS	C601	08C00017		DEICER TRUCK MOUNTED	15w-40	never perfor	268	637 m	300h	CL20-4810	08C00017
DOBBINS	C604	09C00130	09C00131	STAIRCASE TRUCK	15w-40	never- factor	98	624 m	763m	CL20-4815	09C00131
DOBBINS	C316	09C00171		EOD VEHICLE	15w-40	10/12/2016	5387	8017 m	2629h	CL20-4809	09C00171
DOBBINS	D631	09D00614		LODR SCP PT 1 1-2 / 2 CY	15w-40	11/17/2016	311	623 h	640h	CL20-4805	09D00614
										CL20-4803	New Oil

Table 10. Dobbins AFB 15 Month Vehicle Lubricant Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Miles / Hours	Recent Major Engine Maintenance	ARMY Lab Code	ASSET Description
DOBBINS	L275	07L00003	07L00003	TRK CNTRN-MAINT 4X2 SZ 5	15w-40	3/5/2016	4748	5299 h	4910h/40269m	CL21-5794	07L00003
DOBBINS	B180	01B01486	01B01517	Maint Utility Del Van	15w-40	11/9/2017	43895	56913 m	49624m	CL21-5798	01B01517
DOBBINS	B130	02B01782		BUS SCH 42-45 PAX 4X2 DE	15w-40	2/2/2017	23662	23866 m		CL21-5807	02B01782
DOBBINS	D560	03D00112	03D00157	TRAC WHLD IW70	15w-40	2/1/2019	4391	4686 h		CL21-5804	03D00157
DOBBINS	L530	04L00429	06L00431	M1097A2 HMMWV Utility	15w-40	11/18/2016	3227	6319 m	rebuilt radiator, m	CL21-5808	06L00431
DOBBINS	E801	05E00546	16E00041	TUG WHSE 4K	15w-40	never-factor	0	378	300.7h	CL21-5800	16E00041
DOBBINS	L548	05L00475	12L00853	XM1116 HMMWV Up-armored	15w-40	never- factor	0	280 h	280 h	CL21-5796	12L00853
DOBBINS	B361	06B00061		TRK TRAC 6X4 44.5K-46K GV	15w-40	10/27/2017	64069	68262 m	268h	CL21-5803	06B00061
DOBBINS	L145	06L00352		TRK FIRE CRS RESCUE P-19	15w-40	7/10/2013	1405	8911 m	2235h	CL21-5805	06L00352
DOBBINS	L275	92C00166	05L00198	TRK CNTRN-MAINT 4X2 SZ 5	15w-40	5/4/2018	3806	4489 h		CL21-5806	05L00198
DOBBINS	D633	07D00460		LODR SCP PT 4CY	15w-40	2/24/2013	775	775 h	883h	CL21-5802	07D00460
DOBBINS	C601	08C00017		DEICER TRUCK MOUNTED	15w-40	never perfor	268	637 m	300h	CL21-5797	08C00017
DOBBINS	C604	09C00130	09C00130	STAIRCASE TRUCK	15w-40	never- factor	98	1018 m	763m	CL21-5795	09C00130
DOBBINS	C316	09C00171		EOD VEHICLE	15w-40	10/12/2016	5387	9050	2629h	CL21-5801	09C00171
DOBBINS	D631	09D00614		LODR SCP PT 1 1-2 / 2 CY	15w-40	11/17/2016	311	689 h	640h	CL21-5799	09D00614

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Table 11. Dobbins AFB Vehicle Lubricant Analysis

Lab Code	ASSET	Hours	Miles	CEC Soot		D445 100c	D445 40c	TBN D4739		D5185 Elementals																				D6304C Oils		TAN D664			
				Soot	Viscosity			Viscosity	Inflect	Buffer	Al	Sb	Ba	B	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Ag	Na	Sn	Zn	K	Sr	V	Ti	Cd	Water
CL20-4817	07L00003	4851		0.12	10.733	71.349	5.98	4.95	4	<1	<1	337	1234	<1	6	24	5	498	2	116	<1	664	24	<1	26	<1	761	<5	<1	<1	<1	<1	388	0.27	1.21
CL21-5794		5299		0.20	11.571	79.623	6.30	4.65	1	<1	<1	318	1401	<1	3	15	3	493	<1	108	<1	869	10	<1	12	1	976	<5	<1	<1	<1	<1	648	0.15	1.79
CL20-4811	01801517	47335.0		0.54	13.464	98.813	4.09	2.83	3	<1	<1	33	2401	6	6	136	10	62	1	17	4	1051	16	<1	6	4	1231	<5	1	<1	<1	<1	663	2.81	3.03
CL21-5798		56913.0		0.14	14.068	103.323	6.17	6.04	<1	<1	<1	299	1671	1	1	33	3	410	<1	91	<1	1005	8	<1	<5	1	1120	<5	<1	<1	<1	<1	616	1.95	2.19
CL20-4818	02801782	26843.0		0.12	13.614	99.466	5.82	5.30	2	<1	1	61	2248	<1	2	10	2	22	<1	4	<1	1074	5	<1	<5	<1	1206	<5	1	<1	<1	<1	418	1.81	2.10
CL21-5807		23866.0		0.16	13.573	99.484	5.55	5.03	<1	<1	<1	59	2233	<1	2	11	<1	23	<1	4	<1	1093	5	<1	<5	<1	1204	<5	<1	<1	<1	<1	228	1.53	2.10
CL20-4814	03D00157	4626		0.33	13.742	103.672	4.94	3.53	7	<1	<1	52	2292	<1	2	29	27	28	<1	4	<1	1056	6	<1	<5	1	1252	<5	1	<1	<1	<1	626	1.72	2.85
CL21-5804		4686		0.11	13.864	99.770	6.54	5.14	<1	<1	<1	291	1558	<1	<1	7	4	465	<1	94	<1	937	5	<1	<5	<1	1053	<5	<1	<1	<1	<1	664	1.69	1.91
CL20-4807	06L00431	6225.0		0.70	14.614	107.223	5.48	4.44	4	1	3	29	2368	6	31	128	34	25	2	16	3	1145	127	<1	22	14	1272	95	<1	<1	3	12	1502	1.55	2.40
CL21-5808		6319.0		0.74	14.453	108.387	5.78	3.79	2	2	2	28	2335	6	30	131	32	30	2	16	3	1153	118	<1	22	14	1261	94	<1	<1	2	12	528	2.09	2.64
CL20-4816	16E00041	351.0		0.14	12.315	90.534	5.39	3.42	4	<1	<1	350	1326	<1	609	18	4	430	2	81	<1	1094	36	<1	<5	<1	1248	<5	<1	<1	<1	<1	541	1.81	2.81
CL21-5800		378.0		0.20	12.688	91.409	3.86	3.08	2	<1	<1	355	1321	<1	300	17	2	507	2	116	<1	815	27	<1	6	<1	909	<5	<1	<1	<1	<1	575	0.66	2.54
CL20-4812	12L00853	1736.0		0.34	14.677	112.711	8.99	7.18	3	<1	<1	42	2603	4	32	87	26	418	5	40	2	1209	129	<1	5	12	1534	8	<1	<1	<1	<1	958	2.07	2.80
CL21-5796		280		0.38	14.727	112.171	8.84	6.67	<1	<1	<1	40	2569	4	32	90	26	411	5	39	2	1207	124	<1	6	13	1490	10	<1	<1	<1	<1	671	2.51	2.84
CL20-4808	06B00061	65310.0		0.18	13.290	97.558	5.94	4.33	2	<1	<1	53	2219	<1	641	8	<1	61	<1	6	<1	1064	4	<1	<5	<1	1195	<5	<1	<1	<1	<1	185	1.55	2.67
CL21-5803		68262.0		0.28	13.125	96.372	5.25	3.63	<1	<1	<1	45	2199	<1	529	12	1	60	<1	6	<1	1066	3	<1	<5	<1	1195	<5	<1	<1	<1	<1	345	1.84	3.10
CL20-4813	06L00352	2192		0.41	9.030	53.083	3.90	3.38	3	<1	<1	19	1578	<1	516	40	4	353	<1	22	<1	905	6	<1	6	<1	1045	6	<1	<1	1	<1	1217	3.14	3.30
CL21-5805		8911.0		0.45	8.823	51.694	3.40	3.02	3	<1	<1	30	1525	<1	453	47	4	350	<1	26	<1	895	7	<1	8	1	1027	14	<1	<1	1	<1	1390	2.37	3.38
CL20-4806	05L00198	4096		0.21	12.323	88.904	5.36	4.28	6	<1	<1	329	1311	<1	6	33	4	513	2	125	<1	712	23	<1	31	1	806	14	<1	<1	<1	<1	316	0.17	1.64
CL21-5806		4489		0.05	12.654	90.906	6.84	5.77	1	<1	<1	343	1462	<1	3	11	2	500	<1	111	<1	918	8	<1	11	<1	1032	<5	<1	<1	<1	<1	1503	1.34	2.00
CL20-4804	07D00460	883		0.03	13.940	102.716	7.05	6.54	<1	<1	<1	66	2162	<1	<1	4	<1	76	<1	10	<1	1104	7	<1	<5	<1	1220	<5	<1	<1	<1	<1	220	2.15	2.33
CL21-5802		775		0.01	13.501	100.537	7.05	6.57	<1	<1	<1	65	2140	<1	<1	5	<1	76	<1	10	<1	1120	6	<1	<5	<1	1220	<5	<1	<1	<1	<1	440	1.76	2.24
CL20-4810	08C00017	637.0		0.01	13.045	91.233	8.12	7.48	1	<1	<1	4	2401	<1	5	6	1	12	<1	<1	<1	1170	2	<1	<5	<1	1307	<5	<1	<1	4	<1	736	1.75	2.51
CL21-5797		540.0		0.00	13.836	101.313	7.22	6.89	<1	<1	<1	125	2009	<1	2	2	<1	153	<1	30	<1	1083	5	<1	<5	<1	1177	<5	<1	<1	<1	<1	479	1.86	1.98
CL20-4815	09C00130	624.0		0.04	12.649	86.598	6.46	5.40	5	<1	2	9	2324	2	12	40	4	10	1	2	<1	1134	26	<1	<5	1	1264	<5	<1	<1	3	<1	321	1.85	2.64
CL21-5795		1018.0		0.01	12.263	83.273	6.03	4.76	2	<1	2	10	2242	2	14	47	5	10	1	2	<1	1126	26	<1	6	2	1223	<5	<1	<1	3	<1	683	1.88	3.15
CL20-4809	09C00171	8017.0		0.30	12.511	86.167	5.24	3.83	18	<1	<1	5	2339	<1	12	48	2	11	1	<1	<1	1093	8	<1	8	<1	1276	<5	<1	<1	3	<1	369	1.54	3.47
CL21-5801		9050.0		0.30	12.336	85.167	4.65	3.40	18	<1	<1	3	2350	<1	14	57	2	11	1	<1	<1	1117	8	<1	10	1	1295	<5	<1	<1	3	<1	268	1.73	4.63
CL20-4805	09D00614	623		0.62	14.676	107.474	5.89	5.03	2	<1	<1	4	2479	2	4	50	<1	11	2	<1	<1	1198	7	<1	<5	<1	1388	<5	<1	<1	4	<1	911	1.99	3.80
CL21-5799		689		0.67	14.859	109.157	5.52	4.39	<1	<1	<1	2	2450	2	5	55	<1	12	2	<1	<1	1211	6	<1	6	<1	1381	<5	<1	<1	4	<1	768	1.75	2.93
CL20-4803	Fresh Oil			0.01	14.785	108.834	7.76	7.54	1	<1	<1	410	1462	<1	<1	2	<1	546	<1	122	<1	938	8	<1	<5	<1	1056	<5	<1	<1	<1	<1	504	1.50	2.09

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4.6 Laboratory analysis of Misawa AFB Vehicle Lubricant Samples

The vehicles selected for evaluation at Misawa AFB are shown in Table 12 along with the information requested about maintenance and vehicle utilization for the initial sampling. Of the fifteen vehicles selected, all fifteen were sampled at the start of the program. A fresh oil sample was not included with the sample shipment.

The vehicles samples for lubricant evaluation after 15 months of operation at Misawa AFB are shown in Table 13. Only thirteen of the fifteen vehicles selected were sampled at the 15 month interval of the program. The utilization information was recorded from the sample bottles and the units were mixed between hours, miles, and kilometers. The range of utilization for the repeat vehicles was a low of 2 hours to a high of 1170 hours for the 15 month interval. The distance reported ranged from a low of 3694 kilometers to a high of 8891 kilometers for the 15 month period.

The ASTM laboratory analysis of the selected lubricant properties for the Misawa AFB vehicles are included in Table 14. The elemental analysis suggest most of the vehicles were using a variety of different lubricants. The wear elements for the vehicles sampled looked normal except for asset 06L00332 that had high copper (Cu) response for the initial sample and vehicle 05E00084 that had high copper for both samples. Vehicle 06L00332 also revealed low viscosity with the initial sample but appeared to have an oil change that improved the viscosity at 15 months. Vehicles 04B02721 and 04C00438 had low viscosities, depleted TBN, and elevated TAN. Asset 04B02721 also revealed high lubricant soot content. The viscosity numbers improved for 04B02721 at 15 months possibly due to an oil change. The initial water content for 00C00788 was high, but reduced at 15 months. Vehicle 03B00036 had a substantial degradation of the lubricant over the 15 month period, with low viscosity and depleted TBN.

