Swansea Tribology Services

Oil Analysis Services

# Lubricating and Transformer

# Oil Analysis

# Contents



## Why oil analysis?

To save money and improve reliability

## How?

As part of Condition Based (CBM) and Reliability Centred (RCM) Maintenance programme

By maintaining oil quality and reducing lubrication related wear and failure rates

By extending oil drain intervals and preventing unnecessary oil changes

By preventing ingress of contamination and maintaining desired oil cleanliness levels

By monitoring varnish potential (MPC) and extending remaining useful life through active anti-oxidant management (RULER)

By directing limited maintenance resources effectively

By scheduling maintenance to take advantage of planned shutdowns and preventing undesirable outages

By rationalising oil stocks and reducing spares inventory

By ensuring continued safe and reliable operation of critical assets

By enabling uninterrupted production and avoiding costly penalties

## Why us?

Our aim is to help you make the most of oil analysis through technology, training, advice and support

Our commitment to quality of analysis and proven track record with over 25 years experience in the field

Independent advice without conflicts of interest (we are not a supplier of oil or maintenance services)

A comprehensive range of tests for evaluating oil and plant condition including in house Varnish Potential measurement and Analytical Ferrography

Comprehensive, visual and informative multi format reports with full featured web software and 3rd party export format support

Fast analysis turnaround with emergency support

Service tailored to your requirements with multiple options on sample kits, labels, packaging and shipping

# Introduction to oil analysis

Oil is the lifeblood of industrial machinery. It lubricates, coats and protects components, removes heat, insulates and serves a multitude of other functions. Over the years oils have evolved into complex chemical compounds with many options for base stocks and additives. Together these work to achieve the desired functions.

Oil:

- Forms a fluid film between surfaces
- Acts as coolant in removing heat
- Carries away contaminants
- Acts as a hydraulic medium

Additives:

- Protect against wear of highly loaded parts
- Protect against rust and corrosion
- Protect against accumulation of sludge and varnish
- Resist aeration and foaming
- Resist or aid emulsion formation

These functions can be disrupted through

- Contamination with:
  - solids – dirt, wear metals, rust, carbon
  - liquids – water and process fluids, other oils, lubricant supplements
  - gasses – process gases (refrigerants, hydrocarbons) and aeration
- Depletion of inhibitor and anti-wear additives (additives used up to stop oil degradation and to protect machine surfaces from rust and wear)
- The fluid film can be disrupted by overloading, with common causes including improper fitting and misalignment of bearings

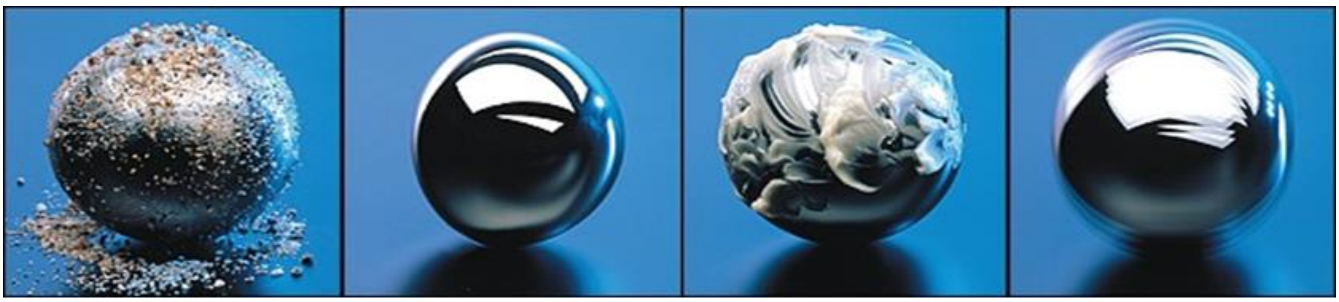
50 to 70% of failures are related to **lubrication, contamination, inadequate maintenance and overloading**.

Oil analysis can identify the above abnormal conditions and predict wear. When used to inform maintenance activity it can help improve machine efficiency, minimise abnormal wear, prevent failure and related stoppages and make the entire maintenance process more efficient.

The following pages detail some of the typical test suites together with some of the additional tests commonly required for a more detailed assessment of the oil's condition and the wear situation.

Oil analysis is a proven technology and can deliver savings many times the cost of the programme. The best examples show benefits of up to 10 times the programme cost. When using an established commercial laboratory it requires no upfront capital expenditure and can be designed to fit specific requirements of the end user.

Here at STS/OAS we aim to deliver high quality analysis, but also to advise on best lubrication practice and aid our customers with advice and guidance to ensure that maximum possible value is derived from the programme. It's not just the analysis – it's what you do with it that counts!



# Applying Oil Analysis to maximise machine life

Oil analysis is a means to an end. It is a source of data that should inform practical decision-making and actions that lead to extended equipment availability and life-span and efficient resource utilisation. The scope for savings is immense with replacement costs for individual machines ranging from many thousands to millions of pounds and potential production losses and penalties costing as much or even more.

A well functioning machine that is correctly sized for the job, has been installed and aligned correctly, is lubricated with an appropriate lubricant that is kept in good condition and free from contamination, should in theory operate reliably until its components start reaching their fatigue limits.

The reality is typically very different, with opportunity for faults and deviations at every stage.

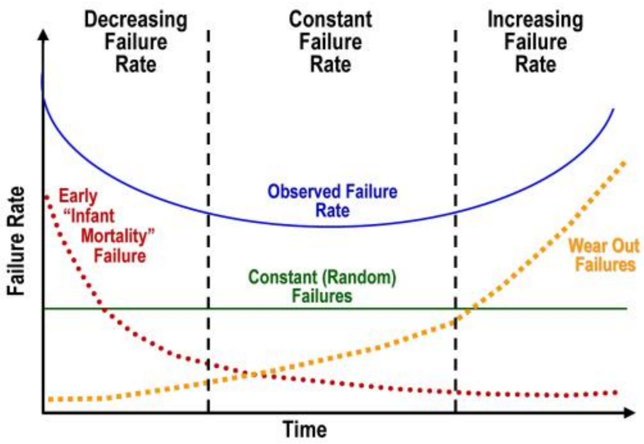
- A poorly aligned machine may shake itself to bits within days of going into service
- Oil that's full of abrasive contaminants may wear the bearings out within weeks
- Degraded lubricant will fail to perform its function leading to poor operation and increased wear
- An incorrectly selected lubricant or one topped up with the wrong oil may not have the necessary load carrying capacity (e.g. too low viscosity or unsuitable additive pack) or may not reach all of the surfaces requiring lubrication (e.g. too viscous) and lead to oil starvation and severe wear

A combination of adverse factors can lead to manifold reduction in useful life.

Oil analysis and other condition monitoring techniques can be used to identify any such deviations from the ideal and to achieve as close to 100% useful life as possible. The starting point can be as low as less than 10% of useful life – doubling remaining life from there is fairly easy with much larger gains also attainable.

# Oil Analysis from the beginning to the end

Machine failure rate can typically be represented by the so called bathtub curve. In the early stages the risk of failure is higher due to installation faults and manufacturing defects, then the failure rate levels off and is attributable to a variety of "random" causes, before increasing again as the unit begins to wear out.




Before the machine is turned on for the first time make sure that the oil going into it is of the right grade, suitably clean/ filtered and has not degraded in storage.

From the first moments of operation use oil analysis to pick up installation faults and wear due to manufacturing defects, fitting errors and contamination, poor alignment and overloading, and thus minimise "infant mortality".

Throughout the unit's life monitor its condition through regular sampling:

- Ensure no lubricant top ups have been compromised by contamination, degradation or incorrect oil being used
- Detect ingress of external contamination and rectify through prevention, filtration and oil changes
- Monitor essential lubricant properties and replace before it loses functionality and causes poor operation, wear or outright failure
- Where necessary manage lubricant switch-over through compatibility studies and post-change monitoring
- Monitor build up of oil oxidation and degradation products (sludge/varnish) and apply suitable controls to maintain anti-oxidant levels and remove insoluble oxidation products through specialist filtration
- Identify wearing components and plan for replacement to maintain maximum availability

At the same time avoid unnecessary oil changes where not warranted, saving time and money, reducing environmental impact and last but not least avoiding maintenance induced errors and failures.

Towards the end of life monitor the condition closely to ensure a suitable replacement can be sourced in good time and a changeover scheduled to minimise disruption to production and optimise resource use.

Where failure could not be prevented use oil analysis to help identify failure mode and prevent reoccurrence.

## Package A analysis suite

This suite is perfect for oil samples from Gearboxes, Pumps, Compressors and Industrial Bearings.

It comprises the following tests:

## Viscosity

A measure of fluid's resistance to flow. Often defined as an ISO or SAE viscosity grade (such as ISO VG 220 or SAE 15W/40). Typically measured at 40 or 100°C.

Each application will have a viscosity range suited to the task. Too high a viscosity can lead to lubricant starvation, wear in circulating pumps, increased temperatures and reduced efficiency. If viscosity is too low, the components will not be sufficiently separated resulting in excess friction and causing wear on the machinery.

A change in viscosity could be due to:

- Contamination with water/fuel/solvents/very small particles/soot
- Oxidation or ageing of the oil
- Incorrect oil being used or topped up
- Mechanical shearing of the oil

Once a change has been detected, its cause can be identified and rectified and oil replaced in line with requirements.

## Acidity or Total Acid Number

Oil oxidizes over time and becomes more acidic, indicating the age of the oil. If the oil is too acidic it can damage metal components and further accelerate the ageing process. This process may also be accompanied by sludge and varnish.

