



THE COMPLETE GUIDE TO FLUID ANALYSIS

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LUBRICANT ANALYSIS SERVICE

WHAT IS MONITOR™? Monitor™ Analysis is a service provided by Fleetguard through dealers to individuals or companies. The user removes the lube sample to be analyzed and submits sample direct to an independent laboratory to be analyzed. The laboratory will then report direct to the user or company that submitted the sample. A copy of each report is directed to the selling dealer.

WHY A LUBE ANALYSIS PROGRAM? Monitor™ provides Product Support when used as an Equipment Management Tool. It is a Preventive Maintenance – Diagnostic Tool which is a picture of the internal condition of a component or system without disassembly.

The **Objective of Lube** analysis is to maximize potential equipment reliability by:

- Finding minor problems so that minor repairs can be made before they become major failures
- Increasing **UpTime** with shorter repair times and preventing unscheduled downtime
- Pointing out oversights in maintenance programs so corrections can be made
- **Scheduling** of downtime for maintenance and repairs, thus preventing the schedule being determined, by equipment failures

To achieve the desired objective, a lube analysis program must establish a **TREND** for each component sampled.

TREND LUBE ANALYSIS All lube analysis programs like Monitor™ are designed to be a TREND analysis which is regularly scheduled (periodic) lube samples over a span of time. A TREND is a unique history over a period of time of what is happening to a unit in its application.

A TREND requires at least three samples:

- 1st Sample is of Some Value - A Reference Point
One sample can be a basic diagnosis of a condition that exists, but not a cause of Failure.
- 2nd Sample is of More Value -
- 3rd Sample is of Great Value - TREND established


With a TREND established, continuing the periodic samples tracks the unit's condition and gives an early Alert to problems. The span of time between the samples should be consistent to see a True Trend. The Lab Report history will show two types of Trends:

- Drain Interval TREND - when the lube sample is only taken just prior to a lube change. The test data will be fairly consistent when the Time on the lube is nearly the same for each sample from a good system. This is the normal TREND for engines with frequent lube drains.
- Accumulative TREND - when the lube sample is taken periodically from a component or system without a lube change. The test data values will be increasing with each sample, since the Time on the lube is increasing. This is normal for hydraulic systems and transmissions which use the same lube fill for a long span of time.

All Test Data on a sample is relevant to:

- 1 - Time on the **LUBE**, how long in service?
With time the lube is accumulating more and more and more.
- 2 - Time on the **UNIT**, how long in service?
Each system has a lifespan and at each plateau there are differences.

All **VALUES** on a **TREND** must be evaluated by these two Factors. Remember the amount of Make-up Lube added to a unit will affect the values on a Trend.



A **TREND** sets the stage for corrections to be made, to clean up and save before a **DISASTER**. It identifies the source of a problem and allows the corrections to be built around the **cause**. Too often only the obviously visual is repaired (the symptom) and the cause is not found.

One lube sample, for troubleshooting or taken after a failure, does **NOT** show the history of how the condition developed or how long it has existed, **ONLY** a **TREND** can do this. With Failure Analysis it is very difficult to reconstruct what caused the problem. The test data for a lube sample sometimes will fail to support the problem or failure, when the analysis service is used as a **ONE** sample failure analysis.

Using Monitor™ for **ONE** lube sample troubleshooting or failure analysis will, most of the time, provide a basic diagnostic picture of the condition that exists. At this point in time, a Lab Report is probably not required as the problem can be seen.

By waiting to use Monitor™ until there is a problem or Failure, the **True Value** and **Purpose** has been **lost**. Trend Lube Analysis as a Preventive Maintenance Tool will give an Early Alert so corrections can be made to prevent a major disaster.

Use Monitor™ to **schedule** maintenance and repair jobs, **reduce** repair times and cost, and **increase** equipment **uptime** and reliability.

**CORRECT RESPONSE
TO ABNORMAL
LAB REPORT**

These periodic samples monitor the operating condition of the system from which they were taken. The **OBJECTIVE** is an **EARLY ALERT** to an abnormal condition by a significant change in the **TREND**. The correct Response to an abnormal report is:

- 1st Perform maintenance or **minor** repairs to correct cause and resample again, at normal or half interval to monitor.
- 2nd Perform other diagnostic tests to confirm condition and possible cause of problem.

A sudden and significant increase in wear rates or contamination level from a previous sample seldom indicates an impending disaster. Normally a **minor** repair correcting a maintenance oversight will return the next sample to normal.

Disassembly of a component is **not** warranted on the basis of a lube analysis report only. There **must** be symptoms of a problem and/or other diagnosis performed which confirms the need for a disassembly.

Remember to check how long the lube has been in service. Wear metals and contaminants accumulate with **TIME**, the longer the lube is in service, the more there will be. A lube and filter change is the first thing indicated when wear metals and/or contaminants are abnormal, especially when the recommended drain interval is near or has been exceeded.

LUBE SAMPLING KITS

Monitor™ is the most advanced lubricant diagnostic service offered as an equipment preventive maintenance program for the parts and service departments. Monitor™ Lubricant Analysis provides a report from an independent lab to evaluate component wear.



HYDRAULIC FLUID ANALYSIS - CC2527

This kit includes all tests necessary to evaluate component wear and contamination, lubricant condition and deterioration **for all hydraulic systems, power shift and power shuttle transmissions.**

Tests include:

- Spectro-Analysis of 24 metals
- Percent of water contamination
- Lube viscosity @ 100 C
- Particle count per milliliter
- Infrared Analysis (checks for amounts of nitration and oxidation of the lube)



BASIC ENGINE ANALYSIS - CC2525

This kit includes all tests necessary to evaluate engine wear and contamination **for all types and makes of engines.** This kit does not evaluate the condition of the lubricant itself. Tests include:

- Spectro-Analysis of 24 metals
- Fuel dilution
- Soot Contamination
- Percent of water contamination



EXTENDED OIL DRAIN ANALYSIS - CC2543

This kit includes all tests necessary to evaluate engine wear and contamination **for all types and makes of engines.** This kit does evaluate the condition of the lubricant itself. Tests include:

- Spectro-Analysis of 24 metals
- Fuel dilution
- Soot Contamination
- Percent of water contamination
- Viscosity @ 100° C
- Total Base Number or Total Acid Number

LUBE SAMPLING KITS (CONTINUED)



ENGINE FAILURE ANALYSIS - CC2544

This kit includes all tests necessary to evaluate component wear and contamination, lubricant condition and deterioration **for engines and non-engines.**

Tests include:

- Spectro-Analysis of 24 metals
- Percent of water contamination
- Lube viscosity @ 100 C
- Particle count per milliliter
- Infrared Analysis (checks for amounts of nitration and oxidation of the lube)
- Total Base Number or Total Acid Number
- Analytical Ferography
- Fuel dilution
- Soot contamination



ENGINE OIL ANALYSIS WITH PRE-PAID MAILER - CC2528

This kit includes all tests necessary to evaluate engine wear and contamination **for all types and makes of engines.** This kit does not evaluate the condition of the lubricant itself. Tests include:

- Spectro-Analysis of 24 metals
- Fuel dilution
- Soot Contamination
- Percent of water contamination

REPRESENTATIVE LUBE SAMPLE

Monitor™ like other TREND lube (oil) analysis services is designed to analyze USED lube samples to determine the condition of a component or system. As a lubricant flows through a component, it picks up and carries with it wear and contaminant particles. Therefore the lab can analyze a lube sample to determine if wear is normal or abnormal.

A lube sample **must** be **representative, timely** and **well-documented**.

- A good sample must be **representative** of the lube in service if the test data is to be meaningful. If sample cannot be taken during equipment operations, take the lube sample immediately after shutdown from a system which has been running at operating temperature for a period of time. This will insure the wear and dirt particles are suspended and not settled out, also that water or coolant has not separated from the lube. A lube sample taken from a cold system may be difficult to draw and invalid due to water condensation.

A lube sample is normally drawn through a plastic tube and should be taken from the **middle** of a reservoir or sump to make sure it is representative. Sludge, dirt and water will collect on the bottom and sampling there will give the impression that the circulating lube is in poorer condition than it really is. Sample port in return line to filter is better. Always take sample from same point under similar conditions.

- Since a lube sample indicates the condition of the component or system at the point in time it is taken, it is important to promptly send it for analysis. The longer the sample sits the less significant it becomes.

LUBE SAMPLES

- A sample must be fully documented with the Unit I.D., interval of time from previous sample, how long the unit has been in service, amount of make-up lube added, date sample was taken, type and grade of lube, operating conditions, and all the information requested on the Component Registration & Bottle Label.

Only when a sample is representative, timely, and well documented can you be sure of getting the most value for your investment.

USED LUBE SAMPLES

Monitor™ lube analysis, as a scientific approach to maintenance management, is designed to analyze **USED** lube samples for wear metals and contaminants. The purpose of Monitor™ is to establish and monitor the typical wear rates of the component or system from which the lube samples are extracted.

Monitor™ lab tests include only a minimum of the physical characteristics of a lube and do not evaluate any lubricant performance tests. Therefore, the Monitor™ lab **cannot** determine if a new lube sample is acceptable or correct for a given application.

NEW LUBE REFERENCE SAMPLE

A New Lube **Reference Sample** is just that, and has only one purpose - **comparison** to the test results of a USED lube sample.

1. To determine the possible source of some metals such as molybdenum, copper, silicon, etc., which may be in the new lube as an additive.
2. To evaluate what may have changed in the USED lube sample from the new lube.

Component Identification

When a unit or component is being “sampled” for the first time, it is necessary to complete and submit the enclosed registration form. Each component from each unit of equipment receives its own computer record. As lubricant samples are submitted, a permanent database record of evaluations is established for the unit or component (provided that multiple samples for each registered component are submitted during each twelve-month period). Therefore, proper component registration and regular samples are important in obtaining accurate “trend analysis” patterns.

Equipment

Since the Monitor™ lab is an independent laboratory, its expertise covers most makes and types of units and systems. Therefore, you can expect a thorough evaluation of most systems.

Lube Data

Check only the box for the component being sampled. ID slip only has mfr, model line, lube type and grade line for one component, therefore, only one component should be checked. A separate ID slip should be issued for each component or use F4 Form to submit all on one form. You may also pre-register components or systems on this unit which you intend to sample in the near future. The lube data requested is very important so the lab can accurately identify deterioration or improper lube mixing.

Application

Check only the box which best describes your usage of the unit being registered. This will assist in the evaluation of your lube sample as to how the working environment affects the unit and lube.

Failure to give all the information requested limits the Monitor™ lab in their evaluation of your lube samples.

BOTTLE LABELS



BEFORE taking the lube sample, fill in the information requested on the sample bottle label.

The labels for the sample bottles are different for each of the four kits. The bottle label identifies the component or system the lube sample was taken from and the analysis tests to be performed.

- A. The Customer Name and Unit I.D. must always be the same on samples from the same unit and agree with the Component Identification form.
- B. The most important history information concerning your lube sample must be supplied on the bottle label of each sample:
 - **Time on the LUBE**, how long has the lube been in service? With time the lube is accumulating more and more wear particles and is deteriorating more.
 - **Time on the UNIT**, how long has the unit or component been in service? Each system has a lifespan and at each plateau there are differences.

Example: A low value (PPM) with long hours = no or little concern.
The same value (PPM) with low hours = could represent a **PROBLEM**.

The accuracy of the Monitor™ lab's evaluation depends greatly on these two factors:

- **Time on the LUBE** (miles/hours since system drain)
 - **Time on the UNIT** (miles/hours on system)
- C. **Sample data** - all that is required is month and day (8/13) sample was taken from unit.