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Table 12. Misawa AFB Initial Vehicle Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Miles/Hours	Recent Major Engine Maintenance	ARMY Lab Code	ASSET Description
MISAWA	B180	00B00795		Maint Utility Del Van				55323m		CL20-5148	00B00795
MISAWA	C601	00C00714		DEICER TRUCK MOUNTED				1523		CL20-5152	00C00714
MISAWA	C604	00C00788		STAIRCASE TRUCK				1534		CL20-5150	00C00788
MISAWA	D630	02D80013		LODR SCP PT 1 CY / UNDER				262		CL20-5149	02D80013
MISAWA	B265	03B00036		TRK S/P 4X2 10000 GVW				72374m		CL20-5159	03B00036
MISAWA	C603	03C00846		LAVATORY SERVICE TRUCK				215		CL20-5147	03C00846
MISAWA	D626	03D00186		TRAC W-BACKHOE / LOADER				1662		CL20-5151	03D00186
MISAWA	B211	04B02721		TRK 1/2T4X4 4600-5799GVW				32121m		CL20-5153	04B02721
MISAWA	C316	04C00438		EOD VEHICLE				1535		CL20-5158	04C00438
MISAWA	D574	04D00082		SNOW BROOM AND BLOWER				3814		CL20-5154	04D00082
MISAWA	D531	05D00083		TRK DP 24000-33000G 4X2				54233m		CL20-5156	05D00083
MISAWA	E958	05E00084		TRK FL 10K AT 463L				191		CL20-5155	05E00084
MISAWA	L143	06L00332		TRK FIRE CRS RESCUE P-23				2680		CL20-5160	06L00332
MISAWA	L530	06L00477		M1097A2 HMMWV Utility				1274		CL20-5146	06L00477
MISAWA	L351	06L00502		TRAC ACFT TWG MB-4				2017		CL20-5157	06L00502

Table 13. Misawa AFB 15 Month Vehicle Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Miles /	Recent Major Engine Maintenance	ARMY Lab Code	ASSET Description
MISAWA	B180	00B00795		Maint Utility Del Van				59017km		CL21-6020	00B00795
MISAWA	C601	00C00714		DEICER TRUCK MOUNTED				1617		CL21-6013	00C00714
MISAWA	C604	00C00788		STAIRCASE TRUCK				929		CL21-6018	00C00788
MISAWA	D630	02D80013		LODR SCP PT 1 CY / UNDER				312		CL21-6011	02D80013
MISAWA	B265	03B00036		TRK S/P 4X2 10000 GVW				123534km		CL21-6021	03B00036
MISAWA	C603	03C00846		LAVATORY SERVICE TRUCK				245		CL21-6010	03C00846
MISAWA	D626	03D00186		TRAC W-BACKHOE / LOADER				1758		CL21-6014	03D00186
MISAWA	B211	04B02721		TRK 1/2T4X4 4600-5799GVW				41012km		CL21-6019	04B02721
MISAWA	C316	04C00438		EOD VEHICLE				5864		CL21-6017	04C00438
MISAWA	D574	04D00082		SNOW BROOM AND BLOWER							04D00082
MISAWA	D531	05D00083		TRK DP 24000-33000G 4X2							05D00083
MISAWA	E958	05E00084		TRK FL 10K AT 463L				193.6		CL21-6009	05E00084
MISAWA	L143	06L00332		TRK FIRE CRS RESCUE P-23				2788		CL21-6015	06L00332
MISAWA	L530	06L00477		M1097A2 HMMWV Utility				1276		CL21-6012	06L00477
MISAWA	L351	06L00502		TRAC ACFT TWG MB-4				3187		CL21-6016	06L00502

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Table 14. Misawa AFB Vehicle Lubricant Analysis

PSponCd	Asset	Hours	km	CEC Soot	D445 100c	D445 40c	D4739 TBN		D5185 Elementals, ppm																						D6304C Oils		D664 TAN		
				Soot	Viscosity	Viscosity	Inflect	Buffer	Al	Sb	Ba	B	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Ag	Na	Sn	Zn	K	Sr	V	Ti	Cd	Water	Inflect	Buffer
CL20-5148	00B00795		55323	0.28	14.126	106.169	6.7	6.09	1	<1	<1	10	2392	1	<1	29	15	138	<1	17	<1	1030	8	<1	<5	2	1138	17	<1	<1	<1	<1	324	1.95	2.26
CL21-6020			59017	0.45	14.104	107.731	5.65	4.61	<1	<1	<1	9	2507	2	2	45	19	112	<1	15	<1	1064	12	<1	8	2	1202	16	<1	<1	<1	<1	691	2.26	2.66
CL20-5152	00C00714	1523		0.05	12.973	96.908	6.65	6.24	1	<1	<1	10	2497	<1	2	6	3	14	<1	6	<1	1002	6	<1	<5	<1	1113	<5	<1	<1	<1	<1	262	2.32	2.18
CL21-6013		1617		0.07	12.829	95.903	6.86	6.43	<1	<1	<1	10	2471	<1	3	7	2	14	<1	6	<1	1002	6	<1	6	<1	1123	<5	<1	<1	<1	<1	324	1.76	2.25
CL20-5150	00C00788	1534		0.14	13.036	93.461	7.71	7.35	2	<1	<1	168	2410	<1	2	23	14	44	<1	40	<1	1042	19	<1	<5	1	1141	22	1	<1	<1	<1	1063	1.64	2.77
CL21-6018		929		0.16	13.098	94.99	7.62	7.15	<1	<1	<1	160	2387	<1	2	24	12	41	<1	35	<1	1055	22	<1	7	1	1170	20	1	<1	<1	<1	479	1.61	2.64
CL20-5149	02D80013	262		0.05	14.636	111.21	7.73	7.59	4	<1	<1	25	1371	<1	<1	3	<1	761	<1	45	<1	1108	6	<1	<5	<1	1259	<5	<1	<1	<1	<1	434	2.37	2.8
CL21-6011		312		0.09	14.524	107.959	7.5	6.71	5	<1	<1	24	1470	<1	<1	4	<1	693	<1	40	<1	1104	6	<1	6	<1	1268	<5	<1	<1	<1	<1	342	2.22	2.14
CL20-5159	03B00036		72374	0.13	12.811	92.173	6.6	5.06	3	<1	<1	25	1488	1	2	15	3	692	<1	74	<1	1014	7	<1	9	1	1177	46	<1	<1	<1	<1	327	0.65	3.87
CL21-6021			123534	0.14	9.829	54.432	0	3.3	1	<1	<1	169	1069	<1	1	10	<1	111	<1	12	<1	831	7	<1	5	<1	954	14	<1	<1	<1	<1	345	1.6	1.85
CL20-5147	03C00846	215		0.06	11.976	84.083	6.91	6.43	2	<1	1	69	2284	1	5	8	4	11	<1	2	<1	1070	4	<1	<5	<1	1199	<5	1	<1	<1	<1	966	2.13	3.03
CL21-6010		245		0.05	13.273	98.983	6.76	6.66	<1	<1	<1	8	2392	<1	1	2	<1	7	<1	<1	<1	968	7	<1	<5	<1	1076	<5	<1	<1	<1	<1	519	1.8	1.98
CL20-5151	03D00186	1662		0.35	13.528	96.688	6.17	4.83	2	<1	<1	138	2465	<1	40	32	2	205	2	142	<1	904	6	<1	5	1	1066	138	1	<1	<1	<1	570	2.76	3.6
CL21-6014		1758		0.11	13.38	100.887	6.31	5.94	<1	<1	<1	29	2421	<1	10	10	<1	48	<1	28	<1	958	4	<1	5	<1	1082	30	<1	<1	<1	<1	455	1.79	2.23
CL20-5153	04B02721		32121	0.98	7.621	41.914	3.79	3.3	1	<1	<1	6	1734	<1	2	13	<1	7	<1	3	<1	654	8	<1	<5	<1	717	<5	<1	<1	<1	<1	264	0.12	2.93
CL21-6019			41012	1.99	13.415	99.5	8.91	6.16	1	<1	<1	46	4137	<1	4	45	<1	18	<1	86	<1	1106	25	<1	5	2	1326	<5	2	<1	<1	<1	650	2.7	2.96
CL20-5158	04C00438	1535		0.13	6.167	30.751	2.33	1.02	2	<1	<1	4	1736	<1	10	40	4	161	1	2	<1	773	6	<1	5	<1	901	<5	<1	<1	<1	<1	460	4.06	4.24
CL21-6017		5864		0.2	5.862	29.371	0	0.92	1	<1	<1	4	1623	<1	10	40	2	146	1	2	<1	705	9	<1	7	<1	823	<5	<1	<1	<1	<1	470	N/A	4.21
CL20-5154	04D00082	3814		0.08	12.1	87.476	5.73	5.48	<1	<1	<1	3	2277	<1	2	8	2	50	<1	3	<1	944	2	<1	<5	<1	1031	<5	<1	<1	<1	<1	654	2.06	2.71
CL20-5156	05D00083		54233	0.18	10.374	66.636	7.23	6.68	2	<1	<1	10	2211	<1	6	12	2	11	<1	6	<1	1041	5	<1	<5	<1	1205	6	<1	<1	<1	<1	408	1.88	2.91
CL20-5155	05E00084	191		0.01	13.47	91.487	8.66	7.88	<1	<1	<1	202	2417	<1	183	5	5	12	<1	157	<1	752	5	<1	<5	<1	828	183	1	<1	<1	<1	536	0.75	1.56
CL21-6009		193.6		0.04	13.405	92.09	8.43	7.76	<1	<1	<1	217	2384	<1	228	5	4	14	<1	152	<1	768	5	<1	8	<1	860	190	1	<1	<1	<1	477	1.1	1.2
CL20-5160	06L00332	2680		0.09	8.789	52.256	7.09	6.1	2	<1	<1	22	1315	<1	69	6	2	590	<1	47	<1	875	4	<1	<5	1	1003	26	<1	<1	<1	<1	436	1.5	1.96
CL21-6015		2788		0.05	12.777	90.918	6.34	6.2	<1	<1	<1	5	2247	<1	11	2	<1	92	<1	7	<1	943	6	<1	5	<1	1045	<5	<1	<1	<1	<1	488	1.95	2.08
CL20-5146	06L00477	1274		0.01	10.872	62.425	7.85	7.8	<1	<1	2	258	2227	<1	8	28	6	107	<1	157	<1	828	18	<1	9	2	903	136	1	<1	<1	2	735	0.9	1.75
CL21-6012		1276		0.05	10.88	63.085	8.13	7.94	<1	<1	<1	269	2237	<1	10	25	4	115	<1	149	<1	821	18	<1	12	1	918	136	<1	<1	<1	2	806	1.23	1.26
CL20-5157	06L00502	2017		0.02	14.091	106.07	6.5	6.3	<1	<1	<1	3	2398	<1	<1	3	<1	10	<1	1	<1	968	8	<1	<5	<1	1047	<5	<1	<1	<1	<1	411	2.69	2.53
CL21-6016		3187		0.06	14.221	106.411	6.51	6.47	<1	<1	<1	1	2426	<1	<1	2	<1	8	<1	<1	<1	974	8	<1	6	<1	1077	<5	<1	<1	<1	<1	282	2.23	2.34

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4.7 Laboratory analysis of Moody AFB Vehicle Lubricant Samples

The vehicles selected for evaluation at Moody AFB are shown in Table 15 along with the information requested about maintenance and vehicle utilization for the initial sampling. Of the fifteen vehicles selected, all fifteen were sampled at the start of the program. A fresh oil sample was included with the sample shipment.

The vehicles samples for lubricant evaluation after 15 months of operation at Moody AFB are shown in Table 16. All of the fifteen vehicles selected were sampled at the 15 month interval of the program. The utilization information was recorded from the sample bottles and the units were mixed between miles and hours. The range of utilization for the repeat vehicles was a low of 0 hours to a high of 202 hours for the 15 month interval. The distance reported ranged from a low of 0 miles to a high of 4,385 miles over the 15 month period.

The ASTM laboratory analysis of the selected lubricant properties for the Moody AFB vehicles are included in Table 17 along with the fresh oil analysis. The elemental analysis suggest most of the vehicles were using a variety of different lubricants that were close to the fresh lubricant in some of the additive ratios. Vehicle 10C243 had low lubricant viscosities and exhausted TBN likely from fuel dilution. Vehicle 05L00379 had extremely low viscosity, exhausted TBN, and depleted additive elements, this vehicle should be checked. The lubricant water content was high for assets 02L00144, 05L00759, and 09C00060. The copper (Cu) wear metals were high for asset 01C00087 for both samples.

