

# Experts in *Oil Analysis*



Covers:

- Lubricant Analysis
- Fuel Analysis
- Glycol Coolant Analysis
- Electrical Oil Analysis
- New Oil Testing
- Condition Monitoring
- How to Read a Report
- Source Elements Guide



**NEW:** Lubrication Fundamentals theory section & Corrective actions section. Version 3.8.1

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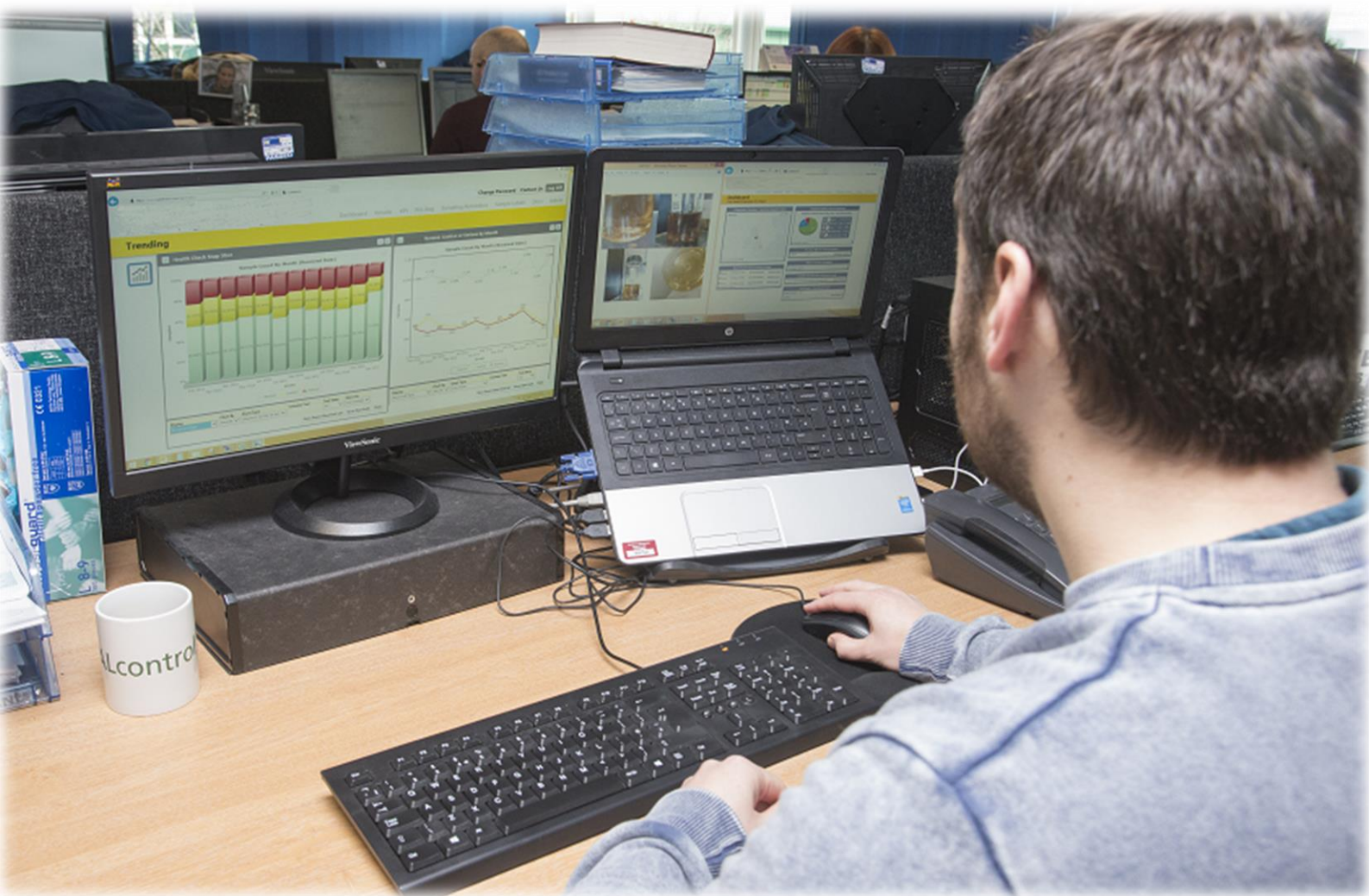
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## About this book

I started writing this book after clients started asking me could I provide some written material so they could learn more about oil analysis. It started as a 10 page summary guide, but as more information was requested it turned into a 100+ page book and growing. This guide (version 3.8) is designed to cover the basic principles of lubrication & Electrical fluid analysis. No prior chemistry knowledge is required and the guide is designed to be an easy to use practical reference for field engineers ultimately reading and taking maintenance corrections based on fluid analysis reports. With the knowledge gained from reading this guide the reader will be familiar with common lubrication analysis scenarios. For more complicated diagnostic situations help is always just a call or email away either by clicking contact us at [Lubetrend.com](http://Lubetrend.com) or telephone (+44/0) 1492 574750. Some of our diagnosticians have over 20 years' experience and would be happy to assist you, even if your question concerns an analysis report that happens to have been performed by another laboratory to ours.

If you wish to enquire about our training courses in Lubrication Management and analysis contact [techservice@alcontrol.com](mailto:techservice@alcontrol.com) for details. Additionally you can message Adam Cutler, the [author of this book on LinkedIn](#) for help and advice, or subscribe to the [Lubetrend Courses YouTube channel where](#) I have made video tutorials too on oil analysis.





# **Section 1 – Oil Analysis Best Practices**



To Watch Scan the code to the left or visit:  
<https://www.youtube.com/watch?v=XRa9pDgWwpw>

## Introduction to Oil Analysis Video (40 min)

### Why Oil analysis

Oil analysis identifies early signs of contamination, fluid degradation and abnormal wear before they cause costly and permanent damage to equipment. Oil analysis determines when the properties of the lubricant have reached a point at which they are no longer serviceable. It helps in 3 main business areas: Maintenance, Management and Uptime.

#### Maintenance

- Identify contamination and wear and identify corrective actions such as lube/filter changes
- Reduce in service failures by improving equipment maintenance.
- Establish condition based lubricant drain intervals & maintenance actions.

#### Management

- Improve business reliability and productivity, hence profits.
- Improve manufactured products quality & reduce waste/spoilage.
- Reduce unnecessary maintenance such as time dependent component changes.
- Assist in product (e.g. lube oils, coolants, greases) selection to allow your assets to run most efficiently.

#### Uptime

- Reduce equipment downtime.
- Increase overall equipment usable life.
- Extend drain intervals, reduce oil consumption, reduce disposal costs and reduce environmental impact.

### Oil Analysis Example benefits

1. **Identification of severe machine faults** – Allowing these to be corrected at an early stage to prevent a major failure.
2. **Reduce power/fuel consumption** – Identifying faults that lead to machine inefficiency / high fuel consumption e.g. a leaky fuel injector.

3. **Reduces Machinery unplanned downtime** - by helping ensure equipment is maintained in a good condition.
4. **Improves your reputation with clients** – if your equipment is running more efficiently then you are less likely to get behind in production / deliveries and hence the client will have a better experience of your service.
5. **Reduces unnecessary maintenance** – this ensures components / lube replacements only occur when needed
6. **Reduces wastage or build-up of intermediate production process items** – if the last stage of the process fails then you risk build-up of stock that may be perishable in the process.
7. **Improves safety** – Identify mechanical or chemical safety concerns with equipment before they cause hazards to others e.g. uncontrolled movements in hydraulics or fire risks.





## Oil Analysis common misconceptions

Common misconceptions that may cause resistance to setting up a programme in your business such as:-

- ***We don't have any failures, so why do we need oil analysis.***
  - This is a common misconception and often is just based on major machine failures, but does not include smaller faults or costs of unnecessary maintenance. A quick check on your company equipment maintenance, parts and lubricant costs over the last 12 months will often show a different story.
- ***It will take too much time and effort to implement.***
  - Setting up an OCM (Oil Condition Monitoring) programme does require effort, but the time and money saved far outweigh any initial setup costs. It is often best to start on only the most critical assets where the benefits are easier to demonstrate and use this as the basis of later expansion of the programme. At every stage of your OCM implementation process your Lubetrend laboratory can support you in setting up the programme with training and advice.
- ***Our oil is quite cheap anyway, so oil analysis will cost more than the benefits of extending drain intervals.***
  - *Your price per litre may be relatively cheap but how many litres are being changed per year unnecessarily? With the right lubricant there is always an option for extension of drain intervals based on OCM findings. A recent Lubetrend analysis of 20,000 engines found that simply going on the OEM oil change interval of 500 hours the oil change time was wrong 95% of the time. This is because in many cases the oil could have gone for longer; whilst in others the oil needed changing much earlier. Hence regular sampling allows you to establish if the oil could have gone on longer or not. Your lubricant and equipment manufacturer will also be able to give you advice on their policies regarding oil drain interval extensions.*
- ***It is covered on warranty – it won't cost me if it fails?***
  - Yes some failures are covered by warranty, but often warranty agreements can have caveats of a certain condition/specification of lubricant must be used and that contamination is kept below a certain threshold. Hence, oil analysis helps prove you are doing this as an oil analysis sample is often used in confirming the validity of warranty claims by OEMs. Additionally, most warranties cover the cost of replacement equipment, but do not necessarily cover the cost of down-time because the equipment is not working, loss of customers because you couldn't deliver on time etc.
- ***Oil analysis will create more work for me and I'm already busy.***
  - Oil analysis is designed for busy people. By introducing a programme and getting your equipment into a good working order enables reductions in long-winded unnecessary maintenance and repairs of major machine overalls.

- ***I like the idea, but I won't be able to convince my boss.***
  - This is usually the hardest part of any process to implement any programme – not necessarily just oil analysis. Please see below some of the job roles and benefits oil analysis brings.

## **I don't think Oil Analysis will benefit me personally**

Everyone in your business benefits from an effective oil analysis programme, but they may not all realise this. Here are some benefits to different job roles that you may never have thought of:

- **Operations / Site / Workshop Manager** – Oil analysis enables you to maintain smooth business operations by not having many sudden machine failures that effect your production or business processes. It also identifies potential cost savings by e.g. extension of drain intervals and reductions in waste production.
- **Health and Safety / Environmental compliance manager** – Oil analysis is an excellent tool to improve safety by identifying equipment in poor mechanical condition so that they can be repaired. Major machine failures can be dangerous and OCM main benefit is in preventing these from occurring. With Regards to environmental compliance if you are using lubricant you must have to dispose of this when changed and so by reducing oil changes you reduce your environmental impact. Additionally, by identifying energy/fuel inefficiency you can also reduce your energy/fuel consumption.
- **Sales Manager** – If you are involved of sales of equipment, parts, lubricant or machinery servicing/repair oil analysis is an excellent added extra to improve your clients' service. It is a good excuse to have regular client contact to discuss their oil analysis reports. It can also be used to provide a before and after your visit service to confirm the good work done e.g. replacing a component, changing filters performing a machine service etc.
- **After Sales / Warranty Manager** – oil analysis is an excellent tool to use when selling extended warranties as it allows you to more closely monitor the equipment condition and give better buy-back prices. It is also an excellent sales opportunity to discuss improved / new products based on the oil analysis findings.
- **Buyer / Procurement** – One of your hardest jobs is searching for the lowest price in machinery parts and services. Further, this must also is to also ensure quality is not compromised. Oil analysis allows you to assess similar suppliers in field trials of filters, lubricants or machinery to assess which option is best for your business.
- **Customer service Manager** – If your machinery is running smoothly, this means your ability to deliver product or services is improved. This

means better product quality, improved turnaround times on order dispatches and ultimately happier customers.

- **Human Resources Manager** - If staff are sitting around waiting for equipment to be fixed this means productivity is greatly reduced and when the equipment is fixed over-time costs will go up. Ensuring the business operations run more smoothly, by having more efficient running equipment, allows better management of staff work rotas and helps reduce unnecessary overtime simply to cover for time lost because of lost production.
- **Technical Manager / Aftermarket** – Oil analysis is an excellent diagnostic tool and helps your technical team quickly and accurately respond to equipment faults and resolve them sooner for your customers.
- **Machine operator** – Simply count the number of times you have not been able to do your job because something wasn't working and you will realise how much oil analysis would benefit you and is an essential tool to help you each and every day.
- **Financial officer / CEO / MD** – For all the reasons listed above oil analysis gives an excellent return on investment, significantly reduces costs and makes your business more profitable

**Lubetrend** analyses your sample from every angle





## Oil Analysis saves you Money, but how much?

Multiple studies across many laboratories have shown consistently an effective fluid analysis condition monitoring programme gives an excellent return on investment. A recent study in 2013 by Lubetrend showed one truck fleet operator with 5000 vehicles saved £4.50 for every £1 spent with Lubetrend. Oil analysis can help:

- Development of more efficient maintenance strategies.
- Reduce number of failures.
- Extend oil drain intervals
- Improve equipment efficiency and reduce energy wastage.
- Decrease equipment downtime.
- Increase your profits

"How much money will it save me?" is quite a difficult question to answer as there are quite a lot of variables involved and each case is unique. It also depends a lot upon how much notice is taken of the diagnostic reports that come back so as to avoid the failures. With the best will in the world if the people doing the sampling and reading the reports are not sold on the idea it risks unrepresentative samples and potentially ignored lab diagnostic advice meaning the machine still fails and no benefit is gained. However, assuming the programme is implemented in your business correctly a good model to use to calculate the potential savings would be one as below. You would complete figures in blue A to I and the calculations using these figures are shown below.

Cost Type	Severe Failure	Moderate Failure	Minor Failure	Weighted Total cost
<b>Downtime</b> (revenue lost because machine unavailable)	A	D	G	
<b>Parts &amp; Lubricant &amp; Filters</b>	B	E	H	
<b>Repair Labour &amp; Machine Operator Overtime Costs</b>	C	F	I	
<b>Total Failure costs</b>	A + B + C	D + E + F	G + H + I	
<b>Probability of Failure Type Without OCM</b> (may vary slightly on industry)	20%	30%	50%	
<b>Weighted cost without OCM</b>	X = (A + B + C) x 0.2	Y = (D + E + F) x 0.3	Z = (G + H + I) x 0.5	S = X + Y + Z
<b>Probability of Failure Type With OCM</b> (may vary slightly on industry)	5%	10%	85%	
<b>Weighted Cost With OCM</b>	P = (A + B + C) x 0.05	Q = (D + E + F) x 0.1	R = (G + H + I) x 0.85	T = P + Q + R
<b>Savings per failure event with OCM</b>				% Saving = ((S - T) / S) X 100

A couple of examples of completed potential cost savings calculations are as follows

Industry example – Mobile plant equipment (example here was done in Euros)

Cost Type	Severe Failure	Moderate Failure	Minor Failure	Weighted Total cost
Downtime (revenue lost because machine unavailable)	50000	10000	0	
Parts & Lubricant & Filters	10000	2000	500	
Repair Labour & Machine Operator Overtime Costs	10000	3000	1000	
<b>Total Failure costs</b>	70000	15000	1500	
Probability of Failure Type Without OCM (may vary slightly on industry)	20%	30%	50%	
<b>Weighted cost without OCM</b>	14000	4500	750	19250
Probability of Failure Type With OCM (may vary slightly on industry)	5%	10%	85%	
<b>Weighted Cost With OCM</b>	3500	1500	1275	6275
<b>Savings per failure event with OCM</b>				67% Saving

Industry example – Energy Production Sector (example here was done in GBP)

Cost Type	Severe Failure	Moderate Failure	Minor Failure	Weighted Total cost
Downtime (revenue lost because machine unavailable)	1000000	10000	0	
Parts & Lubricant & Filters	257000	50000	7000	
Repair Labour & Machine Operator Overtime Costs	10000	5000	2500	
<b>Total Failure costs</b>	1267000	65000	9500	
Probability of Failure Type Without OCM (may vary slightly on industry)	20%	30%	50%	
<b>Weighted average failure cost without OCM</b>	253400	19500	4750	277650
Probability of Failure Type With OCM (may vary slightly on industry)	5%	10%	85%	
<b>Weighted average failure Cost With OCM</b>	63350	6500	8075	77925
<b>Savings per failure event with OCM</b>				72% Saving

# Case Studies of Oil Analysis Success

## Case Study 1 (Truck Market)

A sample of engine oil was submitted to the lab following a recent servicing of the equipment as part of a small condition monitoring trial. It was noted that sodium was present, which indicates a coolant anti-corrosion additive. A pressure test was requested to confirm, which showed a significant drop in pressure confirming a coolant leak.

Engine Oil	Na (sodium)	Al (Aluminium)	Sn (Tin)	Pb (Lead)	Cu (Copper)
1 <sup>st</sup> Sample	110	10	3	14	4
2 <sup>nd</sup> Sample	181	24	8	390	22

The client chose to send another confirmation engine oil sample as well as a coolant sample before replacing any parts. This showed an increase in sodium as well as the presence of Copper, Lead and Tin consistent with bearing wear.

The coolant analysis showed only 17% glycol in the coolant system, significantly below the recommended limit of 50% and also showed evidence of tap-water top-up.

Examination of a bearing from one of the other trucks in the fleet, but not part of the trial, showed similar symptoms and bearing "wiping" before failing. Under the microscope it showed evidence of overheating. The engine repair of this vehicle had cost 26000 GBP.

It appeared the coolant leak had been caused by repeated topup with tap-water rather than pre-mix coolant leading to dilution of glycol causing overheating, pinhole corrosion and a porous liner.

The study was extended to the remainder of the fleet of 2500 vehicles in which 9 similar scenarios were found in the next 3 months of the project

**Total saving: 234000 GBP**



**Case Study 1a** – (Left) pressure of coolant showed significant drop on testing. (right) Bearing shell showed wiping from coolant

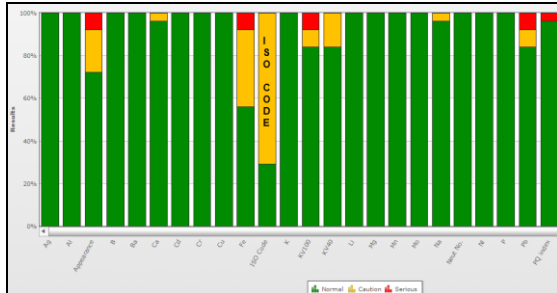


**Case Study 1b** – Analysis of the bearing shell showed evidence of severe overheating.



## Case Study 2 (Mining)

A pilot study with an underground mining customer in which over 150 samples across 30 machines were monitored to determine the condition of the fleet (approx. 500 machines in total). The mine manager ran a KPI using the lubetrend.com web portal showing the predominant failure flag to be ISO cleanliness code on approximately  $\frac{3}{4}$  of the hydraulic samples. It was found that the samples were approximately 16 times dirtier than the OEM recommendations with the servo valves in use, which greatly increases the risk of failure, seizing & uncontrolled movements.

