Oil Condition Monitoring Case Study

BUREAU VERITAS

PROPER TESTING FOR MAXIMUM VALUE & EQUIPMENT CONDITION INFORMATION

BACKGROUND

In order to quickly and accurately determine the "cause and effect" of oil and wear related problems, proper tests and procedures based on the equipment sampled and its application must be utilized. This paper details the appropriate test slates for various types of industrial equipment and applications as well as the additional factors necessary to manage a successful and cost effective oil analysis program.

Oil analysis has long been accepted as a valid predictive maintenance technique. The facts show that when using a qualified laboratory, defining the proper testing and obtaining a full commitment from the user, oil analysis requires the ***lowest cost*** of implementation and provides the ***highest rate of return on investment*** than any of the predictive maintenance disciplines.

CASE STUDY **OVERVIEW**

Industry: Chemical Mfg. / Refining

Est. Annual OCM Spend:
$16,790 ($350 per unit / year)

Est. Cost Savings:
Equipment repair – $4,800
Lost Production – $40,000/day

PROPER UTILIZATION

Oil analysis is most effective when used as a regular component of an ongoing predictive or reliability-centered maintenance program. Users need to sample the right equipment at the right time using the right sampling method.

The decision process for the determining what equipment should be tested should be made based upon the criticality of each piece of equipment. Sample frequencies should be based on the usage or utilization of the equipment. Sampling location and technique should be determined by the ability to capture the most representative sample - upstream or prior to filtration and away from "dead flow" areas.

Equipment criticality covers many items. Consideration should be given to the level of importance the piece of equipment has to the overall production of the plant (or line). The cost of repairs and the cost of replacement also factor into the decision-making process. These costs must include parts, labor and lost production due to downtime. Of least importance is equipment sump capacity. In many instances plant personnel forgo sampling small sump capacity units even though failure could bring an entire production process to a halt. Cost of productivity and repair and replacement costs should drive sampling - not lubricant cost or sump capacity.

Sampling frequency is typically based on hours on the lubricant in use. Another key component in setting proper sample frequencies is factoring the rate of change in wear or lube degradation that can occur over short periods of time.

An example is an abnormal wear pattern that may further accelerate due to the speed of the unit's rotating components, which results in "wear creating wear." Or, equipment with tendencies for lube contamination from outside sources may experience very quick changes in viscosity due to the type of contamination. In these and similar situations, sampling frequencies should be shortened in order to increase the chances for detecting problems earlier.

Proper sampling location and technique is a critical element of a successful program. The lubricant holds much information about the condition of the equipment. Without a proper, representative sample of the lube in use, diagnostics are restricted. Wherever possible, samples must be pulled from the circulating oil upstream of the filter housing. Samples should be taken with the oil at or near operating temperature and no later than fifteen minutes after a shutdown.

Whenever possible, sample valves should be installed and used. This helps guarantee a proper sampling location, with the sample being taken in the same manner each time, regardless of who is taking the sample. In order of preference, samples should be taken via:

1. properly located sample valves
2. with a pump and tubing from the mid-sump point
3. drained oil from plugs or discharge piping, AFTER enough oil has flowed to allow for purging sediment around the plug hole or static oil has been removed from the piping

Two last items in the utilization of a program are proper paperwork and prompt delivery of the samples to the laboratory. Unless the laboratory has the proper required information regarding each piece of equipment enrolled in the program and on each individual sample, the ability to accurately evaluate the test results to determine equipment and lube condition is restricted.

Required equipment and sample information includes:

- identification number (asset #, serial #, id #)
- equipment type (turbine, compressor, hydraulic)
- manufacturer make and model
- oil manufacturer, brand and grade in service
- oil sump capacity
- any unique information about the equipment, its location or application (for example: located in a high ambient temperature area or equipment is located near ….)
- filtration system utilized, # of filters and filter rating
- equipment identification number
- hours of operation on equipment since new (or last overhaul)
- hours of operation since last oil change
- amount of make-up oil (if any) since last oil change
- changes in oil or oil filters at the time of sampling
- sample date

When provided, this information allows diagnosticians to properly assess the equipment and lubricant condition based on utilizing the variable information that is specific to each sample. For example, a test result of 125 ppm of copper on a sample from a Cincinnati worm drive gearbox with 1000 hours of running time on the oil might be considered quite normal while the same unit with the same 125 ppm of copper reported on 200 hours of running time on the oil may represent a significant wear-related situation. In this case, the run time on oil would be the critical factor, representing the time over which the wear products accumulated before the sample was taken.

