Health check-up for farm machinery

Suck it up: The success of oil analysis relies on being able to take a sample which is an accurate representation of the lubricant from an engine, transmission, hydraulic system or final drive. The sample must be well mixed and taken from the correct location otherwise accuracy will be compromised. Photos: Ben White and Josh Giumelli

Wouldn't it be handy to ascertain the internal condition of a tractor's engine or transmission without having to strip it down, or to pre-empt a serious breakdown before it occurs? By **Josh Giumelli**

While crystal balls are in short supply in most workshops, oil sampling and analysis is a valuable tool for predicting breakdowns, monitoring wear levels, contamination or lubricant condition. And the good news is the sampling process is straightforward, and not expensive.

Like a blood test, oil analysis can reveal multiple factors concerning the condition of oil from compartments such as engine sumps, transmissions, hydraulic systems, differentials and final drives. In a similar manner, samples of coolant and fuel can also be analysed.

To use oil sampling to its full advantage, samples are taken periodically over the life of a machine, such as at every engine oil change or every 500 hours for a differential or final drive. Component condition can thus be monitored, and trends in wear metals can provide advanced warning of any impending problems. (see Table 1 for suggested sampling intervals).

The advantage of forewarning is that repairs can be scheduled for a convenient time, with parts at hand, rather than in the middle of seeding or harvest where the cost of a breakdown is multiplied many times by taking a machine out of service when it is needed most.

There are a number of specialist laboratories around the country which can analyse samples. In this *Workshop* article we have used Cat's SOS fluid analysis service, which is independent from any parent oil company. But this article is not an endorsement of the SOS service, rather an example of the kind of service offered by a typical oil sample laboratory.

ANALYSIS BREAKDOWN

There are three main areas of oil analysis that should be carried out by the laboratory:

- **Wear metals** – the type and size of metal particles present in the sample which can indicate abnormal wear of componentry.

Table 1. Recommended oil sampling intervals

Compartment	Sampling interval
Engine	At each oil change as recommended by manufacturer
Transmission	At 250h initially then every 500h
Differentials	Every 500h
Final drives	500h initially then every 1000h
Hydraulic system	500h initially then every 1000h

Note: Recommendations may differ, follow manufacturer or laboratory advice.

- **Physical and chemical tests** – to monitor the presence of contaminants in the sample such as fuel, water and coolant.
- **Oil condition** – this monitors oil viscosity and quality which is handy when assessing the required service interval, for example extending or reducing the oil change interval.

TEST RESULTS

Test results are either mailed, emailed or available online depending on the laboratory used.

Table 2. Examples of engine contaminant levels (ppm)

Metal	Possible source	Normal level	Slightly elevated level	Elevated level	High level
Iron (Fe)	Liners, gears, tappets, rings, gears	0–40	41–70	71–100	>100
Chromium (Cr)	Rings, cams, followers, rolling bearings	0–5	6–10	11–15	>15
Lead (Pb)	Plain bearings, thrust washers	0–15	16–25	16–40	>40
Copper (Cu)	Bearings, bushings, thrust washers	0–15	16–25	26–45	>45
Tin (Sn)	Bearings	0–10	11–15	16–20	>20
Aluminium (Al)	Pistons, some crankshaft bearings, dirt	0–6	7–15	16–20	>20
Silicon (Si)	Dirt, oil de-foamants	0–5	6–10	11–15	>15
Sodium (Na)	Coolant, salt, potential additives	0–5	6–15	16–30	>30

While it is useful to possess an understanding of the various test results, interpretation of the sample is a science and the lab should provide a comment in the report on any possible issues that may exist.

Your oil analysis service may provide resource materials to help understand the results if you wish to learn more. Suffice to say, there is limited room in this article to cover all areas of sample analysis, but a basic understanding is helpful.

INTERPRETING THE SAMPLE

Oil analysis will typically show a range of wear metals and other contaminants. It is the concentration of these elements in the sample that is the key.

Elevated levels of certain metals can suggest wear in particular areas, with concentrations measured in parts per million or PPM (see Table 2).

Iron levels in a sample normally come from wear in cylinder liners and rings in engines, gears and bearings in transmissions, differentials and final drives, and valves and gears in hydraulic systems.