Unit Sampled Before? - If this is the 1st sample sent to Monitor™ lab, check the box for **NO**; if previous samples have been sent to Monitor™ lab check the box for **YES**.

Lube Changed at Sampling Time? - If the lube was changed after sample was taken, check the box for **YES**; if it was not changed, check the box for **NO**.

- D. Be sure to indicate the correct type of component or system the lube sample was taken from by checking the box.

REMEMBER the detail and accuracy you use in the Component Identification form and Bottle Label will result in better detail and accuracy in the evaluation of your lube sample by the Monitor™ lab.

The lab can analyze your lube sample and give you an opinion as to the unit's basic condition without the complete information requested, however, it may be a very limited evaluation due to missing data.

MONITOR™ REPORTS

Lubricant Evaluation Results - all evaluations are based on repetitive sampling “trend analysis” and are reported direct to you generally within two working days from the date the sample is received. Typically, samples received in the morning are processed and evaluated with a report issued the next or following work day.

If, in the opinion of laboratory, a questionable condition exists, they will contact you or your dealer by phone, fax or e-mail, thus the importance of completing your registration form and label attached to the lube container.

The back side of the report includes graphs to help identify trends.

The back side of the report includes graphs to help identify trends.

1

2

3

4

3

7

11

8

10

12

MonitorTM

FLUID ANALYSIS REPORT

www.fleetguard.com

1-800-22FILTER

(317) 808-3751 Fax

SEVERITY STATUS: ***

EQUIP ID: RGS #1 H

ALT ID: HYDRAULIC

CUSTOMER:

LOCATION:

UNIT TYPE: HYDRAULIC

APPLICATION: RAILROAD

MFR:

MODEL:

LUBE/FLUID MFR: CHEVRON

LUBE TYPE:

GRADE:

FILTER TYPE: FULLFLOW

BUMP CAPACITY: 80

HYD SYS PRESS:

MICRON RATING:

LUBE TIME:

UNIT TIME:

LUBE ADD:

DATE SAMPLED: 11/21/2000

DATE RECEIVED: 11/28/2000

DATE PRINTED:

ACT # 000000 0000 0000

LAB # 550605

COMMENT:

Filter change suggested (as applicable); or, Suggest using portable filtration; SIGNIFICANT INCREASE IN PARTICLE COUNT; Bushing/thrust metal and/or most of the copper may be coming from lube cooler (as applicable); SIGNIFICANT VISIBLE DEBRIS OBSERVED IN SAMPLE; Please provide missing lube information. We need manufacturer, type and grade to properly evaluate data for lube;

VALUES EXPRESSED IN PARTS PER MILLION (PPM) BY WEIGHT

WEAR METALS				CONTAMINANT METALS				MAXI-METAL				ADDITIVE METALS				
IRON	COPPER	ALUMINUM	SILICON	CHROMIUM	COBALT	NICKEL	LEAD	IRON	COPPER	ALUMINUM	SILICON	CHROMIUM	COBALT	NICKEL	LEAD	
70	1	1	1	114	21	1	0	0	6	3	2	1	0	0	0	0
56	1	0	1	98	21	0	0	0	4	2	2	1	0	0	0	0
36	0	0	0	134	4	0	1	0	3	1	1	0	0	0	0	0
40	0	0	0	128	4	0	1	0	3	1	0	0	0	0	1	0

TEST DATA

SAMPLED	LUBE	MOC	FRC	-OOW	-PM	V	V	T	T	I-R	I-R	O-H	O-H	I-H	I-H	I-H	I-H	I-H	I-H	I-H	I-H	I-H	I-H	
																								RECEIVED
6/26/98		NO			<.1	6.4				13	13	21	19		15000	8331	4075	1986	501	163				
7/20/98		NO			<.1	6.2				39	39													
7/27/98		NO			<.1	6.2																		
9/13/00	8657	NO			<.1	6.2				19	0	22	20	17	25239	9459	3015	1133	542	158	52	25		
9/21/00	8657				<.1	6.3				20	5	22	22	20	32580	24731	15387	7788	3801	1132	394	174		
11/21/00		UNK			<.1																			
11/28/00																								

Comments are advisory only and are based on the assumption that the sample and data submitted are valid. Missing lube or unit time limits the evaluation. No warranty is expressed or implied. **Polaris** 1999



HOW TO READ THE REPORT

Understanding a Monitor™ Lab Report is easy.

FIRST determine the importance you should place on the report by the Severity Code status assigned.

SECOND identify the unit by the ID number and the Unit Type for the component or system.

THIRD read the laboratory's recommendation and suggested actions in the Comment section, which are based on the test results.

1. SEVERITY CODE:

- **** Critical situation - Requires high degree of concern and immediate corrective action.
- *** Unsatisfactory condition - Requires corrective maintenance action very soon.
- ** Watch condition - Minimum degree of concern - May require some minor maintenance action or Watch to see what happens with next sample.
- * Satisfactory condition

2. UNIT I.D.

Customer: Customer's identity
Location: Customer city/town
Unit Type: Component name relating to sample
Application: Equipment application
MFR: Manufacturer or equipment
Model: Identifies manufacturer's model
Lube MFR: Lube brand
Type/Grade: Manufacturer's lube type and grade
This information comes from a completed ID Slip with first sample sent to Lab

3. COMMENT

Comments by laboratory consultant on lube sample analyzed

4. LUBE SAMPLE HISTORY from Bottle Label (Information taken from bottle label)

Sample Date: Date you removed the sample
Lube: Inservice hours or miles
Unit: Total operating hours or miles
Make-up Lube: If any was added, and you reported
Lab #: Number assigned to report by laboratory
Report Date: Date report was printed

5. NAME AND ADDRESS of Monitor™ dealer to provide product and service support

6. FIRST COLUMN:

Date sample was taken
Date sample was received at laboratory

SECOND COLUMN:

Lube inservice hours or miles at time of sample
Total unit operating hours or miles at time of sample

7. TEST DATA - lube analyzed in parts per million by weight related to wear metals, contaminant metals, additive metals, non-metallic contaminants, and lube data.

8. NOTE: - There is space provided to record laboratory analysis of 5 samples. When the 6th sample is submitted, it will be recorded on the last or 5th line on each report. The record entry for the first sample will be removed from the report. This process will continue each time a sample is submitted on the same unit or same component.

HOW TO READ THE REPORT (CONTINUED)

10. DATE Column repeats sampled date and received data from (Area 6)
CHG - was lube changed after sample was taken?

N = NO, Y = YES, U = UNKNOWN

NOTE: This information comes from Bottle Label

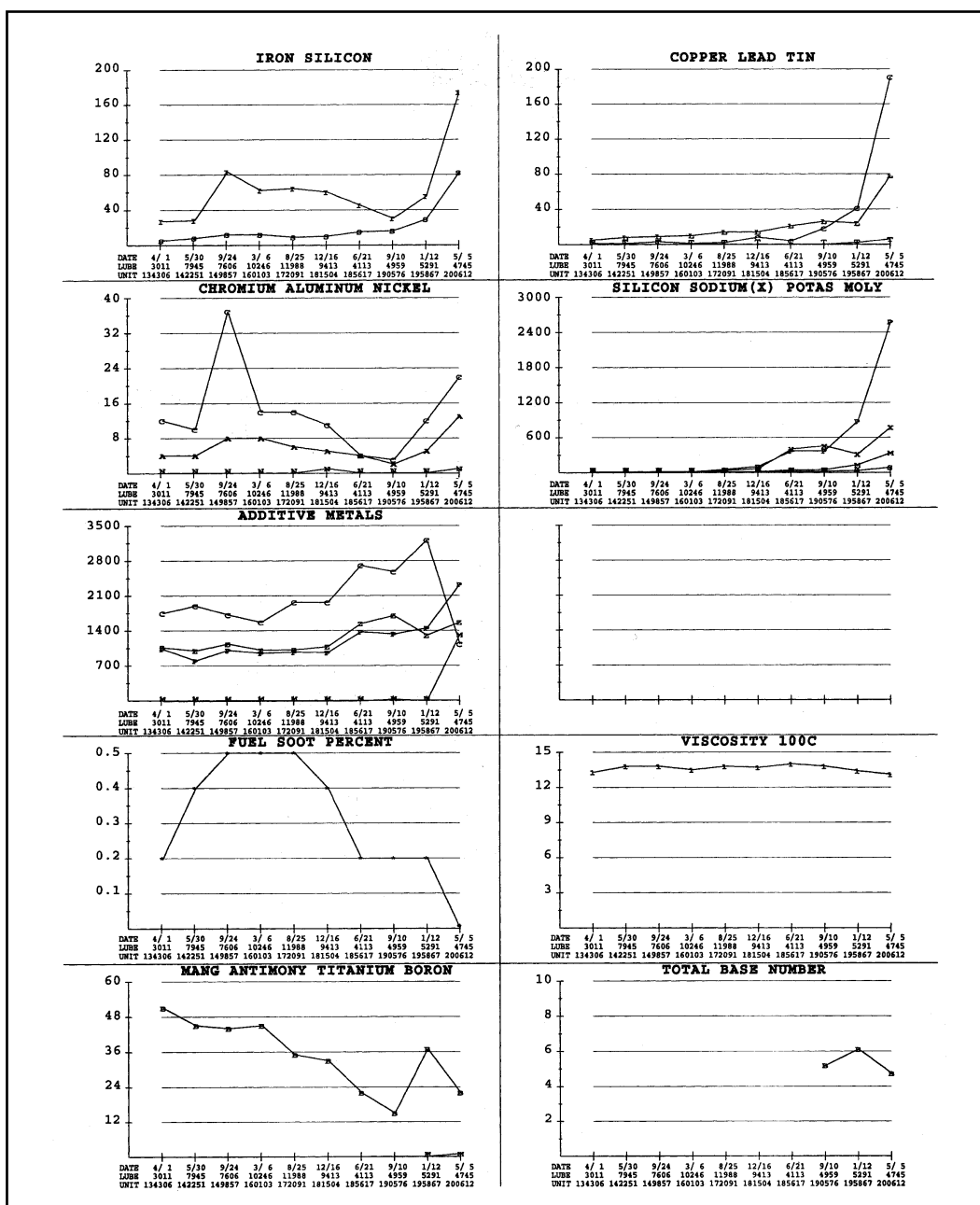
11. PC/ml = PARTICLE COUNT PER MILLILITER

Particle count and micron sizing. Elevation and trend from previous samples with 4-6-10-14-21-38-70-100 micron size particles.

12. IR = Infrared

Infrared reporting on oil condition.

All reports are organized in the same format. The following illustration represents reporting. The Test reported are based on the kit purchased.



SAMPLING INSTRUCTIONS

WHEN TO SAMPLE

ENGINES:

Just prior to oil drain - consult your equipment operator's manual for change interval recommendations.

MECHANICAL TRANSMISSIONS, DIFFERENTIALS, FINAL DRIVE/PLANETARY:

Just prior to oil drain, but at least every five hundred hours of operation, but not less than three times annually.

HYDRAULIC SYSTEMS, POWERSHIFT TRANSMISSIONS:

Just prior to oil drain, but at least every five hundred hours of operation, but no less than three times annually.

WHERE TO SAMPLE

IMPORTANT:

Ensure that the system you are sampling has been well circulated in order to obtain a true representative sample. Dirt, system debris and water tend to settle out to the bottom of the reservoir, while light fuels tend to float on the lubricant. Take all lubricant samples immediately after shut-down for a representative test result. Always take samples in the same manner.

