Time-Based Oil Analysis vs. Real-Time Oil Monitoring

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Introduction

Studies show that 50 to 70% of all equipment failures can be directly traced to a lubrication-related issue, most of which can be found with oil analysis. What most people miss with oil analysis though, is that it can be about much more than determining if the oil is still “good”; it can actually help diagnose other leading causes of machine failure beyond determining if the oil is unfit for continued use.

A simple analogy is oil analysis to blood tests. While a blood test can be used to highlight problems directly related to the health of our blood such as a low iron count, it can also help identify other health problems like high cholesterol or other diseases in the body. Just like how a trained physician can use a blood test to determine the root cause of an illness, a trained oil analyst can use the data from an oil sample to determine the onset of machine failure and detect the presence of unwanted contaminants such as particles, water or even the wrong oil.

For any critical oil-lubricated asset, oil analysis is a vital predictive and proactive condition-monitoring tool. Unlike other condition monitoring technologies, such as vibration analysis and thermography, that predominantly focus on detecting failures, oil analysis is capable of determining the causative factors that can lead to a failure such as the wrong lubricant, degraded lubricant, or contamination from particles or moisture. It is this proactive aspect of oil analysis that makes it such an indispensable tool in the condition monitoring toolbox.

How often should you take oil samples? It is accepted by many in the lubrication field that the optimum oil-sampling interval is every month, but due to the cost of analysis many plants are hesitant to sample this often and opt for a quarterly or even 6 or 12-month frequency. The notion that one month is ideal, probably came from studies of vibration analysis that show the successful identification of incipient failures at about 95% for monthly sampling and only half that with quarterly sampling. The problem with this comparison is that vibration analysis is strictly a predictive condition monitoring tool, which means it identifies the symptoms of a failure.

Oil analysis, while also a useful predictive tool, is primarily a proactive condition monitoring tool. Proactive vs. predictive may sound similar but they are quite different. Where predictive looks for the symptoms, proactive looks for the root cause. We look for particles, moisture and oil degradation; because those are the things that cause machines to wear and ultimately fail. If we can effectively manage those things we get dramatic improvements in MTBF (mean-time between failure) and the savings that go with it. So the real question is; how long are you willing to allow a lubricant problem to persist?

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Challenges with Off-LIne Oil Sampling

Sampling Rate

The single biggest factor that determines how long a machine will last is the rate at which it wears. So, it is important to understand what causes machines to wear in the first place. The most common type of wear in lubricated machinery is abrasive wear and the majority is caused by particle contamination of the lubricant. When clearance-sized particles become trapped between two interacting machine surfaces, they essentially turn one side or the other into a piece of sand paper. Particles and other contaminants are also the primary cause of most other types of machine wear including fatigue, erosion and corrosion. Oil analysis is a very effective tool for identifying and measuring contaminant levels and its effectiveness linked directly to the frequency of sampling. If a hydraulic filter fails, which is common, there may be no indication of a problem other than the particle count itself, as the pressure drop across the filter may actually decrease. If the oil is not sampled for months, significant damage will occur until the problem is identified.

Analysis Delays

Traditionally, oil analysis has been route based, just like vibration analysis. Unlike vibration analysis, where a trained analyst can immediately identify a problem by looking at characteristic defect frequencies or even the time waveform, oil analysis requires the additional step of submitting a sample to an oil-analysis lab—either onsite or offsite—so that detailed physical or chemical tests can be conducted to try to identify issues. This additional step can often add days or, in extreme cases, weeks to determining whether there is a pending problem. While this is not always an issue in slower moving equipment, in higher speed machinery or mobile-fleet applications, any delay can be catastrophic.

Sampling Location

Many sampling errors arise from where the sample is being drawn. Unlike a blood test where the results are homogenous, meaning the analysis should be the same no matter where the blood sample is being collected from, many oil analysis parameters are very sensitive to where and how the sample is taken. Sampling from a large sump or immediately downstream from a filter will provide very little indication of particle ingression. Sampling immediately after a component that is wearing or immediately downstream from a source ingression, such as a bearing housing or hydraulic actuator, is an excellent way of finding a problem early.