QUALIFIED LABORATORIES

There are three sources of laboratory services available to industry: in-house facilities, major suppliers and independent organizations. In-house facilities, which are manned and operated by company personnel, are most prevalent when the sampling facility has unique requirements for testing, are in an extremely remote area or have difficulty in shipping samples to an outside lab due to environmental or legal restrictions.

Major suppliers such as manufacturers and oil companies often provide oil analysis as a requirement for warranty or a value-added service. Testing through a major supplier can be fee-based or included with the purchase of product. Independent organizations such as Bureau Veritas, are laboratories that provide oil analysis as a core business proposition.

Users have multiple choices in oil analysis laboratories. In-house, major supplier or independent is not as important as the laboratory's qualifications. Qualified laboratories are determined by two primary components - the ability to provide accurate test results and accurate, meaningful diagnostics.

The process begins with the need for accurate test results. The data must conform to established industry (ASTM) parameters for repeatability and reproducibility and must be based on the appropriate methodology for the equipment and lubricant being tested. Quality certifications such as ISO 17025, Appendix B, are certainly differentiating factors which help identify quality laboratories.

Beyond certification, a lab should have the knowledge to recommend and perform the appropriate tests based upon the equipment type, application and lubricant in service. It is incumbent upon the lab to demonstrate this knowledge to the user, but it also incumbent upon the user to demand this knowledge and ensure that it's utilized.

Meaningful diagnostics are the end point of the lab services. Once quality data is produced, test results must be interpreted and translated from numbers and values into specific statements of condition with recommended actions to correct the identified problems and their causes.

It is also the laboratory's responsibility to demonstrate the level of diagnostic ability and experience in the user's industry. It is the user's responsibility to ensure they understand the level of expertise the lab possesses and that it is acceptable to the expectation and requirement of the user.

Individual certifications such as STLE's CLS (Certified Lubrication Specialist) or an academic accreditation for a data analyst, such as a degree in engineering, physics or chemistry, will help differentiate the laboratory's ability to provide meaningful diagnostics and recommendations for sample data.

PROPER TESTING

Oil analysis can be comprised of literally thousands of different tests to determine hundreds of different sample properties. However, logic dictates that commercial use for a reliability-centered maintenance program defines oil analysis as a slate or series of tests performed on used lubricants to determine component wear, contamination and certain physical properties of the lube in use.

Generally, oil samples are provided based upon a pre-packaged slate of tests. It is important that the user understand the tests and the methodologies used to perform the tests when selecting the various slates. Lack of test knowledge or strictly price-driven decisions can easily lead to misapplication of the testing and lackluster results in the overall program.

Tests can be categorized into three areas - contamination, physical properties and wear. The tests routinely utilized in used oil analysis include: Sometimes within one section you'll have several examples. Here's a great way of laying those out.

Contamination

Test/Application	Methodology
Moisture or water	KF, Crackle, FTIR, Distillation
Dirt or dust	Elemental analysis, MPF
Hydrocarbons	GC, Flash Point
Particulates	Particle count (laser, pore blockage) Gravimetric Analysis

Test/Application	**Methodology**
Physical Properties	
Viscosity	D445
Neutralization Number, AN, BN	D664, D974, D2896, D4739
Oxidation	FTIR, RULER
Nitration,	FTIR
RPVOT	D2272
Demulsibility	D1401
Foaming Characteristics	D892
Color	Gardner, D1500
Wear	
Spectrochemical	AE, ICP,AA
Ferrography	Microscopic Analysis
Filter Patch	Microscopic Analysis

The key to a successful program is "appropriate" tests for the specific equipment and lubricant in service. Both of these items have a direct bearing on the validity of the analysis and the diagnostics.

An example of this is when a moisture content reported in ppm is required for a piece of equipment where the lubricant in use is heavily additized as part of its normal additive package. The typical test to determine the moisture content is Water Karl Fischer. However, there is more then one technique for running a Karl Fischer.