A rapid increase in the Acid Number may be due to:

- Severe oxidation (often caused by overheating)
- Depletion of additive package
- Top up with a large volume of incorrect oil with a much higher base acidity e.g. hydraulic oil
- Contamination with process fluids; or in case of engine oils with combustion products

## Water Content

Excess water in the oil reduces the lubricating effectiveness by disrupting the oil film, accelerates corrosion (i.e. rusting of iron and steel surfaces), depletes and/or degrades additives and accelerates the aging (oxidation) of oil. Where large quantities of water are present oil may become emulsified. The emulsions can combine with insoluble oxidation products to form sludge which impairs the operation and reliability of equipment. In addition excessive water if present as free water can promote bacteria growth or form hard deposits on bearing surfaces.

An increase in water content may be due to:

- Leaking covers on equipment
- Leaking oil coolers
- Excessively leaking turbine gland steam seals
- Condensation/breathing
- Using water contaminated fluid for topping up

## Particle Quantifier Index (PQ)

A measure of total magnetic ferrous debris in the sample irrespective of particle size.

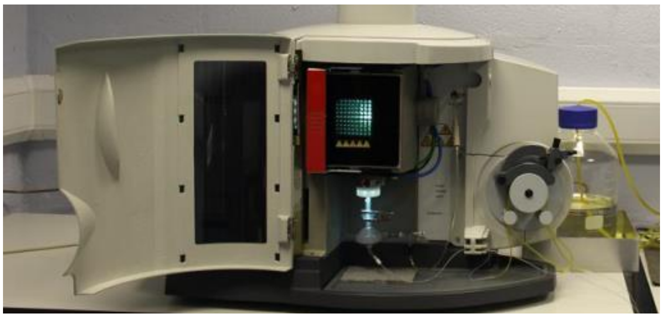
Does not detect non-magnetic ferrous debris e.g. rust.

Combine with Elemental Analysis and ISO Code for comprehensive assessment of the wear situation.

## Elemental Analysis

Optical Emission Spectroscopy is used to measure the concentration of over 20 different elements in the oil. These include wear metals, additives and contaminants.

By monitoring wear metal concentrations the wear rate and its origin can be established. Trending additive levels ensures that the right oil is used and that it remains suitable to the task, while measuring levels of contaminants helps prevent severe wear and loss of function.



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# OIL TEST RESULTS

**SITE:** CUSTOMER SITE 1
**UNIT:** COMPRESSOR STARTER (EQ: 123456)
**SAMPLE POINT:** RECIPROCATING COMPRESSOR
**LUBRICANT:** ISO VG 100

| DATE SAMPLED | 24/11/2009 | 06/09/2010 | 06/12/2010 | 07/03/2011 | 04/06/2011 | 05/09/2011 | 12/12/2011 | 07/07/2012 |
|---|---|---|---|---|---|---|---|---|
| DATE RECEIVED | 02/12/2009 | 13/12/2010 | 20/01/2011 | 15/04/2011 | 21/07/2011 | 14/10/2011 | 13/01/2012 | 29/08/2012 |
| DATE TESTED | 02/12/2009 | 13/12/2010 | 20/01/2011 | 15/04/2011 | 21/07/2011 | 14/10/2011 | 13/01/2012 | 29/08/2012 |
| EQIP HRS / LUB HRS | | | | | | | | |
| IRON (ppm) | 9 | 14 | 23 | 46* | 20 | 16 | 41* | 151** |
| CHROMIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ALUMINIUM (ppm) | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 |
| COPPER (ppm) | 3 | 3 | 6 | 12* | 4 | 2 | 9* | 43** |
| LEAD (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| NICKEL (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| TIN (ppm) | 0 | 0 | 1 | 6* | 1 | 0 | 4* | 23** |
| MANGANESE (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| TITANIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SILVER (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MOLYBDENUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ZINC (ppm) | 75 | 8 | 29 | 4 | 26 | 14 | 36 | 32 |
| PHOSPHORUS (ppm) | 162 | 110 | 128 | 95 | 114 | 93 | 124 | 124 |
| CALCIUM (ppm) | 197 | 19 | 74 | 3 | 61 | 28 | 91 | 67 |
| BARIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAGNESIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SILICON (ppm) | 8 | 1 | 3 | 4 | 2 | 2 | 4 | 4 |
| SODIUM (ppm) | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| BORON (ppm) | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| VANADIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SULPHUR (ppm) | | | | | | | | |
| ISO CODE | | | | | | | | |
| PQ | 40* | 10 | 15 | 32 | 8 | 1 | 22 | 223* |
| WATER (%) / WATER (ppm) | - / 197 | - / 20 | - / 34 | - / 25 | - / 66 | - / 53 | - / 61 | - / 70 |
| FLASH POINT (°C) | | | | | | | | |
| INSOLUBLES (%) | | | | | | | | |
| TBN (mgKOH/g) | | | | | | | | |
| TAN (mgKOH/g) | 0.37 | 0.35 | 0.33 | 0.51 | 0.31 | 0.36 | 0.37 | 0.39 |
| VISC @ 40°C | 101 | 100 | 100 | 100 | 101 | 100 | 99 | 102 |
| VISC @ 100°C | | | | | | | | |
| SOOT | | | | | | | | |
| OXIDATION | | | | | | | | |
| NITRATION | | | | | | | | |
| SULPHATION | | | | | | | | |
| GLYCOL (%) | | | | | | | | |
| FUEL (%) | | | | | | | | |
| WATER (%) | | | | | | | | |
| ANTIWEAR | | | | | | | | |
| NAS 1638 | | | | | | | | |
| BIO | | | | | | | | |
| RPVOT (min) | | | | | | | | |
| DEMULSIFICATION (s) | | | | | | | | |
| RESAMPLE IN | | | | | | | | |
| SAMPLE NUMBER | 20492.003 | 22191.007 | 22323.002 | 22755.009 | 23155.007 | 23512.009 | 23902.009 | 24936.007 |

Abnormal wear trends suspected. Note PQ Index and Iron content as well as Copper/Tin (bearing material). Inspect unit for bearing damage, if acceptable condition change oil to remove contamination. Resample at reduced intervals to verify problem corrected. (Comments refer to Sample No. 24936.007, as highlighted above.)

Table 7

For more information please go to https://www.oas-online.co.uk/reports/

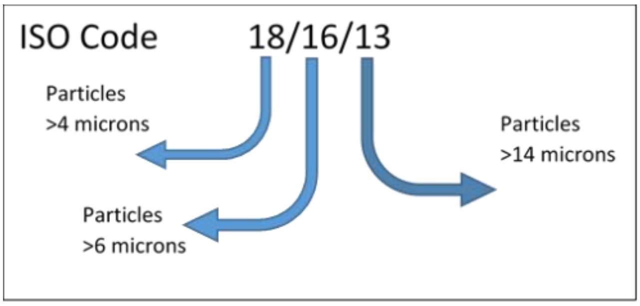
## Package B analysis suite

This suite comprises all of the tests present in Package A and adds the determination of oil's cleanliness as described by the ISO Cleanliness Code.

This package is the routine suite for hydraulic and turbine oils, as well as for any systems where high cleanliness levels are required. It adds a lot of detail about the types of wear particles and contaminants in the oil. Together with PQ Index and Elemental Analysis it delivers a comprehensive overview of the wear situation.

The ISO 4406 Cleanliness Code is a coding system relating the quantity of particles in the different size brackets to specific code numbers, making analysis of cleanliness levels much more straightforward.

The first number in the code refers to particles >4µm, the second to particles >6µm and the third to particles >14µm.




So an ISO Cleanliness Code of 18/16/13 translates to contamination level of between 1300 and 2500 particles >4µm, between 320 and 640 particles >6µm and 40 to 80 particles >14µm per ml.

| | Number of particles per ml | |
|---|---|---|
| Range Number | More than | Up to and including |
| 24 | 80000 | 160000 |
| | … | |
| 18 | 1300 | 2500 |
| 17 | 640 | 1300 |
| 16 | 320 | 640 |
| 15 | 160 | 320 |
| 14 | 80 | 160 |
| | … | |
| 6 | 0.32 | 0.64 |

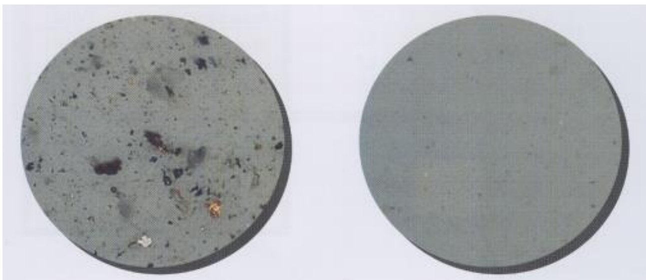
Other commonly used coding systems are NAS 1638 and SAE AS 4059.

There are several ways of obtaining the particle count with the most common being instrumental particle counting and the patch test method.

Most instrumental particle counters relate a change in the amount of light (either visible or laser) transmitted through the fluid into a particle count using a stored calibration. Others measure a pressure drop as the oil is passed through a series of sieves.

Another approach is to pass the oil through a filter membrane and with the aid of microscopy to either count the deposited particles or perform a comparison with reference slides.

The advantage of the patch test method is that, as well as obtaining the ISO Code, the types of wear and contamination particles can be examined and captured. With a range of advanced illumination options on offer we are able to deliver enhanced information and deeper insight into the types of wear or contamination. This method is also insensitive to air bubbles and water droplets, which can interfere with the readings of the instrumental particle counters.



ISO 21/19/17 ISO 16/14/11

We use the patch test to obtain the majority of the ISO Code readings and the instrumental particle counters for particularly clean fluids, where manual counting does not offer sufficient sensitivity.

Where necessary additional microscopic examination can be offered with fully focused images at different magnifications, wide area overview scans and a range of illumination options.