Cross-Contamination & Misapplication of Lubricants

Cross-contamination and misapplication of lubricants is a very common problem and usually does not lead to a catastrophic failure, but it can. More often, it results in a loss of key performance properties and the lubricant mixture, or wrong oil, simply lubricates less effectively than the proper lubricant. With long sampling intervals, this problem may go unnoticed resulting in an abnormally high rate of wear and loss of service life for lubricated components.

Unpredictable Contamination Events

Oil quality and wear debris are typically not static, consistent, or slow changing within assets. Changes typically revolve around events, especially when transitioning from healthy to non-healthy states. Wear debris is lost in bursts over a period of time and may be quickly filtered out by the filtration system. Whether or not the fault is detected, depends on when a sample is taken ***(see Figure 1)***. Contamination events or changes in oil properties, such as water contamination or additive dropouts, also occur in time periods much shorter than standard oil sampling frequencies. This often results in undetected fault conditions, causing further damage that, in many cases, cannot be reversed and may lead to catastrophic failure.

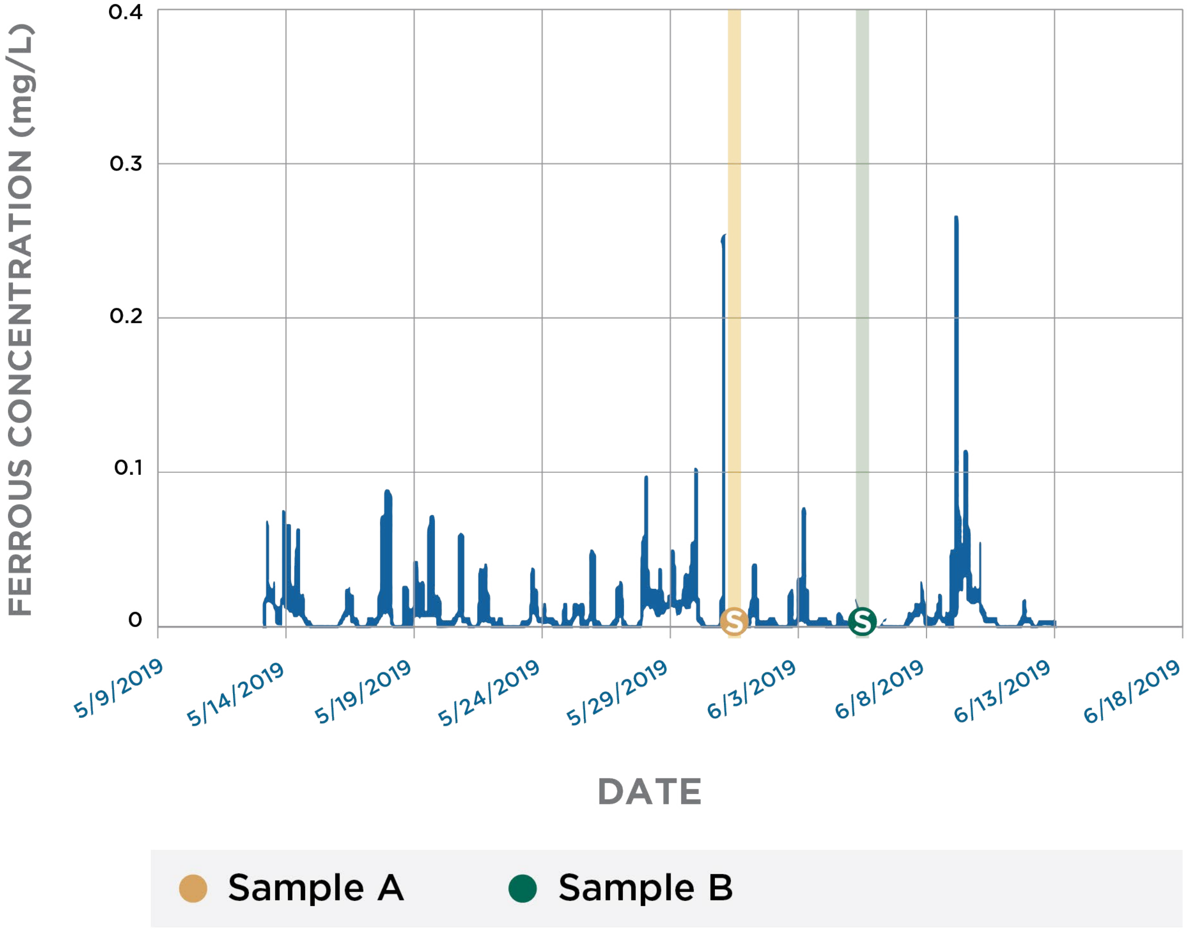


Figure 1: Example of Wear Debris Measurements Over Time vs Manual

Overcoming These Challenges With Real-Time Oil Condition Monitoring

With the rapid expansion of connected products in the industrial world, oil monitoring instruments and condition management products have evolved to utilize this technology. It is now possible to view the particle count, moisture concentration, oil quality and fluid level at any time from a computer, tablet or smartphone. These items, as well as other useful sensor data, can be easily integrated into a simple platform that puts the information at the maintenance professional's fingertips in real time.

In oil analysis, the data is an instantaneous snapshot of how a machine is operating at the exact moment the sample is acquired. This can have a profound effect on the results. Consider the example shown in ***Figure 2.*** The data shows the results of flushing a hydraulic system using a bypass filtration unit during normal operation. To insure that filtration is having the desired effect, the overall cleanliness of the oil is being monitored using real-time particle counting in the 4-, 6-, and 14-μm particle size range per ISO 4406:99. While the overall trend in particle contamination is decreasing, as measured by the linear 4-μm trend, the shot-to-shot variation in all three particle size ranges is significant, corresponding to when pumps, valve, and actuators are starting and stopping.

Now, imagine taking a bottle sample sometime during the trend shown in ***Figure 2***. Depending on the machine-operation phase, it is highly possible that the sample will be taken at either a peak or trough in the particle-count trends. As such, the reported particle count may appear erroneously high or low since the bottle snap is simply an instantaneous snapshot of what is happening in the system. Only by monitoring particle count in real time can the true effectiveness of the bypass system be determined.