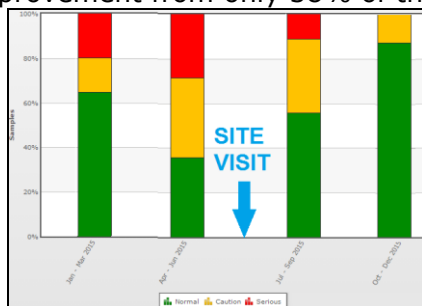


**Case Study 2a –**  
Lubetrend.com  
Analysis by Test KPI  
showing ISO code  
cleanliness of oil  
predominant amber  
flag cause.

The laboratory organised a site visit with the client to investigate. The predominant issue was lubricant storage procedures (see images to right). The oil barrels were stored upright allowing debris & water to collect on top (2b), use of dirty open topup cans (2c) & cracked breathers (2d). All potential source of contamination ingress.

The oils in use were predominantly fully-synthetic with long oil life, combating these contamination issues could give potential cost saving in extended drain intervals. Consultations with the mining equipment operators found that most days there was at least one critical piece of equipment down for part of the shift and ~40 engineers were working full time repairing the equipment.

Following the visit the mine implemented improved lubricant storage procedures and a new automated lubricant delivery system to avoid the use of topup cans. Lubetrend also provided a BINDT ISO 18436 training course in Lubrication Management to a team of 30 engineers to aid in improvement programme. A new KPI ran 6 months after the visit showed an improvement from only 38% of the fleet normal to 88% normal.



**Case Study 2e – KPI**  
showing significant  
improvement in lubricant  
conditions following site  
visit. Left to right number of  
normal/caution/serious per  
quarter.



**Case Study 2b –**  
Storage drums showing  
evidence of dirt and  
debris on barrel top.



**Case Study 2c – Dirty**  
topup cans, showing  
grit and dirt on the  
handle and within the  
container.



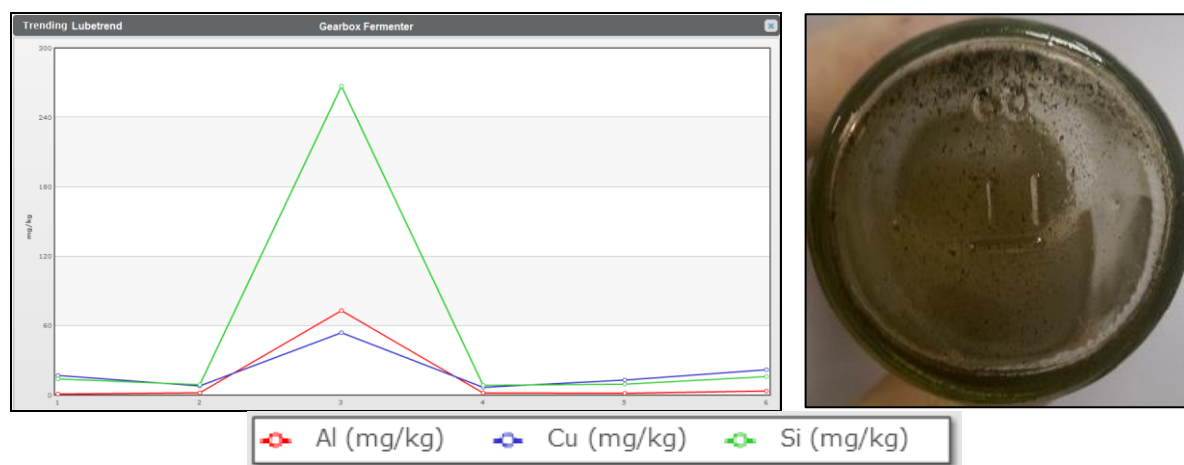
**Case Study 2d –**  
Cracked breather  
introducing dirt and  
debris into lube storage  
tanks.

### Total saving:

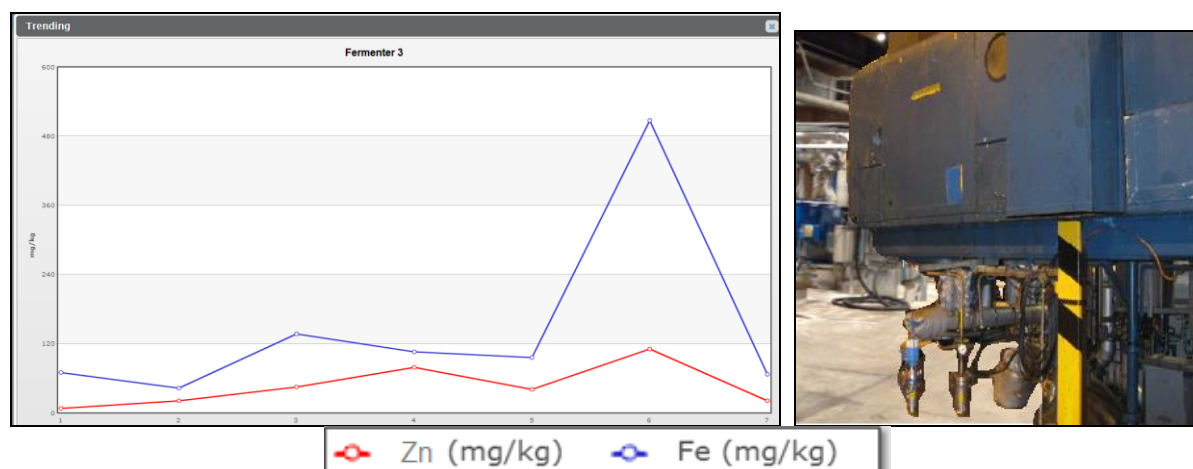
- **525000 EURO**
  - extended drain intervals across entire fleet
- **1/3 of services removed.**
- **Machine availability improved from ~75% to ~85%**

### **Case Study 3 (Industrial)**

A pharmaceutical production facility that have been using the LubeTrend and its previous service viewlabreport analysis service since 1996. Between 2013 and 2015 rises in wear metals were identified in 6 separate gearboxes and a failure was avoided in each. 2 of the examples are listed below. The trending chart data is taken from the lubetrend.com trending section.



**Case Study 3a** – Lubetrend trending charts showing an increase in Copper linked to Silicon and Aluminium. It was found a small amount of dirt / debris had entered the system during a topup/change and caused wear to cage metal. There was also some evidence of iron wear not shown in trend chart above. Owing to the volumes of oil being used, an offline filtration system was fitted to remove this debris. The photograph on the right shows some of the material removed by the filter. Estimated saving 81000 GBP to replace damage components.



**Case Study 3b** – Lubetrend trending chart showing an increase in Zinc and Iron. The Iron was linked to topup with lower load carrying lubricant (using ZDDP rather than EP anti-wear additive). The oil was changed and iron levels returned to normal. Gearbox system shown to right. Estimated saving 52000 GBP to replace damaged components.

**Total savings: 318000 GBP**

**Based on 2013 to 2015 avoided failures repair cost for client.**  
Loss of production costs was not available to calculate any additional savings.

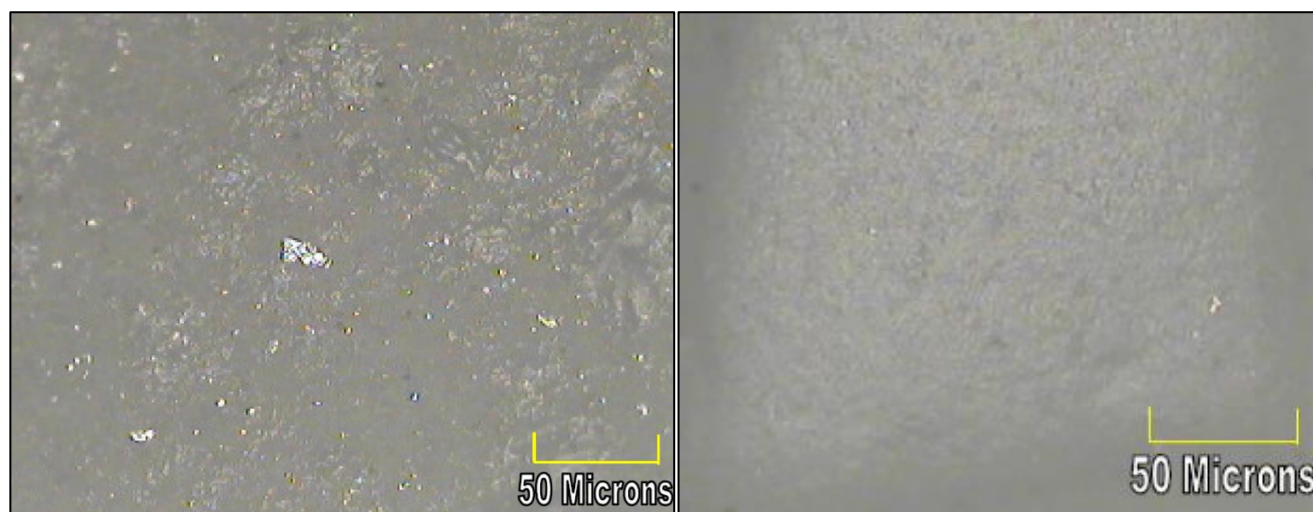
## **Case Study 4 (Power Generation - Wind)**

In 2016 a European based Windfarm as part of their condition monitoring package submitted grease samples from their turbine Front and Rear bearings. High wear was not unexpected as these bearings would commonly have high iron and PQ values due to the operation type. However, it was noted the dramatic difference between the front and rear bearings conditions.

Findings from Lubetrend Analysis Laboratory in UK.

Test	Front Main Bearing	Rear Main Bearing
Iron (ppm)	22480	580
Copper (ppm)	1640	25
Water (ppm)	450	403
PQ	3230	800

The client then took advantage of the laboratories specialist further analysis capabilities and took the advice of the lab diagnostic support to conduct further analysis on these samples. This further analysis included microscopic analysis of the debris.



**Microscopic analysis findings** – (Left – Front main bearing, right rear main bearing sample). The Front Main Bearing showed considerable small sized rubbing/sliding wear particles throughout the sample, which if in a smaller concentration would be considered normal. However, owing to the concentration this suggested the lubricant film was being overcome in one bearing and not the other despite both using the same lithium based grease and having been re-greased at the same time.

The findings supported that the Front bearing was being overly loaded compared to the rear main bearing. Discussions with the client identified that the turbine blades had recently been replaced and it was found that the blades were imbalanced in weight by ~40kg. The blade imbalance was corrected and the system was re-greased with a follow-up at next service to monitor the wear trends.

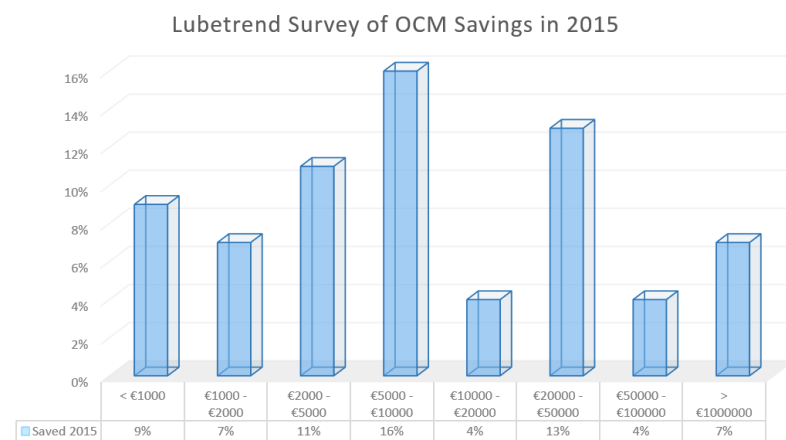
**Total savings: 52000 GBP**

**Based on labour and materials cost to replace the failed bearings. Cost expected to be higher if loss of production costs included.**



## Case Study 5 (Survey of Lubetrend clients)

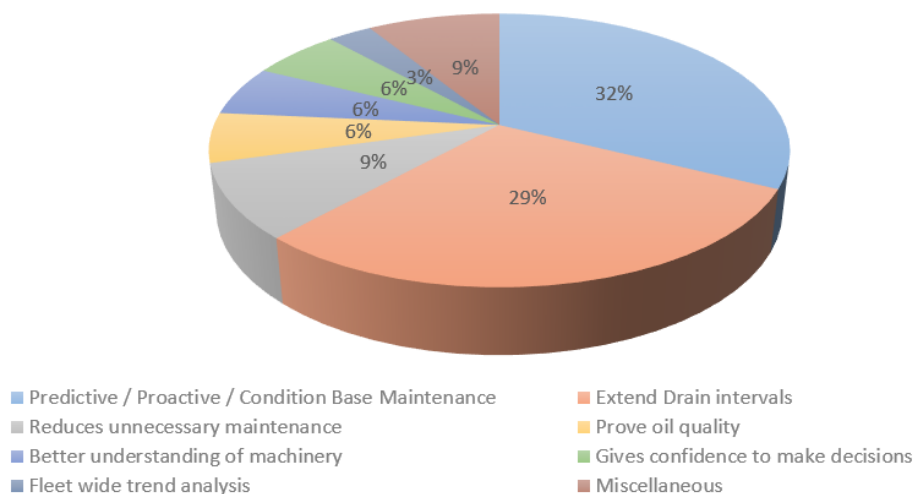
In 2015 Lubetrend.com invited its customers to complete a short survey on the benefits found with the Lubetrend oil analysis programme.



**Lubetrend Survey – Savings with Lubetrend OCM Service** - Survey respondents were given option to anonymise. Respondents that added comment of unsure of savings were removed from survey data above. Survey contained industrial, marine, road haulage, of road mobile machinery, power stations, OEMs, Lubricant Manufacturers, filter manufacturers, combined heat and power, landfill gas sites and maintenance providers. The average saving was ~ €17000 in the last 12 months.

As to reasons they used the Lubetrend OCM service the main reasons were to predict / avoid failures before they occur and extend lubricant drain intervals.

Lubetrend 2015 Survey - Why use Lubetrend OCM?



The responses were free text and summarised and grouped above, but some examples of the responses are below:

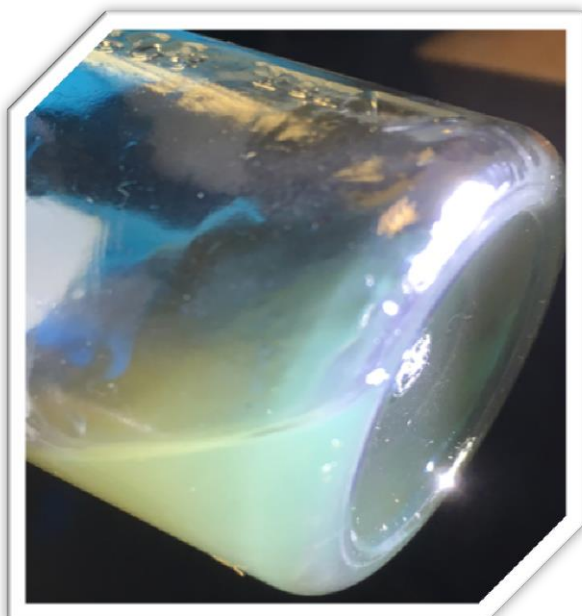
- *I can prove to customers we supplied them with good oil*
- *Not spending money on assets that have no issues*
- *Don't need to strip down to assess the equipment condition.*
- *Get a global view of customers equipment status*
- *Reduces overall service contract costs.*
- *Equipment not suddenly down*
- *Early detection of potential problems allowing us to offer solutions.*
- *It compliments vibration analysis.*
- *Guidance on when to change fluids and advance warning of what maintenance/repairs may be required to gearboxes in the future.*
- *Extend oil service life. Enables us to make equipment / asset decisions on equipment life. The lab results enable us to be specific in the advice we provide [our clients.]*

## **Case Study 6 (A laboratory you can Trust and will Support you)**

In 2016 a Lubetrend client in plastic manufacturing where ISO cleanliness limits are very strict, asked why they were getting consistently high particle counts from the Lubetrend lab laser particle counting system compared to their in-house visual patch testing system. Repeat samples were taken by the client and samples were also run in triplicate for the client by the lab to confirm the data and the particle counts were consistently higher. Analysis of some of the samples showed grit like material, which was commented on in the appearance values to the client. An example of this debris material is in the picture to the left, this also showed wear patterns consistent with the dirt in the system.

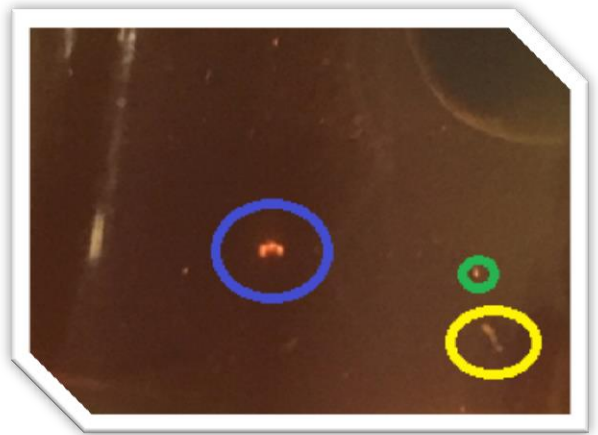


The client accepted the lab findings, but followed up on another sample that a high ISO code, but no wear particles. It was found the sample contained plastic material from the production process (see arrowed to right a 4mm plastic piece), which was not abrasive to the metallic components and hence no metallic wear metals were found.

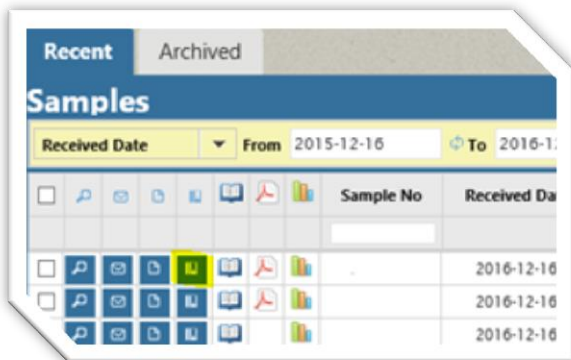


The client had a 3<sup>rd</sup> query where the sample showed no visible debris, had what the client described as a perfect patch by the client and was surprised the value had come back at 25/24/20 by laser. The sample was found to be grossly contaminated with silicone oil (see left picture), which as not solid would not be picked up on the patch sampling as it would flow through the patch. The client was found to have a serious issue with lubricant storage in each of these cases.