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# OIL TEST RESULTS

**SITE:** SITE 1

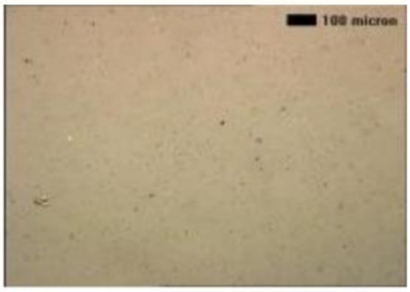
**UNIT:** ABCDE 5678

**SAMPLE POINT:** PUMP

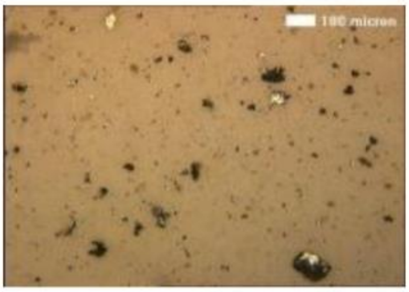
**LUBRICANT:** ISO VG 46

| DATE SAMPLED | 03/10/2014 | 21/01/2016 | 31/03/2016 | 07/04/2016 | 19/04/2016 | 30/08/2016 | 09/09/2016 | 26/09/2016 |
|---|---|---|---|---|---|---|---|---|
| DATE RECEIVED | 14/10/2014 | 22/01/2016 | 01/04/2016 | 12/04/2016 | 25/04/2016 | 31/08/2016 | 20/09/2016 | 27/09/2016 |
| DATE TESTED | 14/10/2014 | 22/01/2016 | 01/04/2016 | 15/04/2016 | 25/04/2016 | 01/09/2016 | 23/09/2016 | 28/09/2016 |
| EQIP HRS / LUB HRS | 897 / Post Fltr | 1846 / - | | 2159 / - | 2207 / - | 2576 / 1 | 2582 / 12 | 2598 / 28 |
| IRON (ppm) | 12 | 29* | 39* | 9 | 16 | 3 | 3 | 37* |
| CHROMIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| ALUMINIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| COPPER (ppm) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| LEAD (ppm) | 3 | 5 | 5 | 1 | 2 | 0 | 1 | 1 |
| NICKEL (ppm) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| TIN (ppm) | 0 | 0 | 0 | 1 | 0 | 3 | 4 | 4 |
| MANGANESE (ppm) | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| TITANIUM (ppm) | 58 | 56 | 55 | 35 | 41 | 6 | 7 | 8 |
| SILVER (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MOLYBDENUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ZINC (ppm) | 16 | 22 | 24 | 7 | 12 | 4 | 4 | 4 |
| PHOSPHORUS (ppm) | 675 | 630 | 611 | 444 | 525 | 496 | 513 | 508 |
| CALCIUM (ppm) | 7 | 6 | 6 | 4 | 4 | 6 | 5 | 5 |
| BARIUM (ppm) | 3 | 3 | 1 | 0 | 1 | 0 | 0 | 0 |
| MAGNESIUM (ppm) | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| SILICON (ppm) | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| SODIUM (ppm) | 5 | 4 | 3 | 2 | 2 | 1 | 1 | 1 |
| BORON (ppm) | 17 | 8 | 4 | 12* | 8 | 0 | 3 | 2 |
| VANADIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SULPHUR (ppm) | | | | | | | | |
| ISO CODE | 17/16/13 | 16/15/12 | 18/17/13* | 17/16/13 | 17/16/13 | 17/16/13 | 17/16/12 | 19/18/15* |
| PQ | 1 | 1 | 6 | 1 | 1 | 1 | 1 | 27* |
| WATER (%) / WATER (ppm) | - / 703 | - / 548 | - / 452 | - / 400 | - / 436 | - / 323 | - / 300 | - / 287 |
| FLASH POINT (°C) | | | | | | | | |
| INSOLUBLES (%) | | | | | | | | |
| TBN (mgKOH/g) | | | | | | | | |
| TAN (mgKOH/g) | 0.89 | 1.08 | 1.13 | 0.41 | 0.54 | 0.27 | 0.30 | 0.31 |
| VISC @ 40°C | 48 | 48 | 48 | 48 | 49 | 48 | 50* | 50* |
| VISC @ 100°C | | | | | | | | |
| NAS 1638 | | | | | | | | |
| BIO | | | | | | | | |
| RPVOT (min) | | | | | | | | |
| DEMULSIFICATION (s) | | | | | | | | |
| RESAMPLE IN | | | | | | | | |
| SAMPLE NUMBER | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 41641.001 |

Abnormal wear suspected. Note the increase in Iron content and PQ Index - metallic particles observed on filter patch. Inspect unit for damage/proper operation. Resample at reduced intervals to verify problem corrected. (Comments refer to Sample No. 41641.001, as highlighted above.)




ISO Image for sample No. [illegible].




ISO Image for sample No. 41641.001.

Table 1

For more information please go to https://www.oas-online.co.uk/reports/

## Routine Fuel analysis suite

This suite is the starting point for checking the condition of your fuel supply.

It comprises the following tests:

## Viscosity

A measure of fluid's resistance to flow.

While not as critical a parameter for fuel samples, it helps keep track of changes in supply and may be useful for detecting bulk ingress of lubricating oil or other contaminants.

## Biological Contamination / Diesel Bug

Water can get into diesel fuel as a result of condensation, rainwater penetration or adsorption from the air. This encourages microbial growth at the fuel/water interface or on tank walls. If left unchecked it can lead to formation of sludge at the bottom of the tank, filter blockages, injector and fuel pump failure.

Here at STS we use dip slides to culture bacteria, yeasts and moulds. The incubation process takes a week to complete, which is why you will typically receive a preliminary report containing the rest of the analysis results, with biological contamination test data following once available.

Depending on the outcome of the test treatment with biocide may be recommended, other interventions relate to removing excess water and preventing ingress, cleaning of the tanks, filtration, etc.

## Water Content

As well as promoting biological growth water in itself is a damaging contaminant. Excess water content can cause injector damage. With increasing concentrations of biodiesel, which is hygroscopic, water contamination of diesel fuel is likely to remain a regular problem.

## Particle Quantifier Index (PQ)

A measure of total magnetic ferrous debris in the sample irrespective of particle size.

Does not detect non-magnetic ferrous debris e.g. rust.

Combine with Elemental Analysis and ISO Code for comprehensive assessment of the contamination and wear situation.

## Elemental Analysis

Optical Emission Spectroscopy is used to measure the concentration of over 20 different elements in the fuel. These include typical wear metals, additives and contaminants.

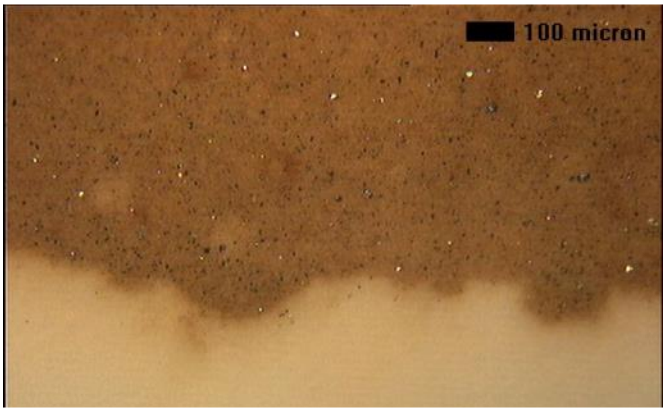
Engine and other lubricating oils are a fairly common contaminant that can be detected through elemental analysis.

Monitoring of the Sulphur content can also help identify out of spec fuel.

## ISO Cleanliness Code/Particle Count/ Patch Test

Modern diesel engines increasingly require high fuel cleanliness, with dirty fuel responsible for many an injector failure.

A patch test can help confirm if sample cleanliness is within the desired 18/16/13 ISO Code range. It can also help identify origin of contaminant particles and detect fuel degradation, which can manifest as fine silt on the filter membrane.




## Additional Tests

Other key tests to consider:

- **Biodiesel or Fatty Acid Methyl Ester (FAME) content** — some engines are less able to tolerate biodiesel
- **Flash Point** — to check for ingress of petrol
- **Cetane Number, Lubricity and Density**
- **Pour Point, Cloud Point and Cold Filter Plugging Point** — help characterise cold weather performance
- **Distillation Profile and FTIR spectroscopy**
- Full specification testing to **EN590** and other standards

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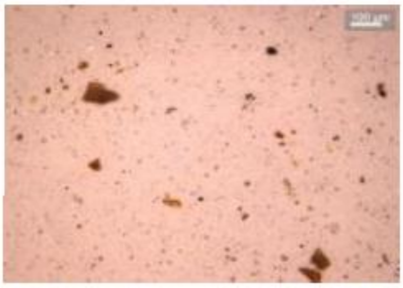
# OIL TEST RESULTS