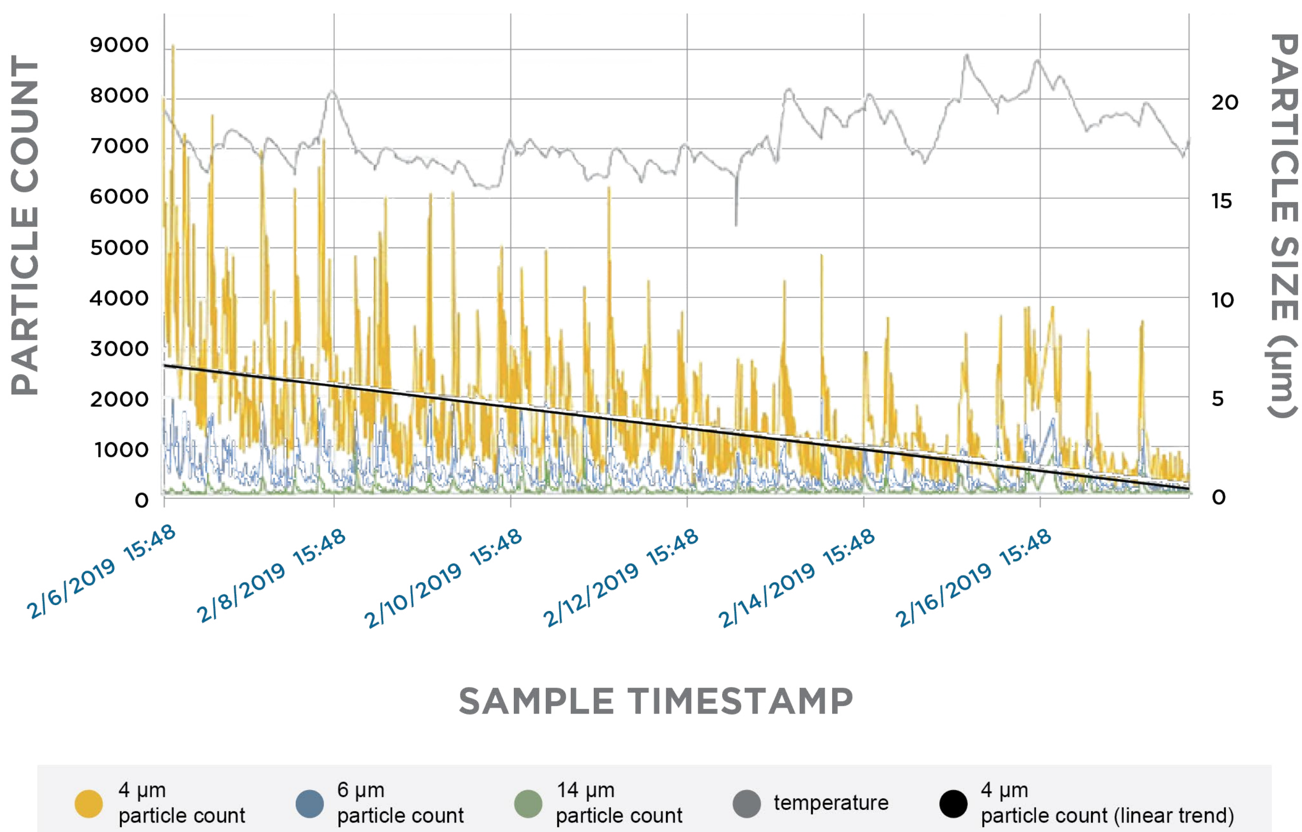


Figure 2: Real-Time Particle Counting During System Flushing Data in this graph show the results of flushing a hydraulic system using a bypass filtration unit during normal operation.

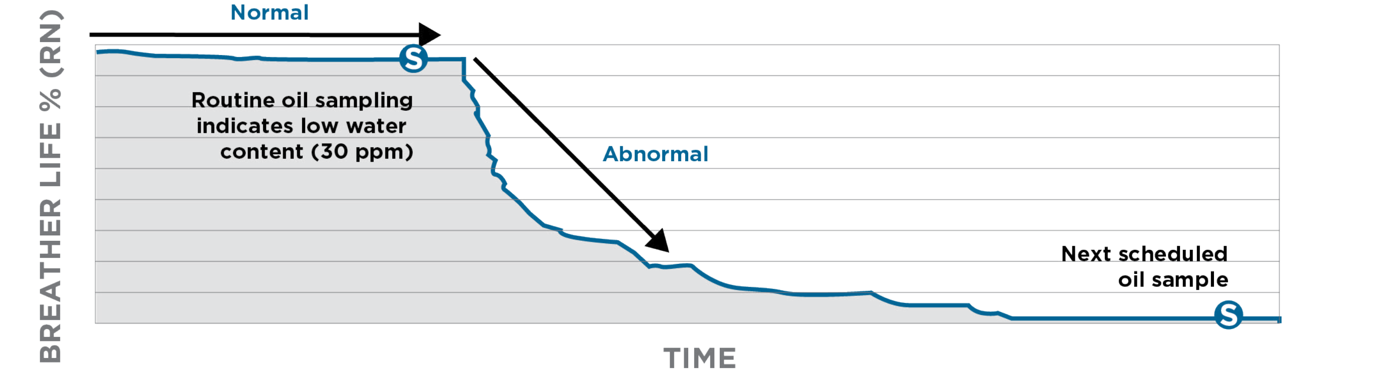


Figure 3: Hydraulic System Water Ingression Graph shows hydraulic system water ingression identified using a "smart" dessicant breather capable of measuring changes in headspace humidity.

Figure 3 shows a similar example. In this case, a connected desiccant breather is monitoring the relative humidity in the headspace of the reservoir of a hydraulic system. Based on a bottle oil sample taken during normal operation, the water content in the oil was measured as 30 ppm (0.003% v/v), well below the limit for this application. However, two days after the sample was taken, the operations crew elected to clean the system using pressurized water. Based on the real-time data from the sensor, the headspace, and hence the breather, saturated within 24 hours.

This alerted the maintenance team, in real time, about a potential catastrophic situation that could have resulted in hydraulic-pump cavitation or other issues. The next routinely scheduled oil sample was 25 days out, meaning that this problem could have continued for another three or four weeks without being identified.

Another example of the benefits of online debris monitoring is shown in ***Figure 4***. During a 14-month timeline, periodic oil samples taken for analysis indicated no significant findings of iron concentrations in a gearbox. In fact, the reported oil cleanliness actually improved in the traditional oil analysis, while concentration levels reported by the online debris monitor increased.