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Table 15. Moody AFB Initial Vehicle Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Miles / Hours	Recent Major Engine	ARMY Lab Code	ASSET Description
MOODY (MOB)	B265	02B00764		TRK S/P 4X2 10000 GVW		10/17/2019	47085 Miles	47106 miles		CL20-4634	02B00764
MOODY (MOB)	L145	02L00144		TRK FIRE CRS RESCUE P-19		1/18/2019	2710 Hrs	2890 hrs		CL20-4629	02L00144
MOODY (MOB)	C164	03C80009		TRK DIGGER DERRICK MAIN			1313 Hrs	1562 hrs		CL20-4628	03C80009
MOODY (MOB)	B222	05B00052		TRK 3/4T CREW CAB 4X4 PU		4/27/2018	79365 Miles	86389 mls		CL20-4627	05B00052
MOODY (MOB)	B130	05B02713		BUS SCH 42-45 PAX 4X2 DE		9/30/2018	17654 Miles	20630 miles		CL20-4632	05B02713
MOODY (MOB)	L142	05L00759		TRK FFGT HMV P-31 4X2		3/26/2018	1053 hrs	1114 hrs		CL20-4636	05L00759
MOODY (MOB)	D676	06D00262		RLR RD TAND 2RL 2.5T			310 hrs	422 hrs		CL20-4626	06D00262
MOODY (MOB)	E925	06E80004		CNVR BELT TM BAGG			140 hrs	346 hrs		CL20-4631	06E80004
MOODY (MOB)	D652	08D01058		GRADER SIZE 5			579 hrs	1066 hrs		CL20-4637	08D01058
MOODY (MOB)	C604	09C00060		STAIRCASE TRUCK			360 Miles	722 Miles		CL20-4640	09C00060
MOODY (MOB)	C157	10C243		TRK MAINT TEL-UT 4X2		3/6/2018	29116 miles	35111 miles		CL20-4630	10C243
MOODY (MOB)	C355	07C00334		Bobtail		Mar-18	10546 Hrs	11005 Hrs		CL20-4635	07C00334
MOODY (MOB)	C355	01C00087		Bobtail			928 Hrs	1337 Hrs		CL20-4639	01C00087
MOODY (MOB)	L125	15L00031		TRK FIRE CRS RESCUE P-23 UHP		12/3/2018	536 hrs	755 hrs		CL20-4633	15L00031
MOODY (MOB)	L532	05L00379		XM1116 HMMWV Up-armored			1528 Miles	5261 miles		CL20-4638	05L00379
										CL20-4625	New Oil

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Table 16. Moody AFB 15 Month Vehicle Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change	Miles / Hours at last	Current Miles /	Recent Major	ARMY Lab Code	ASSET Description
MOODY (MOB)	B265	02B00764		TRK S/P 4X2 10000 GVW		10/17/2019	47085 Miles	47525 mi		CL21-5984	02B00764
MOODY (MOB)	L145	02L00144		TRK FIRE CRS RESCUE P-19		1/18/2019	2710 Hrs	3027		CL21-5979	02L00144
MOODY (MOB)	C164	03C80009		TRK DIGGER DERRICK MAIN			1313 Hrs	1614		CL21-5978	03C80009
MOODY (MOB)	B222	05B00052		TRK 3/4T CREW CAB 4X4 PU		4/27/2018	79365 Miles	88938 mi		CL21-5985	05B00052
MOODY (MOB)	B130	05B02713		BUS SCH 42-45 PAX 4X2 DE		9/30/2018	17654 Miles	23104 mi		CL21-5982	05B02713
MOODY (MOB)	L142	05L00759		TRK FFGT HVM P-31 4X2		3/26/2018	1053 hrs	1154		CL21-5976	05L00759
MOODY (MOB)	D676	06D00262		RLR RD TAND 2RL 2.5T			310 hrs	436		CL21-5972	06D00262
MOODY (MOB)	E925	06E80004		CNVR BELT TM BAGG			140 hrs	367		CL21-5971	06E80004
MOODY (MOB)	D652	08D01058		GRADER SIZE 5			579 hrs	1081		CL21-5975	08D01058
MOODY (MOB)	C604	09C00060		STAIRCASE TRUCK			360 Miles	805		CL21-5973	09C00060
MOODY (MOB)	C157	10C243		TRK MAINT TEL-UT 4X2		3/6/2018	29116 miles	39496 mi		CL21-5983	10C243
MOODY (MOB)	C355	07C00334		Bobtail		Mar-18	10546 mi	11588 mi		CL21-5981	07C00334
MOODY (MOB)	C355	01C00087		Bobtail			928 Hrs	1343		CL21-5977	01C00087
MOODY (MOB)	L125	15L00031		TRK FIRE CRS RESCUE P-23 UHP		12/3/2018	536 hrs	957		CL21-5974	15L00031
MOODY (MOB)	L532	05L00379		XM1116 HMMWV Up-armored			1528 Miles	5348 mi		CL21-5980	05L00379

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Table 17. Moody AFB Vehicle Samples Lubricant Analysis

Lab Code	Asset	Hours	Miles	CEC Soot	D445 100c Viscosity	D445 40c Viscosity	TBN D4739		D5185 Elementals																								D6304C Water	TAN D664	
							Inflect	Buffer	Al	Sb	Ba	B	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Ag	Na	Sn	Zn	K	Sr	V	Ti	Cd		Inflect	Buffer
CL20-4634	02B00764		47106	0.04	14.28	103.313	8.61	8.34	<1	<1	<1	5	1049	<1	<1	5	1	1015	<1	64	<1	1142	5	<1	<5	<1	1302	<5	<1	<1	<1	<1	588	2.41	2.27
CL21-5984			47525	0.01	13.7	97.003	8.66	8.15	<1	<1	<1	<1	1087	<1	<1	7	<1	1017	<1	67	<1	1168	4	<1	5	<1	1313	<5	<1	<1	<1	<1	442	1.86	2.03
CL20-4629	02L00144	2890		0.18	13.123	91.97	8.03	7.08	<1	<1	<1	4	1118	<1	9	6	4	920	<1	61	<1	1110	3	<1	<5	<1	1265	<5	<1	<1	<1	<1	1334	1.97	2.18
CL21-5979		3027		0.34	13.434	89.501	7.61	6.26	<1	<1	<1	2	1130	1	15	8	4	944	<1	63	<1	1123	3	<1	6	<1	1253	<5	<1	<1	<1	<1	467	1.66	2.07
CL20-4628	03C80009	1562		0.44	13.124	94.791	7.59	5.44	3	<1	<1	2	1224	<1	9	31	3	843	2	51	<1	1075	4	<1	<5	<1	1292	<5	<1	<1	<1	<1	276	2.04	2.64
CL21-5978		1614		0.47	13.032	96.219	7.11	4.79	1	<1	<1	2	1232	<1	9	34	3	860	2	52	<1	1091	4	<1	7	<1	1277	<5	<1	<1	<1	<1	500	2.39	2.72
CL20-4627	05B00052	0	86389	0.08	13.127	94.02	6.15	4.63	2	<1	<1	83	1253	<1	2	20	1	769	<1	15	<1	1070	7	<1	<5	<1	1218	<5	<1	<1	<1	<1	277	2.85	2.93
CL21-5985			88938	0.04	12.449	87.35	7.6	6.77	<1	<1	<1	18	1095	<1	2	19	<1	953	<1	55	<1	1139	6	<1	5	<1	1272	<5	<1	<1	<1	<1	235	1.75	2.38
CL20-4632	05B02713		20630	0.07	12.529	88.897	7.44	5.83	1	<1	<1	1	1056	<1	<1	11	1	962	<1	64	<1	1062	4	<1	<5	<1	1264	<5	<1	<1	<1	<1	392	3.22	3.98
CL21-5982			23104	0.16	13.046	93.418	6.79	5.36	2	<1	<1	<1	1069	1	<1	15	<1	986	<1	65	<1	1065	5	<1	<5	<1	1242	<5	<1	<1	<1	<1	457	2.83	3.68
CL20-4636	05L00759	1114		0.07	13.025	92.408	8.81	8.22	<1	<1	<1	2	1063	<1	37	4	2	973	<1	66	<1	1143	18	<1	<5	<1	1297	<5	<1	<1	<1	<1	1401	2.08	2.09
CL21-5976		1154		0.02	13.322	93.213	8.66	8.22	<1	<1	<1	1	1029	<1	24	2	1	969	<1	62	<1	1129	7	<1	<5	<1	1258	<5	<1	<1	<1	<1	954	1.88	1.97
CL20-4626	06D00262	422		0.06	13.356	97.274	8.03	7.38	1	<1	<1	6	1462	<1	10	7	<1	664	<1	39	<1	1069	8	<1	<5	<1	1248	<5	<1	<1	<1	<1	417	2.08	2.08
CL21-5972		436		0.05	13.245	97.223	7.96	7.23	<1	<1	<1	5	1474	<1	11	8	<1	674	<1	39	<1	1082	8	<1	6	<1	1238	<5	<1	<1	<1	<1	459	1.85	2.07
CL20-4631	06E80004	346		0.02	13.466	98.271	7.96	6.74	2	<1	<1	18	1633	<1	4	12	2	566	<1	51	<1	1095	11	<1	<5	<1	1265	<5	<1	<1	<1	<1	328	1.73	2.14
CL21-5971		367		0.03	13.217	97.307	8.21	6.93	<1	<1	<1	19	1640	<1	4	13	2	572	<1	51	<1	1108	11	<1	6	<1	1252	<5	<1	<1	<1	<1	873	1.74	2.05
CL20-4637	08D01058	1066		0.34	13.833	102.407	6.85	5.12	2	<1	<1	8	1489	4	7	35	2	776	<1	46	<1	1121	12	<1	<5	1	1364	<5	<1	<1	<1	<1	794	1.86	3.17
CL21-5975		1081		0.07	13.877	98.71	8.04	7.5	<1	<1	<1	3	1192	<1	2	10	<1	946	<1	63	<1	1111	5	<1	<5	<1	1262	<5	<1	<1	<1	<1	288	1.88	2.46
CL20-4640	09C00060	722		0.09	12.52	87.261	6.85	5.28	6	<1	2	7	1338	2	12	73	9	696	2	48	<1	1102	26	<1	<5	<1	1261	10	<1	<1	<1	<1	1140	1.9	2.48
CL21-5973		805		0.35	12.666	90.159	6.08	5.19	8	<1	2	6	1344	3	15	114	10	696	2	49	1	1114	31	<1	6	2	1252	14	<1	<1	<1	<1	1556	0.26	2.58
CL20-4630	10C243		35111	0.17	9.673	56.058	1.13	1.09	3	<1	<1	44	2020	<1	75	52	<1	12	1	74	<1	615	14	<1	8	<1	708	<5	<1	<1	<1	<1	540	1.62	3.32
CL21-5983			39496	0.01	8.378	43.936	0	2.4	<1	<1	<1	69	1461	<1	40	24	<1	481	<1	277	<1	723	15	<1	8	<1	826	<5	<1	<1	<1	<1	529	1.38	2.73
CL20-4635	07C00334		11005	0.82	13.739	96.647	5.73	5.09	5	<1	<1	2	1052	1	3	88	4	971	1	65	<1	1057	7	<1	<5	<1	1249	<5	<1	<1	<1	<1	693	1.27	3.8
CL21-5981			11588	0.02	13.701	97.418	7.81	7.3	2	<1	<1	1	1054	<1	2	38	2	1008	<1	69	<1	1115	6	<1	<5	<1	1277	<5	<1	<1	<1	<1	347	1.71	2.58
CL20-4639	01C00087	1337		0.1	13.703	99.337	6.77	5.22	1	<1	<1	2	1180	12	127	54	4	884	<1	57	5	1052	10	<1	5	5	1300	<5	<1	<1	<1	<1	392	0.2	3.01
CL21-5977		1343		0.09	13.522	99.869	6.78	5.46	<1	<1	<1	1	1204	14	131	62	3	893	<1	57	5	1034	10	<1	8	7	1279	<5	<1	<1	<1	<1	523	3.46	3.66
CL20-4633	15L00031	755		0.28	11.902	81.235	7.61	6.46	1	<1	<1	2	1060	2	4	11	1	976	<1	65	<1	1097	6	<1	<5	<1	1270	6	<1	<1	<1	<1	454	1.84	2.23
CL21-5974		957		0.45	11.357	73.883	7.29	5.52	<1	<1	<1	<1	1056	4	6	20	<1	976	<1	65	<1	1080	6	<1	<5	2	1225	12	<1	<1	<1	<1	318	1.62	3.04
CL20-4638	05L00379		5261	0.07	4.093	16.483		1.9	1	<1	<1	4	649	1	13	45	15	277	<1	20	<1	447	60	<1	<5	2	522	<5	<1	<1	<1	3	310	1.57	1.35
CL21-5980			5348	0.03	3.312	12.304	0	1.34	0	0	<1	0	0	0	11	0	0	0	0	0	0	351	0	0	0	0	0	0	0	0	0	0	384	1.17	1.5
CL20-4625	New Oil			0	15.079	109.714	8.52	8.45	<1	<1	<1	2	1030	<1	<1	<1	<1	1029	<1	65	<1	1141	5	<1	<5	<1	1282	<5	<1	<1	<1	<1	422	2.72	2.29

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4.8 Laboratory analysis of Robins ANG Vehicle Lubricant Samples

The vehicles selected for evaluation at Robins ANG are shown in Table 18 along with the information requested about maintenance and vehicle utilization for the initial sampling. Of the fifteen vehicles selected, all fifteen were sampled at the start of the program. A fresh oil sample was included with the sample shipment

The vehicles samples for lubricant evaluation after 15 months of operation at Robins ANG are shown in Table 19. All of the fifteen vehicles selected were sampled at the 15 month interval of the program. The utilization information was recorded from the sample bottles and the units were noted as hours. The range of utilization for the repeat vehicles was a low of 0 hours to a high of 999 hours for the 15 month interval.

The ASTM laboratory analysis of the selected lubricant properties for the Robins ANG vehicles are included in Table 20 along with the fresh oil analysis. The elemental analysis suggest most of the vehicles were using a variety of different lubricants that were close to the fresh lubricant in some of the additive ratios. Wear metals were not an issue with any of the Robins assets. Vehicle 05C00320 had low lubricant viscosities, exhausted TBN, and elevated TAN for both samples. Vehicle 06C00030 had low viscosity for both samples. The lubricant water content was high for asset 10E00893 for both samples. Asset 05K00039 had elevated water at 15 months.

