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Automotive Engine Lubrication Oil Analysis and its Value in Determining Internal Engine Component Wear

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Abstract

The purpose of the research was to validate the process of Oil Analysis as used to determine engine wear. This method of testing was designed to detect mechanical failure before it occured. By inspecting the internal parts of engines that had received oil analysis testing the research would determine the validity of the testing procedure.

AUTOMOTIVE ENGINE LUBRICATION OIL ANALYSIS
AND ITS VALUE IN
DETERMINING INTERNAL ENGINE COMPONENT WEAR

A Research Paper for Presentation

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In Partial Fulfillment of the Requirements for

the Non-Thesis Master of Arts Degree

by

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Approved by:

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Introduction

Background

The author's first experience with oil analysis was with the military programs he had worked with while a helicopter mechanic in the Iowa National Guard. Routinely taken samples on the aircraft would be processed and sent to a lab. Soon the reports of metal contents would return with normal or abnormal wear indicated. This analysis was an important maintenance procedure in insuring the safety of the aircraft and its passengers. When the author began teaching automotives he found very little information in textbooks or trade journals about the practice of testing auto engine oil for metal content. Mechanics with whom the author had contact knew very little of the test and most auto suppliers did not carry the testing kits. The value of oil analysis testing would seem to be obvious, but why weren't more mechanics and instructors making use of this important diagnostic tool?

As automobiles become more complex and expensive the need for better engine monitoring to protect one's investment would seem to be justification for this type of testing. Oils used in the crankcase of the modern automobile are also becoming sophisticated and this has extended the drain period recommended by most manufacturers. Therefore the oil's condition should also be monitored for contamination.

Statement of the Problem

Is Engine Lubricating Oil Analysis an appropriate method of determining internal wear? Related questions to be answered were:

1. What kind of oil analysis testing kits were available?
2. Was oil analysis testing cost effective?
3. Were there any limitations of oil analysis testing?
4. What are the oil analysis tests that could be performed on-site?
5. Does a single oil analysis test have the same validity as routinely taken samples?

Purpose of the Study

The purpose of the research was to validate the process of Oil Analysis as used to determine engine wear. This method of testing was designed to detect mechanical failure before it occured. By inspecting the internal parts of engines that had received oil analysis testing the research would determine the validity of the testing procedure.

Assumptions

It was assumed that:

1. The vehicles tested were typical of those operating in the field today.
2. The sampling kit and procedures for all vehicles tested were the same.

3. That the lab doing the testing was typical of those performing this type of testing.
4. That the test results were interpreted correctly by the lab and the recommendations were consistent with relationship to the metal content.

Limitations

The results of the research were limited by the following:

1. The time and scope of the Research Projects course.
2. The resources of the researcher.
3. The performance of the lab equipment and procedures of the Northland Oil lab and one sample tested by WIX Lab.
4. The interpretation of the test results by the researcher.

Delimitations

The research was delimited by the following:

1. Only auto engine oil would be sampled.
2. The vehicles selected for sampling were those of the author and a student in the Auto Engines course at Central High School, Waterloo, Iowa.
3. The sampling kits and labs selected were only those available locally and for uses with any brand of oil.
4. The metal selected as a wear indicator was copper and the internal component selected to inspect was the main bearings.
5. Main bearing clearances would determine the degree of wear.

6. Only one vehicle showing high copper content in the oil tested and one showing normal amounts would be selected for examination, due to the time required for disassembly of the engines for verification of the testing.

Definition of Key Terms

Automotive engine - multiple cylinder, gasoline powered, four cycle power plant used in cars.

Contaminate - elements found in the oil other than those present when the oil was manufactured, such as water, dirt, fuel, metal particles, etc.

Engine lubricating oil analysis testing - Spectroscopic testing used to determine amounts of foreign material found in crankcase oil. Could also include a variety of other tests. Often referred to as Oil Analysis.

Engine wear - an increase in the clearance between the mating parts above the manufacturer specifications.

Internal engine parts or components - crankshaft, camshaft, bearings, pistons, cylinder walls, etc.

Lubricating oil - oil found in the crankcase of the engine.

PPM - abbreviation for parts per million by weight, used as a measurement for amounts of metals found in oil samples.

Sampling kit - equipment used to withdraw and/or hold the oil sample from the crankcase of the engine being tested. Also includes packaging, instructions, and forms. Price includes the lab fee for the testing.

Spectroscopic testing - testing in which a sample's content can be broken down optically and measured, sometimes referred to as spectrometric testing.

Viscosity - the measure of a fluid's resistance to flow. The higher the viscosity number the thicker the lubricant at a certain temperature.

Wear metals - trace metals that are a product of internal engine part wear. Examples would be lead, copper, iron, etc.

CHAPTER II

Review of the Literature

Historical Background

For many years oil analysis testing has been a key tool in determining engine wear for military and industrial users. The historical background of the process began with the railroad industry.

> "Oil Analysis" as it is known today is a generalzed term referring to an analytical process initiated by the Denver and Rio Grand Railroad in the late 1940's and adopted by the U.S. Navy in the 1950's. The main reason for the development of the analytical process was similar for both railroad and the military.
>
> After World War II most of the railroads started to use diesel power instead of steam for the locomotives and while the cost per mile decreased drastically, the problem of wear and engine oil life reared its ugly head.
>
> Operating over the Rockies, the D&RG started to lose engines through excessive wear and catastrophic failures. Their test department looked around for an answer and over a peroid of time established a procedure utilizing new spectrographic methods. During the same peroid of time the U.S. Navy was losing a large number of carrier aircraft due to engine failures. They looked into the work published by the D&RG railroad and initiated a pilot program in the early 1950's at the Pensacola Naval Base (Schwarz, 1980, p. 167).

As with many other technological advances the military played a large part in the further development of oil analysis. As time progressed the military branches soon developed a joint services program to standardize the testing equipment and procedures. In addition, new and better procedures were developed under the leadership of the JOAP or the "Joint Oil Analysis Program" (Schwarz, 1980).

From the early civilian and military programs the oil analysis programs evolved to what we have today. Today the trucking industry, aircraft industry (both private and commercial), and the construction industry are all users of oil analysis programs. These users routinely sample their vehicles as part of a preventive maintenance program.

Oil itself has played an important role in the development of the oil analysis testing programs. Early oils had very little in their additive package and therefore the drain interval for these oils were very low, 1000 miles or less. Today oils are expected to last 5-8,000 miles and the synthetic oils three times that amount. Oil analysis may have not been practical for those early vehicles because of the frequency of oil changes (Moeller interview, 1984).

Oil Analysis Testing

The testing methods can be broken down into three categories:

1. Those used to identify component wear.
2. Those used to determine the contaminate in the oil.
3. Those used to determine the condition of the oil (Northland, 1984).

Most of the tests are done by laboratories that are associated with an oil company but some oil companies use independent labs that work for many customers. Equipment and services may vary from lab to lab but the above categories of tests seem to be universal.

Tests used to identify component wear - Spectrometric Oil Analysis

The test used to detect trace amounts of metals in the engine is called a spectrometric oil analysis.

> Spectrometric oil analysis is based on the fact that movement of metallic parts in an oil-wetted system is always accomplished by friction. Consequently, some surface metal is removed and the microscopic particles are picked up by and are circulated with the oil. Friction is the major cause of wear particle formation, but corrosion, abrasion, scuffing, scraping and spalling are also contributors; in addition, combustion by-products become trapped in the circulating system. Therefore, the circulating oil contains valuable information concerning the system's condition (Schwarz, 1980 , p.168).

There are two types of spectrographic equipment presently used for this type of testing, Atomic Absorption and Atomic Emission. Both of these tests are equally accurate and are widely used by the labs researched. The only reason available for having the two different systems was the size of the labs. Atomic Absorption is a much slower process and large labs use Atomic Emission.

Atomic Absorption (AA) involves aspirating a diluted solution of the oil into a controlled air-acetylene flame. A lamp containing a hollow cathode constructed of a specific element is used to produce a high-intensity beam of that element's emission spectrum. The beam is split in two; one half is used as a reference, and follows an uninterrupted path to a photomultiplier detector. The other half passes through the flame before reaching the detector. The detector system thereby measures any loss of the intensity of the sample beam due to its passage through the flame. Atoms of the element present in the flame will absorb light of that element's characteristic wavelengths, the absorbance being proportional to the concentration of the element in the oil. Oils containing precise amounts of the elements of interest are used as standards. Either absorbance or concentration can be read directly on modern instruments, or fed into a teleprinter or computer (Schwarz, 1980, p. 168).

Atomic Emission is similar to Atomic Absorption but much quicker because the process will take the sample as is without dilution and one testing process is all that is required.

Atomic Emission (AE) is similar to AA; however, it energizes a small oil sample with a sufficiently high voltage to cause the individual metal in the sample to emit a characteristic spectrum of ultraviolet and visible light. For each element in the oil sample, the intensity of a specific characteristic wavelength will be proportional to its concentration (Schwarz,1980,p.168).

Atomic absorption spectrography equipment was the process used by the lab that performed the testing for this research. This method is slower because only one sample at a time can be tested. If seven metals were included in the test then seven separate samples would have to be prepared and each tested separately. Although slower than atomic emission where all metals can be detected from one sample, atomic absorption equipment is much cheaper than atomic emission equipment. A diagram of an atomic absorption spectrophotometer can be seen in Figure 1.

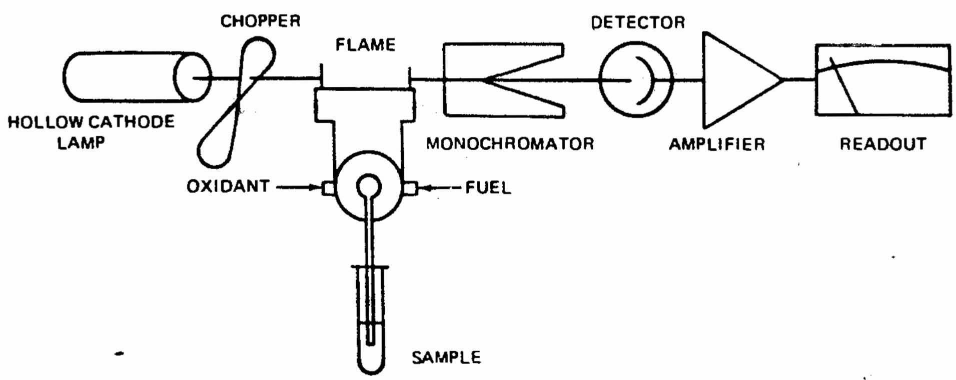


Figure 1. Schematic of atomic absorption spectrophotometer (Klug, 1970, p. 3).

The major draw-back to this type of testing is the size of the particle being tested.

Metal flakes or particles usually found in screens, filters or detectors are not the basis of spectrometric oil analysis. Particles of this size tend to settle out and not appear in the oil sample. Their presence is important, but detectlon must be left to other techniques. As a general rule, the following detectlon techniques are used for different particles size in micrometers.