Online monitoring of metallic wear debris enables these events to be observed and tracked in real time, allowing for adjustments in operation to prevent catastrophic failure and extend operating life until a repair or replacement can occur. Online wear debris monitors provide the additional benefit of allowing the analyst to correlate wear debris data with operational data to pinpoint the cause of fault progression, as identified by debris concentration spikes.

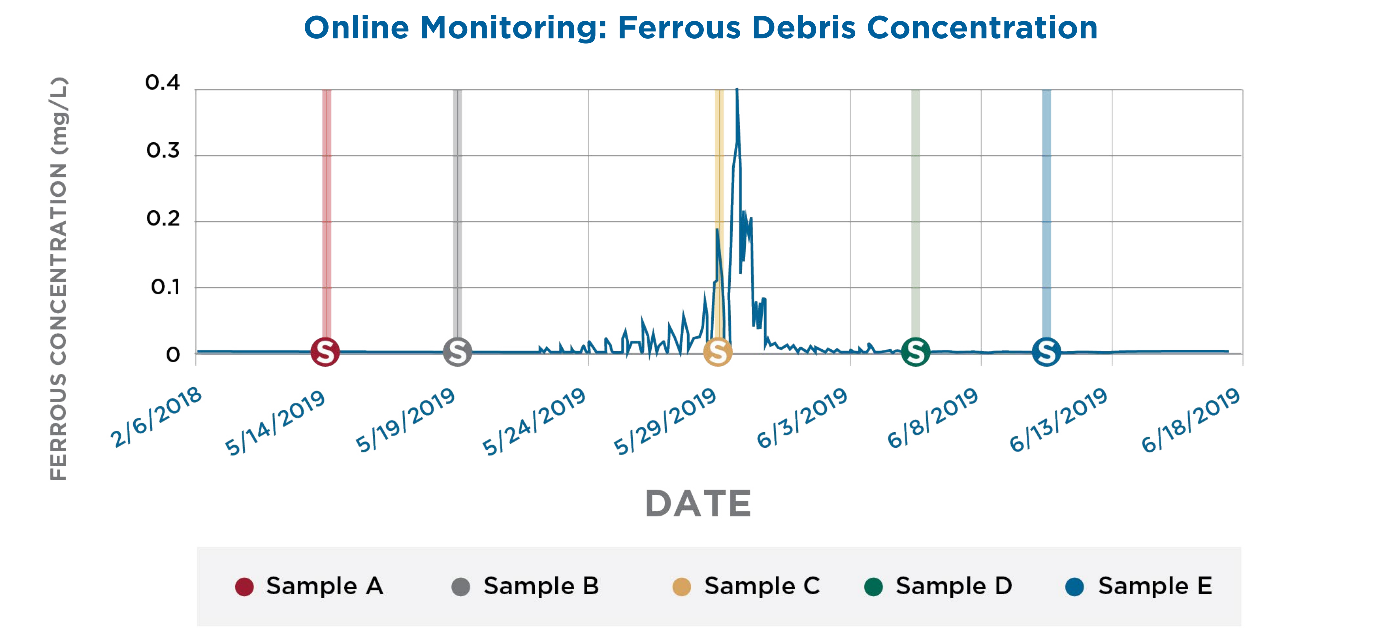


Figure 4: Wear Debris Timeline of a Bearing Raceway Axial Crack Fault within an Industrial Gearbox.

Is Real-Time Condition Monitoring Worth the Investment?

Like most maintenance and reliability issues, if we break it down, it's not difficult to identify the dollar value of sampling on different intervals or even continuously with real-time monitoring. The key to analyzing the value of monitoring frequency is to first understand the value of the thing that is being monitored. With particle and moisture contamination, this is fairly straight forward as the MTBF effects of these contaminants are well known.

If we use moisture contamination in bearings as an example we can use the information in ***Figure 1*** along with some assumptions to create a value model. We start with the current MTBF and the cost of the failure considering both repair cost and the cost of lost production associated with the failure event. For our example, let us say that the failure cost is $10,000 and with a target moisture level of 100 ppm the MTBF is 5 years putting our annual repair cost at $2,000. If the moisture level were to rise to 1,000 ppm, we expect the service life to be reduced by about 80% moving the MTBF to one year with an annual repair cost of $10,000. Using this model, we can say that the benefit of maintaining dry oil in this system is potentially $8,000 per year; but we have to make sure that we maintain a moisture level at or below the target.