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Table 18. Robins ANG Initial Vehicle Lubricant Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Hours	Recent Major Engine	ARMY Lab Code	ASSET Description
ROBINS (ANG)	C355	05C00320		TRAC TOW SUPPORT EQP	15W40	2/12/2019	2166	2671		CL20-4910	05C00320
ROBINS (ANG)	K251	05K00041		TRK CGO 6X6 24M-44500G D	15W40	11/20/2019	2940	2942		CL20-4900	05K00041
ROBINS (ANG)	C301	06C00030		TRK TK FUEL 1200 GL 4X4	15W40	10/1/2019	1136	1151		CL20-4909	06C00030
ROBINS (ANG)	E816	10E00893		TRK FL DED 4000 PT	15W40	4/7/2017	321	628		CL20-4901	10E00893
ROBINS (ANG)	D798	13D00810		Compact Excavator Crawler	15W40	4/5/2019	123	131		CL20-4912	13D00810
ROBINS (ANG)	C316	15C00073		EOD VEHICLE	15W40	2/6/2018	2095	3382		CL20-4908	15C00073
ROBINS (ANG)	E822	91E00168	10E01088	TRK FL DED 6M-6200 PT	15W40	7/27/2018	1065	1243		CL20-4902	10E01088
ROBINS (ANG)	L350	95L00092	97L00335	TRAC ACFT TWG MB-2	15W40	11/19/2018	1760	1819		CL20-4903	97L00335
ROBINS (ANG)	C355	96C00250	96C00252	TRAC TOW SUPPORT EQP	15W40	3/22/2018	3401	3787		CL20-4907	96C00252
ROBINS (ANG)	C601	97C00623		DEICER TRUCK MOUNTED	15W40	9/4/2019	517	517		CL20-4914	97C00623
ROBINS (ANG)	L271	97L00324		TRK HYDRANT FUELING R-12	15W40	0/10/2018	3076	3120		CL20-4913	97L00324
ROBINS (ANG)	L350	99L00301		TRAC ACFT TWG MB-2	15W40	2/28/2018	2296	2457		CL20-4911	99L00301
ROBINS (ANG)	K251	85K00450	05K00039	TRK CGO 6X6 24M-44500G D	15W40	12/10/2019	2882	2883		CL20-4905	05K00039
ROBINS (ANG)	D630	23D08193		LODR SCP PT 1 CY / UNDER	15W40	5/10/2018	516	526		CL20-4906	23D08193
ROBINS (ANG)	D785	13D00811		LoaderSkidSteerTrack MTD	15W40	4/3/2019	176	215		CL20-4904	13D00811
										CL20-4915	New Oil

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Table 19. Robins ANG 15 Month Vehicle Lubricant Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEME NT	VEH TYPE NAME	Oil Type	Last Oil Change	Miles / Hours at last	Current Hours	Recent Major	ARMY Lab Code	ASSET Description
ROBINS (ANG)	C355	05C00320		TRAC TOW SUPPORT EQP	15W40	2/12/2019	2166	3037		CL21-6005	05C00320
ROBINS (ANG)	K251	05K00041		TRK CGO 6X6 24M-44500G D	15W40	11/20/2019	2940	2992		CL21-6004	05K00041
ROBINS (ANG)	C301	06C00030		TRK TK FUEL 1200 GL 4X4	15W40	10/1/2019	1136	1168		CL21-6000	06C00030
ROBINS (ANG)	E816	10E00893		TRK FL DED 4000 PT	15W40	4/7/2017	321	684		CL21-5999	10E00893
ROBINS (ANG)	D798	13D00810		Compact Excavator Crawler	15W40	4/5/2019	123	148		CL21-5994	13D00810
ROBINS (ANG)	C316	15C00073		EOD VEHICLE	15W40	2/6/2018	2095	4381		CL21-6008	15C00073
ROBINS (ANG)	E822	91E00168	10E01088	TRK FL DED 6M-6200 PT	15W40	7/27/2018	1065	1368		CL21-5996	10E01088
ROBINS (ANG)	L350	95L00092	97L00335	TRAC ACFT TWG MB-2	15W40	11/19/2018	1760	1916		CL21-6001	97L00335
ROBINS (ANG)	C355	96C00250	96C00252	TRAC TOW SUPPORT EQP	15W40	3/22/2018	3401	3971		CL21-6007	96C00252
ROBINS (ANG)	C601	97C00623		DEICER TRUCK MOUNTED	15W40	9/4/2019	517	517		CL21-5998	97C00623
ROBINS (ANG)	L271	97L00324		TRK HYDRANT FUELING R-12	15W40	0/10/2018	3076	3291		CL21-6006	97L00324
ROBINS (ANG)	L350	99L00301		TRAC ACFT TWG MB-2	15W40	2/28/2018	2296	2519		CL21-6002	99L00301
ROBINS (ANG)	K251	85K00450	05K00039	TRK CGO 6X6 24M-44500G D	15W40	12/10/2019	2882	2884		CL21-6003	05K00039
ROBINS (ANG)	D630	23D08193		LODR SCP PT 1 CY / UNDER	15W40	5/10/2018	516	595		CL21-5997	23D08193
ROBINS (ANG)	D785	13D00811		LoaderSkidSteerTrack MTD	15W40	4/3/2019	176	230		CL21-5995	13D00811

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Table 20. Robins ANG Vehicle Sample Lubricant Analysis

Lab Code	Asset	Hours	Miles	CEC Soot	D445 100c Viscosity	D445 40c Viscosity	TBN D4739		D5185 Elementals																								D6304C Water	TAN D664		
							Inflect	Buffer	Al	Sb	Ba	B	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Ag	Na	Sn	Zn	K	Sr	V	Ti	Cd		Inflect	Buffer	
CL20-4910	05C00320	2671		0.19	11.424	76.338	2.16	0.64	7	<1	<1	<1	2110	1	2	22	5	249	<1	3	1	1027	11	<1	<5	1	1192	<5	<1	<1	<1	<1	<1	458	6.62	7.19
CL21-6005		3037		0.03	10.993	72.118	4.66	4.22	<1	<1	<1	2	973	<1	2	9	2	882	<1	56	<1	896	21	<1	10	<1	1051	<5	<1	<1	<1	<1	<1	789	3.67	4.31
CL20-4900	05K00041	2942		0.05	13.417	97.088	9.34	8.79	<1	<1	<1	<1	2418	<1	1	4	<1	288	<1	<1	<1	1260	7	<1	<5	<1	1413	<5	<1	<1	<1	<1	<1	536	2.2	2.57
CL21-6004		2992		0.02	13.311	95.105	9.56	9.19	<1	<1	<1	1	2463	<1	2	5	<1	295	<1	<1	<1	1280	7	<1	<5	<1	1449	<5	<1	<1	<1	<1	<1	613	1.82	2.25
CL20-4909	06C00030	1151		0.05	8.118	45.472	7.04	5.87	3	<1	<1	<1	1959	<1	10	42	3	191	1	2	<1	975	5	<1	<5	<1	1064	<5	<1	<1	<1	<1	<1	480	1.27	1.85
CL21-6000		1168		0.03	7.668	42.148	6.83	5.81	<1	<1	<1	1	1954	<1	10	42	3	190	1	2	<1	955	5	<1	<5	<1	1051	<5	<1	<1	<1	<1	<1	444	1.27	1.53
CL20-4901	10E00893	628		0.15	12.947	94.47	9.05	7.71	4	<1	<1	2	2509	<1	3	42	<1	230	<1	2	<1	1223	22	<1	<5	<1	1375	<5	<1	<1	<1	<1	<1	1098	1.89	1.94
CL21-5999		684		0.11	12.885	94.265	9.2	8.18	1	<1	<1	2	2561	<1	3	49	<1	234	<1	2	<1	1263	22	<1	5	<1	1423	<5	<1	<1	<1	<1	<1	1009	1.7	2.32
CL20-4912	13D00810	131		0.03	14.536	104.341	8.5	8.34	<1	<1	<1	13	2295	<1	4	4	<1	248	<1	6	<1	1200	6	<1	<5	<1	1320	<5	<1	<1	<1	<1	<1	470	2.22	2.44
CL21-5994		148		0.02	13.947	98.536	8.86	8.59	<1	<1	<1	14	2325	<1	6	6	<1	260	<1	6	<1	1193	5	<1	<5	<1	1344	<5	<1	<1	<1	<1	<1	352	1.89	2.07
CL20-4908	15C00073	3382		0.07	12.383	86.947	8.26	7.44	38	<1	<1	5	1333	2	4	64	1	773	2	49	<1	1102	7	<1	<5	2	1234	<5	<1	<1	<1	<1	<1	418	1.77	2.34
CL21-6008		4381		0.09	12.237	85.343	8.6	7.59	72	<1	<1	6	1354	3	6	105	2	787	2	47	<1	1120	8	<1	6	2	1271	<5	<1	<1	<1	<1	<1	532	1.85	2.36
CL20-4902	10E01088	1243		0.04	14.482	105.365	9.22	9.01	<1	<1	<1	7	2369	<1	2	5	<1	319	<1	7	<1	1266	12	<1	<5	2	1402	<5	<1	<1	<1	<1	<1	876	1.21	3.42
CL21-5996		1368		0.24	13.434	98.796	9.18	8.37	<1	<1	<1	1	2518	<1	<1	14	<1	327	<1	3	<1	1316	10	<1	<5	<1	1508	<5	<1	<1	<1	<1	<1	724	2.06	2.57
CL20-4903	97L00335	1819		0.07	14.086	101.58	9.12	8.15	<1	<1	<1	4	2452	<1	<1	6	<1	304	<1	4	<1	1264	4	<1	<5	<1	1425	<5	<1	<1	<1	<1	<1	229	2.33	3.02
CL21-6001		1916		0.12	13.821	98.968	8.64	7.04	<1	<1	<1	4	2506	<1	1	12	1	312	<1	6	<1	1263	6	<1	<5	<1	1454	<5	<1	<1	<1	<1	<1	306	2.28	2.57
CL20-4907	96C00252	3787		0.13	13.349	95.881	8.19	5.8	1	<1	<1	<1	2463	1	<1	12	2	295	<1	<1	<1	1256	6	<1	<5	<1	1456	<5	<1	<1	<1	<1	<1	329	2.23	2.84
CL21-6007		3971		0.02	13.514	97.17	8.34	7.56	<1	<1	<1	<1	1208	<1	<1	5	2	962	<1	60	<1	1183	4	<1	<5	<1	1353	<5	<1	<1	<1	<1	<1	387	2.11	2.74
CL20-4914	97C00623	517		0.04	13.653	98.53	9.27	8.42	<1	<1	<1	2	2422	<1	<1	8	<1	281	<1	<1	<1	1246	4	<1	<5	<1	1387	<5	<1	<1	<1	<1	<1	586	2.04	2.89
CL21-5998		517		0.1	13.445	96.672	9.09	8.75	<1	<1	<1	2	2462	<1	<1	9	<1	291	<1	<1	<1	1279	4	<1	<5	<1	1447	<5	<1	<1	<1	<1	<1	505	2.04	2.51
CL20-4913	97L00324	3120		0.04	13.528	97.45	9.29	8.41	<1	<1	<1	<1	2477	<1	1	6	2	290	<1	<1	<1	1257	5	<1	<5	<1	1404	<5	<1	<1	<1	<1	<1	337	2.24	2.59
CL21-6006		3291		0.1	13.167	95.23	8.73	7.57	<1	<1	<1	1	2453	<1	3	9	3	327	<1	4	<1	1279	5	<1	<5	<1	1464	<5	<1	<1	<1	<1	<1	533	2.22	2.61
CL20-4911	99L00301	2457		0.15	13.91	99.434	8.53	6.66	1	<1	<1	<1	2407	<1	1	38	14	333	<1	9	<1	1244	6	<1	<5	2	1407	<5	<1	<1	<1	<1	<1	409	2.27	2.85
CL21-6002		2519		0.22	13.79	99.042	8.3	6.35	<1	<1	<1	1	2338	<1	1	38	17	385	<1	15	1	1254	6	<1	5	2	1446	<5	<1	<1	<1	<1	<1	410	1.98	2.84
CL20-4905	05K00039	2883		0.1	12.511	90.556	8.62	7.23	<1	<1	<1	<1	2508	<1	4	10	1	234	<1	<1	<1	1220	7	<1	<5	<1	1349	<5	<1	<1	<1	<1	<1	868	2.07	2.45
CL21-6003		2884		0.14	12.361	90.832	8.56	6.84	<1	<1	<1	<1	2560	<1	4	10	1	239	<1	<1	<1	1267	7	<1	<5	<1	1422	<5	<1	<1	<1	<1	<1	1083	1.98	2.76
CL20-4906	23D08193	526		0.02	14.43	105.203	9.55	8.91	<1	<1	<1	<1	2466	<1	16	3	<1	286	<1	<1	<1	1243	6	<1	<5	<1	1381	<5	<1	<1	<1	<1	<1	671	2.11	2.05
CL21-5997		595		0.1	14.389	104.122	9.35	8.59	<1	<1	<1	2	2453	<1	43	5	<1	324	<1	3	<1	1251	6	<1	<5	<1	1428	<5	<1	<1	<1	<1	<1	345	2.09	2.1
CL20-4904	13D00811	215		0.09	14.011	102.059	9.24	8.72	<1	<1	<1	14	2464	<1	8	10	<1	268	<1	7	<1	1227	5	<1	<5	<1	1363	9	<1	<1	<1	<1	<1	416	2.27	2.11
CL21-5995		230		0.13	13.982	100.113	10.16	8.97	<1	<1	<1	16	2491	<1	9	15	<1	274	<1	8	<1	1274	6	<1	<5	<1	1444	8	<1	<1	<1	<1	<1	285	2.1	2.22
CL20-4915	New Oil	0	0	0.01	15.024	109.82	8.5	8.44	<1	<1	<1	5	2287	<1	<1	1	<1	257	<1	2	<1	1184	5	<1	<5	<1	1289	<5	<1	<1	<1	<1	<1	605	2.36	2.17

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4.9 Laboratory analysis of Minot AFB Vehicle Lubricant Samples

The vehicles selected for evaluation at Minot AFB are shown in Table 21 along with the information requested about maintenance and vehicle utilization for the initial sampling. Of the fifteen vehicles selected, all fifteen assets were sampled at the start of the program. A fresh oil sample was included with the sample shipment.

The vehicles samples for lubricant evaluation after 15 months of operation at Minot AFB are shown in Table 22. All of the fifteen vehicles selected were sampled at the 15 month interval of the program. The utilization information was recorded from the sample bottles and the units were noted as hours, but some of the values look more like miles. The range of utilization for the repeat vehicles was a low of 5 hours to a high of 1913 hours for the 15 month interval.