The most common technique used by laboratories is where the sample is injected directly into a titration vessel. Unfortunately, in these instances, heavily additized or "well-fortified lubricants cause interference with the methodology and false high readings are reported. The proper methodology is to use an oven method Karl Fischer where the sample is heated under controlled conditions. The moisture in the sample is vaporized and then carried by an inert gas to the vessel chamber for titration. The additives do not enter into the chamber and a correct moisture level is reported.

The following table lists recommended test slates for generic equipment types. Adjustments to these recommendations may be made based upon the specific type of equipment manufacturer, application and lubricant in use. Finalization of testing should be made after the user and laboratory discuss and define the program goals and objectives.

TEST	Compressor	Gear Box	HVAC	Hydraulic	Pump	Turbine	Engine Diesel	Engine Nat. Gas
AN	•	•	•	•	•	•		•
BN	• (1)						•	•
Color	•							
Ferro DR		•				•		
Fuel Dilution							•	
Nitration								•
Oxidation								•
Particle Count				•		•		
RPVOT						•		
Soot							•	
Spectro Chemical (2)	•	•	•	•	•	•	•	•
Viscosity (3)	•	•	•	•	•	•	•	•
Water	• (5)	• (5)	• (4)	• (4)	• (5)	• (4)	• (5)	• (5)
Other								

(1) for ammonia compressors
(2) RDE, ICP or AA
(3) 40° C or 100° C
(4) Karl Fischer
(5) Crackle

A successful oil analysis program will provide the user information that will identify wear rates of oil wetted components, levels of contamination present in the system and certain physical properties of the lubricant. Wear is generally attributed to a “cause and effect” scenario. Contamination and or changes in the properties of the lubricant are the “causes” that create accelerated wear, or the “effect.”

By properly testing for the appropriate contaminants, measuring changes in physical properties and monitoring wear metals, a qualified laboratory can identify problem areas well in advance of outward signs and should provide diagnostic alerts to recommend corrective actions that will not only correct the indicated problem(s) but more importantly, the causes of the problem(s).

USER COMMITMENT

A successful oil analysis program can significantly contribute to the reduction of maintenance costs when all levels of the organization commit to it. Management must commit to budgeting sufficient resources for including all critical equipment and providing sufficient personnel for sampling at the proper frequencies and addressing issues found.

Reliability personnel should demand that their laboratory assist them in the identification of critical equipment, establishment of proper frequencies, provide immediate (24-hour maximum) response on sample turnaround and, if applicable, integrate the data delivery into an existing CMMS program or provide electronic delivery of the data so that it can be easily managed.

Training, with the assistance of laboratory personnel, should be provided to the individuals charged with taking the samples and completing the necessary paperwork.

A full understanding of what is involved in a program and why helps ensure that accurate and complete information is constantly exchanged between the user facility and the laboratory.

For example, samples that are taken in the proper manner with complete and accurate information but are left to sit in a mail room for several days before shipping to the laboratory, defeat the purpose of getting accurate data in return as soon as possible. Generally, an abnormal situation can be considered a critical situation waiting to happen - it's just a matter of time. Should a sample be delayed in getting to the laboratory, it is quite possible that a costly problem might have been avoided. Unless the sampler is aware of this possibility, the urgency in shipping a sample may not exist.

When problems are identified by oil analysis, corrective action needs to be taken immediately. Minor and scheduled maintenance activity is always less expensive then major or unscheduled activity. The productivity or earning capacity of a piece of equipment is always greater than the cost of repair. Unscheduled downtime is an unacceptable event in a reliability-centered maintenance program.

The following is a fully documented case history of a chemical processing plant's commitment to a properly utilized oil analysis program. The proper testing with a qualified laboratory has been identified and all levels of the organization are committed to the program's success.

EQUIPMENT DIAGNOSTIC REPORT

Chemical Processing Plant
Propane Delivery Pump 60P-637A

EQUIPMENT DIAGNOSTIC REPORT

Chemical Processing Plant
Propane Delivery Pump 60P-637A

Equipment Detail

Equipment No.	60P-637A
Description	Propane Delivery Pump
Pump Mfr.	David Brown Union
Size	3”, QD-5240
Type	Reciprocating
Serial No.	CA4448A501
Pump Speed	306
RPM No. of Cylinders	5
Mounting	Horizontal
Main Bearings	4 (2 taper roller, 2 sleeve)
Process Pressure	1,440 PSIG
Coupling Mfr.	Gates V-Belt
V-Belt No.	5VX-1800
No. of Belts	10
Shaft Centerlines	38
inches Motor Sheave Dia.	9 inches
Pump Sheave Dia.	50 inches
Motor Mfr.	Teco Westinghouse
Size	200 HP
Type	Variable Speed
Motor Speed	1,780 RPM Frame 447T
Volts	480
Amps	88
Motor Bearings	NDE: 6318 DE: NU3320