**SITE:** TEST SITE
**UNIT:** TANK 1
**SAMPLE POINT:** FUEL
**LUBRICANT:** DIESEL FUEL

| DATE SAMPLED | 07/01/2019 | 04/02/2019 | 05/03/2019 | 12/03/2019 | 19/03/2019 | 02/04/2019 | 07/05/2019 | 03/06/2019 |
|---|---|---|---|---|---|---|---|---|
| DATE RECEIVED | 08/01/2019 | 05/02/2019 | 06/03/2019 | 13/03/2019 | 20/03/2019 | 04/04/2019 | 09/05/2019 | 05/06/2019 |
| DATE TESTED | 10/01/2019 | 07/02/2019 | 08/03/2019 | 14/03/2019 | 21/03/2019 | 05/04/2019 | 13/05/2019 | 07/06/2019 |
| EQIP / LUB HRS | | | | | | | | |
| IRON (ppm) | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 2 |
| CHROMIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ALUMINIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| COPPER (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LEAD (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NICKEL (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TIN (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MANGANESE (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TITANIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SILVER (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MOLYBDENUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ZINC (ppm) | 0 | 0 | 4* | 5* | 0 | 0 | 0 | 0 |
| PHOSPHORUS (ppm) | 1 | 1 | 3* | 4* | 0 | 0 | 0 | 0 |
| CALCIUM (ppm) | 0 | 0 | 8* | 10* | 1 | 1 | 0 | 1 |
| BARIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAGNESIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SILICON (ppm) | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| SODIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BORON (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VANADIUM (ppm) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SULPHUR (ppm) | 9 | 10 | 15* | 16* | 10 | 10 | 9 | 10 |
| ISO CODE | 15/14/12 | 16/15/11 | 17/16/13* | 17/16/13* | 16/15/12 | 16/15/13 | 16/15/13 | 19/18/14* |
| PQ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 8 |
| WATER (%) / WATER (ppm) | - / 85 | - / 72 | - / 96 | - / 116 | - / 92 | - / 84 | - / 285* | - / 1351** |
| FLASH POINT (°C) | | | | | | | | |
| INSOLUBLES (%) | | | | | | | | |
| TBN (mgKOH/g) | | | | | | | | |
| TAN (mgKOH/g) | | | | | | | | |
| VISC @ 40°C | 3.2 | 3.3 | 3.5 | 3.6 | 3.3 | 3.3 | 3.3 | 3.4 |
| VISC @ 100°C | | | | | | | | |
| NAS 1638 | | | | | | | | |
| BIO | Negative | Negative | Negative | Negative | Negative | Negative | Negative | Positive* |
| RPVOT (min) | | | | | | | | |
| DEMULSIFICATION (s) | | | | | | | | |
| RESAMPLE IN | | | | | | | | |
| SAMPLE NUMBER | **999.020** | **999.021** | **999.022** | **999.023** | **999.024** | **999.025** | **999.026** | **999.027** |

Water contamination with signs of resulting biological contamination (moderate bacteria and yeast contamination). Also note ISO Cleanliness Code. Drain off excess water and inspect for source. Filter or replace fuel and clean tank. Biocide treatment may be necessary. Resample at reduced intervals to verify problem corrected. (Comments refer to Sample No. 999.027, as highlighted above.)

ISO Image for sample No. 999.026.



ISO Image for sample No. 999.027.

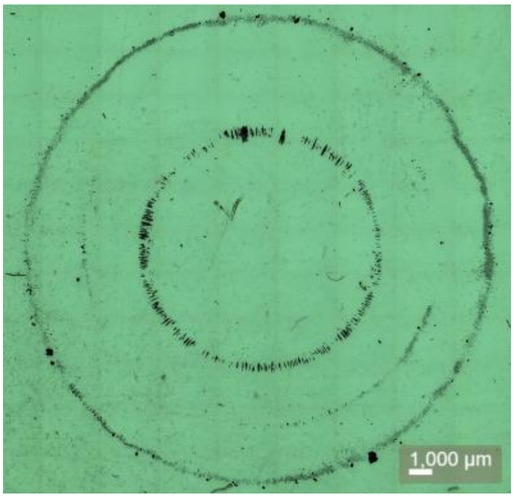
Table 27

For more information please go to https://www.oas-online.co.uk/reports/

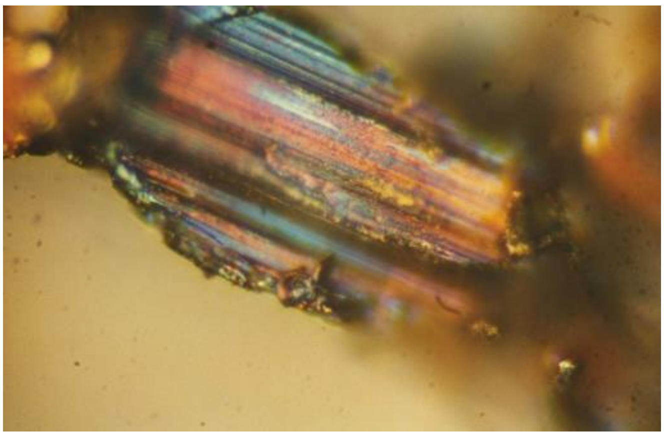
# Analytical Ferrography

Analytical Ferrography is a technique for depositing and analysing wear particles contained in an oil or grease sample.

The sample is deposited onto a glass slide, with the particles trapped by strong magnets and the oil washed away with a suitable solvent. Both linear and rotary particle deposition systems exist. At STS preference is given to a rotary system, which has been developed at the company. It ensures good separation of particles over the three rings, with wear debris also being sorted by size and the larger particles settling out on the inner ring.

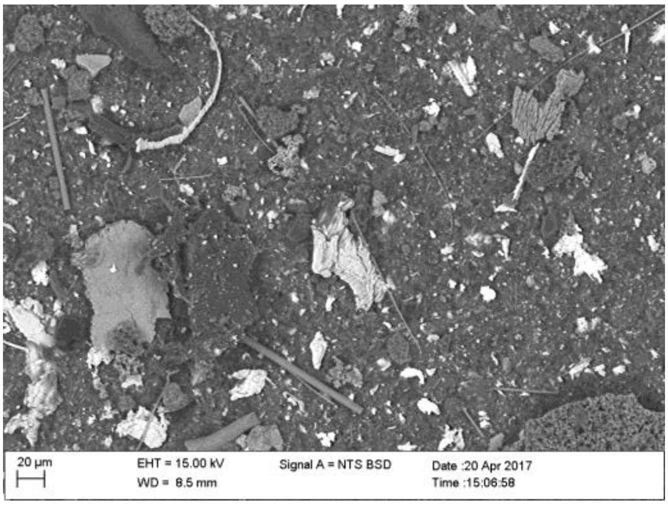



Once deposited the particles are analysed by a metallurgist, who is able to report on the relative quantities, types and sizes of particles present. A Particle Quantifier Index of the slide is also recorded. All of this is taken into account to produce a comprehensive report on the wear rate and situation.



# Scanning Electron Microscopy

Scanning Electron Microscopy with Energy Dispersive X-Ray (SEM-EDX) is used to interrogate individual particles and obtain their elemental composition. The particles can be deposited onto a filter membrane as part of the ISO Code determination or collected from Ferrography slides.



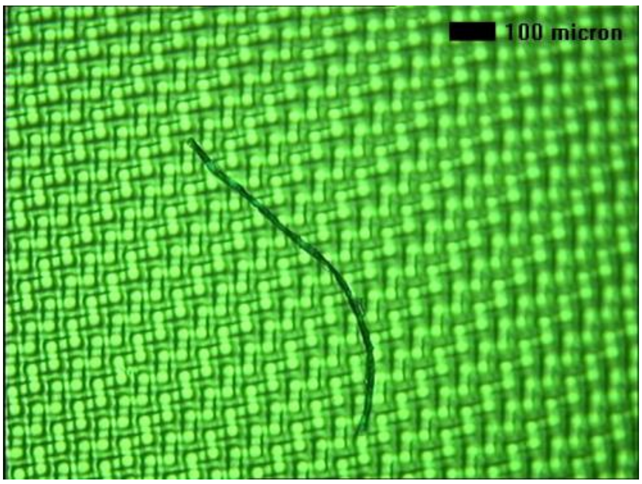

This technique is particularly useful for the larger particles which cannot be processed via conventional elemental analysis (such as ICP-OES).

# Filter Debris and Magnetic Plug Debris Analysis

Filters perform an important function in capturing wear debris and contaminants and preventing their spread throughout the system. A similar function is performed by magnetic plugs. Both can serve as important depositories of information about the wear rate and situation. The debris can be extracted from the filters and plugs with a detailed examination then performed. This typically involves microscopy and elemental analysis, although Analytical Ferrography and SEM-EDX analysis can also be carried out to further enhance the report.

# Fibre Count

Condition of composite bearings can be assessed through monitoring the quantities of fibres in oil.




An example of such application is marine stern tube bearings.

# Swansea Tribology Services

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Tel: 01792 799036 Fax: 01792 799034 Website: www.oas-online.co.uk

Part of the Oil Analysis Services Group

Lab Ref: 99998.001 Report Date: 08/11/2019

| Customer: | Equipment: | Lubricant: |
|---|---|---|
| TEST COMP | NORTH CRANE(ABCD 12345) | LIEBHERR UNIVERSALFETT 9900 |
| Site: | SLEW RING GREASE | |
| EXAMPLE SITE | Sample Date: 04/11/2019 | Equipment Hours: |
| | | Lube Hours: |

Comments:

Medium density deposit

PQ Index 221 (3g slide)

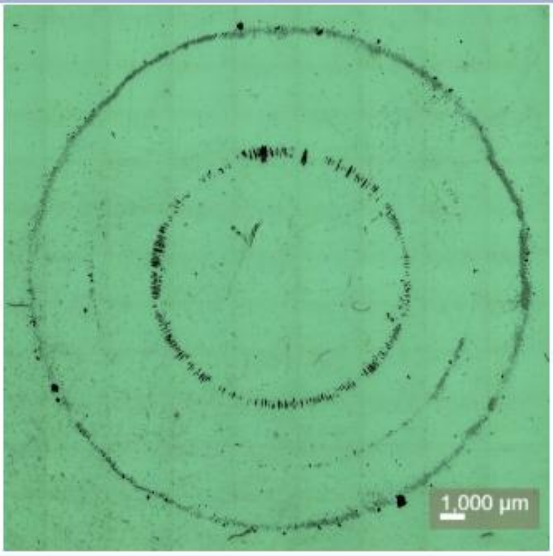
The majority of the particles present were normal rubbing/pitting wear ranging in size up to ~220µm but generally <15µm.