The ASTM laboratory analysis of the selected lubricant properties for the Minot AFB vehicles are included in Table 23 along with the fresh oil analysis. The elemental analysis suggest most of the vehicles were using a variety of different lubricants that were not close to the fresh lubricant in some of the additive ratios. The copper (Cu) wear metal was high for asset 09D00286 for both samples. Vehicle 08C00301 had borderline low viscosity, suspect TBN values, and elevated TAN for both samples. The lubricant water content was high for assets 16C00108, 08C00301, AF23D08544, and 11C00201 only for the 15 month samples.

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Table 21. Minot AFB Initial Vehicle Lubricant Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Miles / Hours	Recent Major Engine Maintenance	ARMY Lab Code	ASSET Description
MINOT	B239	17B00949		TRK CGO 4X4 17M-20999G G			261	261		CL20-5218	17B00949
MINOT	C122	99C80001		TRK FFGT MRT P-30			500	5794		CL20-5205	99C80001
MINOT	C355	97C00176	16C00108	Trac Tow Support Bobtail F350			1015	3648		CL20-5208	16C00108
MINOT	C601	99C00236	00C00831	DEICER TRUCK MOUNTED			156	2487		CL20-5209	00C00831
MINOT	C355	96C00228	08C00301	Tow Tractor Ford Bobtail			241	2873		CL20-5210	08C00301
MINOT	C604	03C00835	07C00060	STAIRCASE TRUCK			19	1205		CL20-5207	07C00060
MINOT	D514	03D00252		CRANE TRK MTD 28TON			273	4823.9		CL20-5217	03D00252
MINOT	D574	02D00095	12D163	SNOW BROOM AND BLOWER			284	878		CL20-5215	12D163
MINOT	D578	91D00692	09D00286	SNO RML U MLTPU 3000 TPH			80	1230		CL20-5214	09D00286
MINOT	D578	91D00556	AF23D08544	Bobcat Loader			229	1336.7		CL20-5211	AF23D08544
MINOT	D626	05D00063	AF16D514	John Deere Loader			451	452		CL20-5212	AF16D514
MINOT	D630	98D80023	11C00201	Staircase Truck F550			385	385		CL20-5213	11C00201
MINOT	D630	23D08108		LODR SCP PT 1 CY / UNDER			109	1167		CL20-5206	23D08108
MINOT	L143	96L00331	16L00031	P23UHP			500	628		CL20-5219	16L00031
MINOT	L351	08L01108		TRAC ACFT TWG MB-4			130	458		CL20-5216	08L01108
										CL20-5204	New Oil

Table 22. Minot AFB 15 Month Vehicle Lubricant Samples

BASE NAME	MGMT CD	REG NUMBER	REPLACEMENT	VEH TYPE NAME	Oil Type	Last Oil Change Date	Miles / Hours at last oil change	Current Miles / Hours	Recent Major Engine Maintenance	ARMY Lab Code	ASSET Description
MINOT	B239	17B00949		TRK CGO 4X4 17M-20999G G			363	7537		CL21-6335	17B00949
MINOT	C122	99C80001		TRK FFGT MRT P-30			140	5940		CL21-6325	99C80001
MINOT	C355	97C00176	16C00108	Trac Tow Support Bobtail F350			432	4506		CL21-6324	16C00108
MINOT	C601	99C00236	00C00831	DEICER TRUCK MOUNTED			44	4400		CL21-6322	00C00831
MINOT	C355	96C00228	08C00301	Tow Tractor Ford Bobtail			288	2920		CL21-6334	08C00301
MINOT	C604	03C00835	07C00060	STAIRCASE TRUCK			40	1226		CL21-6326	07C00060
MINOT	D514	03D00252		CRANE TRK MTD 28TON			35	5002		CL21-6328	03D00252
MINOT	D574	02D00095	12D163	SNOW BROOM AND BLOWER			381	975		CL21-6333	12D163
MINOT	D578	91D00692	09D00286	SNO RML U MLTPU 3000 TPH			75	1225		CL21-6336	09D00286
MINOT	D578	91D00556	AF23D08544	Bobcat Loader			270	1377		CL21-6329	AF23D08544
MINOT	D626	05D00063	AF16D514	John Deere Loader			25	485		CL21-6330	AF16D514
MINOT	D630	98D80023	11C00201	Staircase Truck F550			41	406		CL21-6332	11C00201
MINOT	D630	23D08108		LODR SCP PT 1 CY / UNDER			141	1199		CL21-6327	23D08108
MINOT	L143	96L00331	16L00031	P23UHP			500	830		CL21-6331	16L00031
MINOT	L351	08L01108		TRAC ACFT TWG MB-4			130	526		CL21-6323	08L01108

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Table 23. Minot AFB Vehicle Lubricant Samples Analysis

Sample Code	Asset	Hours	Miles	CEC Soot	D445 100c	D445 40c	TBN D4739		D5185 Elementals																										D6304C Oils		TAN D664	
					Viscosity	Viscosity	Inflect	Buffer	Al	Sb	Ba	B	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Mo	Ni	P	Si	Ag	Na	Sn	Zn	K	Sr	V	Ti	Cd	Water	Inflect	Buffer			
CL20-5218	17B00949	261		0.62	10.744	71.297	7.67	6.2	4	<1	2	63	1788	1	12	72	3	435	7	68	1	1099	46	<1	12	2	1272	108	<1	<1	<1	<1	276	1.03	2.61			
CL21-6335		7537		0.31	13.86	85.185	8.57	8	<1	43	<1	48	946	<1	3	18	<1	1111	1	67	<1	1185	8	<1	6	<1	1281	18	<1	<1	<1	<1	94	1.64	2.56			
CL20-5205	99C80001	5794		0.31	11.802	72.857	8.04	6.7	1	20	<1	45	886	<1	6	24	2	1062	<1	64	<1	1092	7	<1	<5	2	1256	<5	<1	<1	<1	<1	348	0.23	3.66			
CL21-6325		5940		0.16	14.157	87.094	8.83	7.52	<1	37	<1	63	882	<1	2	10	<1	1181	<1	68	<1	1202	4	<1	<5	<1	1295	<5	<1	<1	<1	<1	573	1.57	2.49			
CL20-5208	16C00108	3648		0.42	12.983	81.816	6.04	4.42	3	1	<1	40	928	2	5	51	<1	1162	<1	70	<1	1096	11	<1	6	2	1280	<5	<1	<1	<1	<1	536	0.25	4.89			
CL21-6324		4506		0.21	13.251	81.168	7.04	4.28	<1	21	<1	203	1299	<1	2	16	<1	874	<1	96	<1	1085	7	<1	<5	<1	1187	<5	<1	<1	<1	<1	1286	0.35	3.71			
CL20-5209	00C00831	2487		0.03	13.168	78.097	7.93	7.3	<1	2	<1	291	1434	<1	1	6	<1	728	<1	110	<1	994	6	<1	<5	1	1114	<5	<1	<1	<1	<1	288	0.89	1.93			
CL21-6322		4400		0.08	12.523	76.221	8.25	7.39	<1	8	<1	236	1370	<1	1	7	<1	818	<1	97	<1	1019	6	<1	<5	<1	1113	<5	<1	<1	<1	<1	380	0.82	2.19			
CL20-5210	08C00301	2873		0.15	10.675	60.303	5.7	4.33	8	21	<1	41	777	2	4	74	2	1005	<1	63	1	940	14	<1	<5	2	1130	7	<1	<1	<1	<1	524	4.18	4.72			
CL21-6334		2920		0.22	11.401	66.037	5.53	4.12	7	22	<1	40	825	3	5	85	2	1073	1	66	2	982	13	<1	<5	1	1171	7	<1	<1	<1	<1	1361	4.51	4.75			
CL20-5207	07C00060	1205		0.06	12.686	89.844	8.21	7.64	2	<1	<1	4	2373	<1	1	31	<1	280	<1	5	<1	1237	7	<1	<5	<1	1402	<5	<1	<1	<1	<1	617	2.34	2.4			
CL21-6326		1226		0.12	12.491	87.708	8.46	7.07	<1	<1	<1	3	2382	1	2	33	<1	285	<1	5	<1	1246	8	<1	<5	<1	1376	<5	<1	<1	<1	<1	686	1.88	2.4			
CL20-5217	03D00252	4823.9		0.23	12.776	76.94	8.34	7.11	<1	2	<1	64	893	<1	4	8	2	1146	<1	68	<1	1134	6	<1	6	2	1278	<5	<1	<1	<1	<1	972	1.5	2.41			
CL21-6328		5002		0.09	12.413	75.303	7.82	6.09	<1	2	<1	57	913	1	8	13	4	1162	<1	70	<1	1132	3	<1	5	<1	1263	<5	<1	<1	<1	<1	366	0.18	3.22			
CL20-5215	12D163	878		0.13	13.498	80.995	8.42	7.7	<1	1	<1	59	897	<1	<1	16	<1	1182	<1	68	<1	1147	13	<1	<5	2	1290	<5	<1	<1	<1	<1	344	1.21	2.76			
CL21-6333		975		0.29	13.102	80.365	8.15	6.92	<1	1	<1	53	917	<1	2	28	<1	1202	<1	70	<1	1158	12	<1	<5	<1	1302	<5	<1	<1	<1	<1	318	0.96	2.6			
CL20-5214	09D00286	1230		0.06	13.393	79.836	7.19	6.74	3	<1	<1	144	1052	<1	188	5	1	658	<1	96	<1	970	6	<1	34	2	1077	<5	<1	<1	<1	<1	339	1.2	2.47			
CL21-6336		1225		0.09	13.225	80.646	6.99	6.27	1	<1	<1	106	1042	<1	229	6	1	649	<1	84	<1	966	7	<1	34	<1	1061	<5	<1	<1	<1	<1	776	1.18	1.78			
CL20-5211	AF23D08544	1336.7		0.15	14.806	90.327	8.46	8.01	2	27	<1	123	980	<1	<1	7	<1	1071	<1	78	<1	1111	7	<1	<5	2	1243	<5	<1	<1	<1	<1	601	1.49	2.3			
CL21-6329		1377		0.12	14.55	88.355	9.14	8.31	<1	49	<1	78	903	<1	2	6	<1	1166	<1	70	<1	1212	6	<1	<5	<1	1299	<5	<1	<1	<1	<1	1682	0.32	2.53			
CL20-5212	AF16D514	452		0.08	14.507	87.26	8.99	8.15	2	35	<1	74	869	<1	21	17	<1	1116	<1	77	<1	1160	6	<1	<5	2	1266	<5	<1	<1	<1	<1	573	1.47	2.19			
CL21-6330		485		0.1	14.701	89.214	9.1	8.42	<1	49	<1	70	876	<1	4	24	<1	1202	<1	68	<1	1230	6	<1	<5	<1	1313	<5	<1	<1	<1	<1	293	1.34	2.44			
CL20-5213	11C00201	385		0.08	14.489	89.29	9.22	8.86	9	32	<1	59	858	<1	1	49	<1	1090	<1	64	<1	1155	8	<1	<5	1	1257	<5	<1	<1	<1	<1	970	1.94	2.35			
CL21-6332		406		0.23	14.318	87.69	9.01	7.89	21	34	<1	56	888	2	4	176	<1	1136	1	67	<1	1207	10	<1	<5	<1	1270	<5	<1	<1	<1	<1	1198	0.15	2.3			
CL20-5206	23D08108	1167		0.08	15.072	93.164	9.44	8.05	<1	34	<1	69	868	<1	<1	4	<1	1147	<1	66	<1	1145	5	<1	<5	2	1267	<5	<1	<1	<1	<1	204	1.58	2.36			
CL21-6327		1199		0.23	15.529	95.615	8.87	8.25	<1	36	<1	71	921	<1	<1	5	<1	1234	<1	69	<1	1186	4	<1	<5	<1	1304	<5	<1	<1	<1	<1	350	1.45	2.48			
CL20-5219	16L00031	628		0.48	12.767	77.384	8.47	6.4	4	1	<1	46	922	4	4	18	<1	1106	<1	65	<1	1114	10	<1	5	3	1269	16	<1	<1	<1	<1	291	1.61	2.5			
CL21-6331		830		0.61	12.183	74.838	7.63	6.21	3	3	<1	35	941	4	4	22	<1	1078	<1	63	<1	1110	8	<1	<5	2	1235	13	<1	<1	<1	<1	643	0.21	3.41			
CL20-5216	08L01108	458		0.25	13.283	80.964	8.2	7.06	3	3	<1	56	875	1	5	16	<1	1098	<1	62	<1	1127	6	<1	<5	2	1269	<5	<1	<1	<1	<1	617	1.66	2.32			
CL21-6323		526		0.45	13.202	81.125	7.95	6.25	2	8	<1	54	903	2	12	21	<1	1126	<1	64	<1	1154	5	<1	<5	<1	1280	<5	<1	<1	<1	<1	617	1.9	3.52			
CL20-5204	New Oil			0.03	15.53	95.297	8.27	8.1	<1	<1	<1	285	1425	<1	<1	1	<1	723	<1	104	<1	1019	6	<1	<5	<1	1116	<5	<1	<1	<1	<1	556	2.39	2.08			

4.10 Portable Lubricant Analyzers

A Spectro Scientific Co. FluidScan Q1000, SpectroVisc Q3050, and FDM6000 hand held analyzer kit, along with the sampling supplies, data library, and software were available for use. The portable analyzers are shown in Figure 1. The Q1000 IR analyzer is on the left, the Q3050 viscometer is in the middle, and the FDM6000 Fuel Dilution Meter is to the right along with a sample vial.



Figure 1. Spectro Scientific Portable Analyzers

The Q1000 IR instrument compares the fluids to known library spectra to make a determination. The spectra obtained for the fresh oils from the sites were entered as new library entries in the instrument database. All samples then can be referenced to their library new oil spectra for lubricant life condition estimates. The ASTM D4739 TBN value for each of the fresh oils was entered into the IR analyzer libraries to improve instrument accuracy for TBN.