Chromium particles originate from any chrome-hardened components such as rolling bearing, gear teeth cams and followers, as well as hydraulic components.

Elevated levels of copper, lead and tin indicate wear in plain bearings as used in crankshaft, big end and thrust bearings in engines, or from friction discs in transmissions. Higher than normal aluminium levels point towards piston wear in engines, but can also point towards high levels of dust or dirt contamination.

High levels of silicon can point to a number of sources. By itself, it may reflect the use of a silicone anti-foaming additive in the oil (about 10ppm), or from the breakdown of silicone gasket sealants. In a ratio of about 1:1 and 1:3 silicon to aluminium indicates dirt ingress.

While high levels of calcium, phosphorus and zinc may initially appear alarming, they actually indicate the presence of oil additives and are usually no cause for alarm.

The presence of fuel in the sample can come from a number of sources, such as leakage from lift pumps, injection pump shaft seals, dribbling injectors, over-fuelling or unburnt fuel travelling past the piston rings. A lot of the interpretation will depend on the particular engine design and other supporting factors.

Water is a common oil contaminant and can come from a number of sources. Just the process of burning fuel in an engine produces water, and hot engines tend to draw in air as they cool, allowing moisture to condense inside the engine.

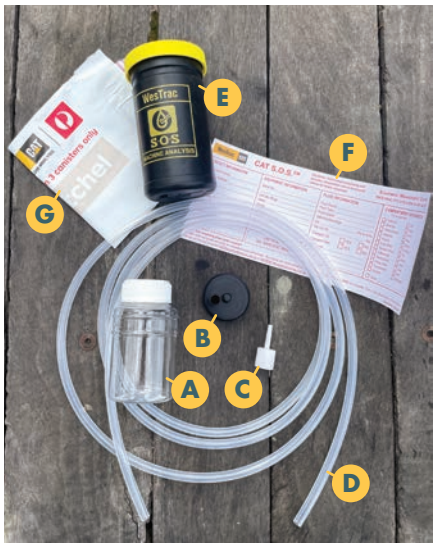
A more serious situation is water leakage due to gasket failure or liner O-ring failure. Further supporting evidence can be found in the presence of coolant inhibitor products in the sample such as boron, sodium and potassium.

SIZE MATTERS

The typical oil concentration of iron in a sample only measures particles of a size of 10 microns or less (one micron or 1µm is equivalent to one thousandth of a millimetre). The oil analysis laboratory should also do an oil Particle Quantification (PQ) test.

The PQ index is a relative measure of the total ferrous metal content in the oil, regardless of particle size. This helps pick up the presence of large iron particles which are not detected by the spectroscopic test. The higher the PQ index, the higher the concentration of ferrous wear metals.

The PQ index has no unit and is a relative value, and values below 25 indicate normal wear. A low iron spectroscopy level under 10µm and a low PQ index point to normal or low levels of wear. A high spectroscopy level and low PQ index indicate normal but more advanced wear rates, and a high PQ index but relatively low iron spectroscopy reading indicate possible impending component failure due to the present of larger ferrous chips or particles in the sample. ▶



A standard SOS sample kit comes complete with the following items: A: sample jar with solid lid. B: ventilated lid. C: valve sample adapter. D: sample tube. E: post cylinder. F: label. G: post bag. The sample kit costs about $30 (including return postage and sample analysis) and is available from Cat dealers or by calling 1300 881 064.

TAKING A VACUUM SAMPLE

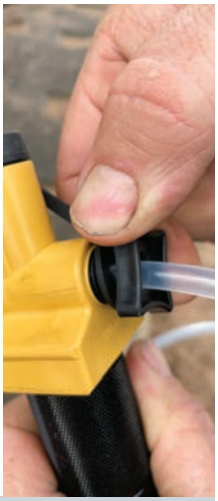
It is most likely a vacuum pump will be needed for the majority of sampling jobs on farm. This screws to the top of the sample jar and is used to draw a sample of oil through a tube and into the jar. It costs about $40. While samples have been taken from the oil stream when draining a sump during an oil change, it is not worth the effort due to the difficulty in obtaining an accurate sample (and the ensuing mess!).