The client again accepted the lab findings as correct, but had a 4<sup>th</sup> sample that had an ISO code of 24/20/13 that was not visibly contaminated when sampled under standard laboratory inspection. However the analyst performing the ISO at the lab, saw the code was high and the bottle looked clean, so they took the sample to the Lubetrend electrical oil department and inspected the sample under polarised light (right). This showed, a small piece of plastic (blue) from the production process,



long fibres (yellow) consistent with paper towel fibres used to clean a sampling point by the client and numerous small fibres <10 microns (hence the skew in the code to the smaller particles) consistent with breakdown of the paper filtration. This was likely linked to the increasing viscosity of the oil due to oxidation causing the filtration breakdown. These fibres, as the patch was also made of paper would not be picked up by the clients' in-house method.



As a result of the repeated proof that the Lubetrend laboratories accuracy was far superior to the in-house patch test the client began to review whether they needed this internal patch test going forward and decided to continue only with the Lubetrend laboratories laser and appearance methods.

Since most of the above problems could be identified on visual inspection, to further assist the client the lab built 2 appearance rigs to take pictures of every non-engine bottle. The client was given access to these pictures on the reports and on Lubetrend.com, simply by clicking  on the results grid (see above). A feature that is now available to any client with lubetrend.com access. Additionally, the pictures were put on the clients sample reports. The appearance rig takes 4-angles including underneath the bottle and a full bottle picture (see to right). Soon after the success of the bottle pictures clients began asking for a way to see paperwork submitted with samples, which was soon added to lubetrend.com next to each sample for these clients too.




Lubetrend are always here to support our clients and are always open to new ways to assist them. Please email [techservice@alcontrol.com](mailto:techservice@alcontrol.com) if you have a suggestion on how we can help you.

## How to make your analysis programme succeed

**Give your programme a goal so you know why you are doing OCM** – Confirm what you want the programme to achieve such as reduce downtime, extend drain intervals, reduce fuel consumption or confirm validity of warranty claims. Perform a cost saving calculation (an example is shown above in “oil analysis saves you money, but how much?”). Write down this goal and share with everyone involved in your programme – including the lab – so that everyone knows the target you are aiming for with the project. Discuss with the lab how well you have implemented fluid analysis to achieve this goal every 6 months for the first 2 years of your programme.

**Confirm the Asset List** – Agree internally what is going to be sampled. Identify what is critical and determine the frequency of sampling. Start with a sampling program that is achievable – there is no point deciding to sample 500 assets a week when you know you only have the resources for taking 100 assets samples. Once you have agreed this asset list, let the lab know the list of assets and email the spreadsheet (a template file can be [downloaded here](#)), or you can setup yourself on lubetrend.com. The essential information required is:

- Client information:
  - Your company (customer), address, depot & end client if reseller.
  - Main contact Name, email and telephone number
  - Any lubetrend.com usernames and email addresses to email reports to.
- Asset Information ([download template csv file to populate here](#) or scan code below to download the file to enter data and email back to [techservice@alcontrol.com](mailto:techservice@alcontrol.com) );



A1		C1		F1		J1		M1		P1		S1		T1		U1		V1		W1		X1	
1	Cliqui	Customer Depot	OEMMach	Machines	OEMMach	Make	OEMModel	Serial Num	Site Locat	System	SystemCti	Capacity	Capacity	LCient	Oil brand	Oil grade	Reference Contact	Address 1	Address 2	Address 3	Address		
2	Lab use	Joe blogs	London	LEAVE BLA	Ford	LEAVE BLA	Ford	XC15 ABC	Canary W	ENGINE	LEAVE BLANK	L	L	Car owner	Premium	15w40	Internal i	Paul	building	road	city	county	
3	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
4	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
5	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
6	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
7	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
8	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
9	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
10	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
11	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
12	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						
13	Lab use			LEAVE BLANK		LEAVE BLANK					LEAVE BLANK	L	L				Internal lab						

- Your Asset ID / Serial
- Compartment name / system description / system
- Make, Machine type (e.g. its function such as crusher or truck or injection moulding machine) & Model
- Lubricant in use / oil brand
- Lubricant grade in use / oil grade
- Sump capacity (so we understand the financial impact of an oil change advice).

Confirm regularly (e.g. every 6 months) if there are additional assets that need adding to your sampling programme and also if any units are being decommissioned and hence will not be sampled anymore. Once the machinery is setup confirm if the schedule and we can setup reminders for samples for you.



## Use labels or the pre-registration system for taking samples

Unfortunately the people taking samples will make mistakes and filling in standard sample forms is a common source of error. Some of these errors can be the sampler has:

- Missed information such as oil brand or grade – which can hinder the diagnosis from identifying when wrong oil is in use.
- Called the information something different e.g. Engine 1 and Generator 1, which can lead to duplicates of assets and lost history.
- Bad hand writing or common letters and numbers errors such as 5 and S in asset IDs for instance.

Overall sample forms although commonly used take up lots of time for the sampler and are a common source of error. Hence to reduce these errors, once the assets are in the system you can pre-register samples or use asset labels.

- **Pre-registration on Lubetrend or via App**

The sample bottle is given a unique code, which you type into LubeTrend and select the asset information to link that bottle to the sample. When the bottle arrives at the lab, the code on the bottle is entered into our database and extracts all the data you entered against it. A quick tutorial is shown on [lubetrend.com](https://lubetrend.com) of how to do this.



**Pre-registration tutorial on lubetrend.com**  
<https://www.youtube.com/watch?v=KbGXonPenZ0>

**Pre-registration tutorial on lubetrend App**  
<https://www.youtube.com/watch?v=YNDtsFvITmC>

- Advantages:
  - 100% no transcription data entry errors by the lab, as with sample submission information as data comes direct from your data provided.
  - You can track samples in transit.
  - You can update sample information whilst in transit.
  - Quicker than hand-writing a form as most of the information on the equipment and client are already populated.
- Disadvantages
  - Need an internet connection and web browser to enter information. (This is not a problem with our [Lubetrend App](#))

- **Sample barcode Labels**


This is a good alternative to pre-registration for those without access to a PC or who prefer to handwrite information. The labels are pre-populated with all the client, asset and lubricant information (which can be updated online if required) and the client handwrites the sample date, unit running hours, oil running hours and any top-ups performed. These are stuck on the bottle and the barcode links all the asset information, then the sample reception team must type in the hand written details in the boxes on the right of the label.



**How to use Lubetrend labels and setup automatic reminders tutorial –**


[https://www.youtube.com/watch?v=Id6\\_2hIoM2A](https://www.youtube.com/watch?v=Id6_2hIoM2A)

### Lube Oil Label

TESTRL - Client Abc Ltd		Unit Hrs/km	<input type="text"/>
End Site		Oil Hrs/km	<input type="text"/>
Make		Samp Date	<input type="text"/>
Model		Topup (L)	<input type="text"/>
<b>Asset ID</b>			
E - System Description			
15W40			
Oil brand			

51372083      K/L Ref L42078260025

### Electrical Oil Label

TC_TEST - Client Abc Ltd		Sample Temp (°C)	<input type="text"/>
Site		Sampled by	<input type="text"/>
MAKE		Samp Date	<input type="text"/>
11000kV		PO # +	<input type="text"/>
<b>Serial Number</b>		Tests RQD	<input type="text"/>
TC - TRANSFORMER			
ANY OIL BRAND			

51287093      K/L Ref L40871960001

- **Advantages:**
  - Simple and easy to use. No computer required on site.
  - Can print your own labels from lubetrend.com labels & assets section (label paper can be supplied upon request).
  - Links into our schedule reminders section (see below).
  - The QR code can be used with pre-registration (see above) too.
- **Disadvantages**
  - Need a printer available to print new pages of labels; however, these can be printed off, in advance of taking samples.

**Take advantage of the email rules and alerts** – Most people have the reports sent out one at a time once complete. However, this is just one of the many ways the reports can be sent. You can also have:

- Samples batch by machine, site or received date and also receive summary overviews of the complete batch of samples in addition to the individual reports.
- Alerts for Caution and Serious reports by Site or individual assets.
- Notifications to confirm sample safe arrival.
- Data sent in a CSV file to import into your own internal databases.

Why not try some of these additional options to make your life easier?

**Take advantage of the scheduler reminders** – The lubetrend.com system allows a sampling schedule to be setup and edited so you can pick the assets, the frequency of sampling (e.g. once every 3 months) and how much notice before sampling required (e.g. 1 week.)

The scheduler will then automatically email out a page of labels with the sample barcode labels only for the assets due for sampling. Therefore, the engineer has a complete page of labels and can confirm all assets have been sampled when the sheet of paper no longer has any labels on it. An example reminder email is below.


Additionally, you can also pre-register due samples straight from the dashboard widget on Lubetrend.com.


**Sampling Reminder for 2015-10-21**

Oil Laboratory

Sent: Wed 14/10/2015 00:05

To:

 Message

 labels.pdf (43 KB)

The following systems have been scheduled to be sampled on 2015-10-21

Machine 1 - Hydraulic - 12345 - Oil brand 123  
Machine 2 - Engine - 12346 - Oil Brand 345

This is your 6 monthly service intervention schedule.

Labels for these systems are attached. Please sample the system as per your normal sampling procedure, attached the label and send to your Oil/Fluid Condition Monitoring Laboratory in Conwy, UK.

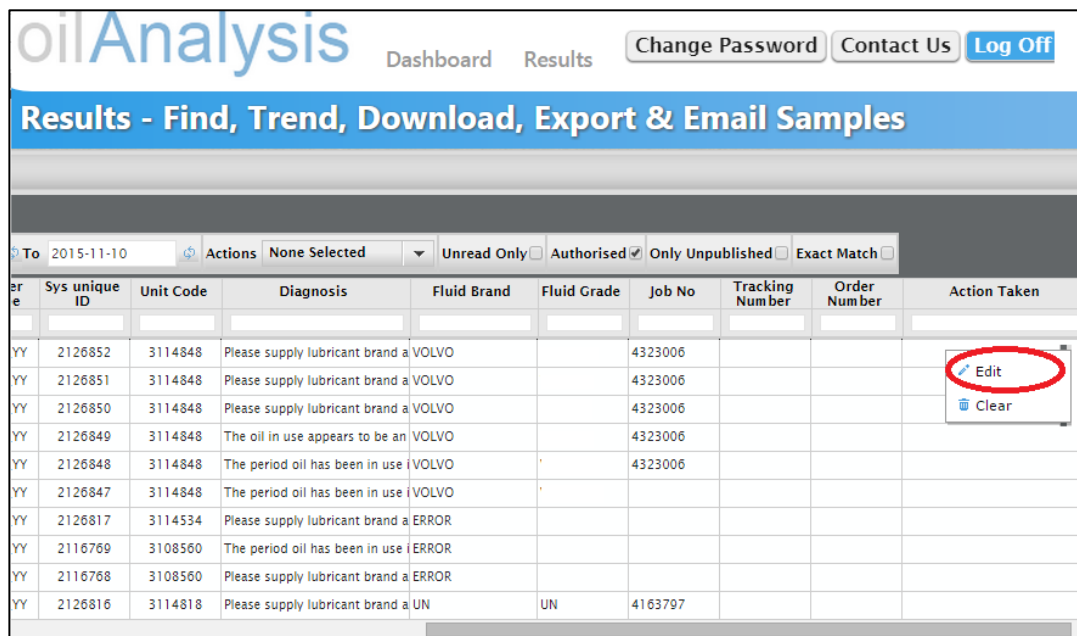
Address

-----  
Unit 6,  
Parc Caer Seion,  
Conwy.  
LL32 8FA.

Thank you for using this service.

Regards,  
The Lubetrend team.

**Feedback** – To get the most out of your lubricant programme, when diagnostic advice is given, it is always best to feedback the findings. For instance, if we suggest pressure checking a coolant system for a coolant leak, because of the presence of sodium in an engine and the pressure check is fine, please confirm your findings, as the diagnostician can then advise on additional sources of sodium ingress such as spray-wash, dirty topup cans etc.



Sample ID	Sys unique ID	Unit Code	Diagnosis	Fluid Brand	Fluid Grade	Job No	Tracking Number	Order Number	Action Taken
YY	2126852	3114848	Please supply lubricant brand a	VOLVO		4323006			
YY	2126851	3114848	Please supply lubricant brand a	VOLVO		4323006			
YY	2126850	3114848	Please supply lubricant brand a	VOLVO		4323006			
YY	2126849	3114848	The oil in use appears to be an	VOLVO		4323006			
YY	2126848	3114848	The period oil has been in use	VOLVO		4323006			
YY	2126847	3114848	The period oil has been in use	VOLVO					
YY	2126817	3114534	Please supply lubricant brand a	ERROR					
YY	2116769	3108560	The period oil has been in use	ERROR					
YY	2116768	3108560	Please supply lubricant brand a	ERROR					
YY	2126816	3114818	Please supply lubricant brand a	UN	UN	4163797			



### Edit Action Taken - Sample #500146815

Oil changed, air filters changed and air intake trunking replaced as visible hole in trunking. This looks likely the source of dirt ingress highlighted in the sample report.

Character Limit - 173 used/82 left

Submit Cancel

Right click on Action taken in the row you wish to add a comment on the results grid. This allows you to feedback your actions taken such as oil changes, filter changes, component replacements etc so the diagnostician can give a more detailed diagnosis next time.

**Provide Reference oils** – Technology moves on and so does oil formulation and additive technology used by the lubricant company. Some lubricant manufacturers use additives metals such as Molybdenum or Titanium that are otherwise considered wear or contamination elements in other products.

So we have the latest formulation information you are using in your system it is advisable to send a single sample reference of the unused fluids from the barrel annually with the Product datasheet and label as “unused reference oil.”



**Training** – It is important to understand oil analysis including its benefits and limitations of certain tests. Hence it is advisable to have at least one 'champion' of oil analysis in your company, who is ISO 18436 trained in oil analysis – click contact us at [lubetrend.com](http://lubetrend.com) if you would like more information about these training courses. Alternatively, a brief introduction presentation is available on YouTube below.



**To Watch Scan the code to the left or visit:**  
<https://www.youtube.com/watch?v=XRa9pDgWwpw>

**Introduction to Oil Analysis Video**  
(40 min)

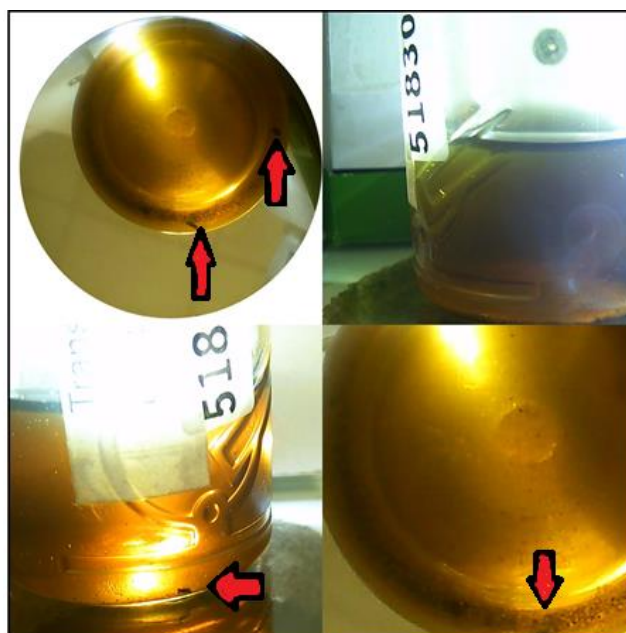
**Management support** – Although they may never take a sample or look at the report, they are important for helping with general awareness of your programme within the company, providing the initial resources for the programme setup and will be your best friend when it comes to helping fight for budget to support the programme.

**Machine operator and maintenance support.** – There is no use the management being on-board without the operators too, as they too need to see the benefits. We would suggest a half day workshop with all the parties involved to formally launch your condition monitoring programme and ensure everyone has bought into the idea.

**It isn't just about oil** – Any of your machinery compartments can be sampled and the fault may also be related to coolant, fuel, grease or adblue. Hence it is advisable to not only sample the lubricating oils, but to expand your programme to include samples from other machinery fluids, so as to get the most information on your equipment condition possible.

If your system has a replaceable filter, it is also advisable to send an annual filter analysis to the lab for investigation, especially if all samples are normal. This is because the filter will concentrate any low level contamination particles and also will filter out some of the wear particles in the system. So if you only ever get green reports – consider the filter may need sampling too.

**Contamination control in sampling** – The most common source of cautionary flags on a sample is actually down to poor sampling where dirt or water enters the bottle at sampling. This may not be debris in the system and hence the sample is not representative. Good practice is to ensure a new length of tubing is used each time, the sample point area is cleaned prior to sampling and sufficient volume of oil is flushed through the sample point before sampling, to ensure any dead legs are flushed. A good idea is to look at the bottle a few minutes after sampling to see if any debris or water has settled to the bottom of the bottle. If this looks more than you believe should be in the system, then consider flushing more fluid through the sampling point & retake the sample.



**Examples of contamination from poor sampling in the bottle.** Debris highlighted with red arrows.

**Speak to the lab before making any major component replacement on the back of oil analysis report.** The analysis service also includes free technical support and diagnostic advice, so please use it. Before undertaking any costly maintenance work on the back of your oil analysis report consult one of our technical support team on [+44 \(0\) 1492 574750](tel:+44201492574750) to discuss the report to see if there are any confirmation tests, on site tests or further investigations that can be performed to confirm the fault before taking any remedial action.