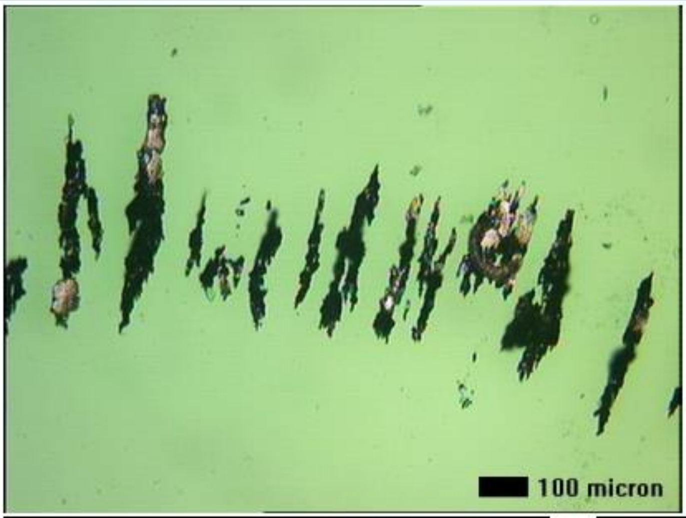
Some fatigue chunks (up to ~15µm) , spheres (up to ~170µm) , cutting wear particles (up to ~130µm) and oxide particles (up to ~175µm) also present.

The occasional particle exhibited localised heating (temper colouring).

The wear rate and the wear situation are both regarded as normal.

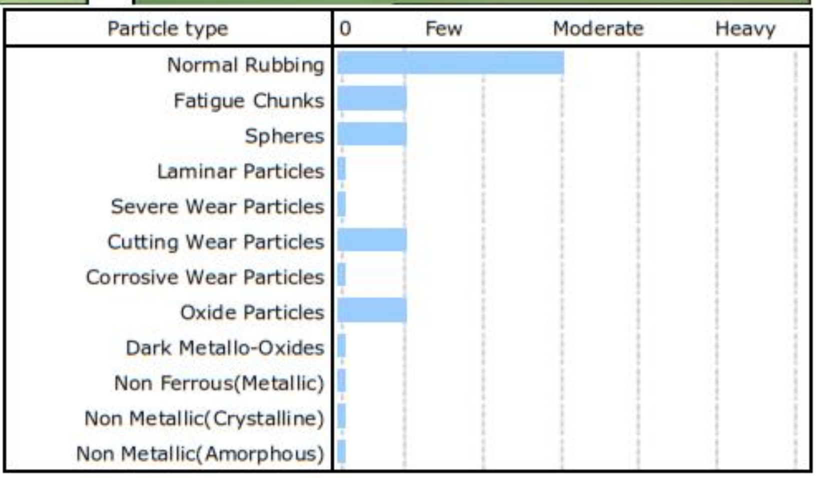
Considered Judgement of Wear Situation: **Normal**





| Elements | | |
|---|---|---|
| PPM | Iron | 380* |
| | Chromium | 10 |
| | Aluminium | 30 |
| | Copper | 0 |
| | Lead | 0 |
| | Nickel | 0 |
| | Tin | 0 |
| | Silicon | 110 |
| | Sodium | 9400* |
| | Boron | 360 |
| | WATER (%)/(ppm) | 1.72* / 17210* |
| | Viscosity @ 40°C | |
| | PQ Index | 51* |



## Oil Oxidation, Anti-oxidant Additives and Varnish Potential, Other Tests

Oil oxidation is an inevitable part of the oil's life cycle. However its onset can be delayed and detrimental effects mitigated through active oil management. The process relies on monitoring of the oil's oxidation stability, the levels of anti-oxidant additives and its varnish potential. These can then inform the maintenance activities – filtration, top ups and oil changes.

Source Wooton

## Oxidation Stability – RPVOT

One of important properties of the oil is its oxidation stability – that is its ability to resist oxidation. One of the standard measures of this property is the Rotating Pressure Vessel Oxidation Test (RPVOT, formerly RBOT). The test presents a simulated worst case scenario, where an oil sample is subjected to the harsh conditions of high temperature and high pressure oxygen atmosphere in the presence of water and a copper catalyst. As oil oxidises the pressure drops and time taken to achieve a specific drop in pressure is recorded.

## Remaining Useful Life Estimation Routine

Remaining Useful Life Estimation Routine (RULER) uses Linear Sweep Voltammetry to measure the levels of Amine and Phenol anti-oxidant additives in the oil. These are typically compared with a baseline measurement obtained from a virgin oil sample (ideally from the same batch of oil). If anti-oxidants are allowed to deplete below a critical level the oxidation process accelerates, leading to reduced oil life. RULER monitoring enables management of the additive levels through top up or partial changes, significantly extending the life of the oil.

## Varnish Potential Measurement via Membrane Patch Colourimetry

Varnish is the sticky residue created by the decay of both mineral and synthetic lubricants and can bring an entire operation to its knees. It can cause premature failure, erratic operation and can be the cause of a costly shut down. There are many signs of varnish build up including sticky valves, overheating bearings, decreased effectiveness of heat exchangers, blocked filters and reduced lubricant life.

A way of detecting build-up of varnish and its precursors early is through Membrane Patch Colourimetry. After a heat and rest cycle to reset the oil's solubility it's filtered through a fine membrane filter and the shading of the patch is measured to obtain the varnish potential value. This value reflects the solubility of the oil (i.e. its capacity to keep oxidation products in solution) and the level of contamination.

If the measured MPC value is high varnish mitigation technologies can be employed to clean up the system. Varnish precursors are very fine sub-micron agglomerations of oxidation products, which can go through conventional filters, although when the oil is saturated they can cause filter blockages. Therefore special filtration technologies aimed at removing the fine sub-micron contaminants need to be utilised. Such technologies include electrostatic filtration, depth media filters and the electrophysical separation process to name but a few. Each comes with its own strengths and weaknesses and should be considered carefully depending on specific application.

## Other Tests

Oil's resistance to oxidation is also affected by its air release properties and foaming characteristics. Entrained air can lead to deterioration of control function as well as micro-dieselling, causing localised high temperatures and accelerated oxidation of the oil. Foam can act as an insulator leading to raised operating temperature, and also increase the surface area in contact with air. For steam turbines the oil's ability to release water from emulsion is also important and can be measured through its demulsification value.

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Part of the Oil Analysis Services Group


**Sample ID:** XXXXX.XXX

**Sample Date:** 18/08/2015

**Machine number:** ABC 1234

**Machine description:** Gas Compressor

**Sample Point:** Tank

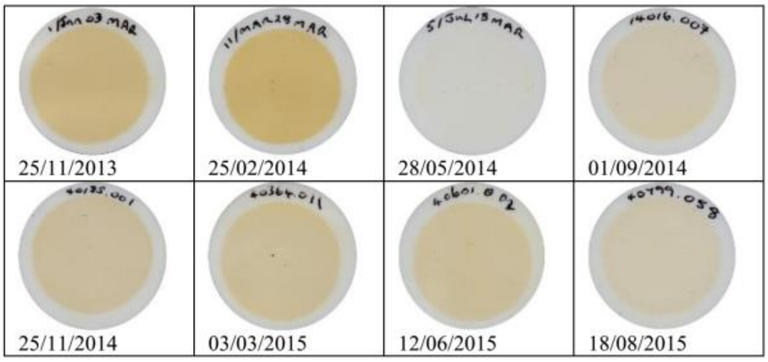
**Lubricant:** XXXXXX XXX XX

**System Volume:** Ltr

**Fill date:**

**Top ups:**

Views of membranes



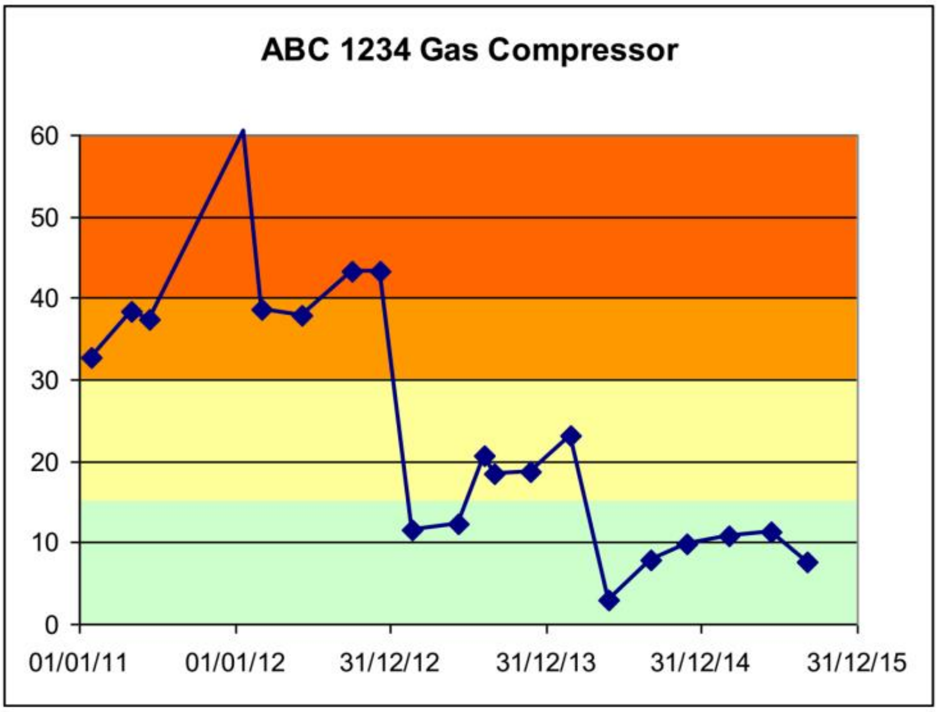

**Results**

| Date | MPC Value |
|---|---|
| 25/11/13 | 18.8 |
| 25/02/14 | 23.2 |
| 28/05/14 | 2.9 |
| 01/09/14 | 7.8 |
| 25/11/14 | 9.9 |
| 03/03/15 | 10.9 |
| 12/06/15 | 11.3 |
| 18/08/15 | 7.6 |

**Comments**

Test result indicates an MPC value of 7.6, which is an improvement when compared with the previous value. It remains in the category of 'Normal' (0-15). Based on the result the oil in this condition has a low risk of creating varnish.