Operational Purpose & Significance

The propane delivery pump injects 8% propane into a 100% pure ethane stream at 1,440 PSI. Customer delivery requires an ethane/propane mix (EP mix) of 92% ethane and 8% propane. There are two 100%-duty pumps so one pump operates continuously. There are two conditions when we do not use the propane delivery pump to inject propane into the ethane stream:

1. Plant economics make it more profitable to re-inject the ethane back into the pipeline (negative number)

2. When a high BTU content is delivered into the plant, we able to make up the 92/8 EP mix directly from our de-methanizer tower.

Ethane production is 40,000 bbl/day at 68% liquid recovery rate. The ethane market varies from a negative number to $2.50/bbl. profit. With an average of $1/bbl, the customer makes $40,000/day profit making the propane delivery pumps critical to plant production.

EQUIPMENT DIAGNOSTIC REPORT

Chemical Processing Plant
Propane Delivery Pump 60P-637A

Conditions Noted

1. Both propane delivery pumps; 60P-637A/B were not in service due to the high BTU content of the inlet gas. Typically one pump is in service under normal pipeline conditions.

2. Pump No. 2 cylinder packing vent line was iced up indicating cylinder packing, leaking gas (propane) into the low pressure flare header (see packing leak photo below). No. 2 cylinder packing was last replaced two years ago.

3. A routine oil sample was visibly diluted and also had a very strong odor from a hydrocarbon dilution such as propane (C3).

4. Oil analysis indicated abnormal component and lubricant conditions: oil analysis report showed possible hydrocarbon contamination in the oil sample.

5. Past vibration trend data did not show any significant increases. The last vibration data on this pump was collected three months ago.