1) Visual screen and filter evaluation: 45-2000 um.

2) Chip detectors: 10-600 um.

3) Microscope examination or ferrography: 4-200 um.

4) Spectrometric: 0-15 um (Schwarz, 1980, p. 169).

Therefore, Spectrometric Oil Analysis cannot always prevent the catastrophic engine failure. Detection of a fracture in a piston for instance, may not generate any particles that can be detected by Spectrometric Oil Analysis. External leaks of the lubricant or coolant often cause engine failure, they are undetectable by oil analysis. What oil analysis can do is determine the amount of metal content in the oil and then through interpretation determine the source of the metal. This, of course, will warn the auto owner of the impending failure so that the needed repairs can be made.

Test Used to Determine Contaminates in the Oil-Infrared Absorption Spectroscopy

Equally important in determining the condition of the engine is the amount of contaminates found in the oil sample. The three contaminates commonly found in oil samples are water, fuel, and antifreeze. The presence of contaminates usually indicates mechanical problems such as a cracked head, stuck choke, etc. and this will affect the quality of the oil. Each of these contaminates can be determined by separate pieces of testing equipment but the literature indicates that the infrared spectrophotometer was a single piece of equipment that could detect the presence of all three (Lubrication, 1969).

Infrared spectroscopy is a fast and accurate way of determining the presence of contaminating substances. Both a used and unused oil sample should be provided for the test. An explanation of the testing equipment and its operation follows.

> When an organic compound is exposed to infrared light, the substances composing the compound will absorb the light at specific frequencies. The amount of absorbance on these characteristic absorption bands is related both to the quantity and type of absorbing material. A 'straight' scan (without reference lubricant) provides information on the actual composition of the substance; a 'differential' scan (using a known lubricant type as reference) provides information on the degree of change between the reference lubricant and the sample in

question. In this way, numerous details of a lubricant's molecular composition and chemical make-up can be determined with relative ease (OSI, 1984, p. 7).

Below in Figure 2 is a diagram of an infrared spectrophotometer.

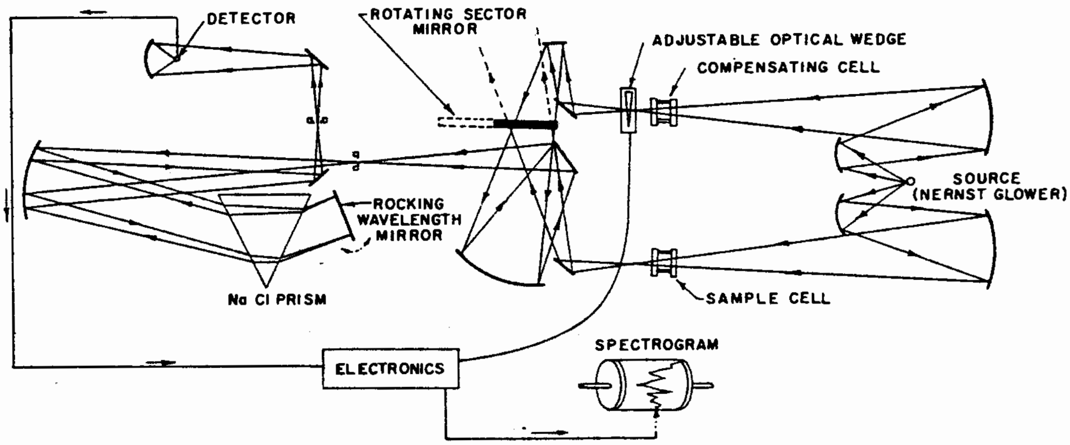


Figure 2. Diagram of an infrared spectrophotometer (Lubrication, 1958, p. 3).

From the Infrared Spectrophotometer we get a print-out in the form of a graph. Be interpreting the graph, the amounts of contaminates can be determined. See Figure 3 below for an example of a differential infrared spectrum of a used gas engine oil sample.

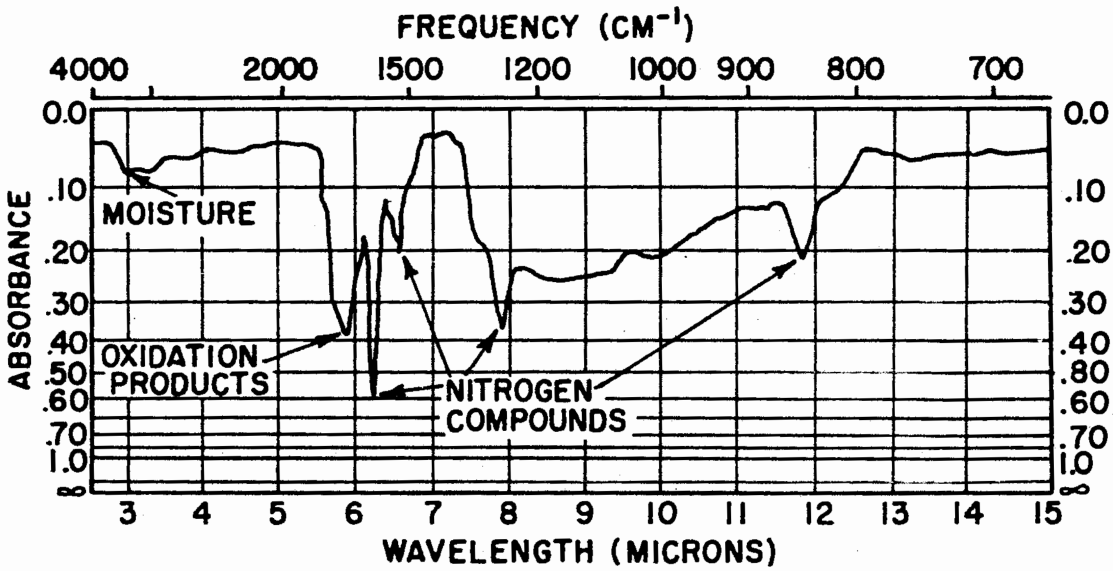


Figure 3. The differential infrared spectrum of a used gas engine oil (Lubrition, 1969, p. 28).

To interpret the graph, the wavelengths that would represent the different contaminates must be known. See Table 1 for the identification of the infrared bands.

Table 1

Identification of Infrared Bands

Wavelengths	Nature of Component	Type of Service Diesel	Type of Service Gas	Reported as
2.9, 6.05	Water (bonded	X	X	% Volume
5.85	Oxidation	X	X	A/cm[a]
6.1, 7.9, 11.6	Organic nitrates	-	X	A/cm[a]
6.4	Nitro compounds	-	X	A/cm[a]
12.4, 12.8	Gasoline dilution	-	X	% Volume
9.3, 9.7	Ethylene glycol	X	X	% Volume
Other bands	Unusual contaminates	X	X	A/cm[a]

[a]Absorbance per centimeter of cell film thickness

Note. From "Engine condition defined by oil analysis" by C. G. Salvesen, 1980, November, National Bureau of Standards Special Publication 584, p.184.

In summary, infrared analysis of engine oil may or may not be crucial in the analysis of drainage oil. Infrared analysis is expensive and there is an extra charge for this when requesting an oil analysis. Infrared not only determines the presence of contaminates but it also determines the amounts. Simpler tests can be done quickly to determine the presence of most contaminates and if none are present then additional testing, like infrared is unnecessary. These simpler tests that can be used to determine the presence of contaminates will be described in the on-site testing section.

Tests Used to Determine the Condition of the Oil

Viscosity

A lubricant's resistance to flow, viscosity, is probably the most important property of an engine oil. A reduction in the viscosity of an oil usually occurs with age, but contaminates can also effect the viscosity of the oil. Water or fuel soots may thicken the oil while liquid fuel will dilute the oil. The viscosity of the oil is measured by one of several means, usually by a falling sphere in a glass tube filled with oil, or a commercial flow gauge. In the case of the falling sphere, the speed of the descending ball as it falls through the oil sample is compared with the speed that it falls through a reference oil sample. The commercial flow gauge measures the time it takes the sample to move through an orifice of a given size to determine the oil's viscosity. The results of such tests are reported in a SAE viscosity grade equivalent. It is important to realize that viscosity equal to the original oil value does not mean that the oil can continue to be used. Sometimes the presence of contaminates will cancel each other out and a change in viscosity will not be apparent. If contaminates are present then the oil will have to be changed.

Fuel Dilution

When fuel gets by the rings in an engine and into the crankcase oil, the oil thins and can cause major component wear. It is normally measured by a gas chromatography, which reports the percentage of the fuel present, or by flash point which measures the degree temperature at which the oil vaporizes. The lower the flash point the larger the volume of fuel in the sample (OSI, 1984).

Other Tests

There are a number of other tests which are performed as part of some oil analysis programs to determine the condition of the oil. Most of these tests are unnecessary unless the customer is interested in extending the drain interval of the oil. Since extending the drain period was not a consideration of this research these other tests were not included in this paper.

On-Site Oil Analysis Testing

There are several tests that can be performed on engine oil in the field to determine its general condition. Most of these tests reveal the presence of contamination of the condition of the oil and not the metal content. They are also less accurate as might be suspected. Some of these tests are performed by labs to determine the general condition of the oil before more sophisticated tests are performed.

On-site tests are performed when the oil's condition seems questionable. If the oil is being routinely changed and it just does not look normal or if the engine has overheated recently then this is a good time to inspect the oil.

Appearance Testing

Appearance testing of the oil is done by placing the oil in a clear glass container and observing the color and condition of the oil. If the oil appears cloudy or milky, then water may be present. If the oil seems thin, roll the container and compare its movement with that of a new sample of equal weight. A viscosity difference should be apparent. Sometimes the oil can be examined with a magnifying glass for solid particles, but the size of these particles will have to be very large to be seen. It may be better to examine the contents of the oil filter with a magnifying glass since particles trapped by the filter will be much larger (Chevron, 1983).

Odor Test

An odor test is simply taking a sample of the oil and smelling it. If an odor of fuel is present then fuel dilution may have taken place. If the oil smells sour then oxidation may have occured. In either case, if the oil has any odor other than that associated with oil, further testing should be done (Chevron, 1983).

Water "Crackle" Test

The water "crackle" test will determine if water is present in the oil sample. If water is present, placing a small drop of the oil on a hot plate will cause a sputtering or crackling sound. To perform this test set the hot plate temperature at 250° f. When performing this test, be careful because the presence of water in the oil may cause the oil to splatter or fly off the hot plate. If no water is present in the oil, the drop will just stay on the hot plate (Chevron, 1983). This is one of the tests used by Northland Oil's lab and was performed on the samples used in this research to determine the presence of water (Moeller interview, 1984).