WARNING:

Clean all lubricant access areas prior to sampling. Assemble sampling tools and materials in a clean area. Follow these precautions to eliminate any contaminants from entering the sampling tools, bottle or system reservoir.

Engine

To obtain engine oil sample, engine must be at operating temperature. Draw lubricant samples through the dipstick retaining tube or sampling valve installed in filter return. Never take samples from a drain pan or a drain plug!



Mechanical Transmissions, Differentials, Final Drive/Planetary

To obtain lubricant samples, the system must be at operating temperature. Draw lubricant samples through oil level check-point or through dipstick retaining tube, whichever is provided. Consult your equipment Operator's Manual for these locations.



SAMPLING INSTRUCTIONS (CONTINUED)

Hydraulic Systems

To obtain hydraulic fluid sample, the system must be at operating temperature. Draw fluid sample through the oil fill port of the system reservoir. Ensure that the sample is drawn from the mid-level of the reservoir. Be sure the sample you take is a representative lube sample of the reservoir condition and is not being taken from the inside of a screen or filter element. (Example some Excavators). **CAUTION:** Some hydraulic reservoirs are pressurized. Relieve pressure before sampling. Engine should not be operated when a pressurized system is open. Consult your equipment operator's manual for hydraulic system precaution.



Powershift Transmission

To obtain lubricant sample, the transmission must be at operating temperature. Draw lubricant sample from oil level plug, or through dipstick retaining tube, whichever is provided. Consult your equipment operator's manual for this location.

Final Drive

Final Drives (For Equipment With Final Drive Lube Reservoir Independent From all Other Systems): Must be at operating temperature. Draw lubricant sample from oil level plug. Consult your equipment operator's manual for this location.



NOTE: Any pressurized system may have a sampling port installed in a return line if convenient for sampling.



HOW TO SAMPLE

DETAILS FOR DRAWING LUBRICANT SAMPLES

Carefully unpack contents of sampling kit. Place material on a clean surface. *Monitor™ Sample Kit does not include pump, QuickDraw, or tubing.



CC2802 Vacuum Pump

COMPLETE UNIT REGISTRATION FORM AND BOTTLE LABEL

Complete the unit or component registration record form. It must be included with your initial lubricant sample. Complete the information requested on a sampling bottle.



CAP THE SAMPLE

“CAP” the sample bottle with the sealing cap. Place the sample in the safety shipping bottle. Clean and store the suction device for future use.



COMPLETE THE SHIPPING CARTON

Complete the mailing label return address and attach to mailer jar. Insert the lubricant sample and registration form, affix appropriate first class postage and mail. If a critical condition is discovered, you or your dealer will be notified immediately by phone, fax or e-mail.



TECHNICAL NOTES

SPECTROMETRIC METALS There are any number of metallic elements to be found in used lubes, but they can be generally grouped into four basic categories.

- **Wear Metals:** The product of friction, corrosion, and/or deterioration of components within a given unit:

Metal	Engines	Transmissions	Gears	Hydraulics
Iron	Cylinder liners, Rings, Gears, Crankshaft, Camshaft, Valve Train, Oil Pump Gear, Wrist Pins	Gears, Disks, Housing, Bearings, Brake Bands, Shaft	Gears, Bearings, Shaft, Housing	Rods, Cylinders, Gears
Chrome	Rings, Liners, Exhaust Valves, Shaft Plating, Stainless Steel Alloy	Roller Bearings	Roller Bearings	Shaft
Aluminum	Pistons, Thrust Bearings, Turbo Bearings (Cat)	Pumps, Thrust Washers	Pumps, Thrust Washers	Bushings, Thrust Plates
Nickel	Valve Plating, Steel Alloy from Crankshaft, Camshaft, Gears from heavy bunker type diesel fuels	Steel Alloy from Roller Bearings & Shafts	Steel Alloy from Roller Bearings & Shafts	
Copper	Lube Coolers, Main & Rod Bearings, Bushings, Turbo Bearings, Lube Additive	Bushings, Clutch Plate, (Auto/Powershift) Lube Coolers	Bushings, Thrust Plates	Bushings, Thrust Plates, Lube Cooler
Lead	Main & Rod Bearings, Bushings, lead Solder	Bushings (Bronze Alloy), Lube Additive Supplement	Bushings (Bronze Alloy), Grease Contamination	Bushings (Bronze Alloy)
Tin	Piston Flashing, Bearing Overlay, Bronze Alloy, Babbitt metal along with Copper & Lead	Bearing Cage Metal	Bearing Cage Metal, Lube Additive	
Cadmium	N/A	N/A	N/A	N/A
Silver	Wrist Pin Bushing (EMD's), Silver Solder (From Lube Coolers)	Torrington Needle Bearings (Allison Transmissions)	N/A	Silver Solder from Lube Coolers
Titanium	Gas Turbine Bearings/hubs/blades, Paint (White Lead)	N/A	N/A	N/A
Vanadium	From heavy bunker type diesel fuel	N/A	N/A	N/A



Multisource Metals are Highly Dependent on the Application and Environment

- **Contaminant Metals:** Abrasives, dirt; contaminated lube storage; casting sand or metal from manufacture; coolant additive metals, etc.:

Metal	Engines	Transmissions	Gears	Hydraulics
Silicon	Dirt, Seals & , Sealants Coolant Inhibitor, Lube Additive (15 ppm or less)	Dirt, Seals & Sealants Coolant Inhibitor, Lube Additive (15 ppm or less)	Dirt, Seals & Sealants Coolant Inhibitor Lube Additive (15 ppm or less)	Dirt, Seals & Sealants Coolant Inhibitor Lube Additive (15 ppm or less)
Sodium	Lube Additive, Coolant Inhibitor, Salt Water Contamination, Wash Detergents	Lube Additive Coolant Inhibitor, Salt Water Contamination, Wash Detergents	Lube Additive, Coolant Inhibitor, Salt Water Contamination, Airborne Contaminant	Lube Additive, Coolant Inhibitor Salt Water Contamination, Airborne Contaminant
Lithium	Coolant Inhibitor, Airborne Contaminant	Coolant Inhibitor, Airborne Contaminant	Coolant Inhibitor, Airborne Contaminant	Coolant Inhibitor, Airborne Contaminant

- **Multi-Source Metals:**

Metal	Engines	Transmissions	Gears	Hydraulics
Boron	Ring Plating, Lube Additive, Coolant Inhibitor	Lube Additive, Coolant Inhibitor,	Lube Additive, Coolant Inhibitor, Grease Additive	Lube Additive, Coolant Inhibitor
Antimony	Lube Additive,	Lube Additive	Lube Additive,	Lube Additive,
Maganese	Steel Alloy,	Steel Alloy	Steel Alloy,	Steel Alloy
Lithium	N/A	Lithium Complex Grease	Lithium Complex Grease	Lithium Complex Grease

Metals placed in the lubricant by the blender to achieve beneficial effects:

- **Additive Metals:**

Metal	Engines	Transmissions	Gears	Hydraulics
Magnesium	Detergent Dispersant Additive, Airborne contaminant	Detergent Dispersant Additive, Airborne contaminant	Detergent Dispersant Additive, Airborne contaminant	Detergent Dispersant Additive, Airborne contaminant
Calcium	Detergent Dispersant Additive, Airborne contaminant, Contaminant from water	Detergent Dispersant Additive, Airborne contaminant, Contaminant from water	Detergent Dispersant Additive, Airborne contaminant, Contaminant from water	Detergent Dispersant Additive, Airborne contaminant, Contaminant from water
Barium	Lube Additive	Lube Additive (rare)	Lube Additive (rare)	Lube Additive (rare)
Phosphorus	Anti-Wear Additive (ZDP)	Anti-Wear Additive (ZDP) EP Additive (Extreme Pressure)	Anti-Wear Additive (ZDP) EP Additive (Extreme Pressure)	Anti-Wear Additive (ZDP)
Zinc	Anti-Wear Additive (ZDP)	Anti-Wear Additive (ZDP)	Anti-Wear Additive (ZDP)	Anti-Wear Additive (ZDP)

TECHNICAL NOTES (CONTINUED)

It is necessary to monitor all of these metal types to fully evaluate a system.

The situation is far from this simple, however, because every metal can at least fit into two categories, some into all three. Furthermore, there are not only engines to consider, but gears, compressors, hydraulics, and the same metals have different meanings in each of these subcategories. Even further complexities exist because different manufacturers utilize different metallurgies, oil companies different additives, and coolant additive manufacturers different materials.

The case of SILICON is perhaps the most complex and interesting. It first may be found up to 15 ppm as silicone polymer defoamant. It may also be found as a major constituent of certain synthetic lubes. It is, of course, found as "dirt" or abrasives. It can be found as a constituent in certain preparatory agents used to lubricate or seal at manufacture. It can be found as a constituent in silicon rubber gaskets or seals. Finally, it can also be found in certain coolant additives - its presence in the lubricant might, therefore, be indicative of a coolant leak. In most situations, an experienced consultant can pin down the source of silicon to a single possibility by evaluating the remaining test data.

Nearly everyone would like to know "limits" for metals, particularly the WEAR variety. It is the WEAR metals, in particular, however, which cannot be assigned GENERIC limits because every piece of equipment develops its own unique wear rate. For this reason chronological, cumulative histories are kept on each individual piece of equipment - in this way we can monitor WEAR RATE or, more precisely, the CHANGE IN WEAR RATE from sample to sample. We do use formulae for monitoring change in wear rates, but these are proprietary. They vary according to manufacturer, model and application among several other items. Make-up lube addition also plays a role in the wear metals concentrations derived.

CONTAMINANT metals can be assigned loosely defined "rule-of-thumb" limits, but, once again, manufacturer and application influence our tolerances.

ADDITIVE metals let us know a great deal about the nature of the additive package placed in the lube. We can usually identify the type of product in use and continue to monitor the quality control of that product as new batches are received.

NOTE: It is recommended that each batch of new lube be tested for spectrometric metals for a baseline. We then monitor the additive metals for relative consistency from sample to sample, assuring customers that the correct lube is being utilized. Such baseline testing is recommended a minimum of every six months.

Other References: SAE Paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

FUEL CONTAMINATION FUEL CONTAMINATION is a measurement of unburned fuel found in the crankcase/sump of liquid-fueled reciprocating engines (LFREs), although there are some specialized application for "fuel" detection. One example might be the desire to measure solvent thinning of hydraulic fluids. Another example would be to spot saturated ("wet") gas engine fuel.

Every LFRE will have a certain amount of raw fuel in its blow-by. Usually the heat of the engine evaporates volatile portions of this fuel at a rate producing an equilibrium (a stable level of fuel contamination). If an equilibrium is not reached, or too high an equilibrium percentage is maintained, there is a problem: leaking injectors, faulty carburetor floats, leaking injector seals, pumps or jumper lines, worn rings, etc.



In over-the-road (OTR) diesel applications, 1.5-2.0% or lower is typical. An pick-up-and-delivery (P & D) application features a much higher percentage of idle time, consequently the engine lube tends to remain too cool to evaporate fuel properly. Further, and particularly true of carbureted fuel systems, there is a distinct over-fueling condition at low idle speeds, which could also contribute to a higher fuel contamination level. In diesels, however, such contribution is usually negligible since fuel is more proportionately metered with injected vs. carbureted systems.

Occasionally there will be units which consistently show fuel contamination levels above 4.0% owing to extremely concentrated P & D work. Under these circumstances no corrective action, short of altering the application in which the engine is used, will prevent such results.