## How to make the reports come back faster

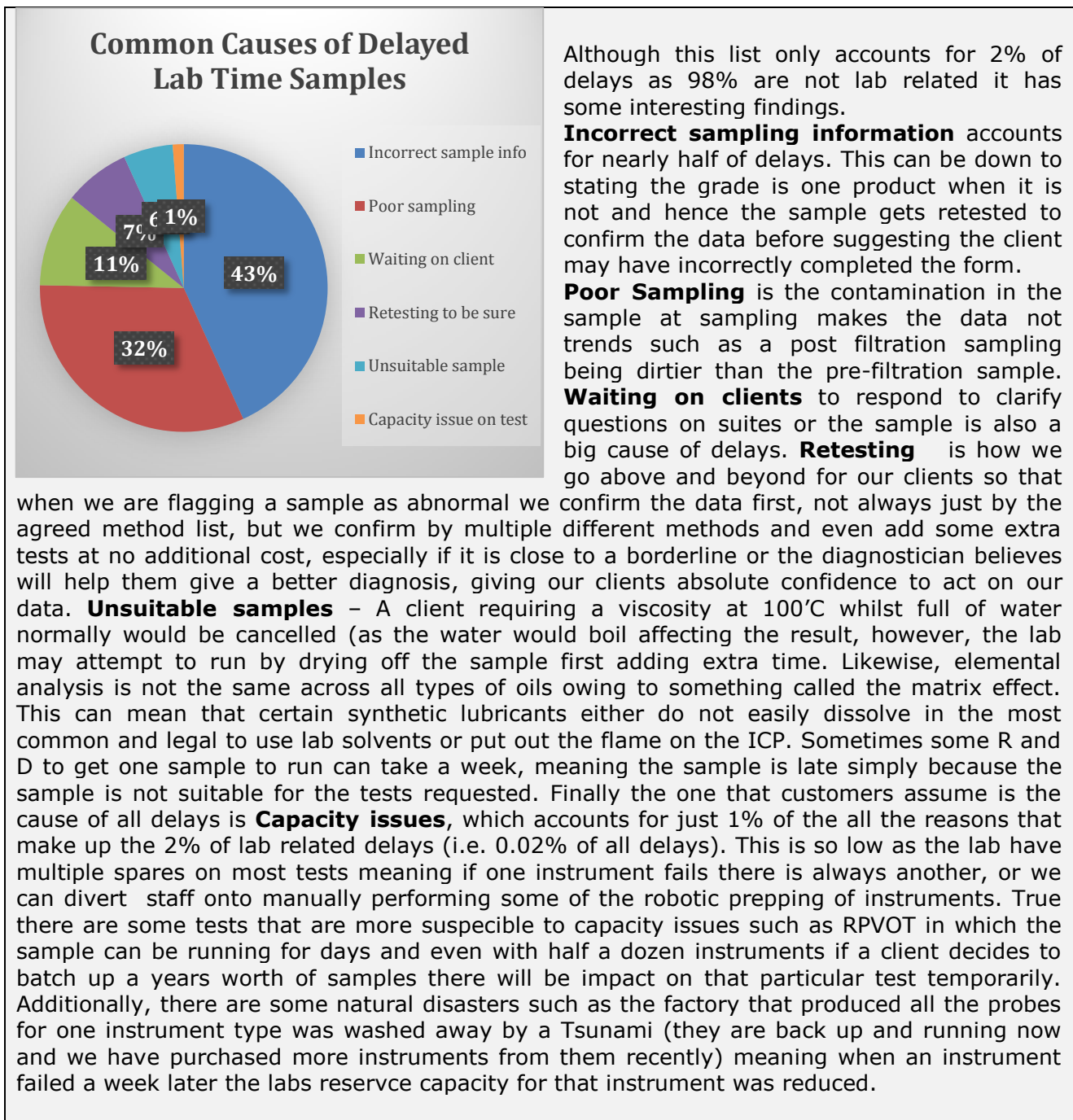
One of the first questions we are often asked when we first meet a potential new client is "How fast can you turnaround the samples?" This is not surprising considering the criticality of some of the equipment we monitor such as the gearboxes on mile long conveyors in mines with downtime costs being greater than \$1 Million for a 2-hour shut down. Therefore, with maintenance decisions having to be so fast this then puts a demand for the oil analysis to be even faster.

So how do we measure the time oil analysis takes? There are two commonly used methods:

- **Lab Turnaround** – I.e. the time from the sample arriving at the lab to a report being created and either emailed or uploaded online. Laboratories tend to focus most of their efforts on keeping this well managed and is the most common assessment method a lab uses to assess their own performance. However, this is an artificial construct as even if the laboratory turns the sample around instantly the delays before and afterwards are still perceived as a laboratory delay to the end client.
- **Total Time** – This is the time from the sampler taking the sample to receiving the report. This includes many factors:
  - **Sampler Time** - Time from when the Sampler takes sample to attempting to post it. This may be direct handing to courier, or taking to a mailroom or head office to post onwards.
  - **Time waiting for collection** – This may be the time from the sampler dropping off in the mail room, or the time between sampling and e.g. the office booking and batching collections.
  - **Time with the courier** – This is the time the courier physically takes to get the samples from one location to another.
  - **Lab Turnaround** – See above.
  - **Post processing** – This is the time the report sits in the client's inbox, or remains unread on Lubetrend. If the reports all go into a central office or person, then the time for them to get around to that sample can also have an impact on perceived turnaround.

Although Labs focus on 'their' turnaround, end clients' perception of turnaround includes all the processes and so delays in those areas may be perceived as a lab turnaround issue. In 2015 and 2016 Lubetrend went through their customer service records for any samples that the client either complained were taking too long, called more than once to check the status of a sample, or simply mentioned on the phone that they believed the report would be ready by now and in 98% all these cases the delays were related to issues outside of the lab turnaround such as samplers leaving bags of samples in their van for a couple weeks, clients using the cheapest mailing option possible to send samples leading to delays in samples arriving. Some case

studies follow explaining some examples of these 98%, however, there is still 2% that did take place within the laboratory. The breakdown of the 2% is shown in the pie chart below.





### **Case Study Turnaround (1) – Streamline your sampling process:**

In Late 2016 an industrial food manufacturing plant client complained to the laboratory that the last 3 batches of oil sample turnarounds were unacceptable and that they were looking to switch suppliers if things did not improve. Whilst the laboratory investigated what had happened the account manager arranged for some complimentary oil analysis training as a thank you for bearing with us whilst we investigated what had happened. The clients agreed turnaround times were 2 working days for their suites and the samples in those batches had only taken on average 1.2 days to process. After much digging the process was identified as follows:

- Monday - Sampler takes samples (a few hours). Sampler hands to office to complete analysis request forms to go with the bottles (a few minutes)
- Tuesday - Following day site office fills in the forms and drops off in mailroom when leaves site at end of day, having missed the Tuesday post.
- Wednesday – Mailroom books collection by courier arriving same day or following day (i.e. collection Wednesday or Thursday sometimes).
- Thursday – Samples arrive at head office maintenance company and forward all samples for all the sites to lab in one big shipment.
- Friday – Samples arrive at laboratories IT and finance depart (the head office googled the address and got the non-laboratory location.) These samples were then collected Friday for a 9am Monday morning delivery.
- Sample arrives on Monday at lab.
- Tuesday reports emailed out to the site. The engineer did not have access to email / too busy to check it, so the office printed the reports off Tuesday afternoon (after his shift had finished).
- Wednesday (report is in hands of the engineer who took the sample).

So, in this case the lab delivering a next day service was perceived to be over 1 week to end client. Following the on-site training day this was explained to the plant manager and the following solution was put in place.

- Cut out sending samples through all the offices which in courier costs was only saving £0.26p a sample than sending direct from site to lab, but costing more than this in processing time.
- Form filling by office dropped for samples and Lubetrend App implemented for taking samples. Phone cost was one-off £85 for a basic smartphone handset, but 7 full man days saved per year from this action alone in speed of sampling with the app.
- Samples taken and courier collection booked day before taking samples in advance, so samples taken Monday, collected Monday and arrived at lab Tuesday and went out Wednesday.
- Since the sampler was now less busy taking samples, he also could ready the reports as they came in rather than following day.

There are countless other examples such as all the reports going back to one individual rather than a group so when they are off on holiday nobody sees the reports. Likewise we also had an occasion where a sampler left the samples in the back of his Van for two weeks and completely forgot to send them in.

## **Time Saved: 6 working days**

## Case Study Turnaround (2) – Let Lubetrend do the hard work for you

In 2014 a UK OEM and Maintenance provider of standby-generators with around 80 engineers had all the samples across the country feed back into one mailbox in which 2 individuals read each report and forwarded onto the different departments / end clients and if the report was serious a quote for the repair work would be attached when sending the samples. This was on average adding 5 days onto the Total turnaround and sometimes up to 8 days when one of the two in the team were on holiday or sick.

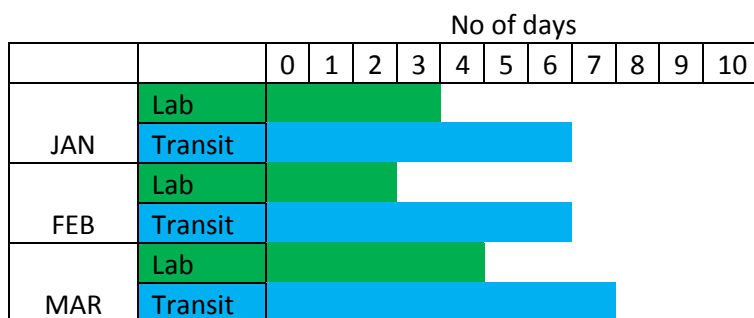
Discussing this turnaround concern with the engineers when they mentioned they were struggling to match competitor service turnarounds due to this delay we changed the customer over to our publishing option. In this case all the normal reports went out as usual direct to the clients, but without the intervention of the anyone, they just went automatically, but the abnormal reports that required quotations were not sent automatically. Instead each day the team of two people were able to see that publishable reports were ready. The individuals would log in, read the report and could copy and paste a hyperlink into the report to take the client to their quotation and click send. This would then send the reports to all the default clients by all the specific email rules they required. Since only 7% were caution and 3% serious this meant a 90% reduction in workload, meaning eventually one of the individuals started following up the emailed quotes with telephone calls and achieved sales person of the month soon after.

**Time Saved: 5 working days**

## What way should I measure the lab speed?

There are many ways a lab can provide you data about turnaround times within the lab (i.e. Time taken from point of arrival at lab to point of the report being loaded online). Some labs measure in days, or average number of days, which although the simplest to understand it says nothing about the lab performance unless you only ever have one sample type with one suite and never any variations. When presenting the data graphically the scales are often presented with lots of days to make the numbers look small and often put next to the courier transit times (i.e. time from taking sample to arrive at lab) which will usually be high unless the client has perfected their own sampling process (see previous sections for some examples).

An example of a traditional presentation of data is something like the below.



Many of our competitors use this style, but as a client trying to compare which lab to pick to start sampling with this data can be meaningless if not put in context. I.e. a lab that 90% of their work is innovative research type analysis will always look bad on that scale, whilst a lab that does the most basic test suite will always look fantastic. For a like for like suite the data may be completely different.

Another common style is showing as a percentage by suite type how many achieved their turnaround or not. This was for many years our method of choice of presenting the data, however, this still did not help the customer because take the scenario there are two labs doing the same suite for a client:

**Lab 1:** Turnaround 90% on time and 10% late.

**Lab 2:** Turnaround 85% on time and 15% late.

Assuming all things equal you would naturally look at Lab 1 and ignore Lab 2 going forward. However, now lets say the desired turnaround was 2 working days.

**Lab 1:** Turnaround 90% of the time in 2 days, but all loaded a few seconds before deadline and the late samples because already late were left an extra couple days and then reported.

**Lab 2:** Turnaround 85% on time, but 75% were done in first day and 25% the lab thought should have some additional retesting to confirm some expensive corrective actions and this meant that 10% were reported the following day (i.e. still within turnaround), but the remaining 15% were all 4 hours late because of that confirming.

With those types of stats there is no incentive once late to try get them out as soon as possible, and there is also no incentive to try impress the client and get some of the work out earlier than expected.

That is why Lubetrend is the first lab to completely change the way turnarounds are presented and introduced the Lubetrend Perfection Index (LPI) for turnaround times.

In an LPI you start with the turnaround being 100. If all samples go out as promised with no late samples then the score is 100. Then values are added or subtracted accordingly.

A sample that is late by <24 hours, e.g. by a few hours gets a score of -1.

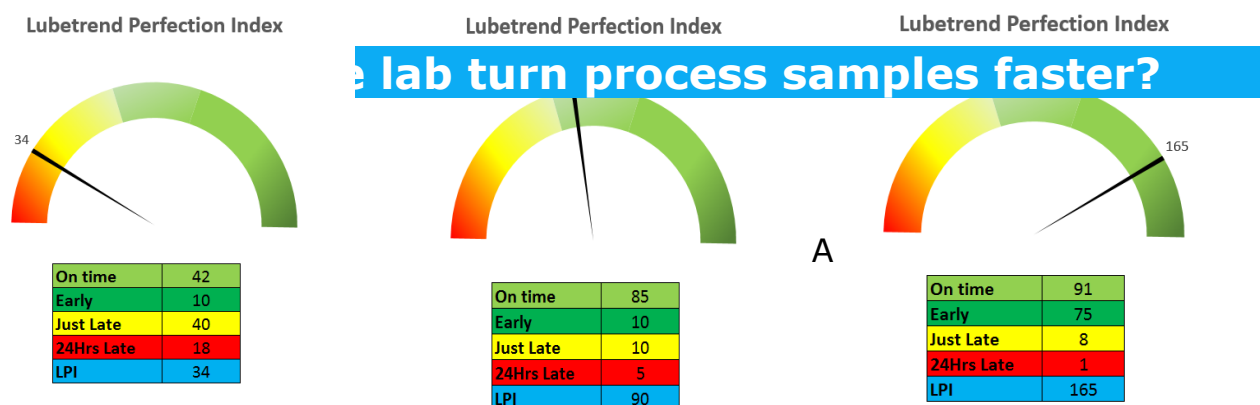
A sample that is even later i.e. by >24 hrs gets a score of -2

However, for every sample that is >24 hours early the score is +1

In this scenario being marginally late occasionally is not penalised as long as the lab make it up by being early on other occasions. There is still an incentive

on late samples to make sure they don't go very late to avoid the score becoming twice as bad. Being more than a day early does not give any additional incentive meaning if the lab let you down and are >24 hrs late then they must make it up to you twice.

Some Example LPIs are shown below (left – lab starting to under-deliver on promises), middle usually delivering what promise and right a lab that is not only meeting their promises but exceeding them. Note between the middle and right graphs there is only 6% difference in traditional turnaround of on time or not, so this Index allows the reader to more accurately determine how the lab is performing and gives the lab the opportunity to impress their clients by exceeding their expectations.



lot can be done to improve the total turnaround times by addressing non-lab associated delays by streamlining your processes (see "I feel the reports are taking a long time to return" previous section). However, you can also help the lab in the following ways.

- **Plan your sampling.**

- **Make sure the lab knows your planned maintenance schedule** – you can programme it into Lubetrend.com.
- If a sample is going to be urgent **take a reference of the QR code on the bottle**, ship on a priority delivery courier and let the lab know the bottle number and courier tracking number so they can expedite that urgent sample for you.
- **Sample well ahead of your planned shutdown or maintenance.** If you know in 1 month you will be shutting down your plant for 2 weeks don't leave it until a couple days before to take the samples, plan in advance so you have time for the routine sampling + further testing on identified problem machinery.
- **Pre-Register** – Rather than fill in a paper form which will need processing by the lab before some tests can be performed, why not register the sample using our online pre-registration or App, so the testing can start the moment the sample arrives with no delay on processing the paperwork. If you really must use paperwork then use the lab paper forms rather than compliment slips, yellow post it notes or marker pen or white liquid paper on the lid.
- **Use the correct container** – Every single day the lab receives samples in coke-a-cola, water bottles, specimen pots by clients who have run out of bottles etc. Not only are these bottles not suitable for



transporting oils, but they also cause delays in extra subsampling must be done to process them, plus since these are often unpaid it can also give both yours and our accountants headaches. Go to your stores now and if you do not have enough samples to take everything you need for the next month and still have some spares for any adhoc or repeat samples then you need to order in more stock.

- **Match the criticality of your sampling reflect your schedule** – We often see clients batch up an entire year of sampling into a couple days to send off and then express all of them are urgent. There are many reasons people do this such as waiting until just before an audit to do sampling, sampling in advance of a shutdown, convenience or to save on transport costs. In each case as mentioned above, letting the lab know in advance what you are planning to do, sampling the batch before the planned shutdown and pre-registering the samples. You also might want to ask yourself if the samples are so critical that they require urgent status then why are you not sampling some of these assets more frequently so you can have your maintenance planned well in advance rather than being so reactive to a single annual check.
- **Look at the bottle before sending it**
  - If you can see a layer of water, pieces of metal, plastic, rubber, sand or grit at the bottom of your sample ask yourself do you really believe that is what is representative of the system you just sampled. If the answer is no, then take another sample first before sending off. There is nothing worse for a client urgently requiring a report to be told they need to resample again when the issue could have been spotted at point of sampling.
  - If the oil volume is quite small and easily changed at minimal cost some corrective actions can be actioned before sending to a lab. For instance, if you see the oil is excessively cloudy, emulsified and has some free water and have confirmed it was not a bad sample then you may choose to do the oil change or filter as the diagnostic advice will usually include an this type of advice as part of the corrective actions. You can then after running the oil for a few hours at operating temperature send a new sample off as a baseline to follow-up the contaminated sample. We still recommend sending the contaminated sample too as this will ensure the diagnostician has a complete history of the equipment and can also help analyse what damage was done by the contamination and potential causes too. You can always add in the sample comments when submitting samples or on the action taken box on the results section of Lubetrend.com what you have done.

## How do I know if the data I am getting is good?

When asking for an analysis service quality is the most important part is having the confidence to act upon the data you have back from the lab. That is why Lubetrend are ISO 17025 accredited laboratory where we are independently audited to confirm we adhering to strict quality standards for every client. We take part in many proficiency testing schemes where blinded analytical grade standards are sent to multiple labs and each lab is compared against the average.

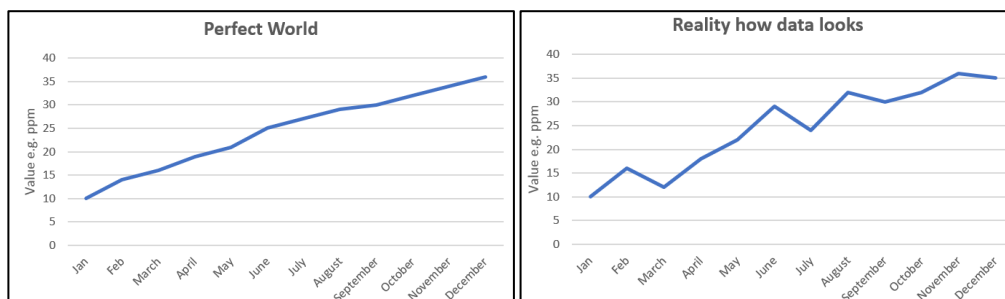
We also want you to have reassurance we are responsibly handling your samples after receiving them and that is why we have ISO 14001 accreditation and invite independent auditors to check our environmental management of the samples from receipt to the final disposal. You also need to know the lab has the credentials to diagnose your reports accurately. Your lab has been analysing samples for over 35 years and processes 1000s of samples per day. The lab is one of the largest independent OCM labs in the world and are the ISO 18436 centre of excellence for lubrication analysis training that even our competition come to train with us. On the electrical oil side our company has the privilege of working with Ron Rogers (the inventor of Rogers ratios) who trained our team and we still use many of the same diagnostic methods he used when working with our lab before retiring.

Even after passing all our quality checks, our laboratory goes an extra step and extensively retests samples that seem to deviate from the trend of your system over time just to give you that extra reassurance and confidence to act.