Traditionally, this is accomplished using oil analysis, which is typically done on an interval ranging from 1 to 12 months. If we only sample every 6 months, and the oil were to become contaminated during that interval, damage to the bearing would occur until the problem is detected and fixed. It is fair to say that on average, the contamination event would occur at ½ of the sample interval meaning the bearing would suffer 3 months of increased wear reducing the benefit by 25% or, in this case $2,000 dollars. In this way, we can analyze the benefit of sampling at different intervals as shown in ***Figure 5***.

As expected, the longer our sample interval is, the less value we realize from our advanced lubrication practices. The only way to get the full value is to inspect for moisture continuously. Since it isn't efficient to take an oil sample every day, this can only be accomplished with on-line instruments. On-line instruments such as moisture sensors, particle counters, level monitors and even oil quality sensors are now available at reasonable price points. Combining these instruments with a digital interface allows any maintenance professional to have 24/7 access to lubricating oil condition and even receive alerts when something goes wrong. With the rising cost of labor and repair costs, these condition monitoring systems are becoming more and more cost effective for a wider range of applications.

Figure 5

How Do I Know What Sensors I Need?

In addition to particle count sensors and connected breathers that measure the degree and direction of breather saturation in real time, the number and type of sensors available for monitoring lubricants has grown dramatically in the past five years. Today almost every physical or chemical property of oil that has traditionally been monitored using lab-based oil analysis can be monitored in real time using a sensor. The table below compares the most common oil-analysis lab tests with readily available sensors that can detect changes in various oil physical and chemical properties.

FLUID PROPERTIES	CONTAMINATION	WEAR-DEBRIS ANALYSIS
Elemental Analysis	Particle Count	Particle Count
FTIR	Moisture	Elemental Analysis
AN (acid number)	FTIR	WPC Ferrous Density
Viscosity/Temperature	Viscosity	Wear-Debris Analysis
BN (base number)	Elemental Analysis	Particle Count

Proactive Monitoring

Predictive Monitoring

Oil-Condition Sensors

Condition-Monitoring and Wear-Debris Sensors

Moisture Sensors

Oil-Analysis Lab

Figure 6: Commonly Available Sensor-Based Oil-Analysis Testing

With many sensors to choose from, the most obvious question is: Which are most effective? The key to answering that question is to understand failure modes and how quickly certain oil properties change with time. While some homogeneous properties of oil, such as viscosity, change much slower than others. Information that can change daily, hourly, every minute, or even every second, is far more valuable to monitor in real time. These include particle and water contamination, wear debris content, and, to some extent, overall oil quality.

Comparing the constantly changing parameters with real-time operational parameters such as load, speed, temperature, operation cycle and execution of certain maintenance procedures can provide unprecedented insight into how the lubricant is responding to normal and abnormal operating conditions.