Excessive fuel contamination must be controlled because lube film strength decreases, adding to the risk of abnormal wear, particularly in the ring/cylinder region. There is also the distinct danger of a crankcase explosion at levels beyond 7%.

The independent laboratory utilizes an FTIR (Fourier-Transform Infrared) Spectrometer to measure fuel contamination.

***Technical Point:** Lubes and fuels both emanate from the same source: crude oil. Fuels are the more volatile portion of the crude product. It is important to understand that fuel does not possess a distinct boiling temperature as does, for example, water, ethyl alcohol, acetone, for it is not a “pure” product or compound. It is a mixture of petroleum products within a boiling RANGE.

A typical ASTM #2D diesel fuel might have an initial boiling temperature of 150° C at standard sea level atmospheric conditions, but as the product is carried over to the distilling receiver, the temperature required to boil the fuel continually increases. A typical ending temperature might be well over 300° C.

ALL fuel contamination detection methods must necessarily be estimates of the TRUE fuel level.

Other References: SAE paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

SOOT CONTAMINATION SOOT represents a measurement of Carbon Combustion By-Products in the lube system.

Diesel Engine Soot develops from incomplete combustion and is blown past rings and valve guides as a normal operational process. It is finely divided carbon, oftentimes less than a micrometer in size and is the cause of routine lube blackening. Lube additive dispersants also play a role in lube blackening as they maintain much of the generated fuel soot in suspension rather than allow it to be filtered.

Proper filtration helps control fuel soot, especially when particles combine with themselves (agglomerate) to form larger particles.

TECHNICAL NOTES (CONTINUED)

Sources of excessive soot in diesel systems include:

1. Over-fueling or restricted air intake
2. Poor injector spray pattern (plugged nozzle, etc.)
3. Worn rings, valve guides, turbocharger or supercharger seals
4. Oxidized fuel and lube products* (poor timing, poor fuel or lube)
5. Plugged or inoperative lube filters

Usually recommendations are for corrective action or drains at or near 3.0% soot in most diesel systems, but the decision to render advice is also based on the unit's pattern on an individual basis as well.

WATER CONTAMINATION

It is recommended that samples be taken when a unit is at operating temperature, or has been shut down for only a short while. As well as providing the most representative sample, it minimizes chances of obtaining samples with condensate water (unless there is a problem with systems using water traps).

Water should not normally be found in most systems at levels above 0.1% (1000 ppm), provided samples are taken correctly. Oftentimes, the laboratory detects metallic coolant additives rather than water because the water is continually evaporated by a unit's heat. When water is detected, these same metals aid in qualifying the source (coolant/condensate/etc.; salt or fresh water in marine situation).

Exemplary Metals Combinations

Chromium	Silicon	Sodium	Boron	Magnesium	Phosphorus	Possible Evaluation
		X	X	OR	X	Washing Compound (e.g. Truck Washrack)
		X				Salt Water or Coolant
		X		X		Sea Water
X		X				Chromate Coolant Treatment
		X	X			Coolant/Glycol
	X	X	X			Coolant/Glycol
	X	X				Coolant/Glycol

Other References: SAE Paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)



VISCOSITY VISCOSITY OF A LUBRICANT IS A MEASURE OF ITS RESITANCE TO FLOW WITH RESPECT TO TEMPERATURE. Two things are therefore necessary in reporting viscosity: a) temperature at which the viscosity is measured; b) the amount of time units for a given amount of the flow through a given passage.

The two most common temperatures for motor oil viscosity are 40° C and 100° C (formerly 100° F and 210° F respectively). The units reported are CENTISTOKES, abbreviated cSt or cs . The change in viscosity temperatures is the result of an effort to standardize to a common world system; essentially it is metrication of the viscosity reporting system.

VISCOSITY INDEX IS THE CHANGE IN RESISTANCE TO FLOW OF A LUBRICANT WITH RESPECT TO TEMPERATURE. As a lube is heated it will get “thinner” (its viscosity will decrease). The amount of thinning which takes place over a given temperature span can be expressed as VISCOSITY INDEX (VI), a term expressed as a number without units. The less tendency a lube has to thin with temperature increase, the greater is VI. Determination of VI requires two viscosities at different temperatures (usually 40° C and 100° C).

SIGNIFICANCE OF VISCOSITY: There are numerous references which cite that the viscosity of a lube is its most important single property, and perhaps this is true, at least when the lube is new. By itself, however, a viscosity does not nearly qualify a lube. It basically defines the film thickness the lube will have for a given application. New lubes placed in engines or other machinery should be inspected for correct initial viscosity. Assuming no errors are made with the initial fill, the following factors can influence viscosity:

Downward Liquid fuel contamination
Non-emulsified water contamination
Shearing of VI-improving polymers
Wrong make-up lube addition

Upward Soot contamination
Certain emulsions with water
Lube oxidation/degradation
Wrong make-up addition

Most modern lubes, particularly engine lubes, are “oxidation-stable” under standard drain intervals so that, unless extended drains are contemplated, it is better to observe the contamination which influences viscosity rather than the viscosity itself. It is possible to have combined contamination such that viscosity remains stable, but an abnormal situation exists (e.g. high fuel and solids). For this reason, the laboratory DOES NOT ROUTINELY DETERMINE VISCOSITY UNLESS EXTENDED DRAINS ARE CONTEMPLATED, for it has limited value in detecting fuel contamination and is oftentimes misleading.

On the other hand, INCREASED VISCOSITY, IN THE ABSENCE OF FUEL OR OTHER CONTAMINATION, WILL USUALLY INDICATE LUBE OXIDATION/ DEGRADATION, and the viscosity is the most convenient means to measure this with reasonable effectiveness. VISCOSITY, along with neutralization number, SHOULD ALWAYS BE REQUIRED BY CUSTOMERS WISHING TO SAFELY EVALUATE EXTENDED LUBE DRAINS.

TECHNICAL NOTES (CONTINUED)

Standard SAE grading for MOTOR oils	SAE Motor Oil Grade or Number Viscosity @ 100° C
	20 Appx. 5.6-9.2 cs
	30 Appx. 9.3-12.4
	40 Appx. 12.5-16.2
	50 Appx.16.3-21.8

It should be noted that 100° C is the ONLY temperature to be used in classifying motor lube by SAE grade. Also note that there are no MOTOR lube grades below 20 or above 60.

There is also no such legitimate term as “weight” (e.g. “30 weight”). The “W” designations found on certain cans or drums refers to a -18° C viscosity requirement for the particular product, and should always be followed by a number (20, 30, 40, or 50) indicating the grading for 100° C. This pertains only to motor lubes. Gear lubes and specialty lubes have other systems for viscosity grading which do not necessarily relate to motor lubes.

It is reasonable to expect a lube to increase at least one grade (e.g. 30 SAE to 40 SAE) during typical drain intervals. This occurs because of routine lube oxidation and the evaporation of more volatile constituents in the lube. Solids, of course, will also contribute. VI-improving polymers are synthesized materials which artificially thicken lubes as temperature increases. They exhibit this ability due to their physical form at various temperatures. At lower temperatures their molecules are very compressed, offering little resistance to lube flow. At elevated temperatures these molecules spread out to their full physical length, impeding flow, or “thickening” the lube. Shearing of these polymers is the actual cutting of the molecular chain into shorter chains, an action which can occur between two rubbing surfaces in the system. Heat also contributes to this phenomenon. In the shorter state these chains no longer impart a thickening effect to the lube, and the polymer is said to have been “sheared”. The lube, consequently, is more nearly as it was prior to polymer treatment and may then fail to have sufficient viscosity at operating temperature.

Expected Ranges of Other Lubes	MIN. cs. @ 100° C	MAX. cs. @ 100° C
ATF (automatic transmission fluids)	5.5	8.5
Hydraulic Fluids (typical tractors)	5.5-9.8	7.0-13.0
90 SAE Axle/Manual Transmission	13.5	23.9
140 SAE Axle/Manual Transmission	24.0	40.9
250 SAE Axle/Manual Transmission	43.0	77.0

Other References: SAE paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

ADDITIVES A motor lube consists of two major parts: BASE STOCK (or BASE “OIL”) and ADDITIVE. The BASE STOCK is the primary lubricant and can be petroleum or synthetic. The ADDITIVE is usually a laboratory or synthesized product, or combination of products, which enhances the BASE STOCK’S performance.

Together the BASE STOCK and ADDITIVE make up the “finished lubricant”. Usually the ADDITIVE comprises less than 20% of the total lubricant volume, but there are not absolute limitations. A lube is qualified primarily by its performance not its additive quantities. Furthermore, the BASE STOCK is equally important to a lube’s performance.



Its chemical structure, resistance to oxidation, wax content, etc. are all critical factors, as well as its compatibility with the proposed additive package.

Detergents	As the name implies, these compounds help maintain engine cleanliness by preventing deposits on critical areas such as ring lands, or by removing such deposits. They also help maintain deposits such as fuel soot in suspension to be filtered out or drained with the lube. Metallic carriers are generally used (except where “ashless” lubes are required) to bring the non-metallic portion, which is the “detergent” part of the compound, to the lube. The metal, however, is also beneficial in itself for its alkaline, acting as a neutralizer for corrosive acids, thus helping to give the lube its Total Base Number.
Dispersants	Dispersants have overlapping properties with detergents, in that they, too, maintain particles in suspension. Many technical people distinguish the two terms by calling metallic particle suspenders “detergents” and totally non-metallic (ashless) particle suspenders “dispersants”. They reduce the tendency of small particles to combine into larger particles, taking some of the burden off the filters, and prevent deposition of these particles on valve covers and moving parts particularly at low temperatures. Monitor™ soot test aids in monitoring the effectiveness of the lube’s dispersants.
Defoamant	This material, usually a silicon polymer, acts in a very complex chemical and physical manner to minimize foaming tendencies of lubes. It has limited solubility in lubricants of a non-silicon nature, and this limited solubility helps its effectiveness in accelerating the formation of large bubbles from small ones which dissipate from the lube much more readily. The larger bubbles rise to the surface quickly and then break.
Anti-Oxidants	There are antioxidants for fuels and lubricants, and most of them are non-metallic. Oxidation is a general term used to describe the combining process with oxygen which a lubricant tends to do. This, in turn, forms undesirable compounds which are far less suitable as lubricants. A number of metals, most notably copper, tend to aid (catalyze) oxidation. Some types of antioxidants, therefore, react chemically with the offending metal to nullify its catalytic effect. Another way to inhibit oxidation is to break the chemical chain by “sacrificing” the antioxidant. This type of compound has a great affinity for oxygen when it appears in oxidation products and can combine with it to form harmless compounds, while simultaneously stopping the oxidation chain.
Anti-Corrosives	These materials prevent chemical corrosion from occurring. They can accomplish this by forming a chemical, protective coating on metal surfaces, or they can directly attack and neutralize materials (usually acids) which cause corrosion.
Extreme Pressure (EP) Agents	EP agents increase the load carrying ability or film strength of lubes. This in turn prevents or at least minimizes direct metal-to-metal contact. Many gear systems need lubes fortified with EP agents to function properly. Some EP agents include sulfurized sperm oils and molybdenum sulfide.
Anti-Wear Additives	These materials are similar in scope to EP agents; some plate or coat while some combine chemically with metal surfaces, particularly ferrous (iron or steel), to form a protective coating, necessary in the event that the lube film is interrupted.
Viscosity Index (VI) Improvers	VI improvers (See pages 19 and 20) consist of polymers whose properties change significantly with temperature, such that a lubricant resists “thinning out” as its temperature increases. Polyisobutylenes were among the early compounds used. The latest technology uses copolymer chemistry, which seems to be far more stable, particularly for use in diesel engines. A VI improver’s function is to enable one to experience much-improved cold starting capabilities while retaining necessary film thickness at operating temperature.