One thing to remember is the sample analysis is based on the sample received, so if the sample sent to the lab is not representative of the system then your report won't be either. The lab is only as good as the quality of the sample received. Hence it is important to follow the recommended guidelines for taking samples every time and if in doubt resample. It is usually underestimated how difficult it is to take a truly representative sample. For parameters such as viscosity that are physical properties will almost always be the same throughout the oil, but products that are dissolved or floating in the oil will always develop a concentration gradient.

Sometimes, when clients ask how wear metals and dirt can show slightly lower levels since the last sample with no oil change we explain sample variation can account for this. For instance, if you take a sample bottle and take a pinch of sand and drop it into the sample, mix well, then pour that sample into two bottles and counted the grains of sand in each they will never be the same. Equally for most organic (oil) reactions they are subject to some reversal of the reactions, breakdown of the end products or subject to solubility of the parameter in the oil, so values can go up and down over time. For instance, if you take a glass of water and add sugar to it until it will dissolve no more and then add some sugar cubes, so you can see them settled at the bottom of the glass, they will not dissolve as the water is saturated. However, if you then remove some of that water with dissolved sugar and then add fresh water, you will see a reduction in the sugar content of the water, but without doing

anything the sugar will start to rise as the sugar cube dissolves in the no longer saturated water. This type of application scenario is common with sludges, oxidation products and varnishes in oils when the oil is changed or cleaned the evidence of oxidation can increase accordingly. Therefore, apart from a few parameters that are usually the same throughout the entire system, everything else is subject to variation. It is not abnormal to see a saw tooth graph of data on samples like below.



## Deciding what to sample

Plan your service so not rushing for result. If something critical sample more frequently so you can spot problems earlier.

Use a proper courier, don't trust basic mail systems if that important

In an ideal world all lubricated equipment on site should be sampled, however, this may sometimes feel a mammoth task when initially setting up the programme. To prioritise which equipment to sample first consider the following points:

- Are my employees or the public at risk if the equipment failed?
  - This may also include systems where the fire-resistant fluid has a fire risk if the water content drops below a certain figure.
  - This may be on critical applications such as hydraulics powering lifts or safety equipment.
- What is the cost to the business if this equipment were not to be available tomorrow or suddenly stop working?
  - This may be through failure to deliver financial consequences such as in power stations, loss of production or increased labour costs due to a shutdown.
  - Can the equipment be easily replaced in the event of the failure and if so what is the expense of replacement.
- Is the work environment one that is likely to cause risk to the equipment?
  - e.g. high dust/dirt, excessive loading, high temperatures and high shock / vibration.
- Is the equipment newly installed or now out of its warranty period?
  - Both of these times are when equipment is most likely to fail and so should be monitored closely.

# Deciding what to Sample Assessment form

\*\*\*\*\* FILL ALL BLUE BOXES WITH RATING AND TOTAL AT END\*\*\*\*\*

Serial/Plant/Asset ID

Assessor Name

Site

Date

/ /

## Safety risk if failure

None	Low	Moderate	Severe	Score A	
0	1-8	9-17	17-25		/25

If the machine had a catastrophic failure, how severe is the risk to safety?

## Typical Downtime cost

None	Cheap	Moderate	Expensive	Score B1	
0	1-2	3-4	5		/5

## Typical Downtime cost

None	Short	Moderate	Long	Score B2	
0	1-2	3-4	5		/5
				C = B1 x B2	/25

**LubeTrend**  
No1 Fluid Analysis

If the machine failed how much will it cost the business in lost production or to hire replacement equipment

## Working Environment

None	Clean	Moderate	Dirty	Score D	
0	1-3	4-7	8-10		/10

How likely is it the lubricant could become contaminated with abrasive, corrosive or water from the environment?

## Cost of complete lubricant change

None	Cheap	Moderate	Expensive	Score E	
0	1-3	4-7	8-10		/10

How much does an oil change cost?

## Cost of replacing machine

None	Cheap	Moderate	Expensive	Score F	
0	1-3	4-7	8-10		/10

How much is replacement cost?

Total A + C + D + E + F

/80

**Recommendation**

All green = Low priority Sampling.

Any Red = Critical sampling.

Score 0 to 10 = Low priority. 11 to 25 = some use. 26 to 45 = advisable sample. 46 to 55 = Strongly Advise sampling. 56+ Critical



## Identifying Sampling points

Once you have identified your sampling point, label it as the sampling point so if someone else is sampling they will know too. A few common sampling points are shown below, but your equipment manufacturer and filter suppliers will also be able to give advice on any specific requirements for sample collection points.

Equipment Type	Common Sampling Point locations
Engines	Dipstick, crankcase sump wall sampling valve or return line before filter.
Hydraulics	Sample valve on return line before filter or midpoint of oil reservoir avoiding tank walls.
Compressors	Crankcase midpoint away from walls Return line after oil separator
Gearboxes	Sump midpoint avoiding collecting side or bottom wall debris and deposits
Turbines	Reservoir tank away from walls and baffles or return line of main bearing. A secondary point can be after any bypass filtration.

## Sample drawing options & Sample Point Fitting

### Ideal method: Non-pressurised and pressurised valves or taps

– Install valves or taps upstream of any filter to ensure any debris or wear in the system is collected in the sample and not underestimated due to filtration removal. If fitting to a lube oil tank or reservoir, ideally the tap or valve should be slight above any drain taps or valves so as not to draw from the bottom of any tank or sump. If the only option is to use the drain valve/tap ensure the oil is sufficiently flushed (at least twice any dead leg volume) to ensure the sample is not just collecting debris from the bottom of the tank.

When selecting or fitting a Sample point valve:

- Choose a turbulent point in the system to keep particles entrained in the oil such as a bend or elbow.
- Take the sample from the centre of the pipe and avoid lower walls where debris may build up.

Oil should always be at operating temperature when sampling.

**Good Alternative: Vacuum Pumps** – This is when a sample is taken with a vacuum pump and tubing. Although note with certain pumps no tubing is required as the pump fits directly onto the sampling point. Ensure new tubing is used for each sample, cut the length of tubing to the same size each time sampling avoiding scraping bottom or sides of tank/reservoir when collecting the sample. The sample should be from the midpoint of the tank and dipsticks can be used for measuring tubing length when required. Additionally, spring steel sampling sticks can be used to attach tubing to for repeatable accurate end of tube placement within the lubricant tank or reservoir.

Lubetrend App 3S'



Scan Machine



Scan Bottle



Send



## When to Sample

Off-Highway - Agriculture, Construction & Mining			
	Hours	Miles	km
Diesel engines	250	6000	10000
Transmissions	500	10000	20000
Gear, Diffs & Final Drives	500	10000	20000
Hydraulics	1000	25000	40000
Engine Coolant	750	10000	30000
Adblue (vehicle)	1000	25000	40000
Adblue (vehicle)	1000	25000	40000
Diesel (vehicle)	1000	25000	40000
Adblue (Bulk)		At delivery	
Diesel (Bulk)		At delivery	
Filters		When changed	

On-Highway - Automotive & Road Haulage			
	Hours	Miles	km
Diesel engines	600	14400	24000
Transmissions	1000	24000	40000
Engine Coolant	750	18000	30000
Adblue (vehicle)	1000	24000	40000
Diesel Fuel	1000	24000	40000
Adblue (Bulk)		At delivery	
Filters		When changed	

Industrial, power generation & Distribution		
	Hours	Time
Diesel/Natural Gas engines	500	Monthly
Landfill Gas engines	250	Bi-monthly
Gas/Steam Turbines	500	Monthly
Compressors	500	Monthly
Gears & Bearings	500	Monthly
Hydraulics	1000	Quarterly
Greased systems	500	Quarterly
Insulating fluid (<250kV)		Annually
Insulating fluid (>250kV)		Bi-Annually
Filters		When Changed

Marine Propulsion		Marine Support Equipment	
	Hours		Time
Engines (High Speed)	250	Auxiliary Engines	500 hours
Engines (Medium Speed)	1000	Compressors	Quarterly
Engines (Slow Speed)	1000	Purifiers	1000 hours
Gas Turbines	500	Deck Hydraulics	Quarterly
Steering Gears	1000	Deck Gears	Quarterly
Cam Shafts	250	Turbochargers	1000 hours
Thrusters	500		
Stern Tubes	1000		

Note. These are general advisory recommendations only. If suspected faults or history of caution / serious flags increase frequency. Additionally be guided by OEM and oil supplier recommendations for your specific machinery. For further information contact [techservice@alscontrol.com](mailto:techservice@alscontrol.com) / +44 (0) 1492 574750



### How to take a sample

**1** **PPE must be worn. Take Care - Oil may be hot / at high pressure**

**2** **Machine should be running for at least 1 hour at operating temperature**

**3<sup>a</sup>** **Sample when machinery is on (if safe to do so)**

**3<sup>b</sup>** **Or within 15 minutes of Shutdown**

**3<sup>c</sup>** **Sample at an approved sample point e.g. dipstick. Maintain consistency in use of this sampling point for trending purposes. Sample after oil has passed components, but before the filter**

**4** **(A) Clean area around sampling point (e.g. A1) using lint free cloth**

**(B) Unscrew bottle cap and screw bottle securely to thief pump.**

**(C)** i. Directly push front nozzle (C1) to machine if sampling point fitted (and go to step E),  
or  
ii. cut length of tubing to dipstick length / sufficient length to reach mid point of oil in sump.

**(D) Push tubing through o-ring seal (D1) into bottle and close o-ring seal.**

**(E) Draw pump back (E1) until bottle is 50% filled and unscrew bottle to break vacuum and stop flow.**

**(F) Discard oil in bottle safely and within environmental legislation. Re fit bottle and refill to 90%.**

**(G) Unscrew bottle from sample & fix lid immediately. Discard tubing safely within environmental legislation.**

[www.lubetrend.com](http://www.lubetrend.com)



Working with





Just as important as taking the sample in the correct manner, using a suitable container is just as important. It is surprising the number of times samples arrive in drinks bottles, urine specimen pots and various weird and wonderful sample container types not designed for sampling oil, fuel, coolant or Adblue.

Drinks bottles no matter how confident the sampler is that they rinsed the bottle and dried it properly always leaves in doubt if water is found in the sample was it from the machinery or from the residue in the bottle.

Likewise specimen pots despite being clean often have residues and chemicals to preserve or inhibit changes in bacterial content etc which are not suitable for condition monitoring type samples. Laboratory bottles for other industries are also not to be used as e.g. water testing samples may have nitric acid residues to help dissolve the sample for processing at an environmental or water lab, but this would give a tremendously high acid number when testing and could affect a machinery diagnosis.

Even within the oil analysis industry there is a huge variation in the types and quality of bottles used on the market. For instance many are designed with mineral oil in mind, but when used with synthetics the bottles become brittle after several hours meaning the bottle breaks when picked up – often feeling as fragile as an egg shell. Those that are not fully brittle are still etched meaning the particle count goes up as dissolved plastics are now in suspension in the oil, and the clarity of the bottle is impacted. Other bottles the issues are around thread durability and bottle resistance to expansion with fridge compressor bottles exploding even when significantly degassed before sealing. The rest tend to have bottles that are too thick or of the wrong material to be fully transparent to allow a complete visual inspection of the bottle.

The Lubetrend bottle range was designed with quality, safety, versatility, durability and practicality in mind. Some of our bottles took several years of design work to perfect before offering to clients involving trailing several plastics manufacturers and testing to destruction. Our most common two bottles of 100ml and 65ml plastic have been dropped, kicked, boiled, frozen, stamped, squeezed, shocked, tested with all major sample type groups and most of the lab solvent list so we know exactly what they can do. We also under promise and over-deliver with regards to what the bottle can do with for instance our maximum oil temperature quoted on the bottle is significantly beneath what we know the bottle can go to, but we have purposely stated it lower to give you that peace of mind when sampling.

We also care about the environment so we now offer the option to have more environmentally friendly cardboard packaging to ship sample bottles to clients that is made using recycled materials and is fully recyclable at no additional cost.



## Lubetrend 65

### Features:

Crystal clear optics allowing for early detection of metallic, water or debris ingress by analyst and with Lubetrend visual appearance camera rig.

Exceptionally durable and sample resistant

Reduced lubricant waste volume from oil sampling.  
Reduced shipping costs.

**Volume:** 65ml, 38mm thread.

**Holds:** Lubricating oils, Adblue, coolant, water, grease, diesel, fire resistant fluids, compressor oils, brake fluids & emulsions.

**Suitable suites:** All universal suites, some gold suites. Not sufficient volume for all platinum suites.

### Weight for return shipping filled with sample\*

83g (Without Mailer-'Bottle & Oil only)

108g (With Mailer)

\*weights taken using a VG 32 mineral oil filled bottle. There will be slight variation depending on sample taken and how full bottle.



## Lubetrend 100

### Features:

Crystal clear optics allowing for early detection of metallic, water or debris ingress by analyst and with Lubetrend visual appearance camera rig.

Increased volume for enhanced suites.

**Volume:** 100ml , 38mm thread.

**Holds:** Lubricating oils, Adblue, coolant, water, grease, diesel, fire resistant fluids, compressor oils, brake fluids & emulsions.

**Suitable suites:** All universal suites, some gold suites. Not sufficient volume for all platinum suites.

### Weight for return shipping filled with sample\*

112g (Without Mailer-'Bottle & Oil only)

137g Grams (With Mailer)

\*weights taken using a VG 32 mineral oil filled bottle. There will be slight variation depending on sample taken and how full bottle.





Also Available in 600ml and 1L options too.



## Lubetrend Fuel Safe

### Features:

Double seal to prevent fuel leaking consisting of an inner plastic bung and outer screw cap. Designed for carrying fuels where flashpoint is close to, but not less than minimum for shipping regulations.

Also available for high temperature sampling where fluid exceeds recommendations for plastic sample bottles.

**Volume:** 100ml , 600ml or 1L

**Holds:** Same as Lubetrend 100 and 65, high temperature fluids such as thermal oils, but should not be used to hold Adblue which can react with the metal over prolonged storage.

**Suitable suites:** All suites where a plastic sample container is not suitable. Size is dependent on suite required.

### Weight for return shipping filled with sample\*

100ml- 171 g  
600ml- 717 g  
1 litre- 1412 g

\*weights taken using UK Road Diesel.



## Lubetrend 1L

### Features:

Higher density plastic for higher stability for shipping with larger volumes and operating at higher temperatures as seen in steam and gas turbines.

Handles nearly all suites offered.

**Volume:** 1L

**Holds:** Ideal for Steam / Gas turbine annual and monthly health checks or new oil testing.

**Suitable suites:** All popular suites offered.

**Weight for return shipping filled with sample\*:** 902g

\*weights taken using a VG 32 mineral oil filled bottle. There will be slight variation depending on sample taken and how full bottle.



## Transcheck Bottle

### Features:

Glass bottle with optics designed to allow for visualisation of normally invisible paper insulation fibres. Container designed for ideal seal of gases in sample for dissolved gas analysis.

More durable than commonly used gas syringes.

**Volume:** 500ml

**Holds:** Insulating oils

**Suitable suites:** All Transcheck suites.

**Weight for return shipping filled with oil sample:** 775g

# Shipping Invoice & Declaration Lube samples (Shipped to UK)

Please print 1 copy of this page for each package of lubricant / insulating fluid samples sent to laboratory.

## **Commercial Invoice for Export**

**(Only to be used for return of Lubetrend Condition Monitoring Sampling)**

Ship to: - ALcontrol Oil Laboratories, Unit 6, Parc Caer Seion, Conwy, LL32 8FA, UK

Company Reg. No: 4057291. VAT Number: 755 5048 20.

Contact Name: Adam Cutler.

Phone Number: (+44/0) 1492 574750. Email: [oillab@alcontrol.com](mailto:oillab@alcontrol.com)

Payment Terms: Cash. Currency: GBP.



Item	Full Description of Goods	QTY	Unit Price in £GBP	Total Value for Customs
A	Small package of lubricant/ insulating fluid samples for testing  Flash point >200°C  Non Hazardous  Not restricted. Complies fully with IATA restrictions  No commercial value – samples will be tested to destruction on day of arrival at laboratory.	1	<1 GBP	<1 £GBP
Total Amount				<£1GBP
LESS THAN ONE POUND £GBP. SAMPLES OF NO COMMERCIAL VALUE				

ABOVE MENTIONED VALUE IS FOR CUSTOMS PURPOSE ONLY.

## **Declaration of contents of package**

To whom it may concern,

The contents of the package are not of a dangerous nature (non-hazardous, non-flammable, non-toxic, non-explosive, non-infectious, non-corrosive and non-radioactive) for and on behalf of the below named company. It is being shipped to ALcontrol Laboratories UK for analysis purposes only. I assure that the contents are/is a non-restricted cargo & is not classified as dangerous goods under IATA Regulations & has a flash point of >200°C. I confirm the material/contents are safe and acceptable commodity for air transport & do not reflect any hazard to the aircraft & to other environment. I declare that the above information is true and correct to best of our knowledge for samples shipped to the laboratory.

Name (please sign)..... Company.....

Date: ...DD ...../...MM.../.....YYYY.....

# Shipping Invoice & Declaration Fuel samples (Shipped to UK)

Please print 1 copy of this page for each package of fluid samples sent to laboratory.

## **Commercial Invoice for Export**

**(Only to be used for return of Lubetrend Condition Monitoring Sampling)**

Ship to: - ALcontrol Oil Laboratories, Unit 6, Parc Caer Seion, Conwy, LL32 8FA, UK

Company Reg. No: 4057291. VAT Number: 755 5048 20.

Contact Name: Adam Cutler.

Phone Number: (+44/0) 1492 574750. Email: [oillab@alcontrol.com](mailto:oillab@alcontrol.com)

Payment Terms: Cash. Currency: GBP.



Item	Full Description of Goods	QTY	Unit Price in £GBP	Total Value for Customs
A	<p>Small package of Diesel / Gas Oil/Biofuel sample samples for testing (UN 1202).</p> <p>Flash point &gt;60.5°C (MSDS attached with package).</p> <p>Not flammable at ambient temperatures.</p> <p>IMO: Not classified as dangerous</p> <p>IATA, IMO, DGR, ICAO, and IMDG: Not regarded as hazardous for transportation in small volumes and restrictions exempt in small quantities.</p> <p>NB: Liquid Volume less than 1L and within the limited quantities exemption for transport according to United Nations Economic Commission for Europe, IATA, IMO, DGR, IMDG, UK Government and US Government regulations (links to regulations on MSDS).</p> <p>No commercial value – samples will be tested to destruction on day of arrival at laboratory.</p>	1	<1 GBP	<1 £GBP
Total Amount				<£1GBP
LESS THAN ONE POUND £GBP. SAMPLES OF NO COMMERCIAL VALUE				

ABOVE MENTIONED VALUE IS FOR CUSTOMS PURPOSE ONLY.