In practice, a drop of fluid is placed on the analyzer upper quartz window shown in Figure 2, the cell closed, and then inserted into the instrument for analysis. Prior to each daily use an IR check fluid was run to validate the instrument response. The quartz windows were cleaned between

each sample. The quartz windows are cleaned with lint free absorbent wipe purchased from the instrument manufacturer. If during a background check the instrument determined the quartz windows were not sufficiently clean, isopropyl alcohol was also used with the wipes to clean the quartz windows.

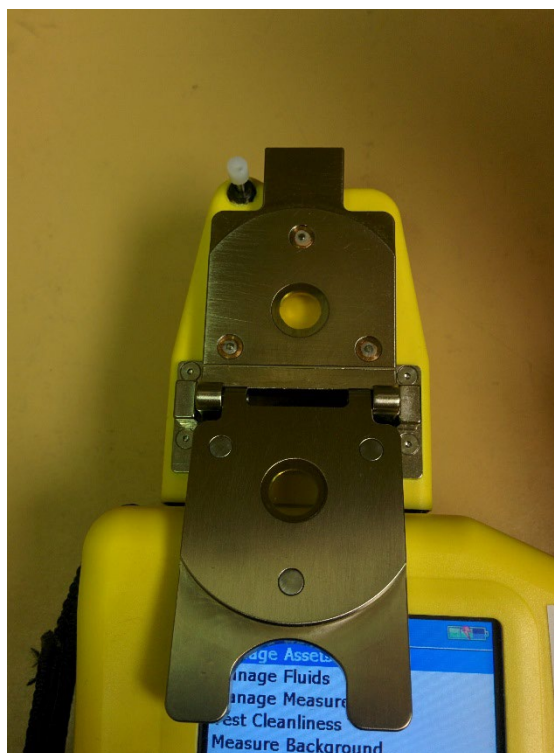


Figure 2. Quartz Windows of FluidScan Q1000 Used for Lubricant IR Analysis

During the training it was noted that the cleaning technique was very critical for getting consistent measurements with the Q3050 viscosity instrument. The instrument had a test cell with micro-channels that flow the sample past photodiodes, that start and stop a timer, when the sample cell was inserted into the instrument. The test cell with micro-channels is shown in Figure 3. A review of the initially collected data suggested that proper viscometer instrument cleaning technique needed to be refined before sample analysis can begin. Cleaning of the instrument micro-channels is required between each measurement. The cleaning technique was refined using high and low viscosity standards, and the cleaning methodology was considered good when ten independent measurements of the standards agreed within 3%. Several SwRI technicians were trained to reliably obtain good viscosity measurements independently during the course of the study.



Figure 3. Sample Cell Micro-Channels of the SpectroVisc Q3050 Used for Viscosity Measurement

The FDM6000 fuel dilution instrument has two probes that puncture the lid of the sample vial so that the measurements can be made. The plastic sample vials are custom manufactured for the instrument and purchased from the instrument manufacturer as a consumable. A felt pad was placed at the bottom of each vial to absorb the 500 μ l of lubricant sample placed in the vial. It was learned that small pieces of plastic could lodge in the vent line causing instrument sensitivity issues. Of note the instrument manual does not mention insuring the vent line should remain clear, nor is a plugged vent line mentioned as a possible fault. Procedures to verify the vent was always clear were initiated.

Another item to mention is the calibration standard for the fuel dilution meter should be made with the fuel used in the field. The Air Force uses JP-8 on the flightline, so Kerosene would be the contaminant in the lubricant. The standards used in this study were made with diesel fuel that is less volatile. Reference 2 discusses the fuel dilution measurement deviations caused by a more volatile fuel. The instrument tends to overpredict the fuel dilution with kerosene fuel.

4.11 Equipment utilization

The program was conceived to have pieces of equipment on a mileage based lubricant service interval that accumulate low annual mileage. Although some of these assets may have low mileage, they have substantial run time at idle. The ideal case would have been both engine hours and mileage supplied but that was not the case. Based on the logging of the engine hour meters at each sample interval, there were several pieces of equipment that were operated less than 200 hours over the fifteen month period, at all test locations.

A cursory review of industrial engine lubricant change intervals revealed oil and filter changes at intervals of 250 hours for Isuzu, Caterpillar, and Cummins engines. Detroit Diesel engines for generator set duty have an oil change interval of 300 hours. Most of the engine manufacturers suggest oil drain intervals may be extended up to 500 hours provided lubricant analysis is used to determine lubricant condition.

As a minimum it would be prudent to change a vehicle lubricant at an engine hour interval, like industrial engines, instead of a mileage based service interval. Extended idling exacts a toll on an engine in the form of condensable combustion by-products and water that do not get consumed or evaporated because the lubricant never gets hot. These condensable vapors can form acids and sludge that can compromise engine durability.

4.12 ASSET LUBRICANT CONDITION – Laboratory Testing

Of the 120 vehicles requested for inclusion in the program, about 102 were actually sampled. Of the 102 assets sampled, about 33 had lubricant conditions that indicate an oil change should have been performed. At least two of those vehicles had severely degraded lubricant. Several assets displayed high copper (Cu) wear metals, without concurrent (Pb) or tin (Sn) present, suggesting the copper could be coming from brazing material in the oil cooler.

Except for the items noted in the prior discussions most of the assets TBN showed good reserve alkalinity remaining and the TAN was still low. The viscosity over the 15 month period appears to be consistent for most of the pieces of equipment, suggesting the lubricant was neither thickening due to oxidation or soot, nor thinning due to fuel dilution or shearing.

4.13 ASSET LUBRICANT CONDITION – Portable Analyzer Testing

Table 24 through Table 31 contain the portable analyzer data for the study asset samples and includes the average and standard deviation of the three measurements taken for the viscosity and fuel dilution measurements for each sample. The fluid analyzer results were compromised because the asset lubricants differed from the supplied fresh lubricant. The analyzer results are only significant if they can be related to the fresh oil. The instrument could not identify the asset samples as being a subset of the fresh oil supplied. The analyzer supplied wave numbers and percent of a generic petroleum oil, that was beyond the scope of the program or staff expertise to investigate and resolve.

Shown in Table 24 are the results for the Macdill AFB assets for ASTM D445 viscosity at 40 °C, the 3 portable analyzer viscosity values and their averages and standard deviations and the averages and standard deviations for the three fuel dilution meter readings. For viscosity the meter average generally trends with the D445 viscosity value, slightly better for lower values. Thus if the actual viscosity is low the meter can identify it fairly well. The fuel dilution meter only showed one sample with high fuel dilution, 97L00170 that also had a low viscosity reading. The two portable meters do indicate the lubricant of asset 97L00170 is compromised.

Table 24. Comparison of ASTM and Portable Analyzer Results for Viscosity along with Fuel Dilution for Macdill AFB Assets

Lab Code	ASSET	D445 40c	Spectro Scientific Q3050 Viscosity Meter, 40 C, Cst					Spectro Scientific Q6000 Fuel Dilution Meter, %	
			Trial 1	Trial 2	Trial 3	Average	Std. Dev.	Average	Std. Dev.
	12K00046								
	12L00364								
	12L00385								
	23D08059								
	05E00654								
CL20-5256	02L00223	84.711	81.1	72.9	78.5	77.50	4.19	0.37	0.64
CL21-6373		101.316	111	97.6	102	103.53	6.83	0.17	0.29
CL20-5257	03C00016	87.833	93	79.9	73.2	82.03	10.07	0.70	1.13
CL21-6375		103.477	123	104	100	109.00	12.29	0.50	0.44
CL20-5254	06C00645	94.192	87.2	84.1	77.6	82.97	4.90	0.60	0.26
	06C01061								
CL20-5251	08L00527	98.278	92.7	91.6	89.1	91.13	1.84	0.67	0.76
CL20-5253	09E80007	108.201	99.7	97.6	110	102.43	6.64	0.07	0.12
CL20-5249	11C00011	104.715	100	95.8	90.5	95.43	4.76	0.13	0.23
CL20-5250	12L01087	105.437	96.5	102	99.9	99.47	2.78	0.20	0.35
CL20-5247	11L00086	92.217	89.6	84.6	77.4	83.87	6.13	0.43	0.45
CL21-6376		80.254	80	80.8	80.7	80.50	0.44	1.60	0.10
CL20-5258	97L00170	62.533	58.1	57.1	32.9	49.37	14.27	7.77	1.71
CL21-6377	96L00204	105.086	107	107	104	106.00	1.73	0.47	0.55
CL20-5248	Fresh	112.046	113	83.8	101	99.27	14.68	0.50	0.40

Shown in Table 25 are the results for the Elmendorf AFB assets for ASTM D445 viscosity at 40 °C, the 3 portable analyzer viscosity values and their averages and standard deviations and the averages and standard deviations for the three fuel dilution meter readings. For viscosity the meter average generally trends with the D445 viscosity value, again slightly better for lower values. Thus if the actual lubricant viscosity of an asset is low the meter can identify it as being suspect fairly well. The fuel dilution meter only showed one sample with fuel dilution above 4 percent, 04C00436 that also had a subsequent low viscosity reading. Jointly the two portable meters do indicate the lubricant of asset 04C00436 is compromised.

Table 25. Comparison of ASTM and Portable Analyzer Results for Viscosity along with Fuel Dilution for Elmendorf AFB Assets

Lab Code	Asset	D445 40c Viscosity	Spectro Scientific Q3050 Viscosity Meter, 40 C, Cst					Spectro Scientific Q6000	
			Trial 1	Trial 2	Trial 3	Average	Std. Dev.	Average	Std. Dev.
CL20-4739	06B01312	88.411	93.7	95.6	86.2	91.83	4.97	2.47	0.50
CL20-4742	01C00241	96.173	100	95.1	97.7	97.60	2.45	0.27	0.23
CL21-6380	03L00274	115.233	119	119	113	117.00	3.46	0.50	0.35
CL20-4735	04C00436	70.361	76.7	71.5	73.2	73.80	2.65	4.13	0.35
CL21-6381		69.165	72	65.6	66.8	68.13	3.40	4.43	1.29
CL20-4744	07L00190	98.235	97	98.7	104	99.90	3.65	0.70	0.10
CL21-6382		108.722	106	109	91.5	102.17	9.36	0.33	0.58
CL20-4741	07L00325	92.731	94.7	87.2	88.9	90.27	3.93	1.13	0.50
CL21-6386		92.543	92	99.4	91.9	94.43	4.30	0.83	0.45
CL20-4743	10C00131	84.261	90.5	86.3	82.5	86.43	4.00	0.20	0.10
CL21-6383		83.647	96.8	100	91.8	96.20	4.13	0.57	0.49
CL20-4734	10E01058	53.234	58.8	56.8	56.3	57.30	1.32	0.20	0.35
CL20-4736	11C00008	71.344	74.2	81.9	71.4	75.83	5.44	0.53	0.42
CL21-6387		58.748	60.1	64.2	61.2	61.83	2.12	1.07	0.51
CL21-6378	12L00939	104.902	109	110	107	108.67	1.53	0.00	0.00
CL21-6379	12L01095	110.601	117	118	118	117.67	0.58	0.00	0.00
CL20-4738	13K00053	70.596	73.6	63.4	68.5	68.50	5.10	0.10	0.17
CL21-6385		70.212	71.4	71.8	69.5	70.90	1.23	0.00	0.00
CL20-4737	23D08482	112.386	112	110	113	111.67	1.53	0.33	0.32
CL21-6388		114.512	144	120	117	127.00	14.80	0.17	0.29
CL20-4740	10L00894	104.427	105	99.1	101	101.70	3.01	0.33	0.42
CL21-6384		104.937	114	104	104	107.33	5.77	0.23	0.21
CL20-4770	Fresh	111.895	114	108	104	108.67	5.03	0.37	0.32

Shown in Table 26 are the results for the AI Udeid AFB assets for ASTM D445 viscosity at 40 °C, the 3 portable analyzer viscosity values and their averages and standard deviations and the averages and standard deviations for the three fuel dilution meter readings. For viscosity the meter average generally trends with the D445 viscosity value, again there appears to be better agreement for lower viscosity values. Thus if the actual lubricant viscosity of an asset is low the meter as a screening tool can identify the viscosity as being suspect fairly well. The fuel dilution meter did not show any samples with fuel dilution above 4 percent.

Table 26. Comparison of ASTM and Portable Analyzer Results for Viscosity along with Fuel Dilution for AI Udeid AFB Assets

Lab Code	Asset	D445 40c	Spectro Scientific Q3050 Viscosity Meter, 40 C, Cst					Spectro Scientific Q6000	
		Viscosity	Trial 1	Trial 2	Trial 3	Average	Std. Dev.	Average	Std. Dev.
CL20-5293	12C00219	112.731	103	93.7	96.1	97.60	4.83	0.00	0.00
CL20-5279	18D00234	58.711	56.8	51.8	51.2	53.27	3.07	1.33	0.81
CL20-5280	06C00774	52.681	54	51.3	48.5	51.27	2.75	0.67	0.21
CL20-5281	17D00412	103.770	106	99.9	98.8	101.57	3.88	0.50	0.44
CL20-5282	17B00298	96.371	92.7	87.4	81	87.03	5.86	0.10	0.17
CL20-5284	18D00136	49.826	44.9	45.5	43.7	44.70	0.92	0.67	0.25
CL20-5285	04E00036	83.662	75.1	73.6	72.3	73.67	1.40	0.13	0.23
CL20-5288	18B00386	103.780	95.3	100	90.8	95.37	4.60	0.23	0.21
CL20-5289	18D00269	97.860	109	95.9	94.3	99.73	8.06	0.47	0.32
CL20-5290	11B02867	94.253	75.6	81.8	88.2	81.87	6.30	0.10	0.17
CL20-5291	17D00410	104.213	91.5	98.9	95.9	95.43	3.72	0.17	0.21
CL20-5292	06C00773	89.271	82.9	85.1	77.5	81.83	3.91	0.23	0.40
CL20-5287	07L00166	114.090	98.3	98.6	97.3	98.07	0.68	0.33	0.58
CL20-5283	10D00355	62.060	58.1	53.3	53.4	54.93	2.74	0.00	0.00
CL20-5286	11C00015	101.206	93.5	91.2	85.4	90.03	4.17	0.57	0.40

Shown in Table 27 are the results for the Dobbins AFB assets for ASTM D445 viscosity at 40 °C, the 3 portable analyzer viscosity values and their averages and standard deviations and the averages and standard deviations for the three fuel dilution meter readings. Again the viscosity meter average generally trends with the D445 viscosity value, with slightly better agreement for lower values. Thus if the actual lubricant viscosity of an asset is low the meter can identify it as being a suspect reading fairly well. The fuel dilution meter showed two assets with fuel dilution above 2 percent. Of those two, 06L00352 also had a subsequent low viscosity reading. Jointly the two portable meters do indicate the lubricant of asset 06L00352 is substantially compromised.