Blotter Spot Test

The blotter spot test is performed by placing a drop of oil on absorbent paper (Whatman No. 5 filter paper). The appearance of the drop is then examined as the oil spreads out. If rings are present, or a darkened center is apparent, then sludge may be present. A simple way to perform this test is to use a drop of oil from the dipstick of the vehicle. Periodic sampling this way will give you an idea of how much longer the oil will be serviceable. As the sludge becomes more apparent, instead of dispersed, the oil will have to be changed. See Figure 4 for examples. The blotter test is another test that is used by Northland Oil to determine the condition of the oil.

Viscosity

Viscosity of an oil can be tested on-site with a falling ball comparator. This device compares the oil being tested with a reference oil. The used oil is placed in a tube with a small ball then the speed and distance which the ball descends is compared to that of the ball in the reference oil. A viscosity reading can then be calculated. The major draw-back to this type of testing is that most used engine

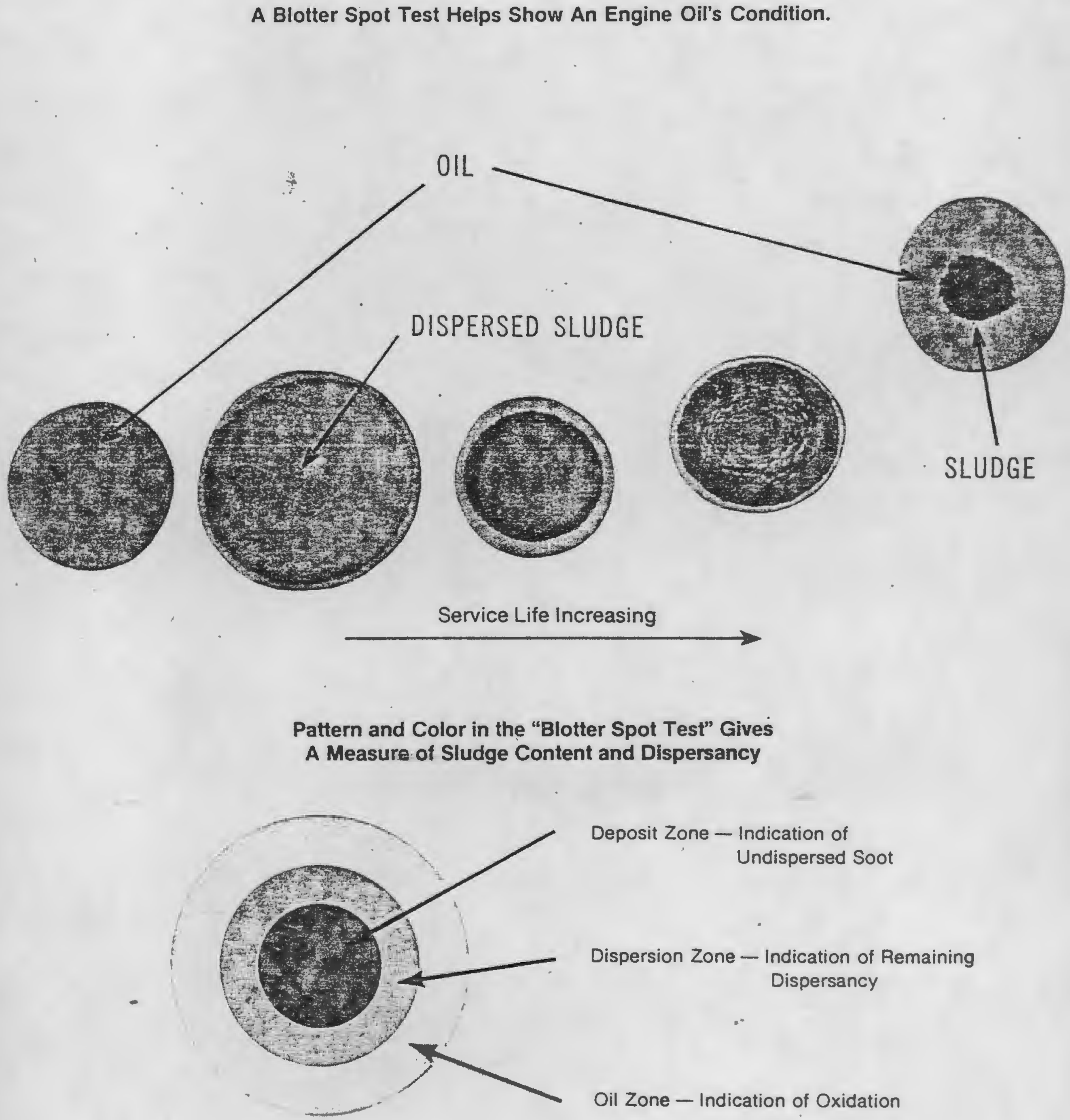


Figure 4. Blotter test example

(Chevron, 1983, p.16).

oils are not clear enough to see the position of the ball; therefore, the practicality of this test may be questionable (Chevron, 1983).

Sampling Equipment and Procedures

A good oil analysis starts with a good sample. A coke bottle filled with oil dipped from a drainage pan is not going to yield an accurate analysis of the engine's condition. Also, if possible, a new sample of the crankcase oil should be submitted to use as a reference sample. In order for the sample to be properly taken, the literature revealed common steps that most labs recommend.

Sampling Considerations

Sampling considerations include:

1. The oil sample must be taken when the oil is HOT. As soon as possible after the engine is shut off, or in the case of an internal valve, the sample should be taken after 15 minutes of operation.
2. Containers must be clean and not contaminated by dirt or other residue.
3. The sampling equipment must be cleaned thoroughly between sampling, so cross sampling contamination will not occur.
4. The area around the drain plug, dipstick holder, or sampling valve need to be cleaned before sampling.
5. Samples need to be drawn from the middle of the crankcase. When using the drain method, allow oil to flow for 2-3 seconds before sampling. When using the pump method, be sure the hose is inserted correctly so the sample comes from the middle of the crankcase.

6. Place samples directly in test containers that are provided with the sampling kit. Do not transfer oil from common containers to the test bottles.

Request Forms

Request forms from the lab usually accompany the sample containers. Requests usually include the customer's name and address, make and model of the vehicle, the brand and type of oil, the miles on the vehicle, and the miles on the oil. In addition, the request form might include questions about the use of the vehicle and the origin of the sample (engine, transmission, etc.). This information, like a properly taken sample, is very important when submitting the sample to the lab. Examples of the request forms are found in the appendix C.

Methods of Obtaining Samples

Methods of obtaining samples were revealed in the literature. The three methods are: The drain method, the suction pump method, and the in-line valve method.

The drain method is the simplest and least costly of the three. However, it is probably the most vulnerable and messy. The container is simply placed in the drain stream of the oil as it leaves the crankcase and filled to capacity. There are problems with this method. Usually the oil is hot and there is a chance of getting burned. The position of the drain plug sometimes requires deflection of the oil so it does not contact a dirty frame member before it enters the sample bottle. Even so, this sampling method was used for this research. See Figure 5 for an example.

The second method is the use of the suction pump. This method is much cleaner than the drain method but it can be just as inaccurate. The sample bottle is attached to the pump and a hose pushed down the dipstick holder. When the plunger is withdrawn the oil is sucked up the hose and directly into the container. The container can then be removed from the pump and capped. Inaccuracies develop when the hose used with the pump is not thoroughly cleaned or replaced between samples, or when the depth of the hose in the oil pan is not controlled to provide a representative sample of the oil. See Figure 6 for an example of this type of sampling equipment.

The third type was the petcock or in-line valve method. A high pressure valve is placed in the engine's oil line or by means of a 't' in line with the oil sending unit. The sample can then be drawn while the engine is operating and a representative sample is assured. The area around the valve must be cleaned and some oil should flow out before the sample is taken. This is the most accurate of the sampling methods and the most expensive because of the cost of the valve and its installation. See Figures 7 and 8 for examples of this type of equipment.

Figure 5. Drain Sampling

Method (Kendall, 1984 , p.2).

Figure 6. Pump Sampling

Method (Kendall, 1984, p.3).

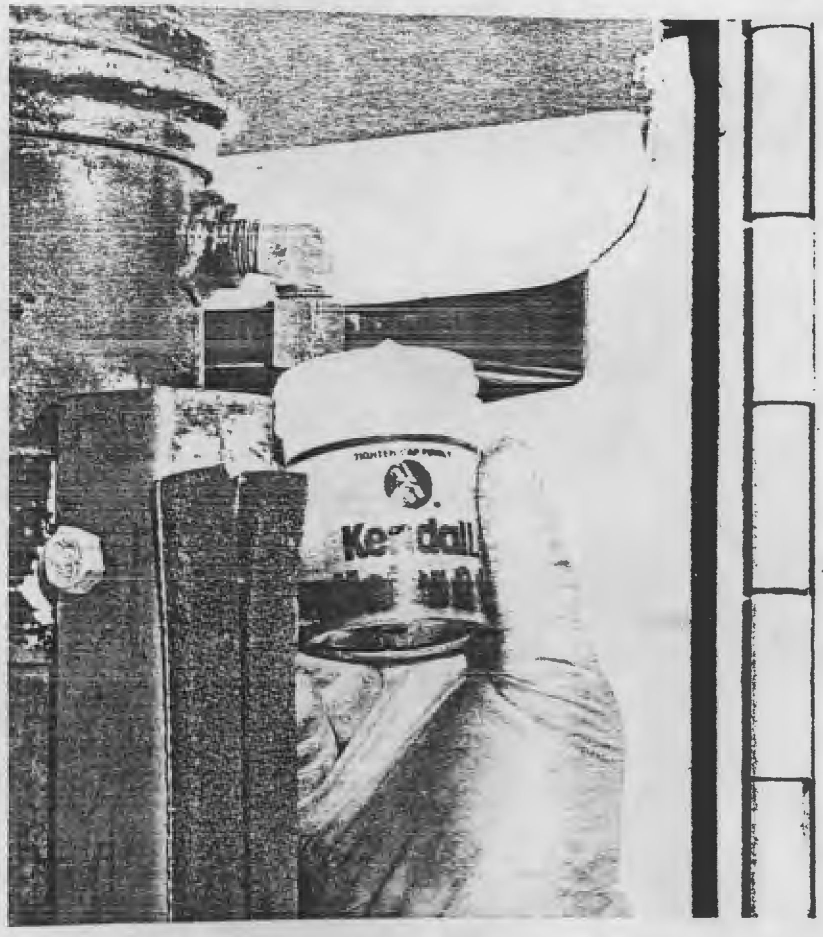
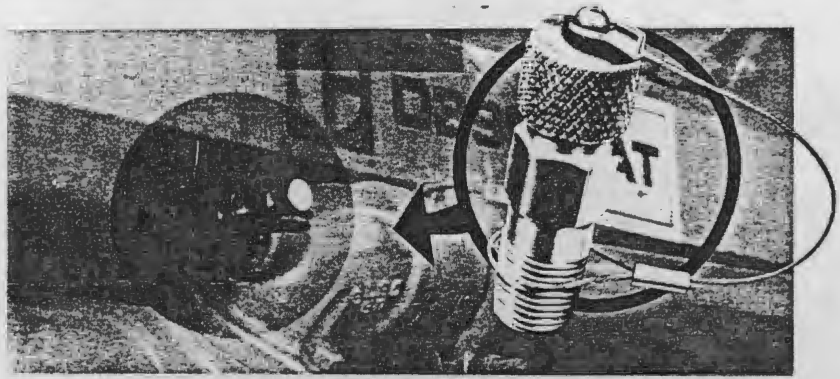
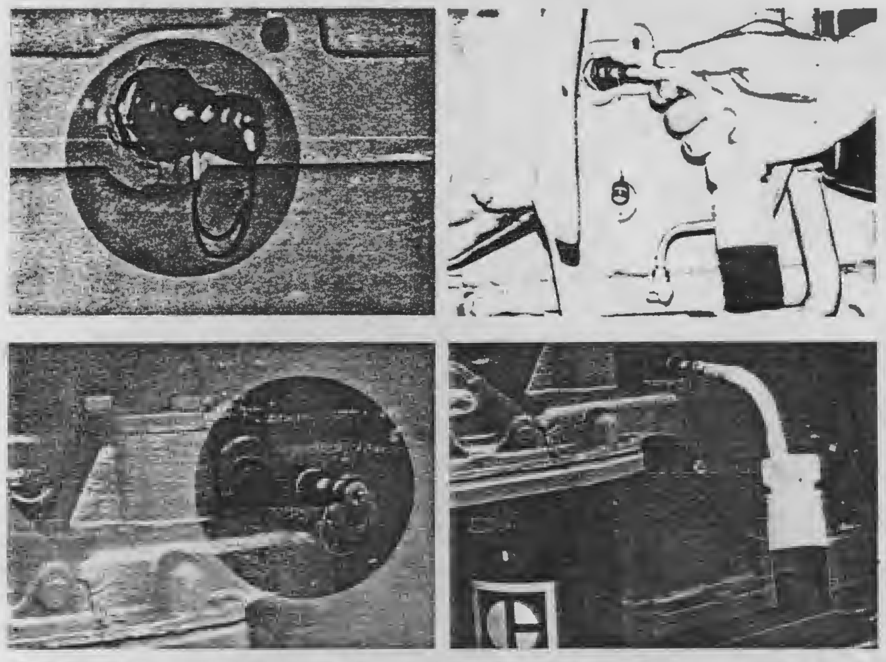