**Trend**

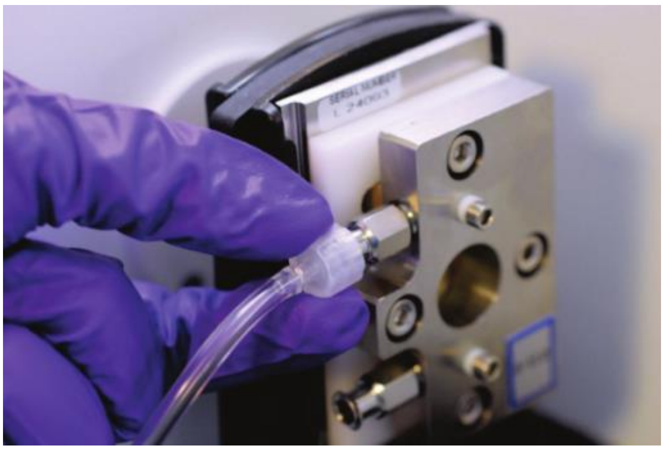


## FTIR Spectroscopy - Introduction

In FTIR Spectroscopy vibrations of molecular bonds in response to infrared excitation are measured, producing an infrared spectrum. Different molecular bonds generate responses at different, often multiple, wavelengths due to the type of the bond and the weights of the constituent atoms. Thus, the peaks of an infrared spectrum can provide information on the molecular bonds present and characterise the compound being measured.

The quantity of organic compounds in existence is vast, with many consisting of a complex arrangement of similar molecular building blocks and therefore having many bonds in common. Presence of multiple substances within the sample can complicate the matter further.

Depending on the type of sample being tested it can be analysed using either a Diamond UATR accessory, as shown above, or a fluid cell pictured below.



FTIR analysis offers multiple tools: direct comparison of tested samples, identification of peaks and functional groups/ compound types, comparisons against libraries of reference substances and previously tested samples, multiple component analysis of mixtures, spectral subtraction and analysis of residuals.

Often when routine analysis is insufficient to definitively identify a contaminant or confirm similarity of two lubricants—FTIR spectroscopy comes to the rescue.

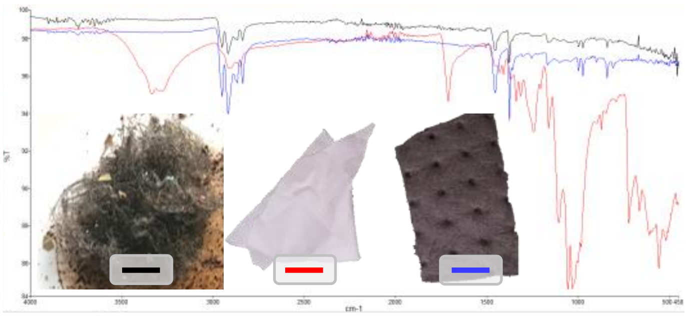
## Application

FTIR Spectroscopy is particularly useful when:

- Comparing lubricant formulation against reference
- Monitoring fuel dilution
- Detecting presence of external contaminants
- Identifying unknown substances and contaminants against reference samples
- Evaluating mixtures
- Assessing levels of oxidation and degradation

## FTIR Application Example 1 - Fibres

A clump of fibres was extracted from an oil sample. Customer supplied candidate samples of rag and absorbent pad materials used on site. Microscopic analysis was unable to differentiate between the fibres. FTIR spectroscopy was able to produce a clear positive match to the absorbent pad material.

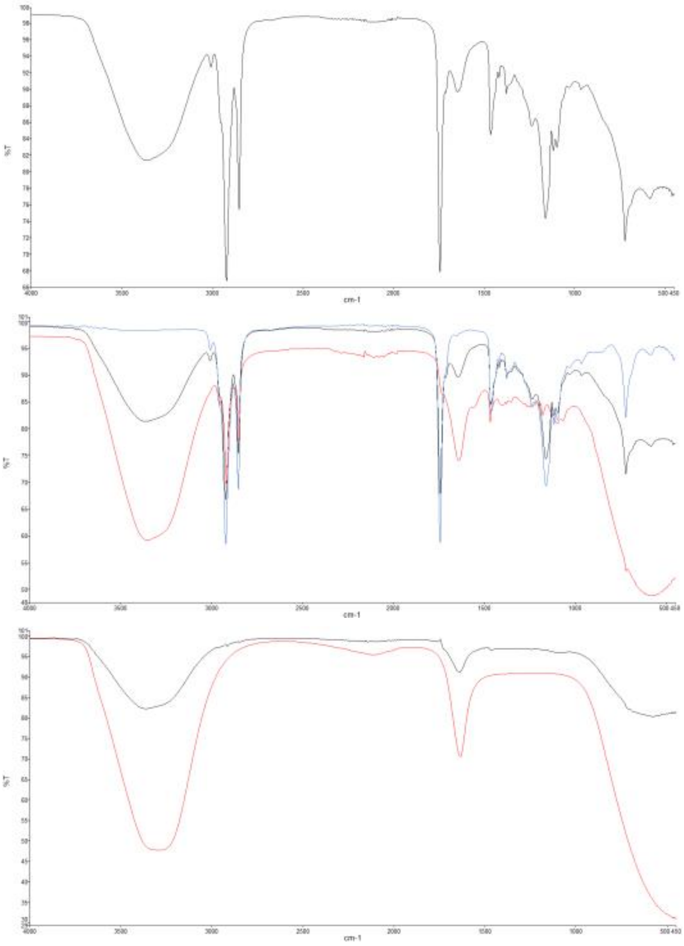


## Application Example 2 - Mixing Oils

Mixing of lubricating and seal oils was suspected in a production critical system. A combination of routine tests and FTIR analysis identified virgin lubricating oil as not matching expected grade, with low viscosity oil being added to the system in error. In addition FTIR spectroscopy with Multisearch was able to predict concentration levels of prepared test mixtures of lubricating and seal oil with a high degree of accuracy, despite the two fluids being substantially similar.  This technique confirmed that no seal oil was entering the lube oil system presently, and that the fault was entirely due to an incorrect lubricant being used.

## FTIR Application Example 3 - Mixtures

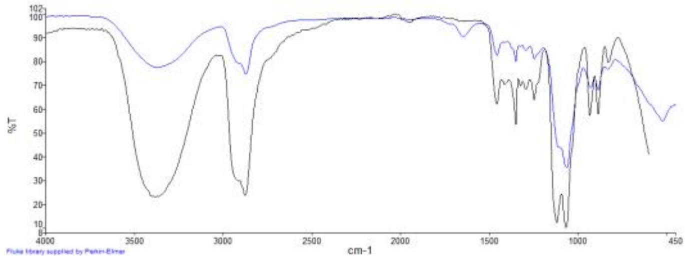
A sample of an oily emulsion was to be compared to a range of candidate contaminant samples from around the process area. The collected sample presented quite a complex spectrum, however during storage a layer of neat oil has separated within the sample. This layer was also scanned, and the spectrum of the top oily layer was subtracted from the emulsion. The residual spectrum was found to be that of water, which was the only contaminant present.



## FTIR Application Example 4 - Unknown Contaminant

Where no candidate samples have been provided, a library search can be used to learn more about the compound. In some cases, a match can be found among the previously tested samples. At other times, a generic library can give indication of the likely composition. Where necessary, scans can be submitted for searches against various other libraries at additional cost.

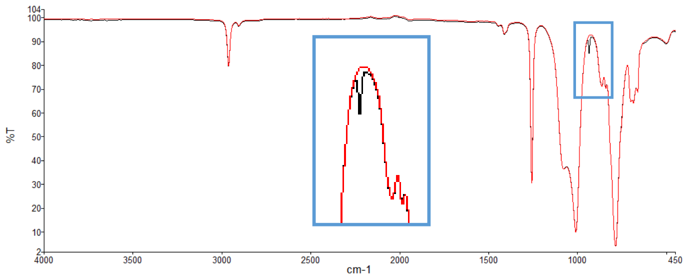
In the following example the contaminant was narrowed down to an ethylene glycol compound, making identification of the source much easier for the customer.




| | Search Score | Search Reference Spectrum Description |
|---|---|---|
| 1 | 0.868394 | TRIETHYLENE GLYCOL ANHYDROUS |
| 2 | 0.866652 | POLYETHYLENE GLYCOL 200 |
| 3 | 0.841754 | POLYETHYLENE GLYCOL 300 |
| 4 | 0.79894 | DIETHYLENE GLYCOL |
| 5 | 0.768104 | DIETHYLENE GLYCOL |
| 6 | 0.706319 | TRIETHYLENE GLYCOL MONOCHLOROHYDRIN |
| 7 | 0.706311 | DIETHYLENE GLYCOL MONOETHYL ETHER |
| 8 | 0.69355 | DIETHYLENE GLYCOL MONOMETHYL ETHER |
| 9 | 0.644168 | DIETHYLENE GLYCOL MONOBUTYL ETHER |
| 10 | 0.611743 | 2-BUTOXYETHANOL |

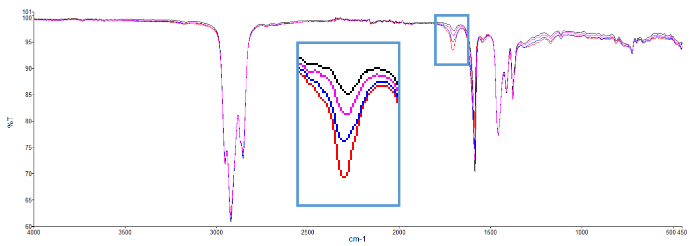
## FTIR Application Example 5 - SF6 Gas in Cable Oil