## **Declaration of contents of package**

To whom it may concern, To the best of our knowledge, the package contains a small amount of diesel fuel/gas oil/biofuel for testing for and on behalf of the below named company. It is being shipped to ALcontrol Laboratories UK for analysis purposes only. I assure that the contents volume fall within the limited quantities exceptions as stated in UNECE regulations, as quantity is <1L & the product has a flash point of >60.5°C making it not flammable at ambient temperatures expected during transport. I confirm that a suitable Laboratory approved Fuel Safe container has been used for transport and the packaging is double layered to reduce risk of contents spillage during transport. I enclose an MSDS sheet for the package to support this declaration.

**Name (please sign)**..... **Company**.....

**Date:** ...DD ...../...MM.../.....YYYY .....

# How to sample (taking a sample pre-register and shipping)

**Page 2 of 2**

**1** [www.lubetrend.com](http://www.lubetrend.com)

**No username/Password?**  
Contact Us

**Full description of Contents**

Lubricant Samples for testing  
Flashpoint >60.5°C  
No commercial Value (<1 Euro)  
Non Hazardous  
Not restricted – Complies fully with IATA regulation

**Ship to Laboratory**

Europe: Oil Labs, Conwy, North Wales, LL32 8FA, UK

Additional Lab addresses:  
[www.lubetrend.com/DocView](http://www.lubetrend.com/DocView)

**6**

**User Guide** **You Tube Guide**

**7** Scan QR code with your phone to download the full User guide or watch a video of how to register

**2** [www.lubetrend.com](http://www.lubetrend.com)  
**oilAnalysis**  
Log In  
Username: yourmail@email.com  
Password:   
Log In

**3** Home Results **Pre-Register**  
**Dashboard**

**5b** Your samples have been registered. Please check your email.

**5a**

**Pre-Registration**

Please select a paper type (Customer Group) **SKN**

Header: To Add new Assets use "Admin" "Customer Admin" to setup new assets for

Sys/Unique #	System Class	Unit Code	S/N, M/C or E	Make
4000730	Drop Box	12345	12345	SE

Examples to Pre-Register

Kit Code	S/N, M/C or Equip	Sys/Unique #	System Class	Kit Ref #	Kit Ref # Confirmation	Fluid Brand	Fluid Grade
240488	123456	4000730	Drop Box	L705126	L705126	Sandvik oil	220
9068	0532	1000424	DROP BOX			Sandvik oil	110

Carefully type kit reference twice from bottle to link the sample bottle to the information you have entered online. Enter any additional sample information such as fluid brand. Make sure all the information entered is correct and none of the kit ref boxes are still red before pressing **Submit All**. You will receive an email confirmation of your registration information. This information can be viewed & edited by pressing **View/Edit Pre-reg data** on home screen.

**4**

**Joe Bloggs Limited equip**

CE

Wfg. year

Type

Serial No. **12345**

Order No

Part No

Model

Sample: SMP AB SE-233 B1 Svedala Sweden

Search for your equipment by serial/asset ID, click **+** for each of the sample points sampled.

System Class	S/N, M/C or Equip#
<input type="checkbox"/>	12345
<input type="checkbox"/>	123456

To add new equipment that is not listed click **Add New Equipment** (admin Users only)

# Lubetrend MSDS sheet to send with sample – Lube or Insulating fluid

## 1) Identification of the substance/preparation and undertaking

1.1 Product Name **USED LUBRICATING OR INSULATING FLUID**  
 1.2 Product Use Condition monitoring sample for testing  
 1.3 Testing Location ALcontrol Laboratories  
 Unit 6 Parc Caer Seion, Conwy, North Wales, UK, LL32 8FA  
 Contact Number & Email +44 1492 574750 [techservice@alcontrol.com](mailto:techservice@alcontrol.com)

## 2) Hazards Information



Signal word **Danger**

Hazard Statements

H304 May be fatal if swallowed and enters airways

Precautionary Statements

P301 + P310 If swallowed contact a poison centre/doctor immediately  
 P331 Do not induce vomiting

## 3) Information on Composition

Mineral or Synthetic Lubricating or Insulating Oil with performance additives

Chemical Name Lubricating fluid, Used  
 CAS No [70514-12-4](#)  
 EINECS 274-635-9  
 Origin Samples of used oil for testing, may contain non-hazardous additives

## 4) First Aid Measures

Ingestion Do not induce vomiting unless prescribed by medical professionals. Never provide anything orally to an unconscious person. If large quantities are ingested seek medical help immediately  
 Inhalation Inhalation at ambient temperature is unlikely because of the low vapour pressure of the substance. If excessive amounts are inhaled, move to fresh air.  
 Eyes Immediately flush eyes with water for at least 20 minutes. If irritation occurs seek medical help  
 Skin Dry skin and irritation may arise from repeated exposure. Remove contaminated clothing, wash skin with large volumes of fresh water & thoroughly wash clothes before re-use. If irritation occurs seek medical help.

## 5) Firefighting

Suitable Media Foam or dry chemicals. Fire water contaminated with Used Oil must be contained and prevented from entering water courses  
 Explosion Hazards This product is not explosive as defined by regulatory guidelines  
 Special Procedures None identified. Fire fighters should wear full PPE and positive pressure breathing apparatus.

## 6) Accidental Release

Contact emergency personnel. Use suitable PPE. Follow fire-fighting measures in section 5

Containment Small spills add absorbent material (soil can be used). Scoop up material and place in enclosed container for disposal  
 Disposal Dispose of via licensed waste contractor; waste code for disposal is 13 02 08

## 7) Handling and Storage

Handling Avoid prolonged contact with skin. Avoid inhaling vapours or spray mists. Wash thoroughly after handling if material is in contact with skin  
 Storage Keep container lid closed. Only open in ventilated environment

## 8) Exposure controls/Personal Protection

Use personal protective equipment as required. Do not ingest & Avoid contact with skin. Avoid breathing fume/mist. Prevent the risk of slipping. Store separately from oxidising agents.

## 9) Physical and Chemical Properties

Flash Point >150°C Pensky Marten Closed Cup Method  
 Colour Brown/Black  
 Physical State Liquid  
 Odour Oily  
 Solubility Insoluble in Water  
 Density <1,000 kg/m<sup>3</sup>

## 10) Stability and Reactivity

Hydrocarbons not readily hydrolysed & aren't generally reactive except in the presence of oxidising agents

## 11) Toxicological Information

There is no specific toxicological information, however used engine oils may contain polyaromatic hydrogens in small quantities. These are suspected carcinogens.

## 12) Ecological Information

Not readily bio-degradeable. Water courses should be protected from contamination.

## 13) Disposal Considerations

This material is hazardous waste. Dispose of in accordance with local regulations

## 14) Transport Information

UN No Not classified as dangerous for transport  
 I.A.T.A Not restricted by I.A.T.A and not classified as dangerous for transport  
 REACH Conforms to regulation (EC) No 1907/2006, Annex II UK

## 15) Regulatory Information

Not applicable

## 16) Other Information

Information in safety data sheet is given in good faith and belief in the accuracy based on the sample types received for testing at the laboratory at date of publication. It does not imply acceptance of any legal liability or responsibility whatsoever by ALcontrol Laboratories for the consequences of its use or misuse in any particular circumstances.



# Lubetrend MSDS sheet to send with sample – Adblue / Diesel Exhaust Fluid

## 1) Identification of the substance/preparation and undertaking

1.1 Product Name **Adblue / Diesel Exhaust Fluid**  
 1.2 Product Use Product Quality Sample for testing  
 1.3 Testing Location ALcontrol Laboratories  
 Unit 6 Parc Caer Seion, Conwy, North Wales, UK, LL32 8FA  
 Contact Number & Email +44 1492 574750 [techservice@alcontrol.com](mailto:techservice@alcontrol.com)

## 2) Hazards Information

Non-hazardous.

## 3) Information on Composition

Chemical Name Carbonyl Diamide  
 CAS No 57-13-6  
 EINECS 270-676-1

## 4) First Aid Measures

Ingestion Do not induce vomiting unless prescribed by medical professionals. Never provide anything orally to an unconscious person. If large quantities ingested seek medical help immediately.  
 Inhalation If excessive amounts are inhaled, move to fresh air.  
 Eyes Immediately flush eyes with water for at least 20 minutes. If irritation occurs seek medical help  
 Skin Remove contaminated clothing, wash skin with large volumes of fresh water & thoroughly wash clothes before re-use. If irritation occurs seek medical help.

## 5) Firefighting

Non-flammable.

If involved in a fire use breathing mask and self-contained breathing apparatus. Use plenty of water. Prevent entry of product into drains and watercourses.

## 6) Accidental Release

Containment Avoid contamination into watercourses and drains. Inform appropriate authority in case of accidental contamination of watercourses.  
 Disposal Any spillage should be cleaned promptly and placed in a clean labelled open container for safe disposal. Depending on the nature of contamination, use an authorised waste facility.

## 7) Handling and Storage

Handling No special rules for handling product other than any PPE worn whilst doing vehicle maintenance.  
 Storage Use an approved lab container – HDPE or LDPE polyethylene. Store in a dry well ventilated location between 20°C and 25°C to avoid crystallisation of the product.

## 8) Exposure controls/Personal Protection

Wear suitable gloves while handling. Clean hands after handling product & do not eat, drink or smoke whilst handling the product. Use safety goggles/face shield.

## 9) Physical and Chemical Properties

Appearance: Coloured liquid  
 Mild odour  
 pH 7.5 – 9  
 Soluble in water

## 10) Stability and Reactivity

The product is stable under normal conditions of storage.

## 11) Toxicological Information

No Biological or exposure limits allocated.

## 12) Ecological Information

Soluble in water and substantially biodegradable in soil and water. Bio-accumulation risk is low.

## 13) Disposal Considerations

Material should be cleaned and placed in a labelled open container for disposal. Use an authorised waste facility.

## 14) Transport Information

UN No Not classified as dangerous for transport.  
 IATA Not restricted by IATA and not classified as dangerous for transport.

## 15) Regulatory Information

Not applicable.

## 16) Other Information

Information in safety data sheet is given in good faith and belief in the accuracy based on the sample types received for testing at the laboratory at date of publication. It does not imply acceptance of any legal liability or responsibility whatsoever by ALcontrol Laboratories for the consequences of its use or misuse in any particular circumstances.

# Lubetrend MSDS sheet to send with sample – Diesel Fuel

## 1) Identification of the substance/preparation and undertaking

1.1 Product Name **Diesel Fuel Sample / Biodiesel Sample / Gas oil**  
 1.2 Product Use Condition monitoring sample for testing  
 1.3 Testing Location ALcontrol Laboratories  
 Unit 6 Parc Caer Seion, Conwy, North Wales, UK, LL32 8FA  
 Contact Number & Email +44 1492 574750 [techservice@alcontrol.com](mailto:techservice@alcontrol.com)

## 2) Hazards Information

Signal word Danger



Hazard Statements

H226: Flammable/combustible liquid and vapour. Closed Flashpoint >60.5°C.

Precautionary Statements

P210 Keep away from heat/sparks/open flames/hot surfaces – No Smoking.  
 P301 + P310 If swallowed contact a poison centre/doctor immediately  
 P331 Do not induce vomiting  
 H332 + H315 Harmful if inhaled and causes skin irritation.

## 4) Information on Composition

Complex mixture of hydrocarbons consisting of paraffins, cycloparaffins and variable amount of Fatty Acid Methyl Ester. May contain trace dyes for tax fraud detection purposes.

Chemical Name Fuels, Diesel Sample / biodiesel sample.  
 Chemical Name Diesel (Hydrocarbons and additives.)  
 CAS No 68476-34-6  
 EINECS 270-676-1

Origin Samples of fuel for testing, may contain additives and dyes for tax purposes to prevent fraud.

## 4) First Aid Measures

Ingestion Seek Medical Attention. Do not induce vomiting.  
 Inhalation If excessive amounts are inhaled, move to fresh air. If symptoms continue seek medical attention. If aspirated into lungs inform physician may cause chemical pneumonitis.  
 Eyes Immediately flush eyes with water for at least 20 minutes. If irritation occurs seek medical help  
 Skin Remove contaminated clothing, wash skin with large volumes of fresh water & thoroughly wash clothes before re-use. If irritation occurs seek medical help.

## 5) Firefighting

**Extinguishing Media** – Use water fog, dry foam, dry chemical or carbon dioxide to extinguish flames. Straight streams of water are not appropriate.

**Firefighting** – Evacuate area; prevent run-off from fire control or dilution from entering water supply. Standard protective equipment should be used and self-contained breathing apparatus in enclosed spaces. Use water spray to cool fire exposed surfaces and to protect personnel.

**Flammability:** Flash point (ASTM D93) - >60.5°C. Flammable limits (approx. vol. % in air) LEL: 0.6. UEL: 7.0.  
 Autoignition temperature >250°C.

## 6) Accidental Release

Containment Avoid contamination into watercourses and drains. Remove any sources of ignition from area. Vapour suppressing foam may be used to reduce vapour. Use clean non-sparking tools to collect absorbed material. Absorb or cover with dry earth, sand or other non-combustible material to transfer to containers. For large spills water spray may reduce vapour. Inform appropriate authority in case of accidental contamination of watercourses.

Disposal Any spillage should be cleaned promptly and placed in a clean labelled container for safe disposal and covered with a non-flammable material e.g. sand or dry earth. Depending on nature of contamination, use an authorised waste facility.

## 7) Handling and Storage

Handling No special rules for handling product other than any PPE worn whilst doing vehicle maintenance and avoid ignition sources such as smoking and using electronic devices e.g. mobile phones whilst handling. Once the sample is in the fuel safe container then no specialist PPE is required.  
 Storage Use an approved lab fuel safe container.

## 8) Exposure controls/Personal Protection

Wear suitable gloves while handling. Clean hands after handling product & do not eat, drink or smoke whilst handling the product. Do not use electronic equipment or equipment likely to produce static/sparks near to open container. Use safety goggles/face shield.

## 9) Physical and Chemical Properties

Appearance Lightly coloured liquid.  
 Odour Petroleum/solvent  
 Flash Point (ASTM D93) >60.5°C

## 10) Stability and Reactivity

Material is stable under normal conditions. Material does not decompose at ambient temperatures and hazardous polymerisation will not occur. Avoid Open flames, high energy ignition sources, Halogens, strong acids, bases and oxidisers.

## 11) Toxicological Information

Inhalation

## 12) Ecological Information

Material expected to be toxic to aquatic organisms. May cause long term adverse effects in aquatic environment. Material expected to be inherently biodegradable. Volatile portions expected to degrade rapidly in air.

## 13) Disposal Considerations

Use an authorised waste facility. Confirm with local authorities any specific regulations that apply.

## 14) Transport Information

UN No 1202  
 Proper Shipping Name Gas Oil  
 Hazard Class 3  
 Hazard ID No 30  
 Packing group III  
 Transport Doc Name UN1202, GAS OIL, 3, PG III  
 Labels/Marks 3

**Road & Sea-** Not restricted in limited quantities (5L)

According to United Nations Economic Commission for Europe, (UNECE) part 3 of the ADR, ([https://www.unece.org/fileadmin/DAM/trans/danger/publi/unrec/rev14/English/03E\\_Part3.pdf](https://www.unece.org/fileadmin/DAM/trans/danger/publi/unrec/rev14/English/03E_Part3.pdf)), UK Government (<https://www.gov.uk/shipping-dangerous-goods/transporting-limited-quantities>) and international Maritime Organisation (<http://www.imo.org>) For quantities less than 5 litres (<5L) of GAS OIL a Dangerous goods safety adviser is not required and not all the shipping, packaging, ADR and labelling regulations apply.

**Air - IATA DGR regulations** – <http://www.iata.org> (Not restricted in limited quantities (10L). Limited quantities for Passenger cargo is 10L.

## 15) Regulatory Information

**Classification:** Harmful. Dangerous for environment.  
**EU Labelling:** Xn, N.  
**EU Directive** 92/85/EEC [...pregnant workers, recently given birth or breast feeding directive]  
 94/33/EC [...on the protection of young people at work]

## 16) Other Information

Information in safety data sheet is given in good faith and belief in the accuracy based on the sample types received for testing at the laboratory at date of publication. It does not imply acceptance of any legal liability or responsibility whatsoever by ALcontrol Laboratories for the consequences of its use or misuse in any particular circumstances.

## Effective Sample taking

1. **Develop a sample schedule** with a consistent interval that is manageable to your business needs. Schedules and reminders can be setup at Lubetrend.com. Click contact us at Lubetrend.com if you would like assistance in setting up your schedule.
2. **Prepare the sampling area** – Inspect the area is safe to sample. Clean the area around the sampling point. Run off enough oil to flush through any dead legs before sampling and use your Lubetrend bottle to take the sample.
3. **Take the sample at operating temperature** – The equipment should ideally be at operating temperature for at least one hour before sampling.

## Common avoidable sampling problems

The most important step of the entire condition monitoring process is the one that the laboratory has no control over and that is the sample taking.