Figure 7. In-line Drain

Sampling Method (Kendall, 1984 , p. 4).



⅛" NPT Standard Mini-Gauge Plug (Part No. 16-513661) is designed to withstand 3,000 p.s.i. Triple seal eliminates leaks, enables sample to be drawn from flowing, homogenous stream within engine. Eliminates "dead space" that can harbor standing fluids to give a false analysis.



Designed for use with all Taylor Mini-Gauge Plug series valves, the Probalyzer collects engine oil samples — while the engine keeps working! This reliable sampling system for large diesel engines is based on Taylor's field-proven testing devices designed for large diesel engines operating in demanding applications.

Mini-Gauge Plug is a registered trademark o

Figure 8. Probalyzer Valve

Sampling Method (Maintenance Technology, 1984).

Interpreting the Lab Report

When the lab report is returned, the results must be interpreted by the customer so that appropriate corrective action can be taken. Most lab reports will include the raw data as well as some recommendations for the source of the abnormal metal or contaminate contents. See example in Figure 9.

When studying the lab report in Figure 9 it is apparent that the report is in three separate sections. The top section has the information that was sent along with the sample and the lab identification number. The middle section has the results of the spectrophotometric analysis and the third section has the data about the quality of the oil sample. In addition to the report the interpretation of the results in each section are included at the bottom of this report. To interpret the results of the test the lab had to know the possible source of the metals found in the oil.

Wear Metals and Their Sources

Oil samples in the research indicated the presence of metal particles. Table 2 shows the metals and their possible sources. These metals were typical of those reported in the testing section of the research.

The amount of metal found in the sample is recorded in PPM or parts per million by weight. These are the amounts found by spectrometric oil analysis explained earlier.

** * ** ** ** ** WIX CORPORATION
*** *** ** * P O BOX 1967
* * ** ** ** GASTONIA,N C 28052
F I L T E R S

AN ANALYSIS OF CONTAMINANT LEVELS IN THE LUBRICATING OIL OF	NATHAN NORTHEY 214 NIAGARA DR. WATERLOO,IOWA 50701	UNIT NO 00100	LAB CONTROL NO NN100100

REQUEST NO.	31342
TOTAL MILES	118,470
OIL MILES	150 H.

************************** ICAP EMISSION SPECTROPHOTOMETRIC WEAR METAL ANALYSIS *********************

ANALYSIS DATE	03-06-84
SILVER	0
ALUMINUM	7
CALCIUM	31
CHROMIUM	2
COPPER	50
IRON	115
MAGNESIUM	35
LEAD	704
SILICON	24
TIN	0
ZINC	26

*************** ADDITIONAL OIL QUALITY TEST RESULTS ***************

SOLIDS	NONE
FUEL	7.2%
ANTIFREEZE	NONE
VISCOSITY	SAE 20-1
WATER	NONE

*************** COMMENTS AND RECOMMENDED ACTION ***************

THE INFORMATION BELOW IS PROVIDED TO HELP YOU INTERPRET THE TEST RESULTS AND RECOMMEND APPROPRIATE ACTION

1 . PLEASE REFER TO ABOVE CONTROL NUMBER WITH ALL FUTURE SAMPLES FROM THIS UNIT.
2. HIGH COPPER--POSSIBLE SOURCES: BEARINGS AND BUSHINGS, FILTER MESH SCREENS, OIL COOLER TUBES, ROCKER ARM AND WRIST PIN BUSHINGS, TIMING GEAR THRUST WASHERS, OIL PUMP DRIVE THRUST WASHERS, FUEL PUMP AND SERVICE METER BUSHINGS.
3. SLIGHTLY HIGH IRON: POSSIBLE SOURCES: PISTON RINGS, CYLINDERS, ROLLER BEARINGS, VALVE TRAIN, CRANKSHAFT, CAMSHAFT, GEARS.
4 . SILICON--HIGH ABRASIVE DUST LEVEL CONTRIBUTES TO HIGH WEAR OF RINGS, PISTONS, CYLINDERS OR BEARINGS. INSPECT AIR CLEANER FOR CLOGGING, BYPASS, DAMAGE; CHANGE IF FAULTY OR SUSPECT. INSPECT FOR BENT OR DAMAGED AIR CLEANER HOUSING, SEALING SURFACES, DISCONNECTED OR DAMAGED AIR DUCTS, VACUUM LINES, INTAKE MANIFOLDS, FUEL FILTERS, BREATHER CAPS, OIL FILLER CAPS AND TUBE.
5. EXCESSIVE VISCOSITY CHANGE-POSSIBLE HIGH SOLIDS, WATER, OR FUEL DILUTION CONTENT. CHANGE OIL AND FILTER.
6 . GASOLINE-FUEL DILUTION. CHECK FOR CHOKING, RICH MIXTURE, TIMING AND PLUGS. COULD ALSO BE EXCESS IDLING, WORN RINGS, OR CYLINDERS. CHECK COMPRESSION IF OTHER EVIDENCE OF BLOW-BY OR WORN RINGS EXISTS.
7 . OTHER WEAR METALS APPEAR TO BE WITHIN ACCEPTABLE LIMITS FOR A SINGLE ANALYSIS OR WHERE NO WEAR-RATE PATTERNS HAVE BEEN ESTABLISHED
8 . RESAMPLING AT REGULAR INTERVALS NEEDED TO ESTABLISH A WEAR RATE PATTERN

Figure 9. Raw Data and Recommendations (Wix Oil, 1984).

Table 2

Spectrographic Analyses Wear Metals

Element	Source
Iron	Liners, Pistons, etc. wear
Lead	Bearing damage
Copper	Bearing damage, oil cooler
Chromium	Piston rings, some coolant inhibitors
Aluminum	Pistons, blowers, bearings
Sodium	Coolant inhibitors, additive
Silver	Special bearings (EMD engines)
Tin	Bearing overlay
Boron	Coolant inhibitor, additive
Silicon	Dirt in air or oil, and antifoamant
Zinc	Additive metal
Calcium	Additive metal
Magnesium	Additive metal
Phosphorus	Additive

Note. From Service bulletin, Wear Check, 1984, Toronto, Ontario, Canada.

Acceptable Wear Metal Content

The metal content considered normal will vary from engine to engine and what one lab might consider normal or borderline, another might indicate as unacceptable. Table 3 shows the amounts the labs consider normal for vehicles using leaded fuel, after break-in, and for engine oil that has 5000 miles of use.

Table 3

Acceptable Wear Metal Content

Aluminum	- 15 PPM	Lead	- 1000 PPM
Chromium	- 20 PPM	Silicon	- 12 PPM
Copper	- 20 PPM	Silver	- 3 PPM
Iron	-180 PPM	Tin	- 10 PPM

Note: Magnesium, Calcium, and Zinc are all additive metals found in the oil in large amounts and along with lead, which is present in gasoline as tertra ethyl lead, are usually not considered when evaluating an oil sample.

Note. From Service bulletin by Wear Check, 1984.

Effects of Silica on Wear Metal

If a sample were found to have a large amount of silica present then the wear rate on most parts would increase. This would change the amount of metals that are ordinarily considered normal. Table 4 shows the effects silica has on the metal amounts previously discussed.

Table 4

Gasoline Engines, Effects of Silica

Silica Range	Iron	Aluminum	Copper	Chromium	Tin
0-10	48.7	8.0	10.9	9.4	1.4
10-20	59.1	10.0	11.1	8.1	2.9
20-30	108.9	15.7	14.6	23.0	5.8
30-40	132.5	21.7	18.0	13.7	7.4
40-50	169.9	35.1	26.1	24.2	13.3
50-60	190.6	32.3	26.2	28.7	12.0
60-100	251.7	47.5	40.2	35.8	15.4
100-150	295.4	77.9	54.8	35.0	18.0
150-200	331.8	98.5	82.5	34.5	27.5

Note. From "C. L. S.-Lubricant Financial Return" by D-A Lubricant, 1984., p. 11 .

Oil Quality Results

Oil quality results are a little easier to interpret. The report, Figure 9, indicates either the presence or the amount of contaminates. The viscosity is listed by the SAE number which makes for easy comparison with the number of the oil submitted. Interpretation of this section is found along with the previous section at the bottom of the report.

Lab Report Recommendations and Results

Lab report recommendations and results are usually best left to the interpretation of the lab because most customers have little knowledge of the source or abnormal amounts of metals found in their sample. But because each lab may have a different set of standards, it is appropriate for the customer to review any previous analysis reports for any trend that might have developed, then consider the contaminates found in the sample and what effect they have on the results. Many times the amounts may be borderline and changing oil and resampling the vehicle at a shorter interval should be done to validate the original findings.