CYLINDER NO. 2 – PACKING LEAK

EQUIPMENT DIAGNOSTIC REPORT

Chemical Processing Plant
Propane Delivery Pump 60P-637A

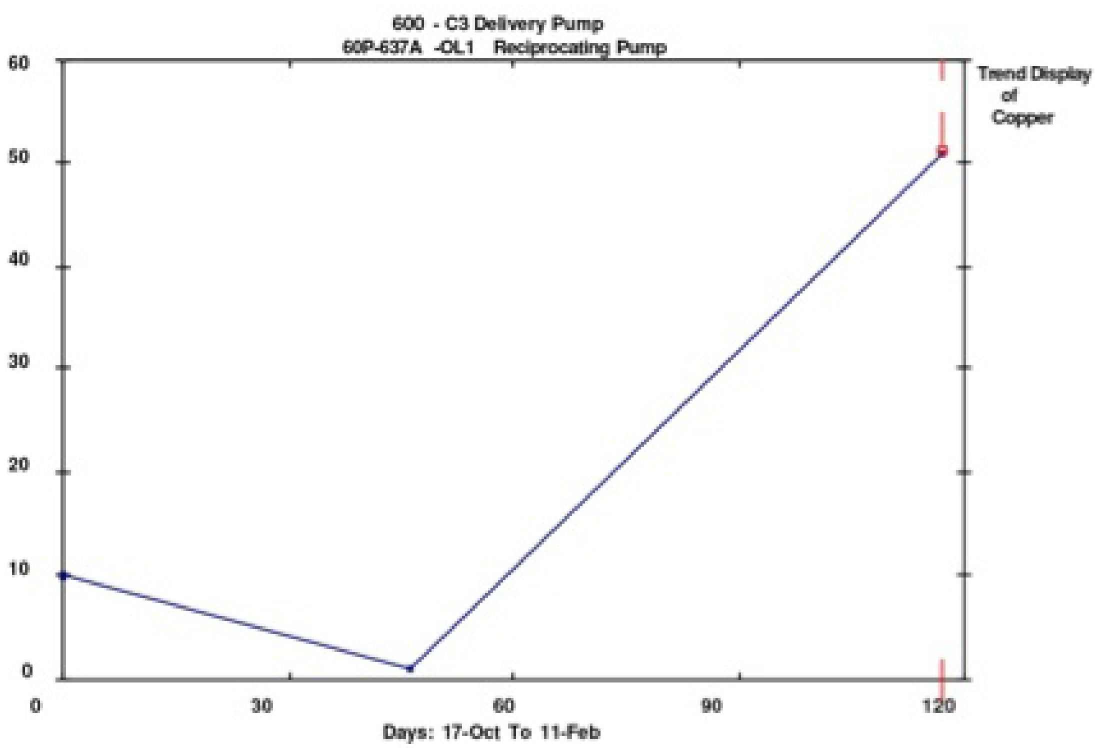
Oil Analysis - Spectrochemical Analysis

Spectrochemical shows copper and tin wear metal content increased. Copper and tin wear metals originate from internal pump components and indicate wear. Copper wear metal content increased from 1 to 51 parts per million by weight (PPM), see trend plot below. Tin wear metals content also showed an increased from 3 to 11 PPM.

Normal wear metal content in oil is less than 15 PPM copper and 10 PPM tin.

Reciprocating pump components containing copper and tin alloys: Bearings, Wrist Pin, Bushings and Thrust Washers.

COPPER ELEMENT TREND PLOT



Spectrochemical Analysis:
Selected metallic elements present as microscopic particles suspended in the fluid to be analyzed are identified and measured in parts per million by weight. The analyzed elements are grouped into three main categories: Wear Metals, Contaminants & Additives.
In addition to the viscosity result, the crankcase oil viscosity class of an engine lubricant may also be expressed as an SAE Grade. 1 Centistoke (cSt) 1 square millimeter per second.

EQUIPMENT DIAGNOSTIC REPORT

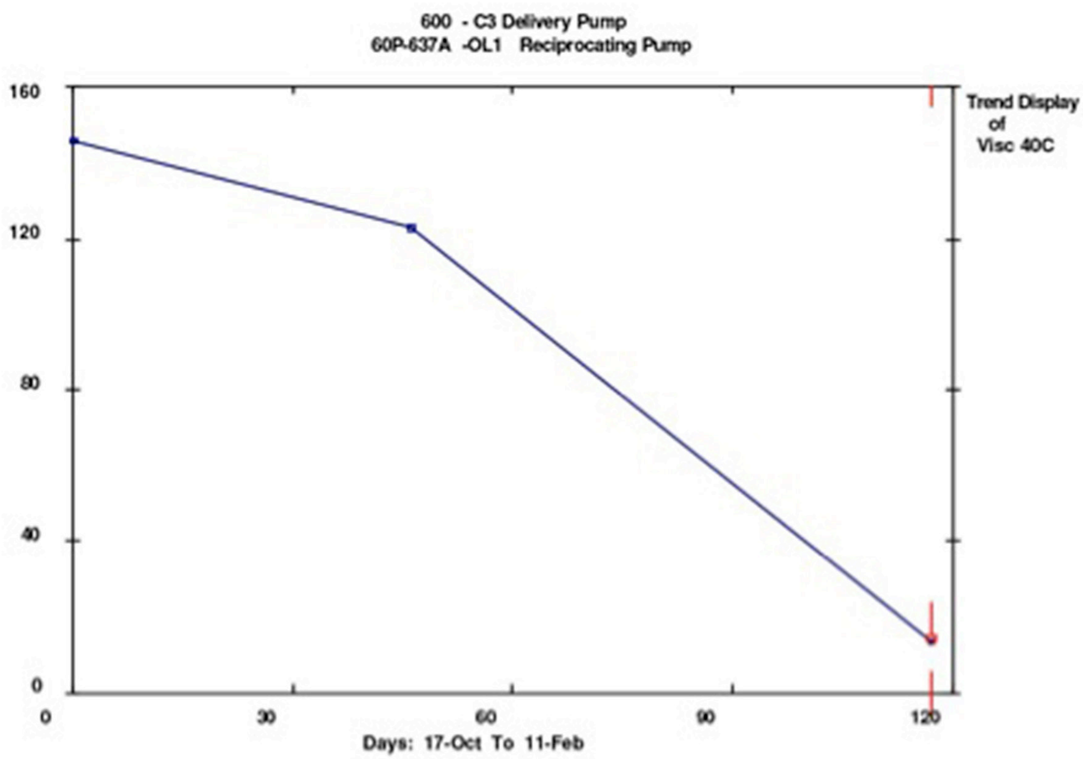
Chemical Processing Plant
Propane Delivery Pump 60P-637A

Conditions Noted

The pump lubricant oil viscosity decreased 91% from 150 to 13.5 centistokes (cSt), see oil viscosity trend plot below. The decrease in oil viscosity was caused from contamination and dilution with a hydrocarbon product.

