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TALKING TURBINE TESTING

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This Technical Bulletin discusses a variety of turbine sample tests – how they are conducted, and what information they provide. The test results enable the best remedial action to be taken for the component in question, in turn boosting the reliability of the turbine by maintaining the oil – which is often a large financial investment – in peak operating condition.

Oil analysis test slates (testing profiles) follow a pretty standard format when it comes to mobile equipment, buses, trucks and bulldozers, for example. Oil wetted components can be divided into engines, clean oil systems (hydraulics, transmissions and compressors) and drivetrain components (differentials, gearboxes and final drives). The sort of tests carried out would involve spectrometric analysis of wear metals, additives and contaminants, viscosity at various temperatures, ferrous density (PQ), water, TBN, TAN, particle counting, fuel determination, infra-red analysis for soot, oxidation and acids and microscopic particle examination. This is actually a fairly narrow range of tests, but they have a very wide applicability which is why they are used for the majority of samples that come into a commercial oil analysis laboratory; they will, in fact, provide a comprehensive service for about 95% of the samples analysed.

The ASTM manuals for petroleum product testing can be obtained on a CD that runs to more than four gigabytes and contains thousands of test methods. Obviously, most of these tests are highly specialised and only have niche applications. However, when they are needed they are very important.

A class of samples that requires quite a few specialised tests are those that come from gas and steam turbines. The usual suite of tests is carried out and includes spectrometric analysis, viscosity at both 40°C and 100°C, water (by Karl Fischer titration), particle counting, TAN, PQ and debris analysis. Let us take a look at these more common tests first and discuss their importance.

Spectrometric analysis (ICP spectrometry) involves heating the oil to a very high temperature where the individual atoms in the sample radiate light of a frequency specific to the particular element of interest. The strength of the light is proportional to the concentration of the element. This test provides information on wear metals which can give an indication of the onset of an abnormal wear situation, additives which allow the analyst to identify and/or confirm the oil in use and the levels of contamination (airborne dust and dirt being the most common.)

Ferrous density (PQ) is a bulk magnetic measurement of the oil carried out by seeing how much the oil sample disturbs a fixed magnetic field. This can give an indication of more severe wear situations that generate particles larger than the ICP can detect.

Viscosity is the measurement of the oil's resistance to flow at a specified temperature and is measured by timing how long it takes for an oil sample to flow through a tube. Knowing the viscosity helps identify the oil. Unexpected changes in the viscosity can indicate deterioration of the lubricant; a sharp increase may indicate oxidation and breakdown of the oil.

Water is a common contaminant and is measured by an electrode during a titration that is very accurate and can measure water concentration down to less than 0.001%. Water contamination can cause severe oil degradation and can act as a source of oxygen which causes rapid lubricant breakdown. Water is also responsible for corrosion and spongy hydraulic action.

Particle counting (ISO 4406) measures the total number of particles in the oil without actually identifying them. The oil is allowed to flow between a laser and a detector and particles of various sizes cast shadows on the detector that are interpreted as the number and size of solid particles in the oil. This gives an indication of the oil's cleanliness; the cleaner the oil, the longer and more efficiently the turbine will operate. Approximately 75% of all premature failures in clean oil systems are due to particulate contamination and 90% of these are due to abrasive wear. Measuring oil cleanliness and keeping oil clean is vitally important.

TAN (Total Acid Number) is also measured by an electrode during a titration and gives a measurement of the acidity of the oil (sort of like a pH). As the turbine oil degrades and ages, the acidity of the oil will increase, so this test can give an indication that oil might need changing or sweetening.

MPE (Microscopic Particle Examination): This test is only carried out if the PQ, ICP or particle count results are very high. The oil is filtered through a five micron membrane and any debris present is examined under a microscope.

This covers the standard tests that are usually carried out on most 'clean oil' system samples. The following tests are the specialised tests that give vital information regarding the health of the turbine and its lubricant.

VPR (Varnish Potential Rating also known as MPC or Membrane Patch Colourimetry): This test measures the potential for the oil to form soft particles of oxidised oil residues. These can plate out onto internal components changing tolerances and hardening into quite tough resinous deposits – which are known as varnish. These are the brownish residues sometimes found in industrial hydraulic samples. Varnish can be responsible for increased wear, valve stiction, filter plugging and poor cooler performance. As a point of interest, API group II and III oils may be more prone to varnish formation than group I oils due to the lower natural solvency of group II and III lubricants. Highly refined oils such as group II and III oils can be thought of as group I oils with the undesirable components refined out of the oil. This increases the stability of both oxidation and viscosity of these oils but unfortunately, the 'undesirables' are natural solvents for varnish.