Testing Services

Ten testing services were found in the literature by the author. Each lab offered a variety of testing services. The price for this analysis also varied from lab to lab. The labs listed in Table 5 provide a package price for basic oil analysis testing as discussed in this paper. This would include spectrophotometric analysis for wear metals, oil contaminate testing, and oil quality testing. The price of the services listed includes the testing kit, lab work, and report on the condition of the sample. See Table 5 for data collected.

The research revealed that the testing services associated with companies like Quaker State and Kendall offer oil analysis services to users of their products only. The price reflects the fact that these companies are concerned about the performance of their products.

Table 5

Oil Analysis Testing Services

Company Address	Base Oil	Price
Analysis Maintenance Laboratories, Inc. Box 4002 Schaumburg, IL 60195	Any	$12.00
Cleveland Technical Center, Inc. 13600 Deise Avenue Cleveland, OH 44110	Any	$11.50
D-A Lubricant Company, Inc. 1340 W. 29th Street Indianapolis, IN 46208	Any	$19.70
Kendall Lubricant Distributor Boyer Petroleum; P.O. Box 633 Des Moines, IA 50303	Kendall Products Only	$ 1.00
Martel Laboratory Services, Inc. 1025 Cromwell Bridge Road Baltimore, MD 21204	Any	$12.00
Northland Oil 1000 Rainbow Drive Waterloo, IA 50701	Any	$10.00
Optimal Systems, Inc. P.O. Box 1182 Atlanta, GA 30301	Any	$13.80
Precision Diagnostics, Inc. 777 Silver Spur Rd., Suite 132 Rolling Hills Estates, CA 90274	Any	$20.95
Quaker State Oil Refining Corporation Attn: Mr. R. G. Sorrell Box 989 Oil City, PA 16301	Quaker State Products Only	$ 2.00 (includes postage)
Wix Corporation (available through Lewis Analysis Lab Motor Supply, Waterloo, IA) P.O. Box 1967 Gastonia, NC 28052	Any	$ 8.50

CHAPTER III

Methodology

The purpose of this study was to determine the validity of oil analysis in determining engine wear. One of the tested vehicles that had a high metal content and one that had a low metal content were selected. Then disassembly and measurement verified the internal wear of the engine component. This information was then used with the data from the oil analysis reports to validate or invalidate the oil analysis process.

Procedures

The following parameters were considered when completing this research.

1. Only engine oil was tested.
2. The sampling kits used were the same for all engines tested, with the exception of the 1970 F-250 which was tested twice, once by Wix lab and then by Northland for further verification.
3. All samples were taken by the drain method.
4. Northland Oil's lab, in Waterloo, Iowa was the primary tester of the oil samples.
5. Four vehicles were tested, 1970 F-250, 1972 Toyota, 1975 Mustang, and a 1981 Plymouth.
6. From the lab reports, the 1970 F-250 and the 1975 Mustang were selected. The F-250 showed high copper content and the Mustang showed low copper content.

7. The main bearings of the two vehicles were selected for examination and measurement.

8. The engines were disassembled and measured for wear.

Review of the Oil Analysis Reports from the Tested Vehicles

The four vehicles selected for testing were assumed to be typical of those used by the general public for transportation unrelated to work.

The lab selected for the testing was the only local noncommercial facility performing oil analysis testing for the general public in the author's locale. It was assumed also that the Northland Oil Lab was typical of the labs performing this type of testing. The results of the testing follows on Table 6.

Selection of the Vehicles

From the reports received from the testing and the interpretation of those results by the lab, the author selected the 1975 Mustang that shows little copper content, indicating little bearing wear. And the 1970 F-250 that showed high copper content or abnormal bearing wear for disassembly and further testing. See test report summaries in Table 6.

Testing of the Vehicles for Internal Wear

The vehicle's engines were disassembled and cleaned. The main bearings were removed along with the crankshaft. Both were measured to determine the amount of clearance between the two parts. This clearance, referred to as the oil clearance, was then compared to the

Table 6

Oil Analysis Reports - Northland Oil

Vehicle	Date	Mileage	Miles on Oil	PB	CU	FE	CR	AL	SI	SN
Reference Oil Trop-Artic 10w-40	3/15/84		n/a	0	0	3	0	0	1	4
Toyota 1972	3/13/84	43,640	2,640	69	13	5	0	0	1	4
Plymouth 1981	3/15/84	35,900	2,900	2	10	10	0	0	2	3
Mustang 1975	3/15/84	87,130	10,000	95	2	34	1	3	3	4
Ford F-250 1970	4/22/84	118,620	150	100+	26	44	0	5	16	n/a

manufacturer's specifications. From this comparison the conclusion was made as to the validity of oil analysis testing. See Table 7 for the data collected from this testing.

Table 7

Engine Wear Measurements

Vehicle	Measurement Source	Main Bearing Number #1	#2	#3	#4	#5
1975 Mustang	Crankshaft	2.244	2.244	2.2435	2.244	N/A
	Inside diameter bearing	2.2455	2.245	2.245	2.2455	N/A
	Oil clearance	.0015	.001	.0015	.0015	N/A
	Manufacturer's oil clearance	----- .0005-.0016 -----				
1970 F-250	Crankshaft	2.748	2.7475	2.748	2.7475	2.7485
	Inside diameter bearing	2.752	2.753	2.753	2.752	2.751
	Oil clearance	.004	.0055	.005	.0045	.0025
	Manufacturer's oil clearance	----- .0005-.0024 -----				

CHAPTER IV

Summary, Conclusions, Recommendations

Summary

As the auto engine has increased in complexity over the years so have the problems resulting in engine failure. Detecting those problems and making minor repairs before they become major has long been the purpose of any preventive maintenance program. The evolution of the modern auto engine has resulted in an increase of horsepower through increasing the RPM's. Even with better engine materials and better engine lubricants, the constant monitoring of the engine is necessary. Without diagnostic tests like those used in oil analysis many motorists might find disassembly of the engine the only method of detecting internal engine wear.

The purpose of the research was to validate the oil analysis process as a means of determining engine wear. The author had experienced the importance of oil analysis testing during military service as a helicopter mechanic. However, as an automotive instructor he had not found the oil analysis process in use. Most mechanics chose to disassemble the engine to determine the wear and many knew nothing of oil analysis.

The review of the literature revealed information on the history of oil analysis, the tests performed on the sample, and the equipment used to process the samples. In addition, less sophisticated tests for condition were also examined. The sampling procedures and equipment were examined and some of the testing services listed.

The methodology used in determining the validity of oil analysis testing involved the sampling of several vehicles and examination of the results from the lab analysis. From the lab results, one vehicle showing high metal content and one showing normal metal content were selected for disassembly. Following the disassembly, the engine parts were measured, and the results were compared with the predicted wear areas reported in the oil analysis report. The results indicated that the oil analysis had been correct in predicting the wear of the internal engine component selected.

Conclusions

Based on the results of the research performed on the vehicles used in this project, oil analysis would seem to be an appropriate method of determining internal engine wear. The amounts of metal particles suspended in the oil can adequately determine the condition of many of the internal engine parts. In the future oil analysis testing should see more use due to the increasing complexity and cost of automobiles. Consumers will want to protect their investment and mechanics will need to use oil analysis to serve their customers better.

Recommendations

The use of oil analysis as a diagnostic tool is largely dependent on the kind and number of vehicles operated and the miles driven.

1. The fleet owner will want to design an oil analysis program with routinely taken samples being used to prevent unexpected engine repairs.

2. The auto owner show does not depend on his vehicle as part of his job will only need to test the oil every 20,000 miles to keep track of the engine's condition.
3. Occasionally, an unexpected engine problem, such as an over heated engine, may warrant an additional oil analysis test to see if damage to the engine has occurred.
4. The frequency of oil analysis testing is important if the vehicle owner wants to develop a trend analysis of the engine's condition. The shorter interval, every 5,000 miles, will cost more but a trend can then be established and rarely will a problem go undetected.
5. The longer interval oil analysis, every 20,000 miles, will reduce costs but the risk of not detecting a problem soon enough to make an economical repair is always present.

The cost effectiveness of any preventive maintenance program is always an important consideration. The cost of the sample testing can range from one dollar, from an oil company, to twenty one dollars, from an independent lab, and much more depending on the tests performed. Therefore, an oil analysis program can be a cost effective method of extending engine life if the results of the testing and the action recommended is followed. The practice of simply reading the odometer and predicting the life of the engine based on past experience is not adequate for most modern engines and often leads to surprise engine failures.

Recommendations for Further Research

In considering further research on the topic the author recommends:

1. A greater number of vehicles should be tested to increase the validity of the process.
2. More labs should be used to process the samples to see what services are available.
3. Samples from the same vehicle should be sent to different labs to test the consistency in reporting.
4. Samples should be selected by different sampling methods to determine if one method is better than another.
5. A trend analysis should be developed for several vehicles for use in further comparative analysis.

Any of these recommendations could be used to further the validation of the oil analysis process.

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Salvesen, C. G. (1980, Nov.). Engine condition defined by oil analysis. National Bureau of Standards Special Publication 584. 183-187.

Schwarz, Charles F. (1980, Nov). Used oil analysis: Past, present, future. National Bureau of Standards Special Publication 584. p.168-171.

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Appendix A

Correspondence Sent

Central High School

WATERLOO COMMUNITY SCHOOLS
Waterloo, Iowa 50701

1350 South Hackett Road
Telephone (319) 235-9591

March 6, 1984

Society of Petroleum Engineers of AIME
6200 North Central Expressway
Dallas, Texas 75206

Dear Sirs:

The students in the Auto Engines course at Central High, in Waterloo Iowa, are currently studying SPECTROSCOPIC OIL ANALYSIS of used engine oil and how it can be used to determine engine wear.

Your organization was selected because of your support of education. If you have information about USED OIL ANALYSIS and how it can be used to determine engine wear we would appreciate the following data:

1. Information about the sampling procedure and cost.

2. Information about the kinds of tests performed on the oil samples.

3. How test results are used to determine engine wear?

4. Any other information you might think relievant to our studies.

Thank you,

Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Central High School

WATERLOO COMMUNITY SCHOOLS
Waterloo, Iowa 50701

1350 South Hackett Road
Telephone (319) 235-9591

MARCH 6, 1984

Wear Check Internation
29-17 Connel Ct.
Toronto, Ontario M8Z5T7
Canada

Dear Sirs:

The students in the Auto Engines course at Central High, in Waterloo Iowa, are currently studying SPECTROSCOPIC OIL ANALYSIS of used engine oil and how it can be used to determine engine wear.