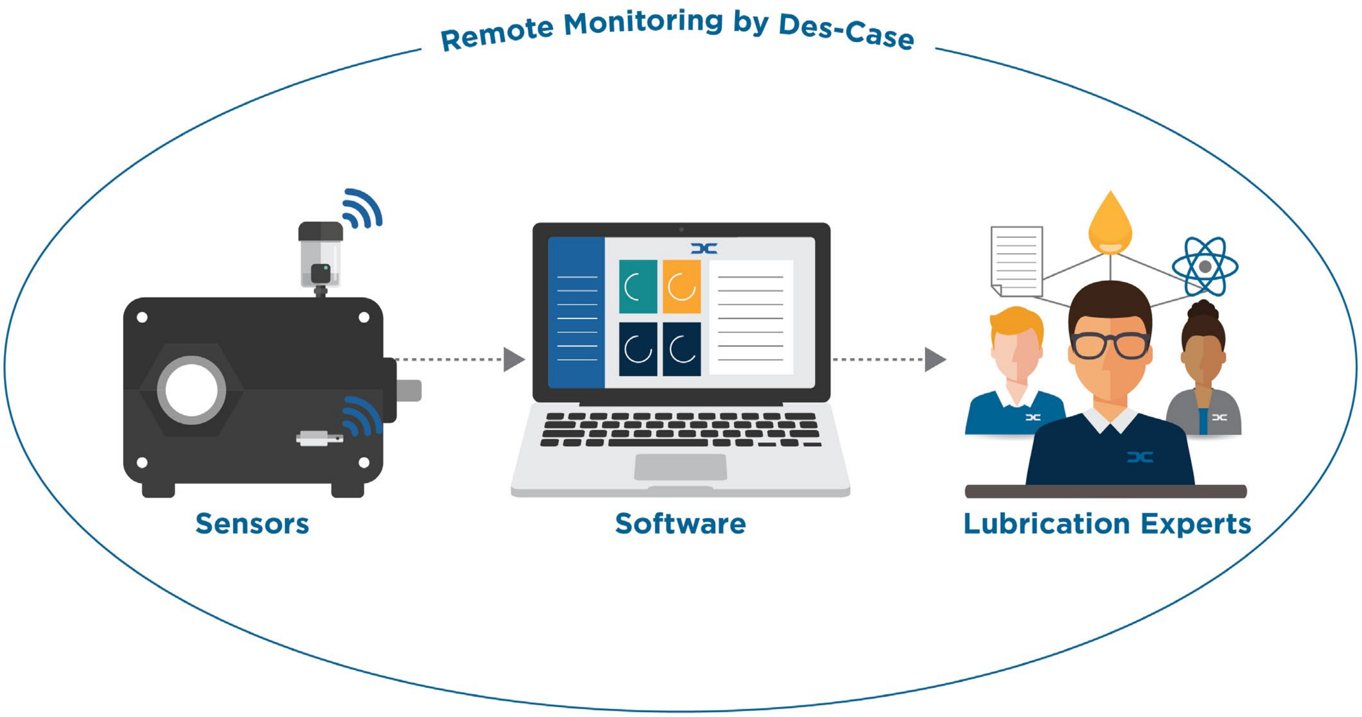
Like all sensor-based condition monitoring technologies, real-time oil analysis is not intended to replace bottle samples and lab analysis. For the short to medium term, there will always be a need to trust the knowledge, skills, accuracy, and precision offered by a commercial oil-analysis lab. In the future, oil-analysis labs will become more like “forensic labs,” using their expertise to determine the underlying root causes and reasons for problem conditions first identified using sensors such as lubricant degradation or increased wear trends. Sensors will become the de-facto warning to check oil or machine condition. Combined with operational data, we are entering a new era in which integrated condition monitoring and operational context will give us unprecedented insight into how our equipment functions. Combined with “big data” machine-learning capabilities, these are exciting times for oil analysis.

Working Smarter, Not Harder

For the first time ever, a new remote diagnostic monitoring service for industrial lubricated assets combines the use of in-line oil sensors with condition monitoring by lubrication experts. You can have peace of mind knowing the lubricant health, cleanliness and humidity inside your critical assets are being monitored by our team of lubrication experts, allowing your millwrights and mechanics to complete other important tasks on time.

The new reality of our working environment – from home or in plant with limited resources – is a large catalyst for the need of this remote monitoring service. Survey results show companies don't have the in-house resources, the time or knowledge necessary to analyze and interpret the data they are receiving across multiple data points, and lubrication expertise to predict and prevent failures and sustain best practices. That's why we want to provide more than just the sensors and software, but also incorporate training, consulting and our decades of in-house knowledge in lubrication. No two reports will be the same because this service is truly tailored to you and solving your unique challenges. Our objective is to be your partner year after year, working together to prevent downtime, reduce maintenance costs and provide continuous training for employees.

Find out more about Des-Case's Remote Diagnostic Monitoring Service at https://www.descase.com/remote-monitoring/.



Conclusion

Periodic off-line oil analysis provides significant value within reliability programs, but often it is not a sufficient tool on its own for meeting the program's reliability goals. Online oil quality monitoring systems have proven to be critical, cost saving tools, providing the data necessary to make optimal maintenance decisions.

Many industries, such as energy, mining, rail, marine, etc., have all started adopting an online oil monitoring program and it is expected that such programs will become standard practice over the next few years. With new sensor technologies, the payback period for investment is usually less than one year, making them one of the best investments for any reliability team looking to adopt the latest best practices.

DES-CASE®
descase.com

Corporate Headquarters
675 N Main St
Goodlettsville, TN 37072, USA
+1.615.672.8800

European Operations
Coenecoop 99,
2741 PH Waddinxveen, The Netherlands
+31 (0) 182.24.48.88

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