A laboratory technician measures the VPR of a turbine oil

The oil sample is mixed with a solvent and then filtered through a 0.45 micron cellulose membrane. The colour of the patch is then rated against a standard reference scale which runs from 0 -100 with 0 representing no varnish potential and 100 representing a severely degraded oil. This is not quite as simple as measuring how 'dark' the membrane is - the separate component 'colours' are measured (think of this as an RGB measurement). Three values are determined and a mathematical model converts these to a VPR index. Extra information may be gleaned from knowing the individual readings and gives an indication of the chemistry taking place in the oil.

RULER (Remaining Useful Life Evaluation Routine): This test involves applying a voltage to the oil mixed with a suitable solvent. The electric current in the solution is then measured. In effect, the sample is given an electric 'shock' and the voltage of the shock is slowly increased until the anti-oxidant additives in the oil start to respond. 'Stronger' anti-oxidants will react to larger applied voltages more strongly than 'weaker' anti-oxidants. So, not only can the RULER evaluate the amount of active additive left by the size of the reaction to the applied voltage, it can also measure the activity of different types of anti-oxidants. The amount of these active additives in the oil is a very good indication of the remaining useful life of the oil.

RULER instrumentation

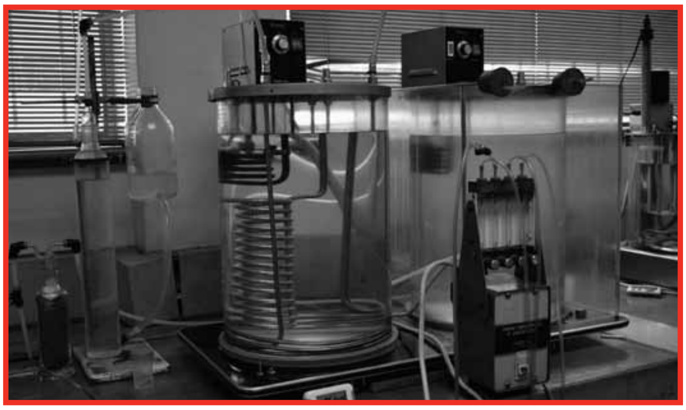
A sample of unused oil is required and the value of the used oil is expressed as a percentage of additives in the new oil. Three values are given, a total value and two sub-values for both the phenol and amine classes of compound. Note that the total value is not a summation or average of the two sub-values.

The loss of anti-oxidants leads to the oxidation of the oil with concurrent build-up of acids, varnish, lacquers and resins. The viscosity and the TAN of the oil will also increase.

Air Release: This test measures the time taken for the oil sample to release a specified amount of air under predetermined conditions. Entrained air that is not readily released from the oil can lead to spongy hydraulic action, inability to maintain oil pressure, incomplete oil films and the acceleration of oxidation of the oil.

The oil is heated to either 25°C, 50°C or 75°C depending on the viscosity of the oil. As most of the samples analysed are going to be ISO 32, 46 or 68, the temperature will be 50°C. The oil is heated to the test temperature and a sinker is placed in the oil and its density (mass) is measured. The sinker is then replaced with an air inlet tube and air is bubbled through the oil. As air becomes entrained in the oil the apparent density of the oil will be reduced. After a set period of time, and a defined temperature and flow rate, the air source is removed and replaced with the original sinker. The sinker will now appear to 'weigh' more as the medium in which it is suspended now has a lower density. The time taken for the sinker to return to its original weight is measured.

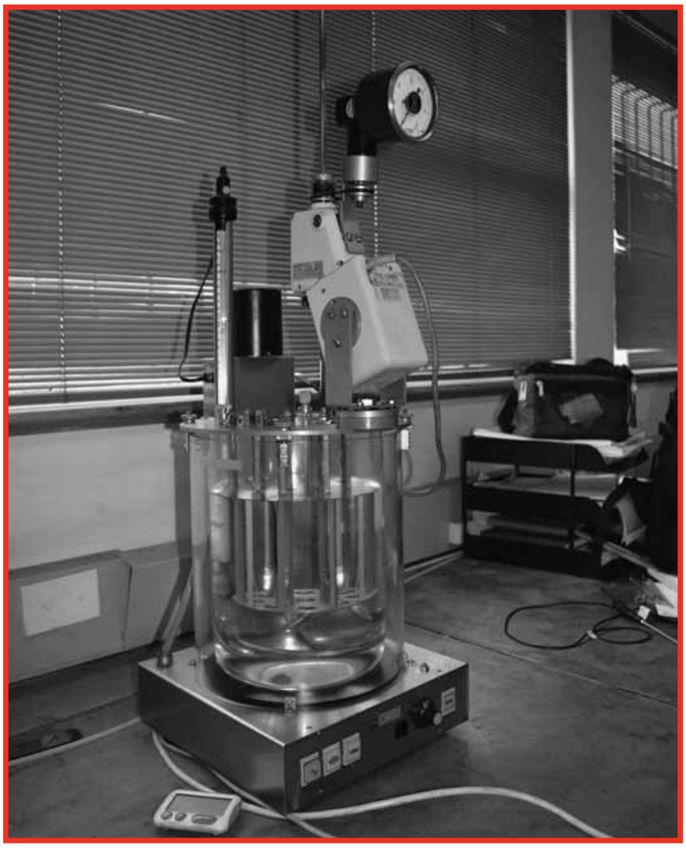
Demulsibility: This test measures the ability of the oil to separate from water. Trace amounts of water will dissolve in turbine oils (50-100 ppm) but free and particularly emulsified water can do a large amount of damage. Water contamination can lead to corrosion, accelerated oxidation, film strength loss, cavitation and filter plugging.