Your lab was listed in an article related to this subjet in the August 1977 Popular Science Magazine. If you are still processing oil samples to determine engine wear could you send us the following information:

1. Information about the sampling procedure and cost.

2. Information about the kinds of tests performed on the oil samples.

3. How test results are used to determine engine wear?

4. Any other information you might think relievant to our studies.

Thank you,

Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Central High School

WATERLOO COMMUNITY SCHOOLS
Waterloo, Iowa 50701

1350 South Hackett Road
Telephone (319) 235-9591

March 6, 1984

Analysis Laboratory
Wix Filters
P.O. Box 1967
Gastonia , NC 28052

Dear Sirs:

The students in the Auto Engines course at Central High, in Waterloo Iowa, are currently studying SPECTROSCOPIC OIL ANALYSIS of used engine oil and how it can be used to determine engine wear.

Your company was selected because the local auto machine shop, Lewis Motor, stocks your analysis kit. We have sent you a sample for analysis and in addition would like some additional data:

1. Information about the sampling procedure and cost.

2. Information about the kinds of tests performed on the oil samples.

3. How test results are used to determine engine wear?

4. Any other information you might think relievant to our studies.

Thank you,

Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Central High School

WATERLOO COMMUNITY SCHOOLS
Waterloo, Iowa 50701

1350 South Hackett Road
Telephone (319) 235-9591

March 6, 1984

Precision Diagnostics, Inc
777 Silver Spur Rd. Suite 132
Rolling Hills Estates, CA 90274
Att. Dept. 101

Dear Sirs:

The students in the Auto Engines course at Central High, in Waterloo Iowa, are currently studying SPECTROSCOPIC OIL ANALYSIS of used engine oil and how it can be used to determine engine wear.

Your company was selected because of a recent ad in Popular Mechanics magazine. This is the only ad the student found in any recent publication. We would like some additonal information about your service:

1. Information about the sampling procedure and cost.

2. Information about the kinds of tests performed on the oil samples.

3. How test results are used to determine engine wear?

4. Any other information you might think relievant to our studies.

Thank you,

Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Central High School

WATERLOO COMMUNITY SCHOOLS
Waterloo, Iowa 50701

1350 South Hackett Road
Telephone (319) 235-9591

MARCH 5, 1984

Quaker State Oil Refining Corp.
Attention: Mr. J. D. Berry Jr.
255 Elm Street
Oil City, PA 16301

Dear Sirs:

The students in the Auto Engines course at Central High, in Waterloo Iowa, are currently studying SPECTROSCOPIC OIL ANALYSIS of used engine oil and how it can be used to determine engine wear.

Your oil company was selected because many of our students use your products. If you have a testing program for determining engine wear through OIL ANALYSIS would you please send us the following data:

1. Information about the sampling procedure and cost.

2. Information about the kinds of tests performed on the oil samples.

3. How test results are used to determine engine wear?

4. Any other information you might think relievant to our studies.

Thank you,

Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

LIST OF CORRESPONDENCE

Ams-Oil, Inc.
Attention: Mr. Richard Amatuzio
Ams Oil Bldg.
2206 Winter Street
Superior, WI 54880

Ana Laboratories
111 Harding Avenue
Bellmawr, NJ 08030

Analysts Inc.
P.O. Box 2206
Rolling Hills Estates, CA 90274

Analysts Inc.
2910 Ford Street
Oakland, CA 94601

Analysts Inc.
820 E. Elizabeth Avenue
Linden, NJ 07036

Arco Petroleum Products Co.
Harvey Technical Center
400 East Sibley Blvd.
Harvey, IL 60426

Cleveland Technical Cemter
13600 Deise Avenue
Cleveland, OH 44110

Conoco Inc.
P.O. Box 1267
Ponca City, OK 74603

D-A Lubcicant Co., Inc.
1340 W. 29th St.
Indianapolis, IN 46208

Exxon Research and Engineering Co.
Attention: E.C. Younghouse
Linden, NJ 07036

Kendall Refininf Co.
Bradford, PA 16701

Lubricon
P.O. Box 348
Wharton, TX 77488

Martel Laboratories, Inc.
1025 Cromwell Bridge Road
Towson, MD 21204

Mobil Oil Corp.
Attention: Mr. Joe E. Penick
P.O. Box 1031
Princeton, NJ 08540

OSI Wear Analysis
6855 Jimmy Carter Blvd.
Norcross, GA 30071

Phillips Petroleum Co.
Attention: Mr. C.F. Cook
Keeler Ave. Between 4th/5th
Bartlesville, OK 74003

Precision Diagnostics, Inc.
777 Silver Spur Rd., Suite 132
Rolling Hills Estates, CA 90274
Attn: Dept. 101

Quacker State Oil Refining Corp.
P.O. Box 989
Oil City, PA 16301

Society of Petroleum Engineers
of AIME
6200 North Central Expressway
Dallas, TX 75206

Wear Check International
29-17 Connel Ct.
Toronto, Ontario M8z5T7
Canada

WIX Filters
Analysis Laboratory
P.O. Box 1967
Gastonia, NC 28052

Appendix B

Correspondence Received

D-A LUBRICANT COMPANY, INC.
1340 W. [illegible] ST. • INDIANAPOLIS, INDIANA 46208 • (317) 923-5321

OFFICE
TELEX 27-2224

LABORATORY
TELEX 27-2225

March 30, 1984

Mr. Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Dear Mr. Northey:

Thank you for your interest in our controlled lubrication service. D-A Lubricant has long been a leader in the field of used oil analysis and hopefully we can begin a program to suit your immediate and future needs.

As you requested, I am enclosing information on our used oil analysis program and a price list. If you desire further information, please contact me.

V. GLEN MAYFIELD - Director of Technical Services

Kendall® 55 MOTOR OIL

NDALL REFINING COMPANY • DIV. OF WITCO CHEMICAL CORPORATION • BRADFORD, PA 16701 814/368-6111

April 5, 1984

Mr. Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Dear Mr. Northey:

Kendall Lubricant Analysis System is made available to all Kendall customers with only the charge of $1.00 a sample bottle. The sample bottles and the necessary sample request forms are available through your local Kendall distributor, Boyer Petroleum, P.O. Box 633, Des Moines, Iowa 50303. Phone: 515-243-4450.

Attached you will find the information you requested with regard to sampling procedure, the actual analysis and interpreting the results of the analysis. Please feel free to duplicate any information which you may deem applicable to your class.

I hope you find this information helpful. If I can be of any further assistance please feel free to contact me.

Sincerely,

Gabe Giordano
Sales Engineer

cc: Cheever

GG/so

AMS/OIL Inc.

AMS/OIL BUILDING • SUPERIOR, WI 54880 • 715/392-7101

Synthetic Lubricants
and
Automotive Products

Quality of Life.

Personal Attention
Products

March 14, 1984

Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, IA 50701

Dear Mr. Northey:

In reference to your letter, AMS/OIL does not currently conduct its own oil analysis testing program, but refers dealers and customers to various independent laboratories. We can provide the following information:

Through Analysts, Inc., we provide sampling kits at our cost of 3 for $4.25. They are preaddressed. The customer pays a discounted price of $15.00 versus approximately $27.00, if he is not an AMS/OIL dealer or customer. We also suggest customers check locally in the yellow pages under "Laboratories - Testing".

Enclosed are copies of several articles on oil analysis which should answer your questions. Please advise if we can be of further assistance. Thank you for your interest in synthetic lubrication.

Sincerely,

AMS/OIL, INC.

Dan Mortensen
Customer Services Dept.
DM/sk

enclosures

Mobil Research and Development Corporation

P.O. BOX 1031
PRINCETON, NEW JERSEY 08540

March 20, 1984

Mr. Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Dear Mr. Northey:

I am replying to your March 5 letter to Mr. Joe Penick. We are pleased that your Auto Engines class is interested in the oil monitoring program at Mobil.

Regarding your questions about spectroscopic oil analysis, I have attached the following articles:

1. "Engine Oil Sampling."

2. "Engine Condition Defined by Oil Analysis," by Clifford G. Salveson, Mobil Oil Corporation.

3. "Diesel Engine Condition Through Oil Analysis," by K. A. Frassa and A. B. Sarkis, SAE paper 680759.

4. "Questions and Answers Regarding Wear Metal Analysis," Martel Laboratory Services, Inc., 1025 Cromwell Bridge Road, Baltimore, MD 21204.

The first article is an excerpt from a field test procedure that explains how to obtain a representative oil sample for testing. Items 2 and 3 describe Mobil's oil monitoring procedures, and how an oil analysis can be used to indicate engine and lubricant condition. Item 4 is a description of a spectroscopic oil analysis offered by a commercial laboratory for $12.00 per sample.

I trust that this information will be useful to you, and wish you and your students success at Central High.

J.R. Canada

c: J. E. Penick
0393B

Central High School

WATERLOO COMMUNITY SCHOOLS
Waterloo, Iowa 50701

1350 South Hackett Road
Telephone (319) 235-9591

Mr Northey -

Enclosed is a good article from Popular Science, copies of test reports, and the ad which details prices. Popular Mechanics will have an article in their April issue & Popular Car will have a feature article in their May issue.

The process is simple. ~~It~~ The customer receives a kit in a mailing carton. Oil is drawn into the container from the oil reservoir (engine or transmission) using the dip stick hole & the device provided. The oil is mailed to a lab and a computer printout will be sent in return.

Any other questions, please write. Thanks,

March 6, 1984

Precision Diagnostics, Inc
777 Silver Spur Rd. Suite 132
Rolling Hills Estates, CA 90274
Att. Dept. 101

Dear Sirs:

The students in the Auto Engines course at Central High, in Waterloo Iowa, are currently studying SPECTROSCOPIC OIL ANALYSIS of used engine oil and how it can be used to determine engine wear.

Your company was selected because of a recent ad in Popular Mechanics magazine. This is the only ad the student found in any recent publication. We would like some additonal information about your service:

1. Information about the sampling procedure and cost.

2. Information about the kinds of tests performed on the oil samples.

3. How test results are used to determine engine wear?

4. Any other information you might think relievant to our studies.

Thank you,

Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

P.S. I don't know the size of your class, but if you want them to buy kits for class purposes, I will sell you a dozen or more at our wholesale price which is 12.00 per kit.

OSI WEAR ANALYSIS
SERVICE OF OPTIMAL SYSTEMS INCORPORATED
P.O. BOX 1182 • ATLANTA, GEORGIA 30301

March 12, 1984

Mr. Nathan Northey
Automechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Dear Mr. Northey:

Thank you for your request for information on the oil wear analysis services offered by the Laboratory Services Division of Optimal Systems Incorporated.

OSI has offered oil wear analysis and lead analysis monitoring programs to both industry and government in the USA and abroad since 1968. During this time our staff has developed considerable experience and expertise in this field which, combined with our sophisticated laboratory equipment and computerized analysis systems, enables us to provide the most advanced oil wear analysis service available. The programs are effective in:

- Reducing Equipment Operating Costs
- Reducing Unscheduled Downtime
- Extending Equipment Life
- Establishing Maintenance Management Information

Several standard wear analysis packages are available and these are described in the enclosed literature.

In response to growing concern regarding diesel fuel, OSI has developed a diesel fuel quality assurance service, offering various, specific tests and a comprehensive analysis package for quality and content. Information on this service is also included in the literature.