To take an accurate, representative sample, it is imperative the machine is brought to operating temperature. In the case of an engine oil sample, simply start the engine and bring to working temperature to ensure the oil is correctly mixed. For another reservoir such as a final drive, transmission, differential or hydraulic system it will be necessary to operate the machine to ensure oil is well mixed.

With the engine at operating temperature, switch off and make sure the unit is in park. Withdraw the dipstick and wipe off any excess oil.

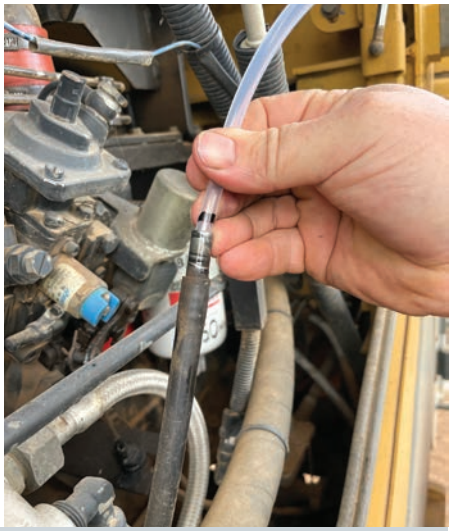
Holding the sample tube alongside the dipstick, mark the length of the dipstick on the tube with a felt tip pen. This will ensure the sample tube draws oil from the around the level of the dipstick. If the tube is inserted too far into the sump it will draw a sample from the base of the oil pan which may not be representative. For other compartments without a dipstick (for example final drives, differentials) ensure the compartment is level and the tube is inserted roughly half-way into the oil.

Now cut the tube to length allowing additional tube length for the vacuum pump to be conveniently operated. Note that the longer the tube, the more difficult it will be to draw a sample. Make sure the tool used to trim the tube is clean and doesn't contaminate the cut.



Insert the trimmed end of the tube into the vacuum pump so that the end protrudes by about 25mm (left). Now tighten the collar nut to secure the tube (right).

Remove the solid cap from the sample bottle and attach securely to the vacuum pump, taking care not to contaminate the inside of the bottle.



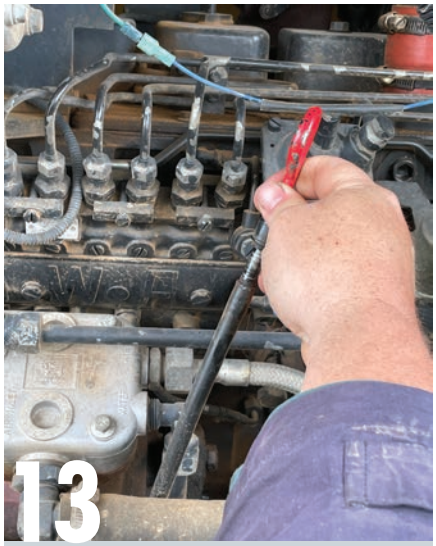
Insert the end of the sample tube into the dipstick tube, taking care not to brush the end against anything than may contaminate the sample. Make sure the tube is inserted to the marked line. It may pay to have a helper hold it in place. Alternatively, secure with a piece of tape.

Hold the pump perfectly level and pump up a vacuum. Oil should flow up the tube and into the bottle. It is not necessary to continually operate the pump, only pump up enough vacuum to draw sufficient oil into the bottle to fill to the line. If you create too much vacuum and over-fill the bottle you will contaminate the pump with oil.

Once oil has reached the marked line on the sample jar, simply twist the bottle to break the seal. Oil will stop flowing into the sample jar.

Carefully remove the sample bottle from the pump and firmly secure the white solid lid. If you are taking several samples at the same time, write on the lid with a felt tip pen to avoid confusion later on.

Loosen the collar nut and clean the end of the sample tube to avoid contamination before withdrawing through the pump body. Inspect the pump for contamination before putting it back in its case.



Don't forget to reinstall the dipstick or plug after the sample tube has been removed.

USING A SAMPLE PORT

Various brands of equipment may be fitted with proprietary oil sample points. The benefit of these is that it is more difficult to introduce impurities into the sample, and the sample is quicker to take. For Caterpillar equipment, a yellow plastic dust cover protects the engine oil sample port which is found on the oil filter. Blue covers are used on hydraulic oil, purple covers on transmission ports and green covers are used on coolant sample ports. These ports can be retro-fitted to other equipment with pressure oil systems.

