WEAR® CHECK
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WEAR CHECK
CONDITION MONITORING THROUGH OIL ANALYSIS

THE BEST OIL ANALYSIS PROGRAMMES START WITH A GOOD SAMPLE

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The accuracy of analysis of an oil sample is greatly influenced by two aspects of the whole procedure the customer controls: how the sample is taken and the information accompanying the sample. The latter has been dealt with in previous technical bulletins (Issue 33 'When oil analysis does not work' and issues 31 and 32 'The humble sub form is a linch pin of oil analysis'). The taking of an oil sample is where the whole analytical process begins. All the sophisticated oil analysis tools, techniques and diagnostic processes are meaningless if the oil sample fails to represent the actual condition of the oil in service in the machine.

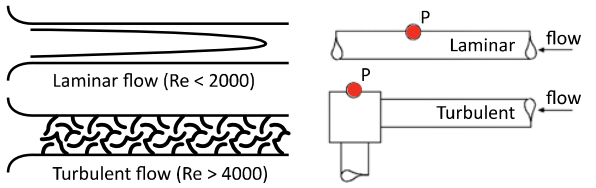
The way a sample is collected, the accessories used and procedures followed dictate how informative the oil sample will be and how beneficial the analysis will be. That is why it is of great importance that the sample be taken correctly. If the oil sample taken is not representative of the oil in the machine then the results of the oil sample will not accurately reflect the condition of that component. The result will be an incorrect diagnosis based on incorrect analysis because of a poorly taken sample. Establishing effective, user-friendly oil sampling procedures helps to build an oil analysis programme that creates value through better maintenance decisions.

In this article we are going to cover the importance of correct sampling procedures and the different methods currently used. If we are going to understand what we are looking for in an oil sample we have to briefly touch on a few fundamentals of hydrodynamics.

The subject of fluids in motion is called hydrodynamics. To understand hydrodynamics as it pertains to oil sampling, the concepts of laminar and turbulent flow need to be understood. The word laminar means layered. This describes a smooth fluid flow. Fluids are made up of particle layers that slide by each other and follow a smooth somewhat consistent path. Turbulent flow describes erratic fluid flow, characterised by small whirlpool-like currents

called eddy currents. The Reynolds number is a dimensionless ratio of fluid flow used to determine the transition point from laminar to turbulent flow.

Live zone sampling – dos and don'ts			
✓	Turbulent zones such as elbows	x	Dead legs
✓	Downstream of system (bearings, gears)	x	Laminar flows
✓	Sample while machine is running	x	After filters
✓	Sample under typical working conditions	x	Machine cold/ not operating
✓	Sample from live fluid zones		



Turbulent flow is ideal for oil sampling because the fluid in this area is turning over itself. This provides a homogeneous mix of particles of different shapes and sizes, which can be more evenly distributed in the sample. The best sampling locations are highly turbulent areas where the oil is not flowing in a straight line but in a turning and rolling action in the machine. The turbulent zone can usually be found in an area where the fluid changes direction at high velocity creating a high Reynolds number.

By contrast laminar flow is quite different, in that larger particles tend to flow in the boundary layer of the system (where the velocity is at its lowest) and the smaller particles tend to flow towards the centre where the fluid's velocity is at its highest. The distribution of larger particles in the oil is influenced by the size and shape of the particle itself so sampling in laminar locations will not provide an accurate distribution of particles (wear particles or contaminants) for analysis.

In layman's terms, because the larger heavier stuff sits at the bottom and the lighter smaller stuff towards the middle, the particles are not evenly distributed throughout the oil. When you take an oil sample to determine the health of a component, it is important to obtain data that is not only consistent but accurate as well. The way to ensure this is by selecting a sampling point that can provide turbulent flow for an accurate data-rich sample.

Now, at this point, you might be asking yourself why all the fuss about how to take a sample? Proper sampling procedures build the foundation of an effective oil analysis programme. Without good sampling procedures, time and money are wasted and incorrect conclusions are reached based on faulty data. This undermines the value and, more importantly, confidence of an oil analysis programme.

