Complexity in Oil Analysis: Part XII

Timing is everything, but there's more to sensors and sampling operating together.

LET'S REVISIT, IN PERHAPS A DIFFERENT CONTEXT, a comparison of events I presented numbers of columns ago and pay particular attention to the timing aspect of information, as depicted in the chart on the next page (*see Figure 1*).

There are four examples of a theoretical diesel engine monitoring sequence wherein both static episodic bench testing (offline) and dynamic (online) sensor monitoring are employed. The advent of Tier 1 OA in the first decade of the 21st Century has introduced a time-phase element that heretofore didn't exist, with respect to in-service lubricant testing and monitoring.

While this is a wonderful development, it also introduces yet another level of complexity, along with added insight, to an evaluator's job. Only when a sensor detects a problem at relatively nearly the same time a Tier 2/3 (offline/offsite) analysis is being performed, do real-time data synchronize with episodic testing. When the two data types are not in sync, more often the case, there are certain considerations to, well, consider.

Scenario 1: Something occurs that is alertable via sensor, immediately following a "normal" test sample. This is a sensor's most shining moment, maximum pre-alert.

Scenario 2: The rarer occurrence of near-simultaneous (and corroborating) warnings from both static and dynamic. The primary benefit is the added corroboration and confidence that is provided, justifying specific maintenance decisions.

Scenario 3: A sensor reading provides an alert that is later vetted with bench testing. The level of the sensor alert might determine if a sample needs to be tested further immediately (much easier to opt for if Tier 2 onsite testing is available).

Scenario 4: The sensor is not in the assessment picture because its sensitivity is not sufficient for the problem at hand or sensors installed don't address that type of trauma.

Stepping back and looking at just the overall OA aspect, and not necessarily the specific suite of tests (yet) or sensors involved (yet), we now have the ability to match up with VIB in real-time, certainly a major gain, and we thus can fill in the blanks to some extent between scheduled sample results. Thermography, an often useful role player for the two primary non-destructive tests (NDT), OA and VIB,* can be put

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*Referring to the July 2013 TLT article, this is only valid if the traditional independence of VIB and OA testing and measuring activities are harnessed into an overarching philosophy of CM tool integration. While this is beginning to occur in isolated instances, it is not yet a rooted practice.

Sensor/Sampling Interplay	JAN		FEB						MAR
SCENARIOS	Week	Week	Week	Week	Week	Week	Week	Week	Week
Highest Sampling Risk	Best case for a sensor: Sensor gives significant warning signs shortly after most recent sample; sampling progam is out of phase								
Dynamic Measure SENSOR >	Sensor	Sensor	Sensor	Sensor	Sensor				
Static Measure SAMPLE >	Sample Due	Extra Sample?	?	?	Sample Due				Sample Due
Machine Condition >	Good?	Repairable?	Too late?	Failed?	Failed				
Example Scenario	A diesel engine develops a coolant leak within hours after last sample was taken; sensor responds strongly to a glycol/water presence								
Post Mortem	While oil analysis was necessary to corroborate the sensor warning, there is little chance the engine would have survived a regular sample interval								
Simultaneous Timing	Sensor gives significant warning signs shortly before next sample is taken; both monitoring systems corroborate each other in real time								
Dynamic Measure SENSOR >	Sensor	Sensor	Sensor						
Static Measure SAMPLE >	Extra Sample?	Sample Due	Sample Vetting		Sample Due				Sample Due
Machine Condition >	Failing?	Urgent	Repairs made						
Example Scenario	As per the diesel engine above, the sensor 'spots' the coolant leak and an unscheduled sample verifies it; repairs are scheduled with a degree of safety								
Post Mortem	The problem is identified somewhat earlier than it would have been with no sensor readings available. There will be times when that extra time is essential								
Sensor In Front	Good sensor case: Sensor gives warning significantly before scheduled sample, triggering a corroborating sample; repair is 'timed' according to problem type								
Dynamic Measure SENSOR >	Sensor	Sensor	Sensor						
Static Measure SAMPLE >	Sample xtra	Sample xtra	Sample Due		Sample Due				Sample Due
Machine Condition >	Failing?	Repairable	Failed?						
Example Scenario	Coolant leak is signalled and corroborated via sensor and sample, respectively, but with sufficient warning time comfort to choose the most $$efficient action								
Post Mortem	Extra time to react is ALWAYS a benefit but coolant leaks, like abrasives, can quickly cause significant damage, underscoring the benefit of earliest warning								
Sensor Lags or Defaults	Sensor not of warning help: Barring malfunction, sensor may lack sufficient sensitivity, or is not the appropriate sensor for the problem type								
Dynamic Measure SENSOR >	Sensor	Sensor	Sensor	Sensor	Sensor	Sensor	Sensor	Sensor	
Static Measure SAMPLE >	Sample Due				Sample Due	Sample Vetting		Sample Due	
Machine Condition >	Good	Good	Good	Good	Repairable	Repairs made	Residuals	Good	
Example Scenario	A wear problem from abrasives may be occurring, but no wear debris sensor is in use (a standard dielectric sensor will not demonstrate sufficient sensitivity)								
Post Mortem	A single sensor will not have the versatility of a full oil analysis; a suite of sensors is better, but quite expensive, and may still miss some possibilities								