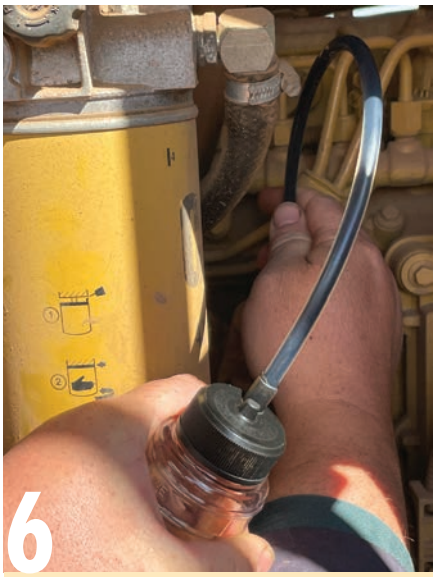
To take an oil sample using a port, no vacuum pump is required. The sample kit should be supplied with a special port adapter as shown here fitted to the end of the sample tube (left). This is simply pushed over the sample port (right) allowing oil pressure to pump a small amount of oil out the port.

As with the previous sample using the vacuum pump, start the engine and run it until it reaches operating temperature. This applies for other compartments, and in the case of transmission and hydraulics you may need to operate the machine to ensure full oil mixing.

USING A SAMPLE PORT (continued)

To take a sample, the test port must be purged first to clean it of any impurities which may bias the sample test results. Using a spare oil sample bottle or other suitable container (eg soft drink bottle), press down on the port adapter with the engine running. Oil should run down the tube into the bottle. Collect about 50ml then discard. Do not use the final sample bottle for this operation, or the sample will be contaminated. Take care to avoid any radiator fans or moving parts and make sure the machine is in neutral and the park brake is applied.

Now you are ready to collect the final sample. Pictured here is the setup required. Remove the white lid from the clean sample bottle and place it in the plastic bag where it is unlikely to become contaminated. Screw the black lid onto the bottle and insert the sample tub through the lid so that about 25mm protrudes. The port adapter should be installed on the other end.



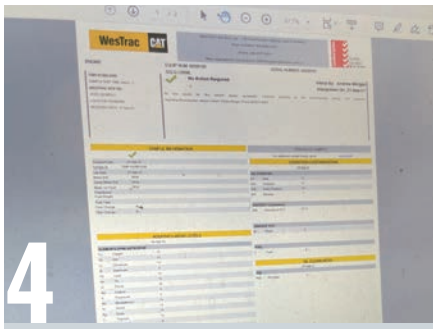
With the engine running, press the port adapter against the port and fill the sample bottle to the fill line. Remove the cap and tube and seal the sample bottle with the white cap.

SENDING OFF THE SAMPLE

Fill in the information card with your details, machine details, serial number and any other relevant information. While all of this information is not necessary for the sampling process, it will be noted in records with the sample, and is especially important with regular, scheduled sampling programs. It is also important to identify the compartment the oil has come from. The acceptable concentration of wear particles for an engine, gearbox or hydraulic system are all quite different and will be taken into account by the lab when interpreting the sample.

Insert both the information card and sample bottle into the mailing tube and attach the lid. The sample can now be placed in the mailing bag and posted.

Another option is to drop the sample off to the laboratory if you are close by. The lab may also have an after hours drop box for samples. Kondinin Group sent one sample by post which took nine business days to arrive and get results for. A second sample which was dropped off after hours took only 2.5 business days for results to arrive. Any hold-ups in the system could be related to the postage system rather than the lab itself.



Results will usually be emailed after a couple of days, or available online through a user portal. In the case of our SOS sample, results were emailed but also available through www.mycat.com provided you have set up an account. This process did not prove to be overly easy and required a few phone calls to sort it out and was potentially complicated by us not being a registered owner of any Cat equipment.

The report will include a multitude of information including wear metal concentrations, oil condition, PQ index, contaminant (eg fuel, water) as well as trend graphs showing movement of levels over time. The latter relies on having previous samples the lab can refer back to, and no trends are possible for one-off or first-time samples.

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