TECHNICAL NOTES (CONTINUED)

Pour Point Depressants The pour point of a lube is simply the lowest temperature at which it will still pour. The amount of wax in a lube influences its pour point. Pour point depressants minimize the size of wax crystals formed in the lube. By so doing, they allow the lubricant to achieve its lowest possible pour point, based on its true viscosity characteristics and not on its wax content. Polymethacrylates are the general class of organic compounds used as pour point depressants, also providing some VI improvement.

The above are only a portion of the various additives developed for petroleum products, but they represent most of the important ones for automotive use. It should also be noted that several of the above properties can, at times, be fulfilled adequately by a single additive compound.

NOTE: ADDITIVES, with the exception of solid lubricants, are SOLUBLE in BASE STOCKS and would normally not be susceptible to filtration depletion from typical automotive filters. It is possible, however, that in the course of being consumed, an additive could form an insoluble product capable of being filtered.

* The laboratory uses industry-standard terminology for synthetic lubricants: products which consist of base stocks manufactured by chemical synthesis and containing necessary performance additives.

Additive Metals ICP spectrometers routinely measure five potential additive metals: Magnesium (Mg), Calcium (Ca), Barium (Ba), Phosphorus (P), and Zinc (Zn). NOTE: Boron (B) and Sodium (Na) may also be additives, as well as Molybdenum (Mo), though less frequently.

These metals are detected to aid in verifying the correct product is being used, but detection of metals alone cannot verify their continued effectiveness as an additive. The reason is very simple: when a spectrometer measures Ca, for example, it is measuring Ca in ANY form (additive or contaminant). When the Ca-containing additive is placed in the lubricant, it has a particular chemical structure and one cannot monitor that structure or its effectiveness with metals detection alone. In analyzing a NEW LUBE, however, any Ca measured is fresh, active additive, and this information helps predict the lube's performance capabilities.

Detergent Carriers Ca, Mg and Ba, in order of current use frequency, are the most common metals in use as carriers. Typically only one of these three metals is found in a specific brand and type of motor lube, dependent on how the suppliers choose to meet the desired specification. It is possible, however, to find new lubes using a combination of metals to achieve the same purpose. There is no rule.

These metals impart alkaline properties to the lubricant, enabling it to neutralize corrosive acids. Mg has the highest alkalinity per given weight amount, Ba the least. For this reason Mg and Ca are nearly exclusively found in high performance motor lubes with sulfated ash limitations.

Anti-Wear/Anti-Oxidants Zinc dithiophosphate, containing P and Zn in roughly equal proportions, is the most common anti-wear/antioxidant compound found in motor lubes and many hydraulic oils, thus is routinely investigated for its presence. There are several types of zinc dithiophosphates, each having its own favorable properties for particular applications.



Zinc dithiophosphate is an additive which provides multi-function capability. In the anti-oxidant role it can break the oxidation chain of a lubricant; in the anti-wear role it chemically “plates” out on such components as cams and lifters, or gears and serves as a lubricant in the event that metal-to-metal contact takes place.

Inasmuch as some Zn and P plate-out, a decrease in these elements might be expected, but make-up lube, as with all additives, tends to restore the level and maintain equilibrium.

It is possible to find lubes having P without Zn used as an anti-wear agent.

There are a number of other metals which are used as additives. Molybdenum (Mo) as molybdenum sulfide is a solid lubricant currently enjoying some popularity as an extreme pressure agent. Unlike most additives, however, it is not dissolved in the base lube, but suspended as minute particles less than one micron in size.

It should be pointed out that when Mo is used as an additive, detection of Mo to evaluate Mo-coated rings is not possible, again due to the lack of distinction between one form of a metal and another by emission spectrometric analysis. Similarly if Zn is an additive, Zn from brass or bronze is masked. If leaded gasoline is an engine's fuel, lead cannot be used to evaluate potential bearing wear.

New lubes should be tested for base data to avoid misinterpretation as to the source of a metal.

“Typical” Levels Most motor oils will have Mg, Ca and/or Ba from 500-3500 ppm, dependent on the specification*. Lubes with high alkaline properties may have anywhere from 5000-8000 ppm Mg+Ca+Ba. Many industrial fluids have no metallic additives.

P and Zn are generally found from 600-1500 ppm. Automotive gasoline and several diesel engines usually require a minimum of 1000 ppm zinc dithiophosphate for valve train protection, as this is the area of highest “unit” loading in such systems.

*Automatic transmission fluids may have similar levels, however, not necessarily normal.

Defoamants The most common defoamant in use is a silicone polymer. It is usually added at the ppm level, thus it is not unusual to see up to 12 ppm silicon in new lubes, although 7-8 ppm is a typical range. Testing the new lube is important, for additional Silicon from the starting level will usually indicate abrasives (“dirt”).

Other Metals Molybdenum, usually as a sulfide, is used as a friction reducer or EP agent in certain specialty lubes. Levels of nearly 1% (10,000 ppm) are not unusual. Boron tends to be found co-existing with Mg additives at up to 4% of the Mg value. Similarly, sodium may be found in the presence of Ca or Ba. There are exceptions to these guidelines.

Other References: SAE Paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

NEUTRALIZATION NUMBERS There are a variety of neutralization numbers utilized in the petroleum industry. This discussion is confined to the two most commonly used versions.

TECHNICAL NOTES (CONTINUED)

TOTAL ACID NUMBER (TAN) Simply stated, TAN IS THE TOTAL AMOUNT OF ACID AND ACID-ACTING CONSTITUENTS FOUND IN THE LUBE. The term “acid” does not necessarily connote metal-corroding materials themselves. Many chemicals, including necessary lube additives, can have an acid number.

SIGNIFICANCE: Increases in TAN of used lubes from the starting point of the new lube (which may NOT necessarily be zero) usually indicate LUBE OXIDATION or CORROSIVE ACID CONTAMINATION.

“OXIDATION” is a general term used to describe the degradation of the basic lube product as a result of operating temperatures and/or churning with air. Generally, oil thickening is associated with oxidation. Organic acids are formed prior to and during thickening which can be detected by TAN increase. Oxidation of lube is not only significant from the standpoint of thickening, but the lubricating quality (lubricity) of the lube itself can also be reduced.

CORROSIVE ACID is formed primarily from sulfur blow-by products in the combustion process. Any amount of water contributes toward activating this acid to the point of parts corrosion. The formation of corrosive acids in engines is unavoidable, but alkaline (basic) materials are added to motor lubes to counteract the acid upon entry into the crankcase. Corrosive acid in non-engine systems is usually an environmental problem. One exception is the formation of corrosive hydrochloric acid in refrigeration systems, where freon deterioration may occur in the presence of moisture.

There are no “typical” TANs, but it is fairly unusual to observe one above 10.0 - an increase of 2-3 above starting point may be unacceptable. The change in TAN is the concept to monitor.

TOTAL BASE NUMBER (TBN) TBN IS THE AMOUNT OF ALKALINE MATERIAL (generally as corrosive acid neutralizers) IN THE LUBE, commonly referred to as ALKALINE RESERVE.

SIGNIFICANCE: TBN IS OF PRIMARY CONCERN IN MOTOR LUBES, as additives are placed in the lube when it is blended to neutralize corrosive sulfur acids formed in the crankcase in the normal process of combustion. Measurement of TBN allows one to know if the starting additive package is still capable of counteracting combustion acids. Therefore, TBN IS AN ESSENTIAL ELEMENT TO THE SAFE EVALUATION OF LUBE DRAIN INTERVALS.

Generally a new lube starts with the highest TBN it will exhibit. From that point TBN will tend to decrease as acids consume its alkaline properties. The addition of fresh make-up lube, however, helps forestall the decline in TBN, oftentimes, allowing (all other factors being equal) extension of lube drains in properly maintained engines. This will naturally vary from unit to unit dependent upon individual conditions.

Typical motor lubes have TBNs of 5-7. “Highly-compounded” oils may have TBNs 12-15. Marine oils using high-sulfur fuel may have TBNs of 35-40, while upper cylinder lubricants in those same engines may exceed 70 TBN.

NOTE: TBN alone is not a relative indicator of lube quality, only its ability to neutralize corrosive acids. A higher TBN clearly demonstrates better capability to counteract acids, but does not mean the higher TBN lube is better than, or even equal to, a lower TBN lube with respect to other important properties.

It should also be noted that most of all motor lubes can have both a TAN and TBN in



the new and used state. If one regards these terms as two distinctly different properties, there is no difficulty in explaining their simultaneous presence. Ideally one would perform analyses for both terms in the inspection of motor lubes, but TBN is by far the more important property of the two for motor lubes. TAN is usually acceptable when TBN is sufficient.

TAN is almost exclusively used for non-engine systems because there is no combustion process taking place and because many non-alkaline lubes are in use in such systems, making the analysis for TBN pointless.

TAN also applies for large stationary 2-cycle gas engines using “mineral oil” type lube.

A WORD ABOUT pH - pH and TAN are oftentimes confused. The concepts are quite involved but, succinctly, pH is relative acid strength while TAN is total amount with no regard for strength. Weak acids, such as lube oxidation products, do not significantly affect pH.

Other References: SAE paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

DRAIN INTERVAL EVALUATION

Today nearly every lubricants user is concerned about costs and availability of product and disposal of used product.

The lube analysis consulting industry is ideally situated to evaluate drain intervals, enabling one to minimize lubes consumption, but with reasonable safety, as opposed to arbitrary drain interval, which can lead to problems whose costs far exceed the lubes “savings”.

Monitor™ lab introduced the “HYBRID” concept in evaluating drain intervals. The principle of the “HYBRID” concept is to place the units to be evaluated on a drain interval analytical program, monitoring lube **DEGRADATION**, as opposed to only **WEAR** and **CONTAMINATION**.

Once the safe lube drain limit is determined, one can then abandon the drain interval analytical program, returning to the more economical wear/contamination. The purpose of this is twofold: 1) Arriving at a maximum **SAFE** drain interval **ECONOMICALLY** for a given lube, system type and application; 2) Monitor the unit to be certain no excessive contamination (and subsequent wear) develops within the system prior to lube change.

The “HYBRID” system presupposes that a uniform lube change interval will be adopted for a given class of units. It is important to understand that varying “SAFE” drain intervals are attainable dependent upon the equipment manufacturer. (For discussion purpose, use of a specific lube product will be assumed.)

If one has a “mixed” equipment set, be it engines, gears, hydraulics or other, one should consider each manufacturer separately. Generally at least half a dozen units of each manufacturer and application should be evaluated thoroughly prior to adopting a drain interval “across-the-board”. Naturally, the larger the test group used, the greater will be the confidence level of the drain interval projections.