Foam presence and stability testing

40 millilitres of the oil sample is mixed with 40 millilitres of distilled water and agitated to form an emulsion; again temperatures and mixing times are controlled. The test takes place in a graduated cylinder so the levels of water/oil/emulsion can be noted. The test mixture is allowed to stand for 15 minutes then the three levels are measured in millilitres. The results are reported as X/Y/Z (Min) where X is the millilitres of oil, Y is the millilitres of water and Z is the millilitres of emulsion; the test time in minutes is also noted. Complete separation would result in values of 40/40/0 (15), note that X+Y+Z must always equal 80.

Foaming: This test measures not only the ability of the oil to form a foam but also the stability of that foam. The foaming tendency is the amount of foam formed on the completion of the test and the foam stability is how long it takes for the foam to collapse. 200 millilitres of oil is heated to 24°C and placed in a graduated cylinder. Air is then bubbled through the sample under controlled conditions and after five minutes the volume of foam is measured (i.e., from the surface of the liquid oil to the top of the foam level). After ten minutes the volume of foam is again measured, this gives a measure of foam stability.



Test apparatus for demulsibility

The test is then repeated at 94° degrees (24°C and 94°C are 75°F and 200°F) and the same two measurements made at the end of the aeration step and again after ten minutes.

The sample in step two is allowed to cool from 94°C to 24°C and any remaining foam is collapsed by stirring - the test is then repeated for a third time.

The results are reported in millilitres as X1/X2 Y1/Y2 Z1/Z2 where X1 is millilitres of foam formed and X2 millilitres of foam left after ten minutes at 24°C. Y1/Y2 measure the same thing at 94°C and Z1/Z2 also measure the same after the Y sample has been allowed to cool back down to 24°C and the test repeated. The dangers of foam formation are the same as for poor air release values.

RPVOT (Rotating Pressure Vessel Oxidation Test): Essentially, this measures the same thing as the RULER, but RULER is very, very much quicker. It is also cheaper and easier to do and can be done on a very small sample of oil. The RPVOT on a new oil, used to determine a baseline, would take more than twelve hours to complete.

A sample of the oil is placed in a pressure vessel along with water and copper wire that act as oxidation catalysts. The whole system is pressurised with oxygen and the reaction vessel is rotated in a water bath at a constant temperature. The pressure in the vessel is monitored and should stay more or less constant as the anti-oxidants in the oil retard the ability of the oxygen to react with oil in a runaway chain reaction manner. Eventually all the anti-oxidants will get used up and an oxidative chain reaction will start with the oil now taking up large volumes of oxygen. This will result in a sharp drop in the pressure of the reaction vessel and it is the time that this takes to happen that is measured.

These specialised tests obviously cost more to carry out and take longer to process. RPVOT testing could take a few days to carry out but all are critical to the good maintenance of gas and steam turbines which now operate under more extreme conditions than ever before (higher speeds and pressure with tighter tolerances). Some turbine sumps could run to tens of thousands of litres of oil and this represents a valuable asset that needs to be maintained at peak operating condition.

The major problems that are encountered are degraded oil and varnish in gas turbines and cooler leaks in steam turbines. Experience shows that foaming (as opposed to air release) is also an issue on all types of turbines. If test results are unacceptable then this gives the maintenance department early warning of an impending problem and remedial action can be taken. Ideally, the full suite of tests should be carried out on an annual basis, RULER twice a year and VPR quarterly. The extra cost is a small investment in terms of keeping valuable industrial equipment running and looking after thousands of litres of oil.

Testing frequencies:

Test	Monthly	Quarterly	Semi-annually	Annually
ICP	*			
PQ	*			
Viscosity	*			
Water	*			
Particle count	*			
TAN	*			
MPE	*			
VPR/MPC		*		
RULER			*	
Air release				*
Foaming				*
Demulsibility				*

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