Our own in-house computer system ensures efficient, rapid production of all sample reports to greatly assist and improve planning and preventive maintenance efficiency. Additionally, if desired, a quarterly report can be generated detailing location, equipment monitored, samples processed, equipment exhibiting defects, totals and percentages.

If, after reviewing the enclosed material, you have any questions, please do not hesitate to contact us. For your convenience our toll-free number is 1-800-241-6315. Thank you again for your interest, and we look forward to hearing from you.

Sincerely,
OPTIMAL SYSTEMS INCORPORATED

Mark F. Hankinson
Marketing/Technical Support

QUAKER STATE OIL REFINING CORPORATION

PENNSYLVANIA PETROLEUM PRODUCTS

OIL CITY, PA. 16301

March 14, 1984

Address Reply To:
Quaker State Oil Refining Corporation
Research Center
Box 989
Oil City, Pennsylvania 16301
814-676-2726

Mr. Nathan Northey
Automechanics Instructor
Central High School
1350 South Hackett
Waterloo, Iowa 50701

Dear Mr. Northey:

We are in receipt of your letter of March 5, 1984. As you requested, attached is information relative to our Customized Oil Maintenance Program (COMP). Many Quaker State users have found COMP to be beneficial in determining the condition of their engine and oil. We would be happy to analyze used oil samples that you send to us.

Under separate cover we are sending to you 10 prepaid COMP mailer kits and information forms so that you may begin sending samples to Quaker State. There is no charge for these 10 COMP kits.

Attached is a complete set of Quaker State product information bulletins, technical information bulletins and special memos. We hope this information will be interesting to you and your students.

Thank you for asking Quaker State. We look forward to hearing from you in the near future.

Very truly yours,

QUAKER STATE OIL REFINING CORPORATION

Joseph V. Brancato, Manager
Technical Services

JVB/bls
attach.

ARCO Petroleum Products Company
Harvey Technical Center
400 East Sibley Boulevard
Harvey, Illinois 60426
Telephone 312 333 3000

Research & Development

March 26, 1984

Mr. Nathan Northey
Auto Mechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Der Mr. Northey,

Your letter to Mr. Slack regarding engine oil analysis was forwarded to me for response.

I'm glad to hear that this most important subject has been included in your curriculum covering Auto Mechanics. A good understanding of lubricant analysis is essential to any quality, preventive maintenance program. Unfortunately, ARCO does not offer an oil analysis program of our own to our customers or the general public. Like many other lubricant suppliers, we rely on the many reputable fee laboratories across the country which specialize in this type of work, for our routine samples. For your information, I have included a tabulation of these labs, together with several good articles which address the other points you brought up in your letter.

Don't hesitate to contact me directly should you wish to elaborate on any subject discussed in the attachment. I'll do my best to find the additional information, if I can.

Yours very truly,

ARCO Petroleum Products Company

John M. Noreyko
Manager, Lubricants
Technical Service

JMN:sjv

ATTACHMENT

Research & Development Department

Conoco Inc.
P. O. Box 1267
Ponca City, OK 74601
(405) 767-3456

April 3, 1984

Mr. Nathan Northey
Auto Mechanics Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Dear Mr. Northey:

In response to your letter of March 5, 1984 requesting information concerning used-oil analysis, I have enclosed the following material which, hopefully will assist you and your students at Central High in your classes:

1. "Testing Used Engine Oils" by Oronite Division of Chevron Chemical Company.

2. A sample data sheet of Conoco Spectroscopic Analysis of a used oil.

3. A table showing the current costs of oil analyses conducted by a commercial lab.

4. A sample Conoco report of oil analysis.

I think these four items cover just about everything you need to know about used-oil analysis, and how it is used as an effective tool to monitor engine condition.

If I can be of further assistance, please do not hesitate to call me at 405-767-5584.

Sincerely,

Ted Naman
Research Engineer
Petroleum Technology Section
Petroleum Products Division

jlg/JG2
attachments

EXXON RESEARCH AND ENGINEERING COMPANY 63

P. O. BOX 51, LINDEN, N.J. 07036

PRODUCTS RESEARCH DIVISION

G. L. HARTING
Director
Lubricants & Specialties Research Laboratory

April 19, 1984

Spectroscopic Analysis
of Used Oils

Ref. No.: 84PR 344

Mr. Nathan Northey
Automechanic Instructor
Central High School
1350 S. Hackett
Waterloo, Iowa 50701

Dear Mr. Northey:

You inquired how Exxon Corporation uses analysis of used oils, especially with reference to determining engine wear. I will reply most specifically to the applications in the U.S.A.

Exxon Company U.S.A. has fleets of vehicles which are monitored for used oil analysis. In most cases the operating regions periodically check the spectrographic elements in used oils, generally at convenient local laboratories which measure wear metals. The main objective is to help predict incipient failures, e.g. engine bearings or rapid wear of other parts.

The list of spectrographic elements and their likely source is given in Table 1. The detrimental level for each element depends on oil drain interval, type of engine and parts, type of coolant and the makeup of additives used in oils. In general, it is best to establish normal levels of each element at the drain period. If there is only a slight change in the elements, then no problem is likely to exist. However, a sharp rise in concentration of an element is the best indicator of a potential problem.

The published literature includes a large collection of papers on the analysis of used oils, much of it emphasizes spectrographic analyses. I have attached copies of three papers which I believe may be useful for your program.

I trust that this information will help guide your students in this interesting course.

Very truly yours,

E. C. YOUNGHOUSE

ECY/esc
Attach.

Appendix C

Oil Analysis Request Forms

TAKE SAMPLE WHEN OIL IS "HOT"

NORTHLAND LABS
1000 RAINBOW DRIVE
WATERLOO, IA 50701
(319) 234-5586

Nathan Northey
NAME

DATE OF SAMPLE

, Waterloo
ADDRESS

3/13/84
DATE OF SAMPLE

1972 Toyota
MAKE UNIT NO.

2640
MILES/HRS ON OIL

Phillips 10W-40
TYPE OIL USED/MAKEUP OIL

43640
MILES/HRS ON UNIT

SAMPLE TAKEN FROM:
☒ ENGINE ☐ TRANSMISSION ☐ DIFFERENTIAL ☐ ________ LAB# ________ (Lab use only)

LUBRICANT ANALYSIS

TAKE SAMPLE WHEN OIL IS "HOT"

NORTHLAND LABS
1000 RAINBOW DRIVE
WATERLOO, IA 50701
(319) 234-5586

Nathan Northey
NAME

DATE OF SAMPLE

, Waterloo
ADDRESS

3/15/84
DATE OF SAMPLE

1981 Plymouth Reliant
MAKE UNIT NO.

2900
MILES/HRS ON OIL

Phillips 10W-40
TYPE OIL USED/MAKEUP OIL

35900
MILES/HRS ON UNIT

SAMPLE TAKEN FROM:
☒ ENGINE ☐ TRANSMISSION ☐ DIFFERENTIAL ☐ ________ LAB# ________ (Lab use only)

TAKE SAMPLE WHEN OIL IS "HOT"

NORTHLAND LABS
1000 RAINBOW DRIVE
WATERLOO, IA 50701
(319) 234-5586

Nathan Northey
NAME

DATE OF SAMPLE

, Waterloo
ADDRESS

3/15/84
DATE OF SAMPLE

1975 Ford Mustang II
MAKE UNIT NO.

10000
MILES/HRS ON OIL

Unknown
TYPE OIL USED/MAKEUP OIL

87130
MILES/HRS ON UNIT

SAMPLE TAKEN FROM:
☒ ENGINE ☐ TRANSMISSION ☐ DIFFERENTIAL ☐ ________ LAB# ________ (Lab use only)

LUBRICANT ANALYSIS

TAKE SAMPLE WHEN OIL IS "HOT"

NORTHLAND LABS
1000 RAINBOW DRIVE
WATERLOO, IA 50701
(319) 234-5586

Nathan Northey
NAME

DATE OF SAMPLE

ADDRESS

4/22/84
DATE OF SAMPLE

Ford F-250 , 1970
MAKE UNIT NO.

150
MILES/HRS ON OIL

Quaker State 10W-40
TYPE OIL USED/MAKEUP OIL

118,620
MILES/HRS ON UNIT

SAMPLE TAKEN FROM:
☒ ENGINE ☐ TRANSMISSION ☐ DIFFERENTIAL ☐ ________ LAB# ________ (Lab use only)

REQUEST FOR OIL ANALYSIS

Analysis Laboratory
WIX Filters
P.O. Box 1967
Gastonia, N.C. 28052

Request Nº 31342
Customer Sample No. 100
Date Feb. 23, 1984

Customer Name Nathan Northey

Street Address

City/State/Zip Waterloo, Iowa 50701

Phone No.

WIX Distributor Lewis Motor

Send Report To: [x] Customer [ ] Other (Specify)

Send Copy To:

Reason For Oil Analysis Excessive oil consumption

VEHICLE DATA

Equipment Make and Model Ford F-250 4x4 1970 Unit No.

Engine Make and Model Ford 360 V-8

Type of Fuel [ ] Diesel [x] Gasoline Leaded [ ] Gasoline Un-leaded
[ ] Propane [ ] Other (Specify)

Operating Period Since [x] New [ ] Rebuilt [ ] Miles 118,470 [ ] Hours

Type of Service [x] Over The Road [ ] Off-Highway [ ] Stationary Engine
[ ] Other (Specify)

Has WIX previously analyzed oil from this unit [ ] Yes [x] No

Is this the first time we analyzed oil for you [x] Yes [ ] No

OIL & FILTER DATA

Name and Brand of Oil Phillips 66 Trop-Artic SAE No. 10w-40

Current Oil Drain Period 118,470 Miles Hours

Current Filter Change Period 118,470 Miles Hours

Time Period This Oil Used 150 Miles Hours

Time Period This Filter Used 150 Miles Hours

Name and Brand of Make Up Oil Used Phillips 66 trop-Artic Quarts Added 2

Note: For complete analysis, sample of new oil being used must be sent in small bottle.

SEND WHITE COPY. KEEP YELLOW COPY FOR RECORDS.