So what do we want? We want an oil sample that effectively represents the body of oil about which we require data in order to increase the effectiveness of oil and machine decisions. The bottom line is to maximise data density and minimise data disturbance.

Vital sampling principles	
✓	Time – when?
✓	Frequency – how often?
✓	Clean, correct tools
✓	Clean sampling ports
✓	Drain dead oil out – 10x volume
✓	Sample bottle 75% full
✓	Sample information – age of oil, age of machine, etc.

So what exactly do we mean by data density and disturbance? Samples should be taken in such a way that there is as much information per millilitre of oil as is possible, i.e. maximising data density. Taking a sample that maximises data density and minimises data disturbance

is of vital importance when selecting a sampling location.

However, maximising data density is dependent upon the nature of the data you desire. For example, if you want to assess the effectiveness of a system's filter, we must collect a representative sample before and after filtration. The difference between the two samples is reflected in the differential particle count across the filter. Depending on the results, a decision to retain or change the filtering practices can be made.

In this instance, maximising density of information requires the analyst to obtain two representative samples from a specific location to calculate the information required. Different objectives require different sampling procedures. The objective should drive the sampling procedure.

The above example applies to transient properties like measuring particles (wear and contaminants). Transient properties depend upon the location from which the sample is collected. By contrast homogeneous properties like viscosity, TAN (Total Acid Number) and TBN (Total Base Number) tend to remain constant throughout the oil. Transient properties pertain to equipment health and contamination while homogeneous properties pertain to the oil and additive health. It is more difficult to maximise data density of transient properties and, for this reason, effective sampling of transient properties is essential if reliable and trendable data is expected.

Data disturbance refers to interference associated with gathering, preparing and analysing an oil sample. Failing to sample from a running machine, where the oil is not hot or well mixed, is a common source of data disturbance. Ideally the machine should be operating at normal load and speed in its typical environment when taking a sample otherwise particles and moisture can settle when the sample is taken, causing data disturbance.

Using dirty sampling equipment and exposing the open bottles and caps to the environment disturb the quality of the data. A common example of data disturbance often encountered is the cleaning of sampling equipment and bottles with diesel or solvents. Even residual amounts of diesel from this cleaning error can be detected by most oil analysis laboratories and mistakenly diagnosed as evidence of a fueling problem on an engine.

By communicating a potential source of interference with a given sampling method or location, the diagnostician can be on the lookout for these pitfalls, reducing the likelihood that the oil analysis results will be compromised. This is especially important when the sampling point or required process is less than ideal due to the location of the machine or operation-related restrictions. In the case of a sample bottle washed out with diesel, the simplest communication by the sample taker could avert an overreaction to the fuel detected in the sample.

The oil sample should be extracted in such a way that the concentration of information is uniform, consistent and representative. It is important to make sure that the sample is not contaminated during the sampling process. At the end of the day we want to ensure that what enters the bottle is both rich in information and remains undisturbed by the sampling process itself. To ensure good data density and minimal data disturbance one should consider the following factors: sampling location, sampling procedure, sampling device and sample bottle.

As with real estate, one of the most important aspects of taking an oil sample is location, location, location. Not all locations in the machine will produce the same data. Some are far richer in information than others. Some machines require multiple sampling locations to answer specific questions related to the machine's health.

There are three main ways an oil sample can be extracted: through the drain plug, using a vacuum pump with a drop tube and via a dedicated sampling valve.

All three methods can deliver representative samples but the sample valve is preferred. Obtaining a representative sample from drain port or

drop tube sampling is influenced by the technical understanding of the potential pitfalls of the process itself. Even though widely implemented, drain plug and drop tube sampling are not considered best practice as the potential for data interference is greater given the human factor.

Why do we sample?

✓	**Lubricant health** • Chemical properties • Physical properties • Contamination control
✓	**Machine health** • Normal/abnormal wear modes • Failure indicators
✓	**Contamination levels** • Dust/water/other oils etc.

Your sampling strategy (location, tests, frequencies) should reflect your goals.