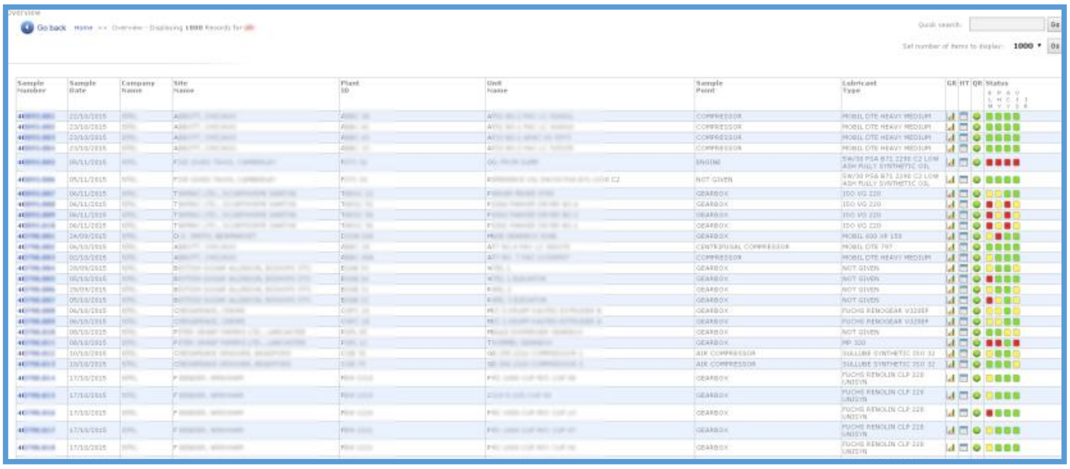
Ingress of Sulfur Hexafluoride gas into cable oil was suspected. FTIR analysis identified the presence of a small additional peak in the spectrum of the in-service sample. Review of reference data for Sulfur Hexafluoride confirmed that the peak coincided with the primary SF6 peak.



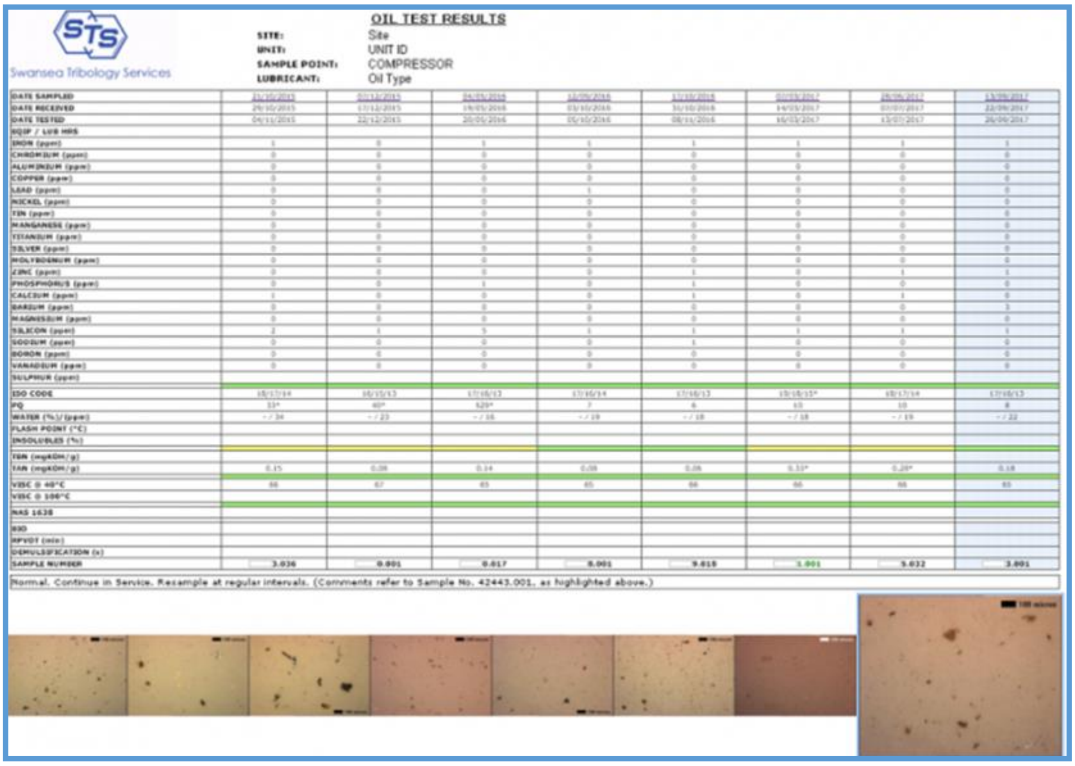

## Application Example 6 - Oxidation

FTIR spectroscopy is particularly useful for spotting significant levels of oxidation. For example lubricant oxidation may be positively identified as the cause of sludge formation, which may allow exclusion of external contaminants from probable causes of sludging.

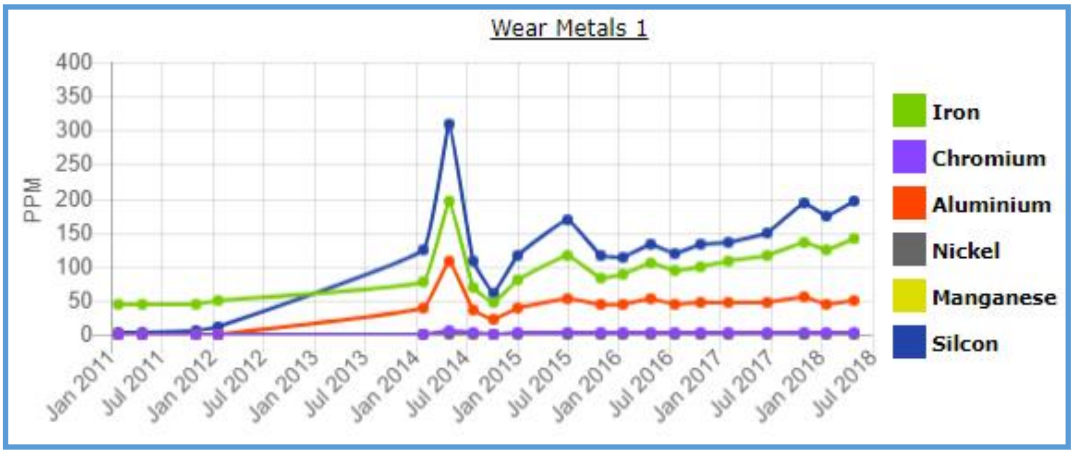




Web database sample overview




Web database history table




Web database customizable graphs

# Transformer Oil Analysis

Just like lube oil analysis mentioned above a lot of value can be derived from transformer oil testing.

The tests for dissolved gases and furfuraldehyde usually indicate the condition of the transformer whilst most of the other tests e.g. acidity, electric strength, fibres reflect the quality of the oil. Since it is not desirable to have any water present, that test can also indicate whether the dryers are functioning correctly.

By measuring the different concentrations of dissolved gases: -

- The presence of a defect can be detected long before any Buchholz alarms.
- The type of defect producing the gases can be diagnosed.
- The severity of the defect can be determined by monitoring the increase in gas concentrations.

Furfuraldehyde is formed by thermal degradation of paper insulation and can aid the diagnosis of defects detected by gas analysis. It should not be used instead of gas analysis.

The benefits of gas analysis lie in knowing if a transformer is in trouble and arranging schedules for planned outages rather than not knowing when plant is about to fail. If surveys are undertaken, then maintenance can be directed towards the worst plant and if defects cannot be corrected easily, possible capital replacement costs for the future can be budgeted. Occasionally plant can be “nursed” to more convenient times for refurbishment by reducing load and by monitoring gases.

For oil quality the control of moisture is most important (maximum of 30mg/l or ppm). It is moisture in combination with fibre in main tanks and selectors and carbon in divertors that so dramatically reduces the electric strength of the oil to very unsafe levels that can result in plant failure.

In tests conducted on a population of 100 primary transformers ranging from 132kV down to 33kV all with on load tapchangers, the loss due to failure of selectors and main tank windings averaged about one per year. During the following period of 8 years in which moisture was monitored on an annual basis and controlled, with 30 ppm set as the value at which units were Ilovaced, the loss was reduced by approximately 90%. Average moisture content being about 18 ppm.

Establishing the importance of moisture did not negate the use of DGA. DGA was adopted as a very useful partner to moisture analysis and testing was carried out on an annual basis. This enabled fault trends in what was an ageing population of transformers to be monitored and remedial action to be taken before fault damage and supply loss occurred. It also allowed capital replacement programs for the plant to be more accurately determined.

The final component of an annual diagnostic testing regime is the targeting of plant maintenance in order to produce substantial cost benefits. The following main plant items are discussed in further details elsewhere (available on request).

## Divertors

To enable maintenance periods to be extended it is better to change contacts in complete sets and to monitor oil for carbon/moisture and electric strength on an annual basis and use this information to supplement and fine tune the annual programme.

## Selectors

Selector maintenance is best targeted using DGA/moisture/electric strength/metal and fibre (fibres normally introduced by fitters using cleaning wipes and leathers during maintenance).

## Main Tanks

An example of annual testing programme is available on request. Initially, when setting up a database, it would be useful if possible to obtain both top and bottom main tank samples of primary transformers but in subsequent years only the bottom needs to be sampled. If a fault is suspected, the sampling frequency for dissolved gas is increased and also top and bottom samples taken at the same time may give more information about the fault.

# Transformer Oil Condition Tests

## Water content

High water content will reduce the insulating properties of the oil, which may result in dielectric breakdown. It can cause breakdown of cellulose based paper insulations in the windings, together with accelerating corrosion.