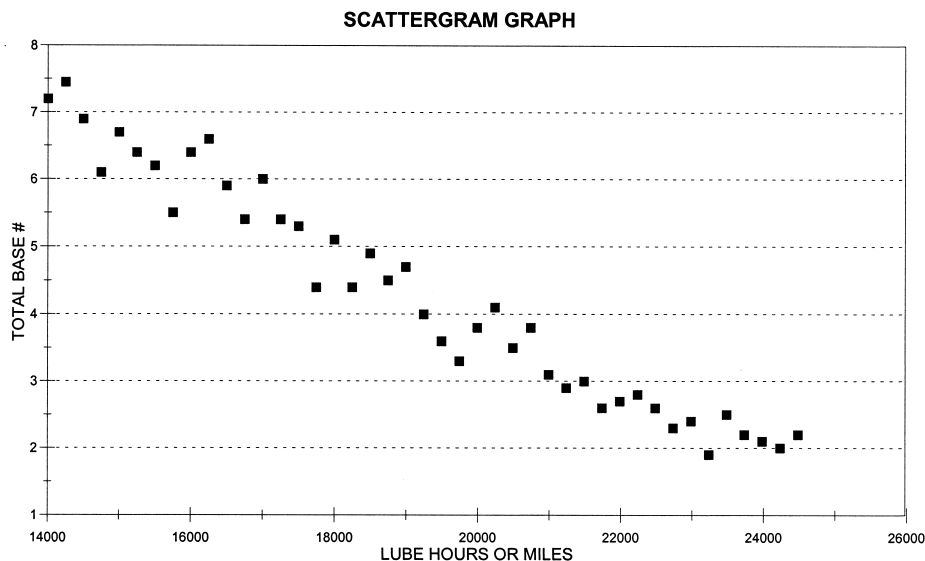
TECHNICAL NOTES (CONTINUED)

THE ULTIMATE APPROACH TO CONSERVATION

The concept of extending drain intervals to achieve optimum oil drain intervals is only viable using a fluid and unit condition monitoring program such as the monitor oil analysis kit part CC2543. By monitoring both the fluid condition and the unit's condition, it is possible to determine at what hour/miles interval you can extend the oil life to without sacrificing life expectancy.

This can be done by monitoring the oil's TBN (Total Base Number or Reserve Alkalinity). Typical engine oil's TBN will start around 8.0 to 10.0. As the oil ages, the TBN decreases to a point where the oil no longer has the alkalinity to neutralize acids that form from the combustion process. Through testing you can determine how far to let the TBN drop before the wear metals start to increase.

The scattergram graph depicts the typical decline of the TBN as the hours/miles increase. Using the graph and monitoring and comparing the wear metals patterns of the engine will give the analyst the information needed to determine the "Optimum Oil Drain Interval."



This determination could only be proved if every unit in the system were sampled (once again manufacturer and application may dictate a sub-system approach). Because scheduling of routine maintenance becomes far more complex when there is a variety of manufacturers and applications, some firms change lubes purely "on condition", i.e., only when lab analysis suggests it. This would further require that every unit be regularly tested using a drain interval evaluation analytical package.

The minimum drain interval evaluation test recommended is:

- SPECTRO METALS
- FUEL CONTAMINATION (liquid-fueled recip only)
- FUEL SOOT (LFRE)
- WATER
- VISCOSITY
- NEUTRALIZATION NUMBER

If **pure** SYNTHETICS are in use, infrared analysis is also useful to detect standard petroleum product contamination of the synthetic.

Monitor™ Kit CC2543 Lube Analysis includes these tests.



FACTORS INFLUENCING DRAIN INTERVALS*

1. LUBE CONSUMPTION:
All other things being equal, the greater the lube consumption, the better the chances for extended drain. In effect, the lube is being renewed or “sweetened”, including beneficial additives.
2. LUBE QUALITY:
Some lubes are simply more effective than others for particular applications, whether due to better base stock or to superior additives.
3. HEAT:
Excessive temperature is an enemy of all lubes, promoting oxidation and other forms of lube degradation.
4. CONTAMINATION:
Excessive contaminants will ultimately render a product ineffective as a lubricant. Type and degree of filtration can influence this area, dependent on the nature and cause of the contamination.
5. How a particular piece of equipment is used plays an important role in lube drain interval and affects all of the above parameters.

*This list excludes the situations where a unit has a serious mechanical problem.

Other References:

SAE paper #740535
Heavy Duty Equipment Maintenance/Management
(June, July, August 1978)

PARTICLE COUNTING

“Particle Counting” is a term denoting the detection of a particulate matter in a fluid with respect to size range and quantity.

There are a number of methods for particle counting. The earliest counts were centered around microscopy, wherein filter patch samples were prepared and then viewed under a microscope with a calibrated grid for sizing. A manual count within grids was then conducted. The process, while certainly useful, is nevertheless tedious and relatively slow by today’s standards.

Particle counting instrumentation includes techniques like light scattering, which is currently the most popular method for inspecting petroleum products. One instrument type causes a thin diameter flow through a sensor-monitored light path. Another utilizes a laser that is rotated to describe a one ml. cylinder in a static sample in the path of the laser beam and its sensor.

Particle counting is becoming a popular analytical method for particulate monitoring in non-opaque fluids. Some of the specific applications include:

Automatic Transmissions	Gas Reciprocating Engines
Coolants	Gas Turbines
Compressors	Hydraulics
Diesel Fuels	New Lube QC
Filter Evaluation	Refrigeration Systems

NOTE: IF A PRODUCT SAMPLE OF TWO INCH THICKNESS WILL NOT PASS LIGHT TO THE NAKED EYE TO ANY REASONABLE DETECTABLE SIGNIFICANCE, IT IS PROBABLY TOO OPAQUE TO YIELD A RELIABLE PARTICLE COUNT BY LIGHT SCATTERING METHODS.

TECHNICAL NOTES (CONTINUED)

The micrometer (also called “micron”) is the particle measurement standard unit. It is one-millionth of a meter. Results are usually expressed in particles per milliliter, or particles per 100 milliliters.

Commonly requested ranges:

A	B
Greater than 25 microns	5-10 microns
Greater than 15 microns	10-25 microns
Greater than 30 microns	25-50 microns
Greater than 50 microns	50-100 microns
	100+

NOTE: 40 MICRONS IS THE THRESHOLD OF PARTICLE DETECTION IN THE AVERAGE NAKED EYE. IT IS DOUBTFUL WHETHER MEASUREMENT OF METALLIC PARTICLES ABOVE 100 MICRONS IS USEFUL, FOR THEY TEND TO SETTLE QUITE RAPIDLY DUE TO THEIR DENSITY, AND RELIABLE COUNTS ARE DIFFICULT TO ACHIEVE.

Sampling There are some sophisticated techniques for taking lube samples for particle counting, but these techniques are almost impossible to achieve in a field environment. For field monitoring, therefore, we recommend VERY CONSISTENT observation of the standard sampling methods one would use for lube. The laboratory’s regular sampling jars are “reasonably clean” and are factory-capped to minimize contamination from the container.

Some Limitations of Particle Counting

1. As mentioned earlier, samples too opaque will simply not pass enough light to allow the sensor to react.
2. Water oftentimes is not differentiated from true particulates, particularly when the water is finely dispersed. Samples with known water, therefore, are normally not amenable to particle counting.
3. Samples which are too “dirty” tend to interfere with the ability of the sensor to properly discriminate. The result is unreliable data. Certainly it is always possible to dilute “dirty” samples with filtered solvent until a count is technically feasible, but extremely high dilution can lead to significant errors once the dilution factor is applied.
4. Particle counters do not care about the compositional nature of particles—only their size and quantity. Unless one is simply making counts for relative purposes, therefore, one will need other tests to help suggest the composition/ source of the particulates.

Evaluation Particle Counts

While samples are not always representative, the following discussion is conducted on the premise one is evaluating reasonably good data.

Particle counts are best viewed on a relative basis just like the rest of the tests run on lubes for maintenance diagnostics. They should also be viewed in conjunction with other test data, again on a relative basis.

As an example, if wear metals rise with particle count, there is an obvious connection. The question might be, however, is the apparent wear FROM the particles, or do the particles simply REFLECT the increased wear metals? One



way to answer this is to watch the particles above 20 microns, which is beyond the threshold of most spectrometers to “see” (the particles are too large to be completely ionized by the spectrometer’s excitation source, consequently only surface atoms are “seen”).

If particles above 40 microns begin to increase significantly, but wear metals do not, component fatigue may be taking place, and a qualitative microscopic examination may help pinpoint the nature of the particulates generation.

General increases in all ranges are the most typical patterns noted, but unnecessarily high levels (even though tolerable) may be avoidable by judicious filter changes. Certainly, as particulates increase regardless of initial cause, they will eventually contribute to wear, even if they are themselves wear particles.

NOTE: CARELESSNESS IN CHANGING LUBE AND FILTERS IS ONE OF THE VERY COMMON WAYS IN WHICH EXCESSIVE PARTICULATES ARE INTRODUCED INTO A SYSTEM. LUBE AND FILTER STORAGE FACILITIES ARE ALSO PRONE TO PARTICULATES PROBLEMS IF NOT PROPERLY MAINTAINED.

New Product

We have seen numerous instances where new lubes are, in fact, “dirtier” than used product. This is apparently due to the effects of filtration equipment placed in the unit’s lube flow stream, removing particles from the new lube. In most cases this “dirtiness” in new lubes is more apparent in particle size about 20 microns, but it need not necessarily be confined to larger particles. The phenomenon simply emphasizes further the need to be diligent with respect to lube handling and storage cleanliness.

INFRARED ANALYSIS

Infrared analysis (IR) is one of numerous spectrometric techniques for analyzing the chemistry of materials (more familiar spectro techniques to the used lube analysis world - see page 14 - are ATOMIC ABSORPTION or ATOMIC EMISSION spectrometric analysis). In all cases “spectrometric” analysis implies a measurement of very specific wavelengths* of light energy, either in terms of amount absorbed by the sample in question, or the amount given off (emitted) from the sample when suitably energized.

IR is an absorption form of spectrometric analysis. Unlike atomic emission or atomic absorption, IR is not concerned with specific elements (such as iron, copper, etc.) but, rather, with groupings of atoms in specific combinations to form what are often called “functional groups”. These various functional groups help determine a material’s properties or expected behavior, i.e., its chemistry, and most of these functional groups respond to infrared waves.

By knowing (through established research) which wavelengths are absorbed by each functional group of interest one can cause the appropriate wavelength to be directed at the sample being analyzed, then measure the amount of energy (or “light”) absorbed by the sample. The more energy absorbed, the more of that particular functional group is existent in the sample. Results can therefore be numerically quantified. Not surprisingly, the units of measurement are usually expressed as “ABSORBANCE UNITS”.

*Wavelength, as used here, may be thought of in the same way as radio waves, wherein one “tunes in” a particular radio station by selecting a certain frequency, while simultaneously “tuning out” all the other competing frequencies (other stations).

TECHNICAL NOTES (CONTINUED)

How Does IR Apply to Lube Analysis Consulting?

While this notion is a definite distortion, it is probably useful for the layperson to treat infrared analysis as (primarily) the chemistry of:

CARBON HYDROGEN OXYGEN NITROGEN SULFUR

and the various combinations in which these elements configure or attach themselves, at least for most purposes that used lube analysis attempts to address.

By identifying and (hopefully) quantifying certain functional groups, one can derive highly dependable information about the lube (whether new or used) including, but not limited to:

1. Basic Physical Composition (Stock)

- a) is it a mineral oil? If so, what kind?*
- b) is it a synthetic lube? If so, what kind?
- c) is it a mixture of mineral and synthetic?

*Most lubes consist of two major components: "BASE STOCK" and "ADDITIVE". As the term implies, base stock is the foundation from which the lubricant is built (by inserting additives), and it is possible many times to distinguish between differing base stocks with infrared for the purpose of quality control. This feature is particularly useful for assurance that a synthetic lube is not being inadvertently contaminated with mineral oil, thereby impairing the synthetic's beneficial properties.

2. Additive Chemistry

- a) does it contain "additives"? If so, what type?*
- b) are the additives yet effective?

*Although not a part of "routine" infrared inspection, an inspection for chemistry (additives) is not difficult, provided one is familiar with the product being analyzed. In a number of instances, the question of specific additive depletion can be answered.