DRAIN PLUG SAMPLING

Samples taken from the bottom of the sump will show higher and unrepresentative concentrations of bottom sediment and water (BS&W) as compared to live zone sampling. The first problem with this method is that, unless stated, the analyst will assume that the well mixed overall concentrations are being measured and are not concentrates from the bottom of the tank. This can lead to an overreaction from a diagnostic point of view. For this reason it is important to inform the laboratory and analyst of the sampling method used.

Drain plug sampling is the least preferred method as there is a good chance that the debris on the outside of the plug and sediment at the bottom of the sump will find its way into the bottle, making results appear worse than they actually are.

If, however, there is no other way then every attempt must be made to ensure the sample is as representative as possible by minimising data disturbance. The first step is to ensure that the oil is at operating temperature. This will ensure that the oil is well mixed and will minimise interference from water condensation. Clean around the drain plug to remove dirt that might contaminate the sample. Remove the drain plug and allow a litre of oil to drain to waste. This will help prevent bottom debris from the sump contaminating the oil sample. Fill the bottle to about the three quarter level allowing for sufficient ullage for agitation in the laboratory. Make sure that waste oil is disposed of in an environmentally sound manner.

Pros

- Only a sample bottle is required (and maybe a first aid kit if you spill hot oil all over your hands).

Cons

- The health hazard of burning one's hand while trying to take an oil sample that may be at an operating temperature as high as 100° C.
- The high likelihood of unrepresentative data due to contamination by sump bottom sediment.
- A greater likelihood of the sample being taken cold to avoid the hazard of working with hot oil.

VACUUM PUMP/EXTRACTION PUMP/ THIEF GUN SAMPLING

The thief gun is a simple vacuum pump. A sampling tube is attached to the pump that works like a bicycle pump in reverse and can be inserted into the equipment to be sampled. A sample bottle is also fitted to the gun and oil can be drawn through the tube into the sample bottle.

Once again make sure that the oil is at operating temperature. Insert the sample tube down the dipstick hole. Draw a small amount of oil to be sampled into the rinse bottle in order to rinse out any previous oil residue from the tubing. Attach the sample bottle to the pump and fill to the three quarter mark. When sampling, try to ensure the tube does not touch the

bottom of the sump. Chamfering the tip of the tubing helps in this regard.

Ideally the sample should be taken from the same depth every time to ensure the data is consistent. This can be achieved by measuring the tubing against the length of the dipstick. Sizing the tubing to the appropriate length will also ensure the tube does not coil up inside the sump above the oil level. As a general rule, thin sampling tubes are for thin (low viscosity) fluids such as engine and hydraulic oils and the thicker tubing is usually intended for thicker (high viscosity) fluids such as final drive and gearbox oils. Disposable tubing is also commercially available and, while more expensive, will ensure that cross contamination does not occur when more than one sample has to be taken at a time.

A sampling gun (WISP)

Pros

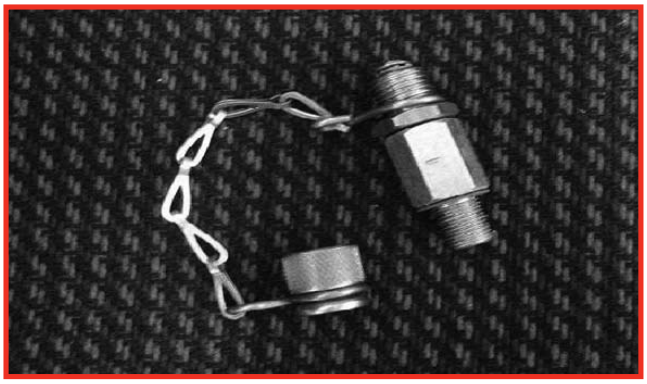
- This is a simple and low cost way to draw a sample of oil.
- The same pump can be used to sample different components.
- The flow of oil can be easily controlled.
- It requires no external modification to the component.

Cons

- The tube that is directed into the dipstick port can be difficult to control. The tube's final resting place can be hard to predict, resulting in samples being taken from different locations within the sump.
- There is always the risk of the tube actually going all the way to the bottom of the sump where debris and sediment can be picked up.
- The possibility of cross contamination of sampling tubes with another oil that has been sampled at the same time.
- The drop-tube method is intrusive. The intrusion introduces the risk of contamination while the machine is being exposed to the environment.