Table 27. Comparison of ASTM and Portable Analyzer Results for Viscosity along with Fuel Dilution for Dobbins AFB Assets

Lab Code	ASSET	D445 40c	Spectro Scientific Q3050 Viscosity Meter, 40 C, Cst					Spectro Scientific Q6000	
		Viscosity	Trial 1	Trial 2	Trial 3	Average	Std. Dev.	Average	Std. Dev.
CL20-4817	07L00003	71.349	75.7	63.9	74.5	71.37	6.49	2.10	0.17
CL21-5794		79.623	77.8	79.7	82.5	80.00	2.36	0.40	0.10
CL20-4811	01B01517	98.813	98.5	102	107	102.50	4.27	0.50	0.10
CL21-5798		103.323	105	106	98.9	103.30	3.84	0.07	0.12
CL20-4818	02B01782	99.466	98.4	98.1	98	98.17	0.21	0.00	0.00
CL21-5807		99.484	103	112	104	106.33	4.93	0.10	0.10
CL20-4814	03D00157	103.672	97.1	106	101	101.37	4.46	0.10	0.17
CL21-5804		99.77	99.1	108	99.6	102.23	5.00	0.23	0.25
CL20-4807	06L00431	107.223	118	115	116	116.33	1.53	0.50	0.26
CL21-5808		108.387	122	123	119	121.33	2.08	0.07	0.12
CL20-4816	16E00041	90.534	99.1	96.3	91.8	95.73	3.68	0.03	0.06
CL21-5800		91.409	105	95.2	92.6	97.60	6.54	0.13	0.23
CL20-4812	12L00853	112.711	120	120	118	119.33	1.15	0.00	0.00
CL21-5796		112.171	119	126	121	122.00	3.61	0.00	0.00
CL20-4808	06B00061	97.558	99.5	89.9	97.8	95.73	5.12	0.07	0.06
CL21-5803		96.372	95.9	102	96.5	98.13	3.36	0.03	0.06
CL20-4813	06L00352	53.083	58.1	52.3	57.1	55.83	3.10	2.43	0.49
CL21-5805		51.694	57.7	55.8	52	55.17	2.90	2.03	0.06
CL20-4806	05L00198	88.904	93.3	97.7	93.5	94.83	2.48	0.47	0.15
CL21-5806		90.906	117	95.4	93.5	101.97	13.05	0.47	0.06
CL20-4804	07D00460	102.716	102	104	103	103.00	1.00	0.13	0.12
CL21-5802		100.537	96.8	97.3	104	99.37	4.02	0.37	0.35
CL20-4810	08C00017	91.233	97.9	93.7	85.9	92.50	6.09	0.53	0.25
CL21-5797		101.313	102	98.8	100	100.27	1.62	0.60	0.20
CL20-4815	09C00130	86.598	90.9	88.6	92.1	90.53	1.78	0.40	0.20
CL21-5795		83.273	80.9	79.2	82.6	80.90	1.70	0.33	0.31
CL20-4809	09C00171	86.167	88.4	84.5	87.6	86.83	2.06	0.50	0.10
CL21-5801		85.167	84.3	86.5	87.9	86.23	1.81	0.47	0.23
CL20-4805	09D00614	107.474	108	107	107	107.33	0.58	0.47	0.38
CL21-5799		109.157	104	115	112	110.33	5.69	0.10	0.17
CL20-4803	Fresh Oil	108.834	115	110	110	111.67	2.89	0.23	0.06

Shown in Table 28 are the results for the Misawa AFB assets for ASTM D445 viscosity at 40 °C, the 3 portable analyzer viscosity values and their averages and standard deviations and the averages and standard deviations for the three fuel dilution meter readings. Again the viscosity meter average generally trends with the D445 viscosity value, with slightly better agreement for

lower values. Thus if the actual lubricant viscosity of an asset is low the meter can identify it as being a suspect reading fairly well. The fuel dilution meter showed one asset with fuel dilution above 3 percent. That asset, 04C004383 also had concurrent very low viscosity readings. Jointly the two portable meters do indicate the lubricant of asset 04C00438 is substantially compromised.

Table 28. Comparison of ASTM and Portable Analyzer Results for Viscosity along with Fuel Dilution for Misawa AFB Assets

Lab Code	Asset	D445 40c Viscosity	Spectro Scientific Q3050 Viscosity Meter, 40 C, Cst					Spectro Scientific Q6000	
			Trial 1	Trial 2	Trial 3	Average	Std. Dev.	Average	Std. Dev.
CL20-5148	00B00795	106.169	105	107	101	104.33	3.06	0.13	0.15
CL20-6020		107.731	114	105	117	112.00	6.24	0.77	0.86
CL20-5152	00C00714	96.908	92.5	90.6	92	91.70	0.98	0.23	0.15
CL20-6013		95.903	94.1	94.7	98.2	95.67	2.21	0.50	0.44
CL20-5150	00C00788	93.461	94.7	91.8	95.1	93.87	1.80	0.20	0.26
CL20-6018		94.99	90.5	95.4	99.5	95.13	4.51	0.20	0.20
CL20-5149	02D80013	111.21	111	110	108	109.67	1.53	0.00	0.00
CL20-6011		107.959	111	107	115	111.00	4.00	0.00	0.00
CL20-5159	03B00036	92.173	95.1	93.6	94.1	94.27	0.76	0.50	0.30
CL20-6021		54.432	55.3	50.8	53.9	53.33	2.30	0.00	0.00
CL20-5147	03C00846	84.083	81.8	82.6	87.3	83.90	2.97	0.70	0.10
CL20-6010		98.983	105	95.4	92.4	97.60	6.58	0.23	0.21
CL20-5151	03D00186	96.688	106	108	93.6	102.53	7.80	0.43	0.45
CL20-6014		100.887	102	103	111	105.33	4.93	0.13	0.23
CL20-5153	04B02721	41.914	45.6	42.1	42.5	43.40	1.92	0.73	0.25
CL20-6019		99.5	109	105	108	107.33	2.08	0.00	0.00
CL20-5158	04C00438	30.751	32.9	31.8	30.6	31.77	1.15	1.30	0.10
CL20-6017		29.371	31.9	29.2	29.9	30.33	1.40	3.57	0.23
CL20-5154	04D00082	87.476	81.9	75.7	85.1	80.90	4.78	0.57	0.42
CL20-5156	05D00083	66.636	69.2	72	67.1	69.43	2.46	0.53	0.68
CL20-5155	05E00084	91.487	94.9	91.7	91.9	92.83	1.79	0.93	1.01
CL20-6009		92.09	91.5	91.2	89.3	90.67	1.19	0.40	0.36
CL20-5160	06L00332	52.256	54.2	51.4	52.4	52.67	1.42	0.77	0.25
CL20-6015		90.918	95.2	90.2	94.4	93.27	2.69	0.50	0.56
CL20-5146	06L00477	62.425	64.7	60.2	59.3	61.40	2.89	0.37	0.64
CL20-6012		63.085	62.1	59.3	59.9	60.43	1.47	0.10	0.10
CL20-5157	06L00502	106.07	104	108	105	105.67	2.08	1.10	1.22
CL20-6016		106.411	112	95.1	111	106.03	9.48	0.23	0.15

Shown in Table 29 are the results for the Moody AFB assets for ASTM D445 viscosity at 40 °C, the 3 portable analyzer viscosity values and their averages and standard deviations and the averages and standard deviations for the three fuel dilution meter readings. Again the viscosity meter average generally trends with the D445 viscosity value, with slightly better agreement for lower values. Thus if the actual lubricant viscosity of an asset is critically low the meter can identify it as being a suspect reading quite well. The fuel dilution meter showed one asset with fuel dilution readings of 7.5 and 8.13 percent. That asset, 05L00379 also had concurrent extremely low viscosity readings. Jointly the two portable meters do indicate the lubricant of asset 05L00379 is substantially compromised and there may be engine or fuel system damage.

Shown in Table 30 are the results for the Robins ANG assets for ASTM D445 viscosity at 40 °C, the 3 portable analyzer viscosity values and their averages and standard deviations and the averages and standard deviations for the three fuel dilution meter readings. Again the viscosity meter average generally trends with the D445 viscosity value, with a trend of better agreement for lower viscosity values. Thus if the actual lubricant viscosity of an asset is low the meter can identify it as being a suspect reading fairly well. The fuel dilution meter showed one asset with fuel dilution values of 4.17 and 7.63 percent. That asset, 06C00030 also had concurrent low viscosity readings. Jointly the two portable meters indicate the lubricant of asset 06C00030 is substantially compromised.

Shown in Table 31 are the results for the Minot AFB assets for ASTM D445 viscosity at 40 °C, the 3 portable analyzer viscosity values and their averages and standard deviations and the averages and standard deviations for the three fuel dilution meter readings. Again the viscosity meter average generally trends with the D445 viscosity value. Again the trend of better agreement for lower viscosity values continues. Thus if the actual lubricant viscosity of an asset is low the meter can identify it as being a suspect reading fairly well. The fuel dilution meter does not show any fuel dilution values above 1.5 percent. Jointly the two portable meters seem to indicate they can trend marginal lubricant conditions.

Table 29. Comparison of ASTM and Portable Analyzer Results for Viscosity along with Fuel Dilution for Moody AFB Assets

Lab Code	Asset	D445 40c Viscosity	Spectro Scientific Q3050 Viscosity Meter, 40 C, Cst					Spectro Scientific Q6000	
			Trial 1	Trial 2	Trial 3	Average	Std. Dev.	Average	Std. Dev.
CL20-4634	02B00764	103.313	101	100	104	101.67	2.08	0.17	0.15
CL21-5984		97.003	88.4	93.3	77.8	86.50	7.92	0.17	0.29
CL20-4629	02L00144	91.97	91.8	89.6	90.4	90.60	1.11	0.60	0.00
CL21-5979		89.501	85.6	89.9	82.7	86.07	3.62	0.00	0.00
CL20-4628	03C80009	94.791	99.8	100	94.7	98.17	3.00	0.17	0.12
CL21-5978		96.219	94.4	91.1	94.9	93.47	2.06	0.13	0.15
CL20-4627	05B00052	94.02	95.2	101	95.5	97.23	3.27	0.70	0.46
CL21-5985		87.35	81.2	80.9	80.6	80.90	0.30	0.37	0.29
CL20-4632	05B02713	88.897	94.5	87	87.1	89.53	4.30	0.17	0.15
CL21-5982		93.418	94.4	91.5	90.7	92.20	1.95	0.00	0.00
CL20-4636	05L00759	92.408	94.5	91.3	98.3	94.70	3.50	0.13	0.15
CL21-5976		93.213	87.1	89	85.1	87.07	1.95	0.10	0.17
CL20-4626	06D00262	97.274	102	100	95.3	99.10	3.44	0.73	0.25
CL21-5972		97.223	92.2	93.3	91	92.17	1.15	0.00	0.00
CL20-4631	06E80004	98.271	94.6	98.5	99.2	97.43	2.48	0.00	0.00
CL21-5971		97.307	95.1	98.5	95.3	96.30	1.91	0.00	0.00
CL20-4637	08D01058	102.407	101	107	103	103.67	3.06	0.10	0.10
CL21-5975		98.71	93.5	64.3	90.9	82.90	16.16	0.00	0.00
CL20-4640	09C00060	87.261	88	87.3	92.7	89.33	2.94	0.27	0.06
CL21-5973		90.159	93.5	91.6	96.9	94.00	2.69	0.20	0.17
CL20-4630	10C243	56.058	56.6	55	55.3	55.63	0.85	2.07	0.21
CL21-5983		43.936	41.6	33.4	38.8	37.93	4.17	1.83	0.31
CL20-4635	07C00334	96.647	95.5	95.7	98.7	96.63	1.79	0.17	0.21
CL21-5981		97.418	92.3	90.1	91.6	91.33	1.12	0.10	0.17
CL20-4639	01C00087	99.337	95.6	99.1	96.3	97.00	1.85	0.13	0.23
CL21-5977		99.869	90.9	91.2	92.4	91.50	0.79	0.00	0.00
CL20-4633	15L00031	81.235	77.9	80.7	78.3	78.97	1.51	0.97	0.25
CL21-5974		73.883	71.7	68.6	70.6	70.30	1.57	0.47	0.21
CL20-4638	05L00379	16.483	22.4	18.7	20.6	20.57	1.85	7.50	2.61
CL21-5980		12.304	12.5	12.5	12.7	12.57	0.12	8.13	0.50
CL20-4625	New Oil	109.714	106	106	106	106.00	0.00	0.57	0.12

Table 30. Comparison of ASTM and Portable Analyzer Results for Viscosity along with Fuel Dilution for Robins ANG Assets