Figure 1

to even better effect, as well, now that OA is Tier 1-capable.

Let's now take another look at some of the measurements listed from last column's chart (*see Figure 2 on the following page*).

What did you make of these variants?

Water is a sensor's best territory. The water is measured where the fluid circulates, therefore allowing for saturation, and the result will be as good as the sensitivity of the sensor with repeatability (stability in measurement, more correctly) accordingly. In the lab, where a difficult-to-take representative sample is sampled yet again to perform the test, the final value, even if determined via Karl Fischer water, the most sensitive test available for water in lubricants, may be questionable. Assessment: *Score one for sensors, sort of*.

Metals detection at earliest opportunity (sensor, real-time) is a great help, for sure, but to my knowledge the most sensitive sensor that sizes ferrous particles with surety is pegged at 40 μ for smallest diameter detectable. It gets worse if non-ferrous metals are being measured in the process: detection is somewhere well above 100 μ.

Contrast that with the fact that emission, or absorption, UV spectrometers begin to have blind spots for particles much greater than 2-3 μ and are virtually unable to detect particles greater than 10 μ. This behavioral fact is muddied further, dependent on the element, its chemical form and the test instrument itself. Assessment: *Looks like a draw—big particles go to sensors, timing-wise; small particles go to labs.* (Wait a minute—don't small particles come before large in the wear continuum?)

Particle Count (unspecified content)—if desired, one can readily install an online particle counter that is virtually equal to a lab's instrument; sometimes they might be one and the same. When this is the case, the online instrument has the advantage. *Comparable to the situation with water, the primary advantage is a truly representative sample of the particulates in circulation.* After water, a particle count is the most difficult property to be accurately represented in a sample container.

Viscosity—a very interesting proposition, actually. Unless one has a captive chamber to stabilize the temperature of an oil to prepare it for viscosity measurement, such an instrument is not available to my knowledge. Sensors must make some assumptions regarding conversion of a value that is determined by the operating temperature of the lubricant while working. Obviously, variations in temperature over time will make trending difficult at best.
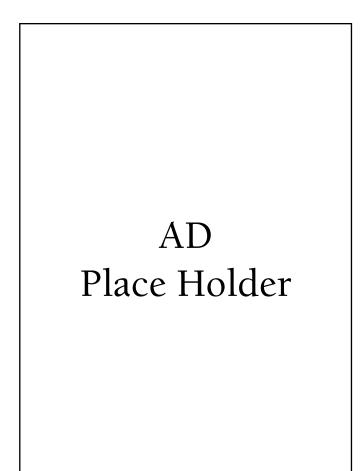
One could rationalize that for industrial lubes, temperature remains fairly constant in a tight range unless there is something amiss. But many labs will have not considered the many circumstances, particularly with diesel engines, where operating temperature can vary substantially with duty cycle. Yet, too, there is the matter of rationalizing the non-standard temperature to a standard one: 40 C for most industrial