VALVE SAMPLING

Using a sample valve to take an oil sample is the preferred method as it is easy, clean and simple. If you make things easy, clean and simple you increase the likelihood that they will be done correctly. It is also the best way to avoid contaminating the sample. The machine has to be running in order to take the sample and the sample will always be taken from the same location. As with the first two sampling methods, the oil also has to be at operating temperature. Remove the dust cover that prevents contaminants from entering the valve body, clean the valve orifice and attach the connector that releases the valve and allows oil to flow. Allow half a litre of oil to drain into a rinse bottle. This will help purge the sampling tube of previous oil residue. Disconnect the rinse bottle and attach the sample bottle. Fill the bottle remembering to leave sufficient ullage. Where to position the sampling valve if one is not already fitted? Golden rule: after the component but before the filter. The valves come in different sizes with a variety of connectors with high pressure options.



An Imperial engine sampling valve (WVEB)

Sampling tubing and fitting (WVCE)

Pros

- More consistent and representative results as the machine has to be running and the sample will always be taken from the same location.

Cons

- Requires mechanical modification of equipment if the valve has to be retro-fitted.

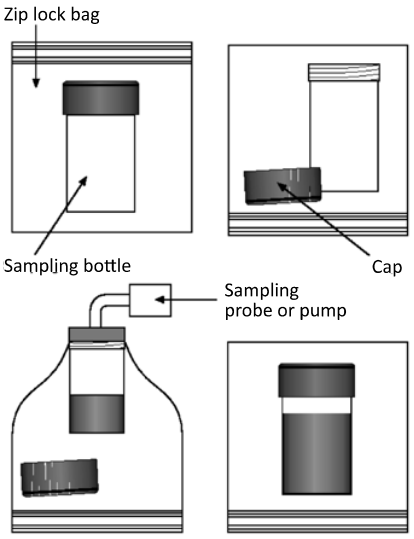
- Modern oil analysis programmes include tests that can be influenced by environmental contaminants entering the sampling bottle during the sampling process like particle counting and elemental spectroscopy. In situations where there is considerable dust in the environment at the time of sampling, an effort should be made to ensure that this dust does not contaminate the oil. High risk environments include mine sites, primary metal industries and pretty much anywhere there is a desert.

This might seem like over-kill but experiments on the influence of environmental dust on particle counts have shown ISO codes to increase 2-3 range numbers when a sampling bottle has been left open for just a few minutes. So how do you take an oil sample without opening the bottle to the environment? I assure you this is not a beer drinking trick.

The method is called “clean oil sampling” and involves the use of a zip-lock sandwich bag. The capped sample bottle is placed in a thin zip-lock sandwich bag and zipped closed sealing the surrounding air along with the bottle in the bag. This part of the process should preferably be done in a clean indoor environment. The accompanying sampling hardware such as vacuum pumps and probe devices should also be bagged until the moment of sampling to avoid environmental contamination.

When ready to sample oil from a system ensure that the sampling valve or vacuum pump and probe have been adequately flushed. Twist the bottle cap off without opening the bag and allow the cap to fall to the side inside the bag. Now move the mouth of the bottle so that it is away from the zip-lock seal remembering not to unzip the bag. Thread the bottle into the cavity of the sampling device (pump or probe or valve connector), allowing the plastic tube to puncture the bag during the process.

The sample is then collected in the usual fashion until the correct quantity of oil has entered the bottle. To complete the process, grip the bottle inside the bag and unscrew it from the pump or probe cavity. With the bottle free and still inside the sealed bag retrieve the cap inside the bag and manoeuvre it onto the mouth of the bottle and seal tight. It is now safe to unzip the bag and remove the bottle. Do not reuse the zip-lock bag for further sampling or sandwiches. This simple process effectively allows samples to be taken without exposing the oil or the bottle to atmospheric contamination. This method minimises the risk of dirt entering the bottle.