Lab Code	Asset	D445 40c Viscosity	Spectro Scientific Q3050 Viscosity Meter, 40 C, Cst					Spectro Scientific Q6000	
		0	Trial 1	Trial 2	Trial 3	Average	Std. Dev.	Average	Std. Dev.
CL20-4910	05C00320	76.338	75.1	77	76.6	76.23	1.00	0.47	0.15
CL21-6005		72.118	75.7	74.3	75.5	75.17	0.76	0.83	0.15
CL20-4900	05K00041	97.088	98.3	94.9	97	96.73	1.72	0.80	0.10
CL21-6004		95.105	96.6	93.8	96.2	95.53	1.51	0.00	0.00
CL20-4909	06C00030	45.472	44.9	45.9	44.6	45.13	0.68	4.17	0.42
CL21-6000		42.148	43.3	40.8	41.5	41.87	1.29	7.63	1.00
CL20-4901	10E00893	94.47	94.8	94.9	99.4	96.37	2.63	0.27	0.46
CL21-5999		94.265	90.4	90	92.8	91.07	1.51	0.13	0.23
CL20-4912	13D00810	104.341	79.7	97.8	99.6	92.37	11.01	0.13	0.23
CL21-5994		98.536	94.6	92.9	96.6	94.70	1.85	0.00	0.00
CL20-4908	15C00073	86.947	84.8	84.7	83.6	84.37	0.67	0.03	0.06
CL21-6008		85.343	94.1	81.8	86.5	87.47	6.21	0.93	0.60
CL20-4902	10E01088	105.365	105	103	103	103.67	1.15	0.40	0.35
CL21-5996		98.796	96.3	105	97	99.43	4.83	0.17	0.29
CL20-4903	97L00335	101.58	101	98.9	101	100.30	1.21	0.00	0.00
CL21-6001		98.968	95.5	96	101	97.50	3.04	0.13	0.23
CL20-4907	96C00252	95.881	97.2	64.1	91.1	84.13	17.62	0.33	0.35
CL21-6007		97.17	98.9	94.7	94.4	96.00	2.52	0.20	0.26
CL20-4914	97C00623	98.53	99.3	96.3	96.5	97.37	1.68	0.33	0.31
CL21-5998		96.672	96.3	88.7	88.3	91.10	4.51	0.30	0.52
CL20-4913	97L00324	97.45	105	94	94.2	97.73	6.29	0.30	0.36
CL21-6006		95.23	89.4	89.6	92.2	90.40	1.56	0.00	0.00
CL20-4911	99L00301	99.434	99.7	97.8	95.9	97.80	1.90	0.20	0.35
CL21-6002		99.042	97.3	79	101	92.43	11.78	0.13	0.23
CL20-4905	05K00039	90.556	95.4	94.4	87.2	92.33	4.47	0.23	0.32
CL21-6003		90.832	90.9	88.7	91	90.20	1.30	0.43	0.12
CL20-4906	23D08193	105.203	105	105	112	107.33	4.04	0.23	0.32
CL21-5997		104.122	110	103	98.3	103.77	5.89	0.00	0.00
CL20-4904	13D00811	102.059	98.2	103	101	100.73	2.41	0.60	0.66
CL21-5995		100.113	101	101	98.3	100.10	1.56	0.00	0.00
CL20-4915	New Oil	109.82	108	106	105	106.33	1.53	0.00	0.00

Table 31. Comparison of ASTM and Portable Analyzer Results for Viscosity along with Fuel Dilution for Minot AFB Assets

Sample Code	Asset	D445 40c	Spectro Scientific Q3050 Viscosity Meter, 40 C, Cst					Spectro Scientific Q6000 Fuel Dilution Meter, %	
		Viscosity	Trial 1	Trial 2	Trial 3	Average	Std. Dev.	Average	Std. Dev.
CL20-5218	17B00949	71.297	68	65.7	67.2	66.97	1.17	0.53	0.12
CL21-6335		85.185	89.3	80.5	86.8	85.53	4.53	0.23	0.21
CL20-5205	99C80001	72.857	70.4	68.9	67.6	68.97	1.40	0.40	0.53
CL21-6325		87.094	82.9	81.2	84.7	82.93	1.75	0.30	0.52
CL20-5208	16C00108	81.816	84.9	76.9	77.5	79.77	4.46	0.13	0.15
CL21-6324		81.168	81.8	79.1	79.7	80.20	1.42	0.20	0.20
CL20-5209	00C00831	78.097	72.9	42.7	68.1	61.23	16.23	0.20	0.26
CL21-6322		76.221	72.9	76.8	75	74.90	1.95	0.24	0.40
CL20-5210	08C00301	60.303	39	55.9	55.1	50.00	9.53	1.43	0.67
CL21-6334		66.037	75.3	68.8	76.3	73.47	4.07	0.77	0.21
CL20-5207	07C00060	89.844	79.1	78.9	54.6	70.87	14.09	0.57	0.32
CL21-6326		87.708	88.4	94	95.6	92.67	3.78	0.80	0.44
CL20-5217	03D00252	76.94	67.9	68.6	69.2	68.57	0.65	0.37	0.31
CL21-6328		75.303	75.2	77.3	78.6	77.03	1.72	0.00	0.00
CL20-5215	12D163	80.995	72.5	72.8	72.2	72.50	0.30	0.17	0.15
CL21-6333		80.365	78.7	87.5	75.4	80.53	6.25	0.20	0.35
CL20-5214	09D00286	79.836	58.1	60.4	71.1	63.20	6.94	0.53	0.25
CL21-6336		80.646	76.7	77	79.5	77.73	1.54	1.27	0.32
CL20-5211	AF23D08544	90.327	81.6	71.1	83.1	78.60	6.54	0.10	0.17
CL21-6329		88.355	93.2	82.5	91.1	88.93	5.67	0.77	0.67
CL20-5212	AF16D514	87.26	98.4	76.8	79.2	84.80	11.84	0.00	0.00
CL21-6330		89.214	87.2	78.7	88.7	84.87	5.39	0.00	0.00
CL20-5213	11C00201	89.29	80	79.1	80.6	79.90	0.75	1.07	0.81
CL21-6332		87.69	88.5	85.7	86.1	86.77	1.51	0.20	0.35
CL20-5206	23D08108	93.164	80.3	85.5	80.2	82.00	3.03	0.23	0.21
CL21-6327		95.615	100	94.4	91.4	95.27	4.37	0.63	0.46
CL20-5219	16L00031	77.384	71.6	70.1	71.6	71.10	0.87	0.97	0.64
CL21-6331		74.838	72.2	69.2	76.7	72.70	3.77	0.77	0.21
CL20-5216	08L01108	80.964	71	64.6	71.4	69.00	3.82	0.10	0.10
CL21-6323		81.125	79.6	79	82.8	80.47	2.04	0.67	0.58
CL20-5204	New Oil	95.297	105	99.8	89.3	98.03	8.00	0.77	0.74

4.14 ASSET LUBRICANT CONDITION – Portable Analyzer and Laboratory Testing Comparison

For all the Vehicle Directorate assets the previously discussed Tables compare the ASTM method data with the portable analyzer data for the viscosity at 40 °C. Included in the tables are the averages and standard deviations of the three readings from the portable viscosity analyzer. An estimate of repeatability, **r**, and Reproducibility, **R**, can be defined by a draft technical specification for Expeditionary Fluid Assessment Capability (EFAC) devices.(1.a.i.3) The instrument repeatability, **r**, and Reproducibility, **R**, are defined by the equation and coefficients that follows:

$r/R = C1 + C2 * X^{C3}$ with the equation **C1**, **C2**, and **C3** values are shown in the table below:

Where:

Parameter	Specification	C1	C2	C3
Viscosity at 40 °C	r	1	0.08	1
	R	1	0.1	1

Repeatability, **r**: X=average of readings from same instrument

Reproducibility, **R**: X=average between instrument average and lab result

Viscosity results appear to trend well between the portable analyzers and the laboratory tests. To illustrate the trend between laboratory and portable analyzers, the viscosity data from the vehicles at Robins ANG are plotted in Figure 4. Similar trends were seen at the other sampling sites. The results are for the viscosity at 40 °C for all Robins ANG assets from the portable instrument and the laboratory, with the portable instrument results falling within the calculated repeatability and reproducibility tolerances. The portable viscometer measures a slightly lower viscosity for most assets. A lower viscosity reading would err on the conservative side if the oil change would be based on lubricant service viscosity.

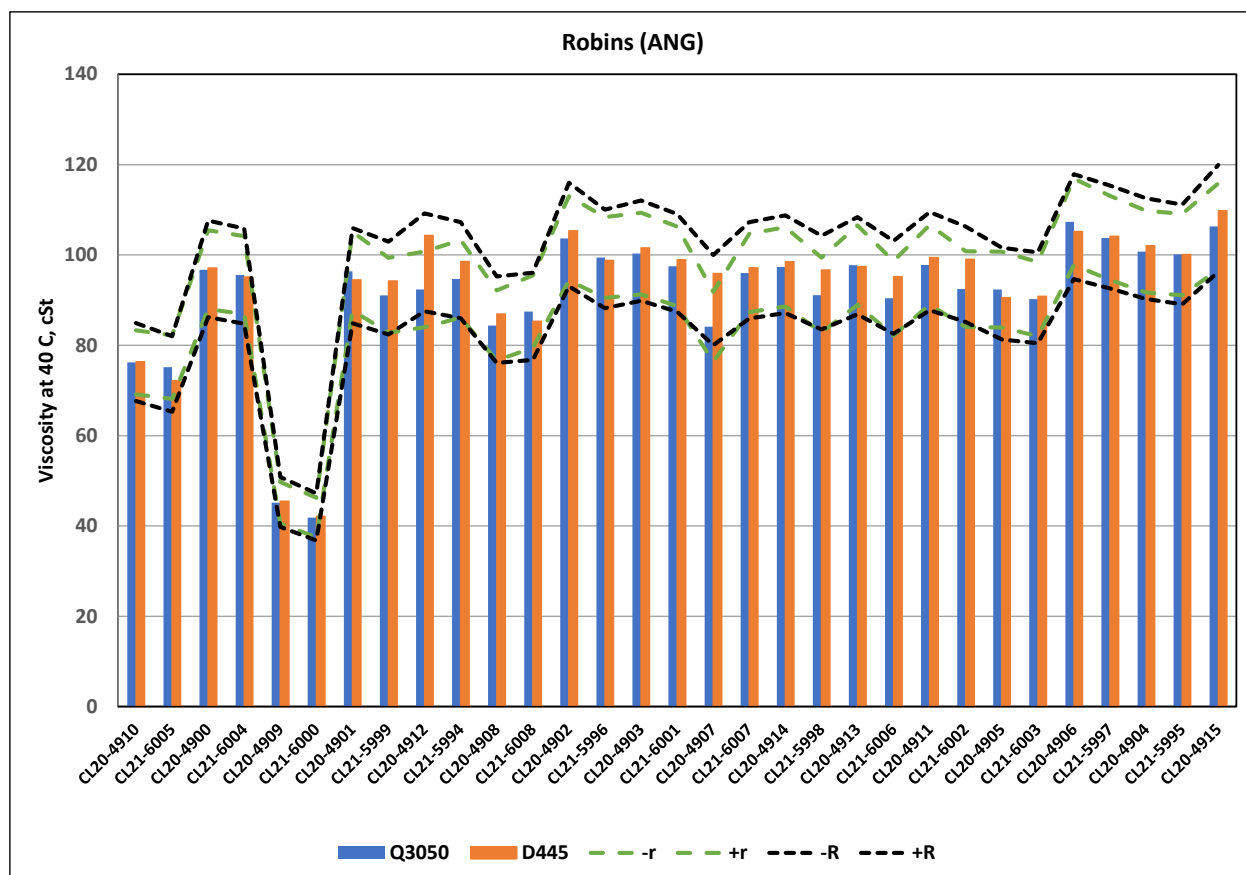


Figure 4. Viscosity Trends for Robins ANG Assets for Portable Analyzer and Laboratory Readings

4.15 Asset Lubricant Change Intervals

At the engine hour accumulation rates seen during this study over 15 months, a mileage based change interval appears to negatively impact about 30% of the assets analyzed. Rather than suggest that all oil changes be changed to a fixed time period, utilization logging and oil sample analysis would be beneficial for determining specific vehicle oil change intervals. Manufacturers of the diesel engines generally recommend oil change intervals at 200 hours or greater. Quite a few of the assets exceeded 200 hours of operation but could likely have had low mileage. Unfortunately in the study either hours or mileage was logged, not both.

Directionally the Q6000 Fuel Dilution and Q3050 Viscometer portable analyzers measure relevant lubricant condition parameters. The instruments show good agreement with low viscosity values. The combination of the two instruments can indicate engine issues based on lubricant condition. Based on the results of this study the portable analyzers have sufficient data integrity, as

evidenced by comparisons to laboratory tests, to be useful for determining vehicle asset lubricant change intervals.

5.0 CONCLUSIONS

Within the limitations of the study, the following conclusions can be made from the cumulative knowledge of analyzing crankcase lubricants of diesel engine powered vehicle assets at eight U.S. Air Force locations:

- Based on information provided some assets monitored had not had their lubricant changed for years because they appear to be operating on a mileage based oil change criteria.
- A substantial number of assets revealed compromised lubricant.
- Over the course of the study portable analyzers appeared sufficiently accurate for monitoring lubricant viscosity for degradation when compared to ASTM laboratory test results, and fuel dilution.
- Potential readiness improvements exist, stemming from condition based monitoring of lubricant versus mileage based mandatory oil changes.

6.0 RECOMMENDATIONS

The technical feasibility of using portable lubricant analyzers to monitor vehicle asset crankcase lubricant conditions for a fifteen month period has been investigated. Based on the data accumulated the following recommendations can be made:

- Track engine hours AND mileage routinely so that Vehicle Directorate assets can have their oil change intervals based on utilization instead of mileage.
- It would be recommended as a minimum to change lubricant at 200 hours operation, following industrial engine practice.

7.0 REFERENCES

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3. "Expeditionary Fluid Assessment Capability (EFAC) Technical Secification," www.ncms.org/wp-content/uploads/EFAC-Tech-Specs-DRAFT-FEB-2016.pdf, February 2016.