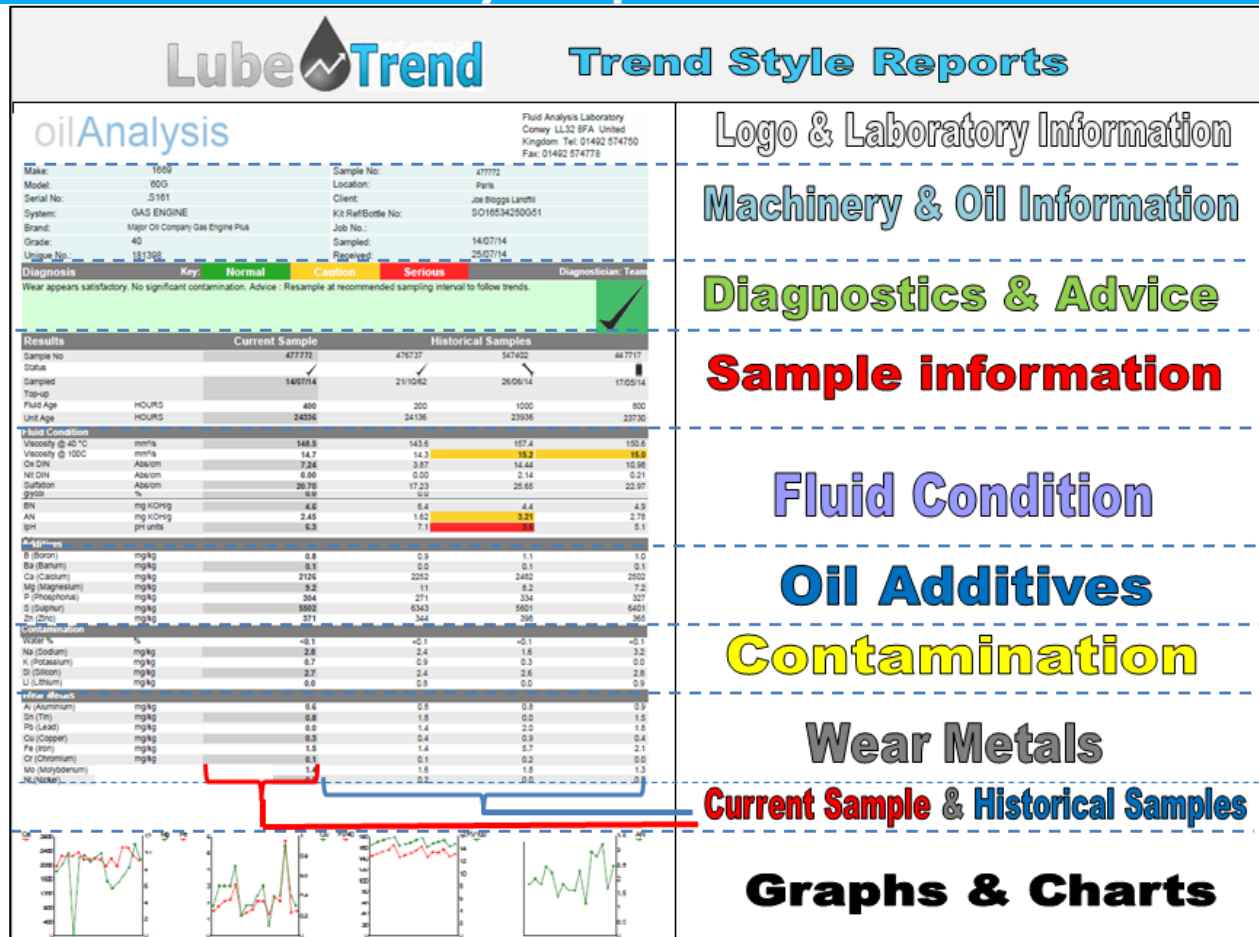
1. **Incorrect sample bottle** – We have seen it all from oil samples sent in drinks bottles to filters sent in trashcans. Not only are the samples not designed to hold lubricants, but they usually contaminate the sample too. If you have run out of sample bottles please just contact us at Lubetrend.com. If you are in urgent need for a sample bottle we can usually get sample containers shipped to you to receive next day delivery (or best DHL export time available).
2. **Incorrect labelling / insufficient labelling** – Please provide as much detail as possible about your sample. The most critical information about a sample may be in your head, but never reaches the lab as we are not informed by the sampler. Simply describing the oil brand as Mobil or Shell with no other information is not considered sufficient as these manufacturers produce thousands of lubricant products. Equally, keep a consistent naming convention for your equipment to ensure trending history is not lost. For example one engineer may call a system “engine 1”, another “generator 1”, yet another “Standby Gen 1”. Each of these would be treated as a separate piece of equipment. Hence we advise using the Lubetrend barcode labels that can be provided free of charge to Lubetrend customer to label your equipment for identification purposes.

# **Section 2 – Analysis Tests & Diagnostic Significance**

# Lubetrend reports introduction

Lubetrend offers several bespoke formats of report, but the most commonly used ones are the Trend style report, Specification style report and Multi-page Summary Reports. Below goes through these types of [report](#).

## Lubetrend Trend-Style reports.



This is by far the most common report style for lubricated machinery. The top section contains the logo and laboratory information, which can be rebranded on Key Client accounts.

## Machinery & Oil Information


This section contains the Machinery information, but does vary on certain customers reports. By default the order is:

- **Make** – This is the manufacturer of the equipment such as Volvo, MWM etc.
- **Model** – This is the equipment model.
- **Serial Number** – This is your unique name for the equipment which may be a fleet number, asset ID, Machine serial, Machine Registration or VIN Number. Essentially, this is however you wish to describe the equipment to allow the laboratory to uniquely identify it.
- **System** – This is the description of the system sampled e.g. Hydraulic Main tank, Engine oil sump etc.



- **Fluid Brand** – This is the brand and product name such as Fuchs, Mobil & Total.
- **Grade** – This is the viscosity Grade e.g. SAE 15W40 or ISO VG 32. A full explanation of Viscosity Grades is given later in this document.
- **Unique No / System ID**– This is the unique identifier the lab set to the system sampled that can be used for trending purposes. This avoids confusion with serial number where e.g. Engine No1 and Generator No1 may in fact be the same piece of equipment, but described differently by the sampler. Hence the unique number allows unique identification of a sample compartment.
- **Sample No** – This is the number the laboratory assign to the bottle on arrival for quality and auditing purposes.
- **Location** – This is the end client location.
- **Client** - This is used when e.g. the laboratory's customer has an end customer that they have sampled on their behalf.
- **Kit Ref/Bottle No**: This is an identifier given to every sample to allow the customer to track progress, identify if a sample has arrived yet and to register their samples online using pre-registration.  
To see how to pre-register your samples online try this link <https://www.youtube.com/watch?v=KbGXonPenZ0>
- **Job No** – This is a client Job reference / purchase order (if applicable.)
- **Sampled** – This is the date sampled by the client.
- **Received** – This is the date received by the laboratory.

## Diagnostics & Advice



### Diagnostics & Advice

#### Diagnosis comments & Advice


Diagnosis

↓

Key: Normal Caution Serious


Wear appears satisfactory. No significant contamination. Advice : Resample at recommended sampling interval to follow trends.

#### Traffic Light Diagnosis Key








#### Diagnostician

Diagnostician: Jamie Phillips



#### Action Flag

None	In rare cases where customer has asked for a data only report with no diagnostic comments.
Normal 	Condition appears Normal. No additional action advised. Simply keep sampling as usual.
Re-Sample 	Diagnostician recommends resampling. If flagged Caution then advise sample sooner than next planned sample if possible. If flagged serious then advise sampler as soon as possible.
Filter 	Contamination evident should be removable by filtration. Customer should consider cost effective and most practical solution vs an oil change and/or consult filter supplier.
Oil Change 	Contamination / fluid degradation should be correctable by fluid change. Customer should consult oil supplier for a more detailed recommendation if necessary
Check Unit 	Either abnormal condition or wearing process identified. Customer should consider taking action to correct, which may be simply inspecting oil pressure, if filters need changing or any abnormal noise and heat in the machinery. If changing filters consider submitting filter for analysis to lab.

Note these are comments are advice only. Diagnosis assumes samples provided are representative of bulk of fluid in the system. Do not undertake costly oil changes / machine stoppages without first confirming sample is representative of bulk of fluid and/or consulting your oil/filter/equipment supplier. Confirmation of faults can be confirmed with a more detailed filter analysis report. Click contact us at lubetrend.com for details.

**Traffic light system** – Lubetrend uses a traffic light system of Normal, Caution and serious. Serious red reports should be given the most urgent attention by the engineer reading the reports, followed by the cautions and lastly by the normal samples.

**Action Flag symbol** – This is the diagnosis action flag to help assist the engineer of what to do next.

## Sample information

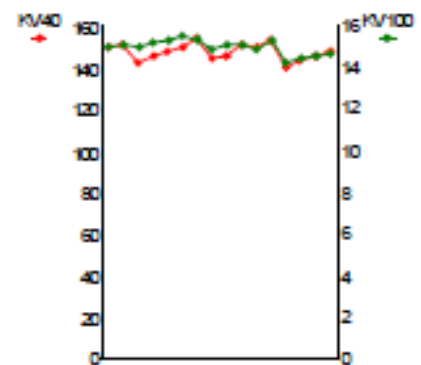
- **Sample No** - This section contains current and historical sample numbers.
- **Status** - shows the current and historical Action flags
- **Sampled** - Dates sampled
- **Top-up** - Volume of oil topped up during sample period.
- **Fluid age** - Number of Hours, Miles or Kilometres oil has been in use since last complete oil change.
- **Unit age** - Number of Hours, Miles or Kilometres machine has been in use since machine build.

**Fluid condition, Additives, Contamination and Wear metals** - These contain the relevant sample data with the relevant units. See **sections of Lubetrend report** below for details.

## Graphs and charts

These are charts that show on the bottom of the report to trend important aspects of the report. In the example on the right; Viscosity at 40°C (KV40) vs 100°C (KV100) are plotted on the left and right Y axis.

As a rough general rule, if a value is staying roughly the same and the graph is horizontal then there is no problem, but a sudden rise or fall can indicate a possible abnormal condition in the system. The graphs help graphically show this to the reader.



## Sections of Lubetrend report

**Fluid condition** – These are physical properties of the oil such as the viscosity (how thick the oil is), Acid Number (how acidic) to determine if the fluid has degraded or is still serviceable.

**Contamination** – This is where contaminants such as wrong oil, water, fuel and dirt are identified.

**Additives** – this is where metal additives such as detergent and dispersants and anti-wear additives are monitored.

**Wear Metals** – This is the most recognisable part of condition monitoring to most people and those with Non destructive testing (NDT) backgrounds. As components wear in the system these are monitored for abnormal trends.

**Units** - This ensures the data is presented in a format that is understood. A value of 80 for water may look high if it is in percent, but if the value is in parts per million (move the decimal place 4 times = 0.008%) then this is very low. Hence the units used are important, especially if a customer has recently switched laboratory supplier.

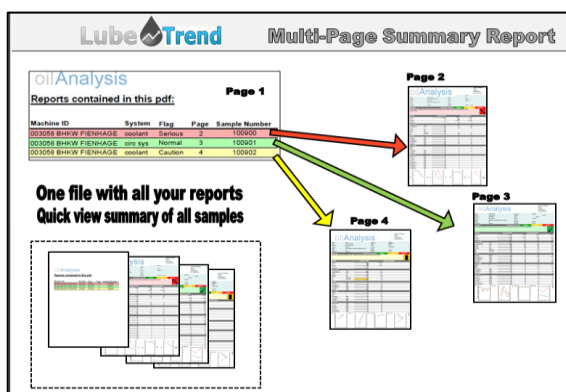
## Specification style reports

Results	Current Sample	Min Limit	Max Limit
Sample No.	58033		
Status			
Sampled			
Fluid Age	18885		
Unit Age			
<b>Fluid condition &amp; other tests</b>			
Viscosity @ 40°C	mm <sup>2</sup> /s	2.7	4.5
Water	ppm	72	201
Appearance	-	Clear & Bright	
Flashpoint	°C	77	54
Density	kg/m <sup>3</sup>	837.8	846
FAHIE	%	5.04	7.01
Sulphur	ppm	7	11
Total Contamination	mg/kg	0.5	24.1

Specification style reports are the same as the trend style reports except that rather than showing sample history they show minimum and maximum alarm limits. These are best for specification testing where a sample either passes or fails a standard e.g.

Fuel specification testing such as road diesel (EN590), off-road machinery (BS2869) and Marine fuels (ISO 8217).

## Multi-page reports



The multi-page report is the same as the trend style report, but it batches all samples for a machine or location into one report with a quick view summary of the status of all the sampling points sampled.

## Tests on Lubetrend report (Fluid Condition)

📺 **Viscosity** (10ml)– This is defined as resistance to flow, or how thick an oil is.



It changes with temperature i.e. as you heat an oil it will begin to thin and as the oil is cooled it will begin to thicken. The importance of viscosity is that at high temperatures the lubricant film must be thick enough to separate the two surfaces, but thin enough to still be energy efficient. Many diesel engines are produced with a lower viscosity base oils with special Viscosity Index Improver additives so at low temperatures they are fuel efficient in cranking the engine, but at high operating temperatures still give sufficient film thickness to prevent wear. These oils are called multi-grades (e.g. 15W40, 5W30 etc). Viscosity is measured at two temperatures.

- Viscosity at 40°C – All lubricating fluids (as standard) are measured at this temperature and is the standard temperature to measure fluids for industrial applications with ISO Viscosity grade ratings.
- Viscosity at 100°C – This is performed on all multi-grade (denoted with a “W” in the grade, where **W** = **W**inter) and SAE grade fluids used in engines and automotive gear oils.

Viscosity	Common Causes	Potential Result	Potential advice
High	<ul style="list-style-type: none"> <li>• Contamination with a high viscosity product e.g. grease</li> <li>• Aging of an oil (oxidation etc).</li> <li>• Excessive sooting.</li> <li>• Incorrect lubricant used.</li> <li>• Leaking head gasket / coolant leak/water ingress.</li> <li>• Heavy fuel oil dilution</li> </ul>	<ul style="list-style-type: none"> <li>• Increased cost</li> <li>• Engine overheating</li> <li>• Harmful deposits or sludges</li> <li>• Blocked filters</li> <li>• Component seizure</li> </ul>	<ul style="list-style-type: none"> <li>• Confirm oil grade</li> <li>• Check air to fuel ratio.</li> <li>• Inspect internal seals</li> <li>• Check unit for excessive heat</li> <li>• Check for leak injectors and fuel lines.</li> <li>• Change oil (small volume systems) or top-up / renew with new oil on larger volume systems to bring back to correct oil viscosity.                             <ul style="list-style-type: none"> <li>◦ Send a sample of used and new oil to your Lubetrend Lab laboratory to help find volume</li> </ul> </li> </ul>
Low	<ul style="list-style-type: none"> <li>• Contamination with a low viscosity product e.g. diesel.</li> <li>• Normal mechanical working of an fluid in</li> </ul>	<ul style="list-style-type: none"> <li>• Increased cost</li> <li>• Poor lubrication</li> <li>• Metal to metal</li> </ul>	



	multi-grade products (Polymer shear). • Incorrect lubricant used.	contact.
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Lubetrend Viscosity Grade Chart				
Kinematic Viscosity		Grade System		
40'C	100'C	ISO	SAE Engine	SAE Gear

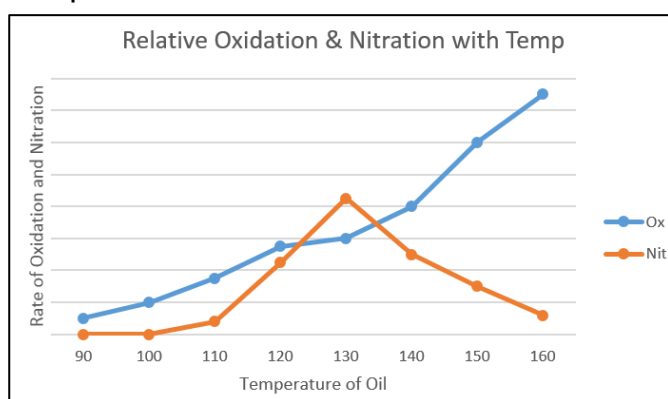
2000				
	70			
	60	1500		
1000	50	1000		250
800	40			
700		680		
600	30			140
500		460		
400				
300	20	320	60	
200		220	50	90
		150	40	
				85W
100	10	100	30	
80				
	9			
	8	68		80W
60				
	7		20	
50				
40		46		
	6			
			12	75W
30	5	32	15W	
			8	
			10W	
	4		5W, 0W	
20		22		
		15		
10		10		





**Oxidation** (30ml) – high temperatures and oxygen (in air) increase the rate of oxidation of lubricants where the oxygen chemically bonds with the oil to form organic acids (measured by Acid Number) that can cause corrosion in machinery. Excessive oxidation can result in oil thickening, sludges and varnishes in machinery.

**Nitration** (30ml) – This is typically only starts at higher loads, and at prolonged temperatures >70°C as the bonds of nitrogen (N<sub>2</sub>) in air requires approximately



twice as much energy to break as the bonds of Oxygen (O<sub>2</sub>) in air. The rate of nitration formation increases up to a peak of ~130°C, however, at extremely high temperatures (>150°C) nitration products break down leading to a reduction in nitration formation (see graph to left).

It is heavily influenced by the air/fuel ratio, reduces when crankcase ventilation and oxygen improves. Like oxidation this can result in oil thickening and sludge formation. Additionally, when combined with water this can form nitric acid causing corrosion to components.

	Common Causes	Potential Result	Potential Advice
High Nitration	<ul style="list-style-type: none"> <li>Improper expulsion of gases from cylinder (scavenge)</li> <li>Abnormal blow-by.</li> <li>High temperatures, but &lt;150°C and or poor cooling</li> <li>High load, cylinder imbalance.</li> </ul>	<ul style="list-style-type: none"> <li>Increased cylinder wear</li> <li>Increased acid number (AN), oil thickening and acidic by products.</li> <li>Increased viscosity</li> <li>Reduced BN</li> </ul>	<ul style="list-style-type: none"> <li>Shorten oil drain interval.</li> <li>Check for poor engine cooling.</li> <li>Check engine running not too hot or too cold.</li> <li>Check crankcase venting correctly.</li> <li>Compression check system.</li> <li>Ensure proper air/fuel mixture.</li> <li>Consult oil supplier for alternative lubricants.</li> </ul>
High Oxidation	<ul style="list-style-type: none"> <li>Overheating (low levels occur at all temperatures and will increase with temperature).</li> <li>Over-extended drain interval.</li> <li>Excessive blow-by</li> </ul>	<ul style="list-style-type: none"> <li>Reduced life of equipment</li> <li>Increased viscosity</li> <li>Increased AN, reduced BN</li> <li>Decreased engine performance</li> <li>Increased wear</li> <li>Decrease filter life and increase filter blocking.</li> </ul>	

**Sulphation** (30ml)– Sulphur present in fuel or engine oil during combustion can combine with water produced during the combustion process to form sulphuric acid (battery acid) which can cause corrosion to engines. Engine oil lubricants are designed with an specialist antacid additives (Base Number) to neutralise the acids (Acid Number).



📺 **Acid Number (AN)** (30ml)– This is the concentration of acid in the fluid. The new oil value may not be zero since some oil additives react similar to acids with the reagents used for testing. Hence it is important to monitor the trend in change of TAN from a baseline sample or new oil reference. In engine applications this can be used in conjunction with a Base number value with the crossover of the two values a common method of deciding when to change oil. However, always be guided by your lubricant provider and OEM recommendations.

📺 **Base Number (BN)** (30ml)– This is the amount of alkali additive remaining in the engine lubricant. This is used in conjunction with an AN

value and oil changes are typically either on a drop of 50% from a baseline sample or when the value becomes less than the AN. Again, always be guided by your lubricant provider and OEM recommendations.