## Acidity

High acidity can result in corrosion and varnish deposits, together with degradation of oil and paper in the windings. Consequently, sludging can occur within the oil, thus reducing heat dissipation qualities of oil and causing overheating. Reduced insulating properties and an increase in water content normally go hand in hand with high acidity.

## Electric Strength

Low electric strength indicates oil is no longer capable of performing the vital function of insulating under high electrical fields. Poor electric strength is often linked with high water and fibre content.

## Colour

An indication of level of oxidation and degradation of oil.

## Fibres

Under high electric fields the behaviour of fibres can cause a dramatic reduction of insulating qualities of oil. Although invisible to the naked eye fibres are often introduced via poor maintenance techniques.

## Polychlorinated Biphenyls (PCBs)

PCBs are insulating liquids used for their non-flammable properties, mainly in transformers, whether a fire would be unacceptable and as the dielectric in capacitates. Unfortunately the mineral oil used in transformers has become cross contaminated over the years. As PCBs are fairly non-biodegradable and tend to collect in food chains legislation was brought in to prevent wide-spread contamination. Liquids containing over 50 mg/kg must be classed as injurious substance and disposed of via costly high temperature incineration. It is therefore essential those responsible for plant know their level of contamination and have strict controls on oil movements to site.

# Machine Condition Tests

## Dissolved Gas Analysis (DGA) and Buchholz gas analysis

This is the single most important test performed on transformer oil and is used to determine the concentration of certain gases such as nitrogen, oxygen, carbon monoxide, carbon dioxide, hydrogen, methane, ethane, ethylene and acetylene. The concentration and relative ratios of these gases can be used to diagnose certain operational problems and incipient faults in transformers, which may or may not be associated with a change in physical or chemical property of the insulating oil. For example, high level of carbon monoxide relative to other gases may indicate thermal breakdown of cellulose paper while hydrogen in conjunction with methane may indicate a corona discharge. Acetylene is considered a significant gas generated as it is formed in breakdown of oil at temperatures in excess of 700$^{o}$C and can indicate a serious high temperature overheating fault.

## FFA (Furfuraldehyde)

This is a measure of the degradation of cellulose paper in the windings i.e. as the paper ages its degree of polymerisation (DP) reduces and thus so does its strength as it becomes more brittle. The DP of paper can directly related to the concentration of furan derivatives in the oil which are formed as a direct result of the breakdown of the polymeric structure of cellulose paper. New paper has a DP rating of 1250 while at 250 the paper is sufficiently brittle to fall away from the windings. It is therefore possible to use FFA to estimate the used life of the transformer as well as which will be dependent on factors such stresses on plant, overheating etc. FFA formation can also indicate low temperature overheating.

## Metals in oil

Elemental data helps to pinpoint the origins of faults for example iron and copper can be indicative of arcing between a copper contact and iron core.

OIL ANALYSIS SERVICES

# OIL TEST RESULTS

**COMPANY:** SWANSEA TRIBOLOGY SERVICES
**SITE:** TRANSFORMER NO. 1
**UNIT:** TRANSFORMER SER. NO.

| SAMPLE POINT | BOTTOM MAIN TANK | BOTTOM MAIN TANK | BOTTOM MAIN TANK | BOTTOM MAIN TANK | BOTTOM MAIN TANK | BOTTOM MAIN TANK | BOTTOM MAIN TANK | BOTTOM MAIN TANK |
|---|---|---|---|---|---|---|---|---|
| DATE SAMPLED | 18/05/2008 | 09/10/2008 | 14/08/2009 | 14/08/2009 | 17/06/2010 | 04/04/2012 | 25/02/2013 | 03/03/2014 |
| DATE RECEIVED | 24/05/2008 | 11/10/2008 | 15/08/2009 | 15/08/2009 | 23/06/2010 | 07/04/2012 | 10/03/2013 | 16/03/2014 |
| DATE TESTED | 02/06/2008 | 13/10/2008 | 19/08/2009 | 19/08/2009 | 21/07/2010 | 17/04/2012 | 11/03/2013 | 17/03/2014 |
| HYDROGEN (vpm) | 46 | 25 | <5 | <5 | <5 | <5 | <5 | <5 |
| OXYGEN (vpm) | 17591 | 27942 | 12469 | 12469 | 12175 | 13856 | 20354 | 25395 |
| NITROGEN (vpm) | 63891 | 65131 | 64345 | 64345 | 66017 | 59855 | 57025 | 63642 |
| CARBON MONOXIDE (vpm) | 40 | 55 | 80 | 80 | 18 | 12 | 32 | 30 |
| METHANE (vpm) | 0.4 | 0.9 | 1.0 | 1.0 | 0.6 | 1.7 | 1.7 | 1.8 |
| CARBON DIOXIDE (vpm) | 448 | 678 | 949 | 949 | 1255 | 296 | 660 | 599 |
| ETHYLENE (vpm) | 0.5 | 0.6 | 0.7 | 0.7 | 0.3 | 0.5 | 0.6 | 0.8 |
| ETHANE (vpm) | 0.4 | 0.5 | 0.5 | 0.5 | 0.2 | 0.4 | 0.2 | 0.9 |
| ACETYLENE (vpm) | <0.1 | <0.1 | 0.2 | 0.2 | <0.1 | <0.1 | <0.1 | 0.1 |
| ROGERS RATIO CODE | 5:0:1:0 | 0:0:1:0 | 0:0:1:1 | 0:0:1:1 | 0:0:1:1 | 0:0:1:0 | 0:0:2:0 | 0:0:0:1 |
| CO2:CO RATIO | 11.2 | 12.33 | 11.86 | 11.86 | 69.72 | 24.67 | 20.62 | 19.97 |
| MOISTURE mg/kg | 29 | 21 | 23 | 23 | 10 | 14 | 10 | 12 |
| ELECTRIC BREAKDOWN kv | 60+ | 60+ | 60+ | 60+ | 60+ | 60+ | 46 | 22 |
| ELECTRIC W/STND 22kv - 1min | PASS | PASS | PASS | PASS | PASS | PASS | PASS | FAIL |
| COLOUR | 3 | 3 TO 4 | 3 TO 4 | 3 TO 4 | 3 | 3 TO 4 | 3 TO 4 | 3 TO 4 |
| ACIDITY mgKOH/g | 0.058 | 0.061 | 0.067 | 0.067 | 0.054 | 0.056 | 0.058 | 0.057 |
| FIBRE COUNT | FEW LONG MEDIUM & SHORT | FEW LONG MEDIUM & SHORT | FEW SHORT | FEW SHORT | FEW SHORT | CLEAR | MASSES SHORT | HEAVY SEDIMENT |
| PCB's | | | | | | | | |
| TYPE 1260 mg/kg | | | | | | | | |
| TYPE 1254 mg/kg | | | | | | | | |
| TYPE 1242 mg/kg | | | | | | | | |
| TOTAL PCB's | | | | | | | | |
| FURFURALDEHYDE mg/l | 0.365 | 0.313 | 0.440 | 0.440 | 0.220 | 0.306 | 0.246 | 0.181 |
| APPROX LIFE EXPENDED % | 65.25 | 63.88 | 66.92 | 66.92 | 60.74 | 63.69 | 61.72 | 58.99 |
| RESAMPLE NEXT IN | 6 MONTHS | 6 MONTHS | 6 MONTHS | 6 MONTHS | 6 MONTHS | 6 MONTHS | 6 MONTHS | IMMEDIATELY |
| SAMPLE REF NO. | 9999.001 | 9999.002 | 9999.003 | 9999.004 | 9999.005 | 9999.006 | 9999.007 | 9999.008 |

The gases were low and satisfactory. The oil's electric strength was poor mainly because of the masses of short fibres and heavy sediment that were observed in the sample. The sediment may have been picked up from the sample valve. Re-sample immediately to confirm the oil quality. (Comments refer to Sample No. 9999.008, as highlighted above.)

TABLE 1

## Water Analysis

As well as oil analysis STS/OAS are also able to offer a range of water tests. These include bacteria counts, pH and total alkalinity, hardness, levels of nitrate, nitrite, sulphate, phosphate and ammonia, chemical oxygen demand, settleable solids and others.

## Reports, Comments, Customer Engagement and Software – the bits that you see

At STS/OAS we understand that the most important outcome of any oil analysis programme is the maintenance activity which is informed by it. Our goal is to empower asset managers, maintenance engineers and technicians to interpret and apply the results of the analysis to their maintenance practices. We aim to engage and educate our customers, offer comprehensive analysis and advice as well as carefully designed clear and informative reports. On top of a variety of individual report formats we offer an intuitive and powerful web database and are also able to export to 3rd party software packages, such as vibration monitoring suites and asset management software.

## About us

Both STS and OAS were founded on expertise.

STS evolved from the Swansea University Tribology Centre and was synonymous with research and innovation in the fields of Tribology and Oil Analysis. Founded by Mervin H Jones it has now been a limited company for over 25 years with analysis histories available for up to 30 years back! Whilst part of Swansea University it hosted numerous scientific conferences with Mervin involved in multiple committees developing the fields of Condition Monitoring, Tribology and Oil Analysis.

The founder of OAS Ivan H Brown is a qualified electrical engineer experienced on transmission systems up to and including 132kV. He was also involved in formulating oil and maintenance policies for London Electricity and had years of experience in locating and correcting faults on a wide variety of plant including cables, switchgear and transformers. Having encountered oil analysis in his engineering days Ivan was so impressed with the benefits that he had to start his own company, which has now been a successful business for over 30 years.

## Our customers

We serve a wide range of clients both in the UK and globally, reaching as far as Brazil and North America in the West and South China Sea in the East. Industries served include oil & gas exploration, power generation and distribution, renewables, mining and steel manufacture, research and development, hydraulic and filtration services, marine, military and aerospace, commercial vehicles, manufacturing, building services, utilities, food and numerous others.

## Contact details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