COMP ANAYLSIS ON QUAKER STATE PRODUCTS ONLY

Quaker State comb
CUSTOMIZED OIL MAINTENANCE PROGRAM

INFORMATION FORM

Please Type or Print

(to be completed and returned with initial sample from every component)

Person to Notify: ______________________ Quaker State Distributor: ______________________

Company Name: ______________________

Address: ______________________

City: ______________________ Quaker State Salesman: ______________________

State: __________ Zip Code: __________

Telephone No.: AC (   ) __________

Unit No. __________ Year: ______ Make: __________ Model: __________
(Please Limit to 4 Digits)

Sample From:
- ☐ Engine
- ☐ Transmission
- ☐ Hydraulic
- ☐ Differential
- ☐ Convertor
- ☐ Planetaries
  - ☐ Left ☐ Front
  - ☐ Right ☐ Rear
- ☐ Other: __________

Fuel: ☐ Gasoline ☐ Diesel ☐ LPG

Above **components** from which sample was taken: Make __________ Model No.: __________

Total miles/hours on **component** __________ Last Overhaul __________ miles/hours

Oil Change Interval __________ miles/hours

Servicing: Oil Filter __________ miles/hours

Air Filter __________ miles/hours

Thermostat: ☐ Yes ☐ No

Temperature Range __________

Anti-Freeze: ☐ Yes ☐ No

Oil Cooler: ☐ Yes ☐ No

Sample Interval __________ miles/hours

Method of Samples:
- ☐ Drain (Mid-Stream)
- ☐ Dip-stick Pump
- ☐ Petcock
- ☐ Other __________

Crankcase Additive: ☐ Yes ☐ No

QUAKER STATE OIL (Type) __________ SAE GRADE __________

Describe any unusual operating conditions (such as extremely dusty or wet environments) and other pertinent data. Use back of sheet if necessary.

Signed: __________ Date: __________

COMP ANAYLSIS ON QUAKER STATE PRODUCTS ONLY

Form TS811

Appendix D

Oil Analysis Reports

** * ** ** ** ** WIX CORPORATION
*** *** ** * P O BOX 1967
* * ** ** ** GASTONIA, N C 28052
F I L T E R S

AN ANALYSIS OF NATHAN NORTHEY UNIT NO 00100 LAB CONTROL NO NNI00100
CONTAMINANT LEVELS IN
THE LUBRICATING OIL OF WATERLOO, IOWA 50701

REQUEST NO.	31342
TOTAL MILES	118,470
OIL MILES	150 H.

************************* ICAP EMISSION SPECTROPHOTOMETRIC WEAR METAL ANALYSIS *********************

ANALYSIS DATE	03-06-84
SILVER	0
ALUMINUM	7
CALCIUM	31
CHROMIUM	2
COPPER	50
IRON	115
MAGNESIUM	35
LEAD	784 o*
SILICON	24
TIN	0
ZINC	26

*************** ADDITIONAL OIL QUALITY TEST RESULTS ***************

SOLIDS	NONE
FUEL	7.2%
ANTIFREEZE	NONE
VISCOSITY	SAE 20-1
WATER	NONE

*************** COMMENTS AND RECOMMENDED ACTION ***************

THE INFORMATION BELOW IS PROVIDED TO HELP YOU INTERPRET THE TEST RESULTS AND RECOMMEND APPROPRIATE ACTION

1 . PLEASE REFER TO ABOVE CONTROL NUMBER WITH ALL FUTURE SAMPLES FROM THIS UNIT.
2. HIGH COPPER--POSSIBLE SOURCES: BEARINGS AND BUSHINGS, FILTER MESH SCREENS, OIL COOLER TUBES, ROCKER ARM AND WRIST PIN BUSHINGS, TIMING GEAR THRUST WASHERS, OIL PUMP DRIVE THRUST WASHERS, FUEL PUMP AND SERVICE-METER BUSHINGS.
3. SLIGHTLY HIGH IRON: POSSIBLE SOURCES: PISTON RINGS, CYLINDERS, ROLLER BEARINGS, VALVE TRAIN, CRANKSHAFT, CAMSHAFT, GEARS.
4 . SILICON--HIGH ABRASIVE DUST LEVEL CONTRIBUTES TO HIGH WEAR OF RINGS, PISTONS, CYLINDERS OR BEARINGS. INSPECT AIR CLEANER FOR CLOGGING, BYPASS, DAMAGE; CHANGE IF FAULTY OR SUSPECT. INSPECT FOR BENT OR DAMAGED AIR CLEANER HOUSING, SEALING SURFACES, DISCONNECTED OR DAMAGED AIR DUCTS, VACUUM LINES, INTAKE MANIFOLDS, FUEL FILTERS, BREATHER CAPS, OIL FILLER CAPS AND TUBE.
5. EXCESSIVE VISCOSITY CHANGE-POSSIBLE HIGH SOLIDS, WATER, OR FUEL DILUTION CONTENT. CHANGE OIL AND FILTER.
6 . GASOLINE-FUEL DILUTION. CHECK FOR CHOKING, RICH MIXTURE, TIMING AND PLUGS. COULD ALSO BE EXCESS IDLING, WORN RINGS, OR CYLINDERS. CHECK COMPRESSION IF OTHER EVIDENCE OF BLOW-BY OR WORN RINGS EXISTS.
7 . OTHER WEAR METALS APPEAR TO BE WITHIN ACCEPTABLE LIMITS FOR A SINGLE ANALYSIS OR WHERE NO WEAR RATE PATTERNS HAVE BEEN ESTABLISHED
8 . RESAMPLING AT REGULAR INTERVALS NEEDED TO ESTABLISH A WEAR RATE PATTERN

1000 RAINBOW DRIVE • POST OFFICE BOX 418 • WATERLOO, IOWA 50704 • TELEPHONE (319) 234-5586

70

Northland Products Company

MAIL TO: Mr. Nathan Northey
Central High School
Waterloo, Iowa

ATTENTION:

OIL ANALYSIS REPORT

MODEL	ID NO.	COMPARTMENT	OIL CHANGED	OIL ADDED	OIL TYPE/GRADE
PHILLIPS TROPARTIC 10W-40 REFERENCE OIL					

	LAB#	DATE TAKEN	SERVICE METER	HRS/MI ON OIL	PB	CU	FE	CR	AL	SI	SN	WATER	FUEL%	ANTI-FREEZE
1.	30	84/3/15	NA	NA	0	0	3	0	0	1	4	NA	NA	NA
2.														
3.														
4.														
5.														

1.

2.

3.

4.

5.

SPECIAL TESTS

VISCOSITY AT 100 = 94

SAE GRADE = 40

TOTAL SOLIDS =

TBN =

INFRA RED SCAN =

PB = LEAD
CU = COPPER
FE = IRON
CR = CHROMIUM
SI = SILICA
AL = ALUMINUM
SN = TIN

1000 RAINBOW DRIVE • POST OFFICE BOX 418 • WATERLOO, IOWA 50704 • TELEPHONE (319) 234-5586

Northland Products Company

MAIL TO: MR. NATHAN NORTHEY

ATTENTION:

OIL ANALYSIS REPORT

MODEL	ID.NO.	COMPARTMENT	OIL CHANGED	OIL ADDED	OIL TYPE/GRADE
TOYOTA 72		ENGINE			PHILLIPS 10W-40

	LAB#	DATE TAKEN	SERVICE METER	HRS/MI ON OIL	PB	CU	FE	CR	AL	SI	SN	WATER	FUEL%	ANTI-FREEZE
1.	32	84/3/13	2640	43640	69	13	5	0	0	1	4	NEG	NEG	NEG
2.														
3.														
4.														
5.														

1. DISREGARD LEAD IF USING LEADED GAS. WATCH COPPER NEXT SAMPLE
CONTAMINANTS NORMAL
2.
3.
4.
5.

SPECIAL TESTS

VISCOSITY AT 100 = 82
SAE GRADE = 30
TOTAL SOLIDS =
TBN =
INFRA RED SCAN =

PB = LEAD
CU = COPPER
FE = IRON
CR = CHROMIUM
SI = SILICA
AL = ALUMINUM
SN = TIN

1000 RAINBOW DRIVE • POST OFFICE BOX 418 • WATERLOO, IOWA 50704 • TELEPHONE (319) 234-5586

Northland Products Company

MAIL TO: NATHAN NORTHEY

ATTENTION:

OIL ANALYSIS REPORT

MODEL	ID NO.	COMPARTMENT	OIL CHANGED	OIL ADDED	OIL TYPE/GRADE
PLYMOUTH 81		ENGINE			PHILLIPS 10W-40

	LAB#	DATE TAKEN	SERVICE METER	HRS/MI ON OIL	PB	CU	FE	CR	AL	SI	SN	WATER	FUEL%	ANTI-FREEZE
1.	31	84/3/15	2900	35900	2	10	10	0	0	2	3	NEG	NEG	NEG
2.														
3.														
4.														
5.														

1. WEAR METALS & CONTAMINANTS NORMAL
2.
3.
4.
5.

SPECIAL TESTS

VISCOSITY AT 100 = 85

SAE GRADE = 30

TOTAL SOLIDS =

TBN =

INFRA RED SCAN =

PB = LEAD
CU = COPPER
FE = IRON
CR = CHROMIUM
SI = SILICA
AL = ALUMINUM
SN = TIN

1000 RAINBOW DRIVE • POST OFFICE BOX 418 • WATERLOO, IOWA 50704 • TELEPHONE (319) 234-5586

Northland Products Company

MAIL TO: Mr. Nathan Northey

ATTENTION:

OIL ANALYSIS REPORT

MODEL	ID NO.	COMPARTMENT	OIL CHANGED	OIL ADDED	OIL TYPE/GRADE
MUSTANG 75		ENGINE			NA

	LAB#	DATE TAKEN	SERVICE METER	HRS/MI ON OIL	PB	CU	FE	CR	AL	SI	SN	WATER	FUEL%	ANTI-FREEZE
1.	33	84/3/15	10000	87130	95	2	34	1	3	3	4	NEG	NEG	NEG
2.														
3.														
4.														
5.														

1. DISREGARD LEAD IF USING LEADED GAS. CONTAMINANTS NORMAL
2.
3.
4.
5.

SPECIAL TESTS

VISCOSITY AT 100 = 79

SAE GRADE = 30

TOTAL SOLIDS =

TBN =

INFRA RED SCAN =

PB = LEAD
CU = COPPER
FE = IRON
CR = CHROMIUM
SI = SILICA
AL = ALUMINUM
SN = TIN

NORTHLAND TECHNICAL
LABORATORIES

74

LUBRICANT ANALYSIS

P. O. BOX 418
1000 RAINBOW
WATERLOO, IOWA 50704

MAIL TO: Mr. Nathan Northey

Waterloo, Iowa 50702

ATTENTION:

OIL ANALYSIS REPORT

MODEL	ID. NO.	COMPARTMENT	OIL CHANGED	OIL ADDED	OIL TYPE/GRADE
Ford 250		Engine			Quaker St. 10W-40

	LAB# TAKEN	DATE METER	SERVICE ON OIL	HRS/MI	PB	CU	FE	CR	AL	SI	SN	WATER	FUEL%	ANTI-FREEZE
1.	78	84/4/22	150	118,620	100+	26	44	0	5	16		Neg.	Neg.	Neg.
2.														
3.														
4.														
5.														

REMARKS:

Lead and Copper hig, Aluminum and Silica marginal. May indicate bearing wear. Resample to verify.

SPECIAL TESTS		
VISCOSITY AT 100	=	64
SAE GRADE	=	30
TOTAL SOLIDS	=	
TBN	=	
INFRA RED SCAN	=	

PB = LEAD
CU = COPPER
FE = IRON
CR = CHROMIUM
SI = SILICA
AL = ALUMINUM
SN = TIN