Normal oil viscosity for Mobil SHC 629: ISO VG 150

OIL VISCOSITY TREND PLOT



Viscosity is a lubricant's internal resistance to flow at a given temperature (40° C) in relation to time and is considered to be the single most important physical property of a lubricant. Changes in viscosity indicate improper servicing, dilution, contamination or lubricant breakdown in service.
Viscosity is usually determined with a kinematics method and the results are reported in centistokes (cSt).
In addition to the viscosity result, the crankcase oil viscosity class of an engine lubricant may also be expressed as an SAE Grade. 1 Centistoke (cSt) 1 square millimeter per second.

EQUIPMENT DIAGNOSTIC REPORT

Chemical Processing Plant
Propane Delivery Pump 60P-637A

Oil Analsysis - Recommendations for Corrective Action

1. Replace pump cylinder No. 2 packing.
2. Investigate possible propane gas leakage into pump oil system.
3. Drain, flush and replace pump oil with synthetic Mobil SHC 629, 10 gal capacity.
4. Increase oil sample frequency from 60 days to 30 days.

Corrective Action Taken

1. Maintenance changed pump cylinder No. 2 packing and all 5 crosshead pump lip seals.
2. Maintenance drained, flushed and re-filled pump crankcase with 10 gallons of synthetic Mobil SHC 629 oil.
3. Routine oil analysis to be monitored every 30 days.

Oil Analysis – Root Cause Analysis

Possible route of entry for the propane gas into the pump crankcase is from the crosshead lip seal shown below. No. 3 crosshead lip seal showed oil leakage from the pump crankcase.

CYLINDER NO. 3 LIP SEAL

EQUIPMENT DIAGNOSTIC REPORT

Chemical Processing Plant
Propane Delivery Pump 60P-637A

Cost Savings

Following are the pump parts and related costs for rebuilding the pump due to a lubrication-related failure:

Cross-head Pin (5)	$805.00
Bearing, Connecting Rod (5)	$785.00
Deflector, Cross-head Stub (5)	$145.00
Bearing, Inner Race (2)	$412.00
Bearing, Outer Race (2)	$142.00
Shim, Crankshaft (1)	$9.00
Shim, Crankshaft (1)	$8.00
Shim, Crankshaft (1)	$11.00
Oil Seal, Crankshaft (1)	$39.00
Oil Seal, Cross-head Stub (1)	$19.00
Gasket, Crankshaft Cover (1)	$16.00
Gasket, Crankcase Inspection Cover (1)	$18.00
Labor Costs (2 x 24 x $50)	$2,400.00
Total Potential Cost Savings	**$4,809 per failure x 4 = $19,236**

The above cost analysis assumes the connecting rods were reused, if connecting rods were damaged they would cost an additional $882 each x 5 cylinders = $4,410 per failure.

Analysts, Inc., oil analysis has detected a decrease in oil viscosity on 60P-637A and B pumps on four occasions. The oil was replaced with no interruption in production and no internal pump repairs. The cost for replacing the synthetic oil was $80 per occurrence. The cost for each oil analysis was $32 per sample.

SUMMARY

Oil analysis should be implemented with established goals, expectations and user requirements and will provide extraordinary returns on invested resources if implemented with open lines of communication between maintenance personnel and a qualified laboratory.

A cost effective oil analysis program can be implemented and maintained and will provide significant information to maintenance and reliability managers on the condition of oil-wetted components and lubricants from critical equipment in use within their organizations - information that identifies wear related problems, contamination and changes in lubricant quality that will effect equipment performance. Reaction to this information and follow-up on recommended maintenance activities will result in increased uptime, lower cost of operation and reduced & delayed capital outlays for equipment replacement.

Findings were compiled in conjunction with Vibration Institute.