3. Is the Lube Contaminated?

- a) with water?
- b) with glycol?
- c) with mineral oil (if a synthetic is in use)?
- d) with oxidation products?

IR is particularly useful for detecting oxidation products, from liquid to semi-solid state. Such products, of course, are detrimental to good lubrication, if present in significant quantity. It is also sensitive to coolants (water or glycol), although metallic coolant additives in the lube (through the well-known metallic "SPECTRO-ANALYSIS") are usually sufficient for this function, and generally preferable, as there is a higher degree of sensitivity when monitoring internal coolant leakage.

As mentioned earlier, IR is excellent for monitoring synthetic lube contamination. It would also be very applicable if, as an example, a manufacturing plant produced certain types of chemicals which were potential contaminant problems to the lube or machinery being lubricated, such that IR could detect chemicals' presence as they accumulated in the lube.

4. Is the Lube Degraded?

- a) from "oxidation" (undesirable inclusion of oxygen in the lube's molecular structure)?
- b) from "nitration" (undesirable inclusion of nitrogen in the lube's molecular structure, or formation of nitro compounds which degrade the lube)?



* These questions are difficult to answer at times, even with a new lube reference, unless one is familiar with the product in varying degrees of degradation.

Oxidation is developed from varying combinations of heat, air (which contains oxygen) and lube agitation (which promotes entrainment) and is characterized by lube thickening.

Whenever a lube thickens, oxidation is usually suspected, but while this is more often than not the case, it is not the only cause of lube thickening (see pages 16-18).

Nitration is a chemistry phenomenon similar to oxidation, but with nitrogen (found in even greater abundance than oxygen in air) it is an offender, along with oxygen. It, too, promotes lube thickening. Nitration is a particular problem where gas reciprocating engines are used, influenced by air/fuel ratio, as well as heat and agitation.

Once nitrates exist, there is also the potential for corrosive nitric acid to form, to go along with the problem of lube thickening. Therefore, IR is a highly useful tool for monitoring this potentiality and for making the distinction between oxidation and nitration when viscosity increases (comparison of acid # and viscosity is also useful).

Brief Synopsis of IR For Routine Used Lube Analysis

Oxidation - Measurement of keto, carbonyl and carboxylic functional groups from base line (mineral lube only).

Nitration - Measurement of nitro type functional groups from base line.

IR Application Summary For Routine Used Lube Analysis

Extended Drains - IR is certainly useful in terms of investigating extended drains in any lube -wetted system, and its use should be strongly considered in that circumstance.

Gas Recip - In the analysis of lubes from reciprocating gas engines, from small fork lift size to pipeline transmission size, IR may well be a "necessary" test, in conjunction with other analyses.

HOW DO I INTERPRET THE DATA?

This is a question frequently asked by customers. Normally one should not have to interpret test data as the laboratory provides this important function. The data are presented primarily to let the customer know which, if any, of the values triggered maintenance recommendations. These values are usually flagged. Following are some of the laboratory's considerations.

Wear Metals

One of the least understood concepts to the layperson is "wear metals". They are the first 11 metals listed on the report (and, occasionally, Zinc or Magnesium), and they simply represent the amount of each metal detected in the lube at sampling time, though NOT its chemical form. As an example, when iron is reported from the ICP spectrometer (the instrument used to detect and quantify metallic elements), it is not known if it is in an oxide form (rust, e.g.) or if it represents relatively recent erosion of an iron-containing part in the system.

TECHNICAL NOTES (CONTINUED)

Additive Metals - (Magnesium, Calcium, Barium, Phosphorous, Zinc)

Within reason, the amount of each metal detected is irrelevant as long as the amount deposited in the lube remains at a constant, stable rate with respect to time or mileage on the lube from sample to sample, i.e. it is possible that metals quantities will climb the longer a lube remains in the crankcase/sump. Under extended drains, the values may become further magnified, but may still be indicating a “normal” wear rate pattern for that particular unit. It is WHEN THE WEAR RATE ESTABLISHED FOR A GIVEN UNIT INCREASES SIGNIFICANTLY THAT CORRECTIVE ACTION OR INSPECTION MAY BE ADVISABLE.

Each engine (or other machine) make exhibits particular tendencies. Some tend to show metals increases at a constant rate, others tend to stabilize after various time or mileage plateaus. There are numerous reasons why this is so, even between models of the same manufacturer, among them: LUBE CONSUMPTION RATE (probably the most significant), SUMP CAPACITY RELATIVE TO SURFACES LUBRICATED, STANDARD ORIGINAL EQUIPMENT FILTRATION, UNIT SUPERCHARGED OR NOT, BMEP RATING. Even identical units may show quite a variance from: AGE DIFFERENCE (lube consumption), SPECIAL AFTER-MARKET FILTRATION, APPLICATION, TYPE OF LUBE. DON'T ASSUME THAT A GIVEN UNIT MUST HAVE A PRE-DETERMINED THRESHOLD VALUE FOR WEAR METALS, EVEN FOR A SPECIFIC INTERVAL - LET ITS TREND SERVE AS AN INDICATOR.

Contaminant Metals - (Silicon, Sodium)

These metals tend to remain fairly stable, but can easily fluctuate +20% -20% as a normal circumstance. Drastic changes, or the elimination or emergence of an element that was or was not present prior indicates the addition of make-up lube whose additives differ from the prime supplier's. It could also indicate (if the change remains) that one's supplier has changed formulation. Remember, it is possible for a wide variety and quantity of additives to be used to meet the SAME spec, and remember, too, the level of additives detected is not necessarily an indication of the useful life of such additives.

These metals CAN have pre-determined limits, once one has tested the NEW LUBE for initial base line data. Increases in Silicon alone usually mean the entrance of abrasives (“dirt”). The effect, if any, is easily noted by observing the change in wear metals. An increase in all three contaminant metals, or Sodium and/or Potassium may indicate coolant leakage (as these are elements from chemicals typically placed in coolants). Once again we must note the starting concentration of each metal in the NEW LUBE. If glycol antifreeze is in use, we can confirm its presence with a test.

Other Physical Contamination - (Fuel, Soot, Water)

These products, when found in excess of their norms, usually indicate a need for corrective action as well as a lube drain. The exception is when solids build up over an extended drain interval, in which case, they just show a need to drain lube and/or change filters. Here again, age of the unit, make-up lube rate, application, lube type and BMEP (Brake Mean Effective Pressure; applicable to recip engines) play a major role.

Lube Condition Indicators

Like wear metals, these values have tolerances. It is very important to have NEW LUBE base data on these parameters before attempting to diagnose changes and trends. The laboratory has a wealth of such data in its files. Such data have a habit of becoming obsolete over extended time periods, as oil companies find improved ways to meet particular specs and thus, change their formulation for a product whose trade name



remains the same. For this reason, one should periodically have the laboratory test incoming NEW LUBE batches, certainly not every time, but for example, every six months. If one is already on the program, it will probably tell you if and when this occurrence takes place. Change for the better is GOOD - not knowing about it could be confusing. "So now, why can't I start evaluating my own reports?" You can, and you will eventually become competent at it for your own operation, depending on individual background, BUT analyzing trends is a complicated process (and this approach is proprietary) and involves the interplay of ALL the test data, not just wear metals or contamination separately. That's why it is usually best to leave the primary interpretation to the laboratory. YOUR help is, needed in providing a "current" evaluation of a troubled unit, for you may have information which can aid in pinpointing problems. This exchange, which occurs when data analysts contact you with a problem result, might be called a "follow-up" or secondary interpretation.

Advising the laboratory of action taken and FINDINGS is equally important to program success. In the first place, NO consulting firm of this type can be 100% right, but with RARE exception, an abnormal finding means a problem, even if not what initially suspected. Your feedback enables the approach to be altered in a positive manner, to improve precision, all of which ultimately benefits YOU.

Other References: SAE #740535
Heavy Duty Equipment Maintenance/management
(June, July, August 1978)

FUEL ANALYSIS

Diesel Fuel Test Descriptions

Objective: The Monitor Fuel Analysis program allows you to determine if the diesel fuel you are using is negatively effecting fuel filter life or engine performance.



GO/NO GO ANALYSIS - CC2650

This kit will tell you if your fuel will contribute to premature filter plugging.

Tests Included:

- Pour Point
- Water and Sediment
- Bacteria, Fungi, Mold
- Thermal Stability
- Spectro-Analysis of Metals



Diesel Fuel Quality Analysis - CC2651

This kit will tell you if your diesel fuel meets ASTM D975 #2 diesel fuel specifications.

Tests Included:

- Pour Point
- Water and Sediment
- Bacteria, Fungi, Mold
- Thermal Stability
- Spectro-Analysis of Metals
- Viscosity
- Sulfur %
- API Gravity
- Distillation



FUEL ANALYSIS

Diesel Fuel Test Descriptions

Water and Sediment	Fuel cleanliness is vital to a healthy fuel system. Water and sediment present in fuel can cause corrosion and wear in a fuel system. The presence of water can also lead to bacterial growth and premature fuel filter plugging. The limit for water in fuel is no greater than 500 ppm (0.05%). The limit for sediment is no greater than 100 ppm (0.01%).
Bacteria, Fungi and Mold	When fuel storage tanks are not properly maintained, water can build up at the bottom of the tank. This is an ideal breeding ground for biological growth. The presence of bacteria, fungi or mold in a fuel samples indicates the need for improved storage tank maintenance.
Thermal Stability	When diesel fuels are heated degradation products can be produced. These products are tar-like, resinous substances (sometimes termed “asphaltenes”) that are most often responsible for fuel filter plugging. Some diesel fuels produce these degradation products at an accelerated rate, which leads to drastically reduced filter life. A fuel having a thermal stability value of 80% reflectance or greater is a stable fuel and should not cause premature filter plugging. Fuels having values between 60% and 80% reflectance are marginal fuels and could affect fuel filter life. Fuels with thermal stability values of less than 60% reflectance will lead to significantly reduced fuel filter life.
Pour Point and Cloud Point	This is a measure of a fuel’s tendency to form waxes at low temperatures. Cloud point is the temperature at which wax crystals begin to form. The pour point is the lowest temperature at which lube or fuel will still pour. Refer to ASTM D975 for acceptable limits for a particular North American Region.
Flash Point	Flash point is the lowest temperature at which the vapors of a combustible liquid will ignite momentarily in air. Low flash points indicate contamination of diesel fuel by more volatile fuels such as gasoline. The limit for flash point of #2 diesel fuel is a minimum of 52 C (ASTM D975).
API Gravity	API gravity is a measure of the density (weight per volume) of a diesel fuel. The higher the API gravity, the less dense the fuel sample is. API Gravity can provide useful information concerning a fuel’s composition and performance- related characteristics such as power economy, low-temperature properties and smoking tendencies.
Cetane Index	Cetane Index is a measure of the ignition quality of a diesel fuel. The higher the Cetane Index, the better the ignition quality. The limit for a # 2 diesel fuel is a Cetane Index of at least 40.
Distillation	The distillation temperature is the temperature at which 90% of the diesel fuel volume can be distilled off. The distillation temperature relates to the volatility and hence the Cetane Index, density, flash point and viscosity of a fuel. The specification for a # 2 diesel fuel is a minimum distillation temperature of 282 C and a maximum of 338 C.
Metals	The presence of metals in a fuel samples indicates either corrosion somewhere in the fuel system or storage tank or lube contamination. In general any metal in concentrations greater than 10 ppm is a good indication that there may be a corrosion or lube contamination problem occurring.
Viscosity @ 40°C	Viscosity is a measure of a fuels resistance to flow. The higher the viscosity, the greater the resistance to flow. Fuels with viscosity out of spec can lead to reduced injector performance. The spec for # 2 diesel fuel is a minimum viscosity of 1.9 and a maximum of 4.1 CST. (unit for viscosity).
Sulfur %	Sulfur content will effect SOx emissions and can have adverse effects on many NOx and PM emission reduction devices. It is important to determine if the sulfur level in fuel is appropriate for a specific application.