Sampling best practices in a dusty environment	
1. Place sealed bottle in a clean zip-lock bag and seal	
2. Prior to sampling remove the cap without opening the bag	
3. Thread the bottle on to the sampling device without opening the bag	
4. Puncture with the sampling tube	
5. Recap the bottle after taking the sample without opening the bag	
6. Remove the sealed (capped) bottle from the bag, label if needed and dispose of the bag	

What follows are a few golden rules:

- Always sample from running machines, avoid sampling cold systems and remember that the ideal behind taking an oil sample is to obtain a snapshot of the system under normal working load and conditions.
- Flush the sample tubing with the oil from the system you intend to sample from. Avoid flushing sampling equipment with water, diesel or solvent. Modern day oil laboratories employ equipment that can accurately measure concentrations of water contamination below 0.01% and fuel below 2%. Any water or diesel detected in the oil sample might result in an overreaction to what is essentially data interference as a result of poor sampling practices. If diesel or solvent is used to flush sampling equipment, make sure that the equipment is then flushed with the oil that is about to be sampled.
- Ensure that samples are taken at a proper frequency. Factors to take into consideration when deciding sampling frequency should be environmental severity (high dust, load or temperature), machine age (bedding-in/wearing-out) and economic penalty of failure (cost of downtime and repair/replacement). A vital component of oil analysis is trending data received from the oil or, more to the point, trending the rate of change of wear and contamination. In this way one can build up a representative history, essentially a historical mechanical biography of the component being sampled. Having a representative history allows the analyst to spot potential deviations from the norm and alert the customer. It is difficult to build a representative history if the sampling frequency is erratic.
- Sample upstream of filters and downstream of machine components. Filters are designed to remove unwanted debris from the lubricating system so if you take an oil sample after the filter, all the valuable data pertaining to the wear and contaminants will be lost. The exception to this however is sampling before and after the filter as a means to gauge filter operation.
- Ensure that all sampling equipment (valves, vacuum pumps) are thoroughly flushed prior to taking a sample. Do not use dirty sampling equipment or reuse sample tubing without flushing out oil residue from a previous sampling. Cross contamination has always been a problem in this regard. Flushing is an important task that is often overlooked. Failure to flush the sample location properly will produce a sample with a high degree of data interference. To obtain representative data, sampling hardware has to be thoroughly flushed prior to taking a sample. This is usually accomplished by using a spare bottle to catch the purged fluid. It is important to flush five to ten times the dead space volume before taking the sample. All

hardware with which the oil comes into contact is considered dead space and must be flushed.

- Forward the sample to the oil analysis lab immediately after sampling. Do not wait more than 24 hours to send the sample out. Remember you have taken a snapshot of the oil at that point in time. The health of the component and oil can change dramatically in a short period of time. The earlier a problem is detected the less chance there is of catastrophic failure. Oil analysis is a form of predictive maintenance. The whole idea is to detect potential problems before serious consequences arise.

At the beginning of this article I made a statement about how the accuracy of oil analysis is dependent on two aspects of the whole procedure the customer controls: how the sample is taken and the information accompanying the sample. Therein lies the problem: oil analysis is a holistic process.

Summary – sampling practices

High ROI		Time and money wasted	
✓	Live zone sampling	✓	Sampling from drain port
✓	Upstream of filters	✓	Sampling cold systems
✓	Downstream of system	✓	Sampling directly after an oil change
✓	Good, repeatable sampling procedures	✓	Dirty sampling procedures
✓	Proper frequency	✓	Cross contamination
✓	Proper information to accompany sample	✓	Waiting days/weeks before sending samples to lab
✓	Short site-to-lab time	✓	Drop tube sampling instead of using valves

The word holistic can be defined as "emphasising the importance of the whole and the interdependence of its parts". The way you take an oil sample and the information supplied is part of the whole that is oil analysis.

Sending an oil sample to an oil laboratory with no accompanying information is like sending an unidentified blood sample to a pathology laboratory and expecting them to know what to look for in the blood. Sending a poorly taken sample to an oil analysis laboratory is like taking a blood sample from a complete stranger and expecting the pathologist to diagnose what is wrong with you.

In layman's terms my analysis is only as accurate as the sample and information you give me. Hopefully from this article you will see that developing and implementing effective sampling procedures is one of the most important components of a successful oil analysis programme. The bottom line is: what you put in is what you get out. Happy sampling!

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