SUBJECT	ONLINE SENSOR (Tier 1)	OFFLINE LABORATORY (Tier 2)	OFFLINE LABORATORY (Tier 3)
General Characteristics			
SENSITIVITY	Usually not as good as Tier 3 Lab	Can help vet the sensor alerts	Usually best available
REPEATABILITY	Good-Very Good	Good-Very Good	Very Good
ROBUSTNESS	Very good, but could foul or malfunction	Excellent if quality control maintained	Excellent if quality control maintained
SCOPE	Good but needs vetting	Better	Best
Specific Items			
WATER	Perhaps most accurate (!?)	Issues with sampling, not the test	Issues with sampling, not the test
METALS [BIG 4: Fe, Al, Cu, Pb]	Only Fe, with a 'guess' at other metals without specificity. Minimum diameter is 40µ	Benchtop units are available for large particle ferrous screening in scalar or ppm units	Indiviual metals, but limited to <<5µ unless PQ or similar testing for Fe is used
OIL CONDITION (extended drain)	Nebulous (Oil Condition Sensor, dielectric) Fuel, Water, BN depletion, AN, etc.	Specific, to extent of available testing	Specific
VISCOSITY	Good (enough)	Better	Best
AN (ACID NUMBER)	Nebulous (Oil Condition Sensor, dielectric)	More Specific, can be Specific	Specific
BN (BASE NUMBER)	Nebulous (Oil Condition Sensor, dielectric)	More Specific, can be Specific	Specific
PARTICLE COUNT	Can be fitted with Lab-grade device	Can utilize a Lab-grade device	Lab-grade device
FUEL DILUTION (diesel)	If VIS available, *Good* If VIS not available, *Nebulous*	Benchtop VIS to help vet VIS sensor Possible inclusion of a flash test	VIS + Gas Chromatography vetting
POSSIBLE LUBE MIXING	Nebulous (Oil Condition Sensor, dielectric)	Somewhat Specific, but can be Specific if advanced instrumentation is involved	Specific to extent of instrumentation used

Figure 2 | **The interplay of online (sensors) and offline oil analysis.**

fluids and 100 C for reciprocating engines and compressors, as well as a variety of axle lubricants.

While there's no argument that a sensor provides a more accurate VIS, there is something to be said about a VIS value that is abnormal, and a sensor-based VIS reading, while perhaps not as sensitive, is able to spot clear departures from reasonable values versus the fluid's specs. As important as VIS is within the variety of tests available, it could be too late if a major trauma, such as a fuel leak into a diesel engine crankcase, develops significantly before the next routine sample is to be lab-tested. Assessment: *Here the sensor has at least a slight edge, and maybe more, if basic fluid characteristics change at a rapid, significant pace.*

Fuel Dilution—while one could set up an FTIR in Tier 2 (onsite) position, that's probably the closest one could get to providing credible fuel dilution measurements. I'm on record for stating I don't like the notion of fuel dilution measurement using FTIR. It's relatively insensitive, at best 5 percent first detection quantity. More important, unless one has constructed reference samples with very similar fuels as are used in the diesel engine under test, there is little confidence to be had with the result. Can it be done? Sure, if there's a stable source of fuel used over time, wherein the fuel's properties are repeatable, batch after batch, delivery after delivery. It's simpler to use GC (gas chromatography), but one is not likely to find a GC onboard a drilling rig, though it could be installed. Assessment: *One could also apply a flash point to Tier 2 level; that leaves direct fuel dilution measurement to the labs at Tier 3 (offsite).*

Next column we'll sort this out to some extent for all testing tiers, and some tests and component types, including the notion of wear particle development. As to the latter, perhaps timing is not everything. Perhaps size also matters.

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