COOLANT ANALYSIS SERVICE

What is Monitor C™?

Proper coolant maintenance is vital to heavy-duty engine operation. **40% of engine problems can be traced back to an improperly functioning cooling system.** Fleetguard's Monitor C coolant analysis program allows operators of heavy-duty diesel engines to effectively monitor their cooling system maintenance practices and conditions through reliable and expedient coolant analysis.

Coolant Sampling



CC2700 Coolant Kit
CC2706 Coolant Kit
with Return Postage

Obtaining a representative coolant sample is vital to obtaining representative results. With Fleetguard Monitor C kits, CC2700 Coolant Kit or CC2706 Coolant Kit with return postage, you will be supplied with a sample bottle, an outer mailing bottle and the appropriate sample ID and mailing labels. Sample coolants either directly from the radiator (DO NOT remove the pressure cap from a Hot System! Allow the system to cool completely before sampling.) or from the radiator drain valve. DO NOT take a sample from the overflow tank, unless coolant circulates through that tank. Coolant from a non-circulating overflow tank will not be in the same condition as coolant in the radiator. Place the coolant in the clean sample bottle provided. DO NOT use other sample containers (such as empty oil bottles, soft drink bottles, etc.) to avoid cross contamination. Label the samples as described in the following section.

Sample Identification

On the Monitor C sample label provided place your account # in the designated area. You will not need to fill out the client information section. However, if you do not have an account number fill out the client information section. There are also designated areas to fill in unit #, sample date, miles/hours on coolant, miles/hours on engine, engine type and sample type. Fill these out as completely as possible to insure that data are interpreted correctly.

Interpreting Results

Service recommendations will be on the bottom of the Monitor C report and flags will be next to any results indicating potential cooling system problems. The following sections will go into more detail as to what individual results mean from a cooling system standpoint.

pH The pH is an indicator of acid build-up in a coolant. As glycol degrades in a system, acids are produced. High acid levels will lead to coolant corrosivity and accelerated nitrite depletion (and hence decreased liner pitting protection). As these acids build up, pH will drop. A pH level below 7.7 is potentially harmful to a cooling system. At a level below 7.5, the coolant should be drained, flushed and refilled. A pH level that is too high, often due to coolant contamination, is also harmful to a coolant. If the coolant pH is 11.0 or greater, the coolant should be drained, flushed and refilled.

% Glycol and Freeze Point

Glycol levels play an important role in freeze point protection. A glycol level between 40 and 60% is recommended for cooling systems. At levels below 40%, coolants can hard freeze, causing severe system damage.

At levels above 60%, silicate gelation and accelerated coolant aging can occur. When levels fall out of range, they should be adjusted with either good quality makeup water or a fully formulated heavy-duty coolant concentrate meeting TMC RP 329 or RP 330 specifications.



% TDS	TDS stands for Total Dissolved Solids. It is a good indicator of potential over-treatment of a cooling system. When a system is over-treated, that is, an excessive amount of SCAs (Supplemental Coolant Additive) or OAT Extenders have been added, this can have a detrimental effect on water pump seals. When the TDS levels rises above 4.0%, coolant life is nearing its end. There is nothing that can be done to rescue high TDS levels short of draining and refilling with new coolant. Drain coolant when %TDS exceeds 4.5%.
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Liner Pitting	Both nitrite and molybdate work in conjunction to prevent liner pitting if they are maintained at the appropriate level. Liner pitting protection present in a coolant is given in terms of SCA units/gallon. SCA units/gallon values less than 1.2 indicate that coolant maintenance practices are not sufficient to provide continuing liner pitting protection without cause for concern. When SCA values are below 1.2, adding a precharge to the coolant will be the recommendation at the bottom of the Monitor C report.
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Although it is important to have sufficient nitrites to ensure liner-pitting protection, too much nitrite can be detrimental to solder. Nitrite levels above 3333 ppm can be harmful to lead solder. Nitrites exceeding this level will generate a recommendation to drain the coolant and refill.

Corrosion Products	When corrosion is occurring in a cooling system, the metal components of the cooling system (iron, aluminum, copper and lead) will build up in the coolant. Excessive levels of these in a coolant indicate a corrosion problem. Levels above 10 ppm indicate that a problem may be starting. At levels above 20 ppm, a problem is definitely occurring and the coolant should be drained, flushed and refilled.
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Silicate Levels	Silicates are very useful components of a heavy-duty coolant blend. They provide excellent all-around corrosion protection, especially for aluminum. However, if silicates become over-concentrated, gelation can occur. For a premixed coolant silicate levels should remain below 125 ppm.
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Buffers	Coolant buffers help keep coolant pH at an acceptable level. They do this even in the presence of excess glycol degradation acids. Phosphate, borate or a combination of the two comprise the buffering system of all heavy-duty coolants. It is important that one or both of these be present in the coolant at the appropriate level. OAT Coolants contain very limited amounts of buffers and as a result have very low reserve alkalinity.
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A sample Monitor-C report is attached on page 38.

Sample and testing information shows you when the sample was taken, when it was tested and the miles on the unit and on the coolant. Referencing the lab sample number will expedite any questions concerning your sample.

Adequate glycol levels must be maintained to insure adequate freeze point protection. Glycol levels must also not be too high or additive drop out and decreased coolant life can result. A glycol range of 40% to 60% is recommended.

Appropriate pH range is vital to corrosion inhibition. The pH range should remain between 7.5 and 11.0.

Excessive Total Dissolve Solids (TDS) can lead to water pump leakage. TDS levels should not exceed 4%.

High corrosion product levels in a coolant indicate that a corrosion problem may be occurring. Levels greater than 30 ppm are definite indications of a corrosion problem.

A current sample plus up to four preceding samples can be shown.

Monitor-C™ COOLANT ANALYSIS REPORT

www.fleetguard.com
1-800-271-FILTER
(317) 868-3751 Fax

Acct#: MONITC-0000-0002
Customer:

Unit # R2591 D
EG COOLANT (A/F WATER SCA Engine: CUMMINS)

Date Sampled:	07/20/00	02/12/99	03/09/98	06/19/97	04/08/97
Date Tested:	08/01/00	03/02/99	03/16/98	06/27/97	04/15/97
Miles on Unit:	547,601	408,828	284,217	193,090	168,251
Miles/Hrs. on Coolant:		408,828	284,217	193,090	84,000
Lab Sample Number:	507869	350805	014643	781617	711272
pH:	8.7	9.4	9.7	8.8	8.6
% Glycol:	28*	52	55	57	55
Freeze Point F:	7*	-38	-47	-53	-47
TDS (%)	0.5	1.5	2.2	3.6	2.9
Liner Pitting					
- SCA (Units per Gallon):	0.6*	3.3*	3.4*	3.7*	4.4*
- Nitrite (TMC RP328):	186	1973	1902	2071	2814
- Molybdate (TMC RP328):	280	330	960	1050	990
Corrosion Products					
- Iron:	0	0	0	0	0
- Aluminum:	0	2	2	2	3
- Copper:	0	3	5	8	4
- Lead:	1	0	0	0	0
Silicate (TMC RP328):	80	100	250	120	120
Buffers					
- Phosphate (K2HPO4):	2430	6500	12930	27900	18830
- Borate (Na2B4O7):	651	890	730	670	520
- Hardness:					
- Degradation Acids:					
- Chloride:					
- Sulfate:					

NOTE: Chemical analysis results are PPM except where noted.

MONITOR C TESTS ARE NOT SUFFICIENT TO EVALUATE COOLANT RECYCLING PROCESSES!!

RECOMMENDATIONS:

SCA IS UNDERCONCENTRATED. GLYCOL CONCENTRATION IS OUT OF RECOMMENDED RANGE FOR COOLANT USE (40-60%). PRECHARGE SYSTEM AT 1.5 UNITS SCA PER GALLON AND INSTALL A SERVICE FILTER. REVIEW MAINTENANCE PRACTICES.

Appropriate SCA levels are vital to liner pitting protection. An SCA level of 1.2 is the MINIMUM required for liner pitting protection. However a level of 2.5 is best for a long life coolant.

Excessive Nitrite levels can lead to solder corrosion. The MAXIMUM acceptable nitrite level is 3333 ppm.

Excessive silicate level can lead to gelation. Silicate levels for a 50/50 coolant should not exceed 125 ppm.

Monitor-C coolant reports provide you with maintenance recommendations based on our in-depth analysis. This takes the guesswork out of how to interpret coolant analysis results.



COMPASS

The Complete Tool for Managing an Oil Analysis Program

COMPASS is a software database product that allows users to manage their oil analysis program on local PC or network. Large oil analysis programs can generate an overwhelming amount of information that is almost impossible to manage without a software management tool.

COMPASS helps users reduce their maintenance costs and justify decisions in the equipment purchase process. COMPASS allows users to store all of their equipment and sample information on their PC, allowing fast and easy retrieval of information. Management reports allow the user to “Mine the Database” in many ways:

- Itemize the problems found, justifying with upper management the expense versus the dollar savings of oil analysis.
- Monitor how frequently all components are being sampled over the last year and see the severity status of each sample.
- List those components due to be sampled according to the users expected sampling interval.
- Summarize problems found by oil analysis categorized by Unit Type, Manufacturer, or Model. This helps the customer modify their maintenance practices and help in the equipment purchase process by pointing out the problem models or manufacturer.
- Generate a listing of all samples that meet any user entered criteria.
- Print jar labels allowing the user to simplify the sample taking and identification process.
- Export the data to other program formats.

COMPASS has a wide range of graphing capabilities that allow users to see their sample results in a graphical format. The standard viewing programs allow users to switch with one click from a spreadsheet style viewing format to or from a color graphical format.

For the advanced oil analysis user, COMPASS has several statistical analysis programs. The Data Analysis report allows users to find what test results are typical, and at what point test results become statistically abnormal, for their different manufacturer and model of components. The Correlation programs allow users to find cause and effect relationships between test results. The Scattergram graphing program allows users to visually confirm the existence of any correlation.

COMPASS allows users to get their sample results back very fast via an e-mail attachment file. E-mails are automatically sent once a day for any COMPASS user if any samples were completed that day. A sample report is shown.

HORIZON

Web Based Reporting of Test Results

HORIZON is a web based application that allows you to get oil analysis reports 24 hours a day anywhere you have access to the internet. As the results are completed in the laboratory they are posted to HORIZON every 15 minutes. This allows you access to your test results as soon as they are completed. In addition, HORIZON can notify you by e-mail or electronic pager if you have severity three or four reports. HORIZON also allows you to add comments and forward reports to other individuals who may not have access to HORIZON.

Three easy steps to access reports electronically:

- Step 1: Call 1-800-22FILTER (1-800-223-4583) and establish a login and password
- Step 2: Go to HYPERLINK "<http://www.fleetguard.com>"
- Step 3: Click on Services
- Step 4: Click on Monitor Fluid Analysis
- Step 5: Under "Already in program?", click on [click here](#)
- Step 6: Login system
- Step 7: View and print reports and graphs

HORIZON is simply the fastest and most efficient way to retrieve results from the laboratory.