	Common Causes	Potential Result	Potential Advice
High Acid Number	<ul style="list-style-type: none"> <li>Overheating</li> <li>Excessively extended drain interval</li> </ul>	<ul style="list-style-type: none"> <li>Decreased BN</li> <li>Corrosion</li> <li>Oil Thickening and Sludging</li> </ul>	<ul style="list-style-type: none"> <li>Evaluate oil drain interval.</li> <li>Establish new baseline BN / AN values.</li> </ul>
And/or Low Base Number	<ul style="list-style-type: none"> <li>Wrong lubricant</li> <li>High sulphur fuel</li> </ul>	<ul style="list-style-type: none"> <li>Increased wear</li> <li>Filter blocking</li> <li>Component Seizure.</li> </ul>	<ul style="list-style-type: none"> <li>Change oil</li> <li>Submit fuel sample for analysis</li> <li>Submit coolant for analysis</li> </ul>
High Base Number	<ul style="list-style-type: none"> <li>Wrong oil added / topped up.</li> <li>Cylinder oil contamination</li> </ul>	<ul style="list-style-type: none"> <li>High Ash (SAPS) production</li> <li>Wasted cylinder oil.</li> </ul>	<ul style="list-style-type: none"> <li>Reduce Cylinder oil fuel rate</li> <li>Confirm correct lubricant in use.</li> </ul>



**Automatic Titration of Acid Number & Particle counting lab – Conwy UK.**

## Tests on Lubetrend report – (Contamination)



### Understanding ISO cleanliness codes

Particle counting techniques have been used to measure the cleanliness of fluids for many years. Once this practice was implemented, it soon became evident that fluids, which looked clear and bright, were often very dirty. Microscopic examinations would reveal many harmful abrasive particles, which could potentially have lead to an unexpected failure. In fact the number of particles present were often too unwieldy to comprehend and appreciate. Numbers, such as 14712586 particles per 100 millilitre greater than 6 microns and 1275916 particles per 100 millilitre greater than 14 microns and so on.

The International Standards Organisation (ISO) considered this problem and devised a simple index system to rationalise these large numbers.

Some pre-2001 OEM guidelines used a 2 code system, which was later replaced with the 3 code system (table below). So 18/15 in the old system relates to the last 2 codes in the new system e.g. XX/18/15

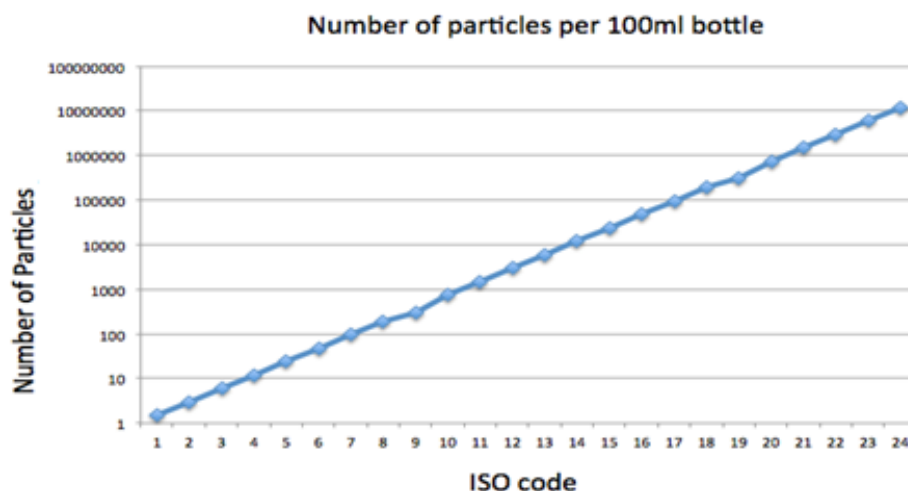
OLD SYSTEM	NEW SYSTEM
MICRONS	MICRONS
	4
5	6
15	14

▶ **ISO Particle count** (60ml) – Particle counts measure the relative cleanliness of a fluid. This can be performed at different particle sizes from 4 microns all the way up to 70 microns. The most common cleanliness method is the ISO code system that measures the number of particles at 4, 6 and 14 microns. Traditional thinking suggests particles between 6 and 14 microns are the most damaging to equipment, but current thinking suggests smaller particle sizes such as 4 microns may also be damaging to systems with small machine tolerances, hence these are measured too. To easily express the cleanliness and allow comparison of large numbers. The code is expressed from smallest to largest from left to right, so a code of 20/19/15 means a code of 20 (500k to 1m particles in 100ml sample) greater than 4 microns, a code of 19 (250k

to 500k) particles greater than 6 microns per 100ml sample and an iso code of 15 (16k to 32k) particles greater than 14 microns in a typical 100ml sample container.

Particle counts on reports are typically expressed per ml rather than 100ml since early 1990s, and the 100ml example above is just for simplicity to explain the number of particles in the sample bottle.

	Common Causes	Potential Result
Increased cleanliness code (dirtier lubricant)	<ul style="list-style-type: none"> <li>Water contamination</li> <li>Incorrect sampling and flushing before sampling</li> <li>Inefficient filtration</li> <li>Recent oil change</li> <li>Dirt ingress through seals / header tank</li> </ul>	<ul style="list-style-type: none"> <li>Engine gelling and seizure</li> <li>Poor fuel efficiency / mpg</li> <li>Blogged filters</li> <li>Reduced filter life</li> <li>Increased wear</li> <li>Carbon deposits.</li> </ul>





No of particles /ml	Number of particles / 100ml bottle	ISO cleanliness code
5M – 10M	500M – 1000M	30
2M – 5M	200M – 500M	29
1.3M – 2M	130M – 200M	28
640K – 1.3M	64M – 130M	27
320K – 640K	32M – 64M	26
160K – 320K	16M – 32M	25
80k to 160k	8M – 16M	24
40k to 80k	4M – 8M	23
20k to 40k	2M – 4M	22
10k to 20k	1M – 2M	21
5k to 10k	500K – 1M	20
2.5k to 5k	250K – 500K	19
1.3k to 2.5k	130K – 250K	18
640 to 1300	64K – 130K	17
320 to 640	32K – 64K	16
160 to 320	16K – 32K	15
80 to 160	8K – 16K	14
40 to 80	4000 – 8000	13
20 to 40	2000 – 4000	12
10 to 20	1000 – 2000	11
5 to 10	500 – 1000	10
2.5 to 5	250 – 500	9
1.3 to 2.5	130 – 250	8
	64 – 130	7
	32 – 64	6
	16 – 32	5
	8 – 16	4
	4–8	3
	2–4	2
	1–2	1



Cleanliness of a lubricant is important as dirt and debris ingress can considerably decrease component life within machinery.

The three tables to the right show how to estimate the increased performance / component life gained by the improvement in cleanliness.

A value of 1 suggests the improvement in cleanliness has little effect on component life, whilst a value of 3 means theoretically, assuming the only failure type was contamination the component would last up to 3 times longer than if the cleanliness was not improved. In most cases the improvement will not be this large because of the difficulties in e.g. filtering the hydraulic lubricant to 4 codes less (16 times less particles) to achieve a 3 fold improvement.

Hydraulic Servo & Engine U/C (film thickness ~0.3um - 5um)						
Lubetrend Estimated machine performance & life index due to cleanliness						
Actual ISO Code	Target ISO Code					
		16/14/12	18/16/14	20/18/16	22/20/18	24/22/20
	16/14/12	1				
	18/16/14	1.5	1			
	20/18/16	3	1.5	1		
	22/20/18	5	3	1.5	1	
	24/22/20	7	5	3	1.6	1

Element bearings (film thickness ~0.1um - 3um)						
Lubetrend Estimated machine performance & life index due to cleanliness						
Actual ISO Code	Target ISO Code					
		16/14/12	18/16/14	20/18/16	22/20/18	24/22/20
	16/14/12	1				
	18/16/14	1.5	1			
	20/18/16	2	1.5	1		
	22/20/18	3	2	1.5	1	
	24/22/20	4	3.2	2.1	1.4	1

Gear Shafts (film thickness ~0.5um - 5um)						
Lubetrend Estimated machine performance & life index due to cleanliness						
Actual ISO Code	Target ISO Code					
		16/14/12	18/16/14	20/18/16	22/20/18	24/22/20
	16/14/12	1				
	18/16/14	1.3	1			
	20/18/16	1.5	1.3	1		
	22/20/18	2.5	1.5	1.3	1	
	24/22/20	3	2.5	1.5	1.2	1

Note these values above will vary between equipment manufacturers, load, operating temperature, lubricant type and maintenance practices in use. Some examples of typical cleanliness of the new oil and cautionary value are shown below. In many instances the new oil requires additional filtration to reach the target cleanliness codes and hence why oil changes should be avoided as the sole method of reducing high cleanliness codes.

Application Type	Typical new oil	Usual cautionary value
Construction equipment hydraulics	20/18/15	22/20/17
Servo Valves	20/18/15	18/16/13
Gearbox	21/20/17	22/21/17
Steam turbine	20/18/15	19/17/14





**Soot** (30ml)– This is a normal process of the fuel combustion process. This is a good indicator of combustion efficiency in the engine and should be monitored as part of any diesel engine analysis package.

	Common Causes	Potential Result	Potential Advice
High Soot / insoluble	<ul style="list-style-type: none"> <li>• Poor fuel quality</li> <li>• Low compression</li> <li>• Worn / badly sealing engine rings</li> <li>• Defective spraying</li> <li>• Improper air/fuel ratio</li> <li>• Excessive oil hours</li> </ul>	<ul style="list-style-type: none"> <li>• Engine gelling and seizure</li> <li>• Poor fuel efficiency / mpg</li> <li>• Blogged filters</li> <li>• Reduced filter life</li> <li>• Increased wear</li> <li>• Carbon deposits.</li> </ul>	<ul style="list-style-type: none"> <li>• Change oil</li> <li>• Change filters</li> <li>• Assess if drain intervals need changing</li> <li>• Reduce excessive idling</li> <li>• Check air induction and turbos working correctly.</li> <li>• Check injectors not excessively dosing system.</li> </ul>

**Water** (20ml) – Water content found in the system. This may be a freshwater source e.g. tap water, or saline water (with sodium), or coolant (with sodium and/or potassium and possibly glycol). In water based fluids, the water content needs to be within certain concentrations to maintain fire-resistance properties. If water is a contaminant in the system then it needs to be prevented from entering or removed after ingress (see Section on symptoms and corrective actions for details on how).

**Glycol** – this is an analysis linked to the water content. Glycol contamination suggests a coolant leak, incorrect sampling or use of a dirty top-up can.

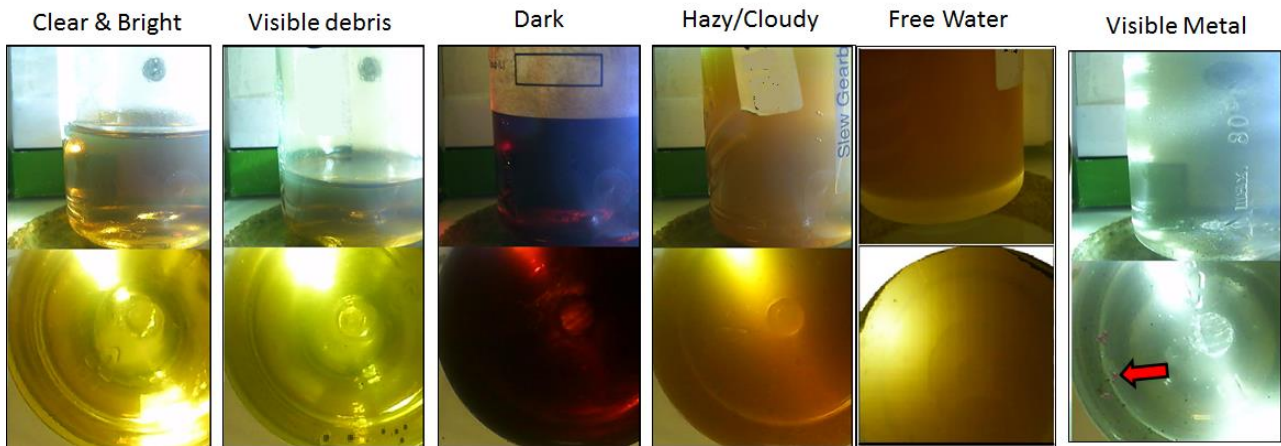
	Common Causes	Potential Result	Potential Advice
Water / Glycol	<ul style="list-style-type: none"> <li>• Low temperature.</li> <li>• Poor seals</li> <li>• IBC contamination / improper storage.</li> <li>• Coolant leak</li> <li>• Leaking solenoid valve on purifier</li> <li>• Condensation / humidity</li> <li>• Exposed/free breathing tanks/header tanks</li> <li>• Leak of gland (Sterntubes)</li> </ul>	<ul style="list-style-type: none"> <li>• Poor lubrication</li> <li>• Rust</li> <li>• Engine failure</li> </ul>	<ul style="list-style-type: none"> <li>• Pressure check cooling system.</li> <li>• Check lube &amp; coolant levels for any change.</li> <li>• Check if coolant or lube top-up increasing.</li> <li>• Check for source of contamination ingress.</li> <li>• Inspect oil cooler – submit coolant sample.</li> <li>• Check head gasket and tighten bolts if needed.</li> <li>• Check engine temperature not too cold causing moisture from combustion to condense.</li> </ul>

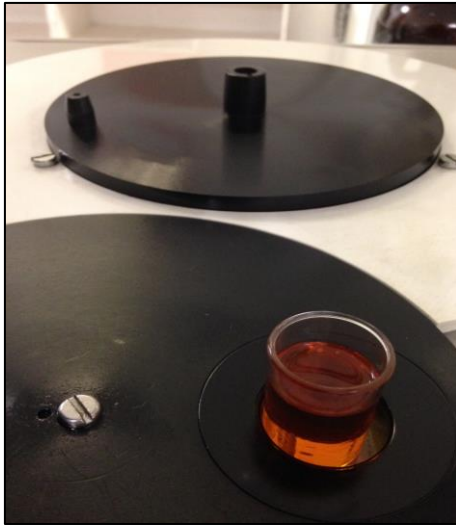


**Diesel Fuel** (20ml) – This can be provided as a normal, caution or serious result based on flash point, or as a percentage dependent on your test suite type. Excessively high fuel dilution may also pose a fire risk. Diesel systems converted to run on biofuels such as B20, B80 and B100 the fuel dilution can be provided as a percentage FAME (Fatty-Acid-Methyl-Ester) content.

	Common Causes	Potential Result	Potential advice
High Fuel dilution	<ul style="list-style-type: none"> <li>Excessive idling</li> <li>Injector fault</li> <li>Incomplete combustion</li> <li>Stop start operation</li> <li>Incorrect air to fuel ratio.</li> <li>Incorrect timing</li> </ul>	<ul style="list-style-type: none"> <li>Excessive cylinder and ring wear</li> <li>Metal to metal contact as lubricant removed by "fuel wash"</li> <li>Reduced mpg</li> <li>Decreased engine life</li> <li>Reduced engine performance</li> <li>Reduced lubricant life.</li> </ul>	<ul style="list-style-type: none"> <li>Check for leaking injectors.</li> <li>Check timing.</li> <li>Replace worn rings</li> <li>Submit sample of fuel for testing</li> </ul>

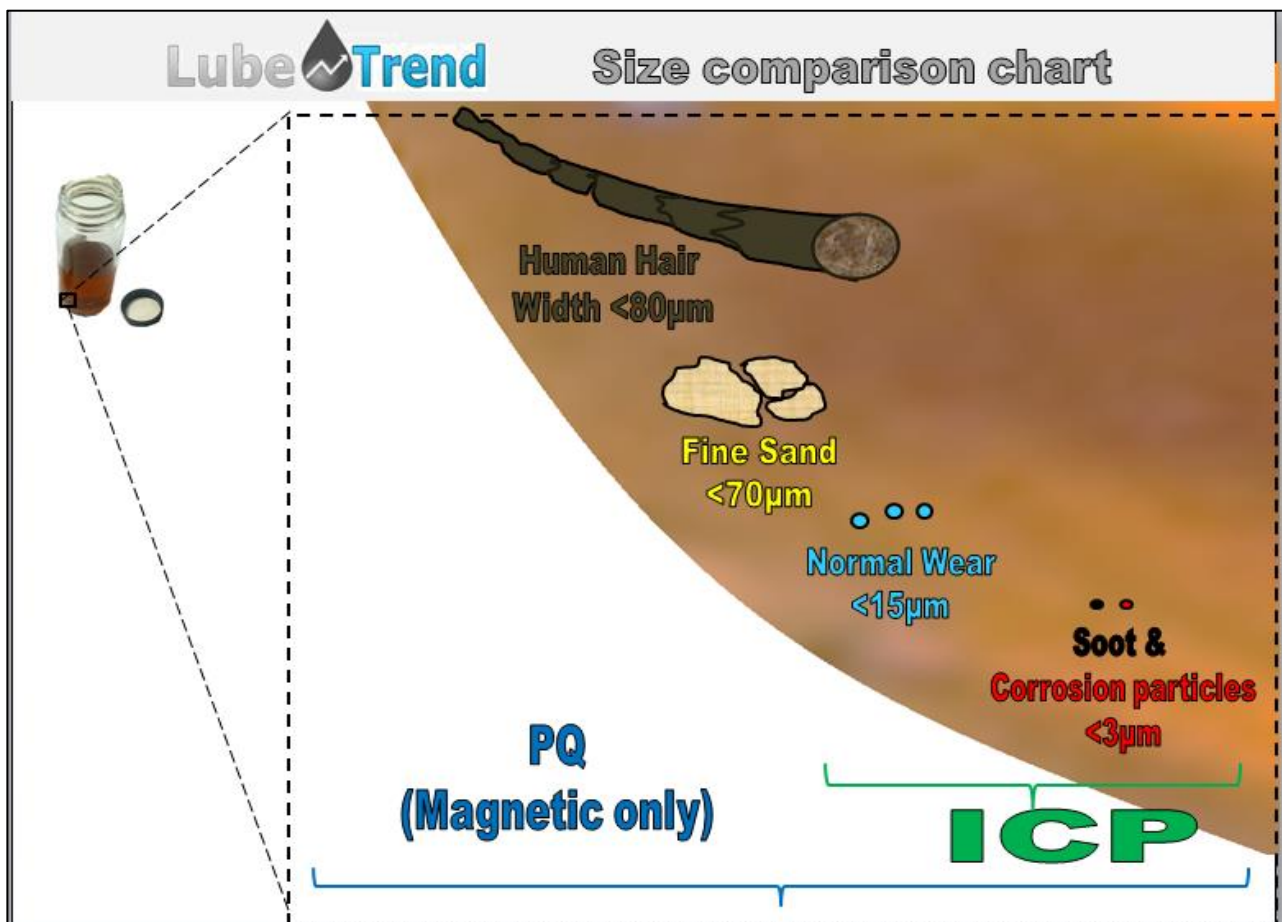
**Appearance** – This is a test performed on all fluid samples except diesel engines (as the oil is too black to see through). The sample is analysed visually for contamination or visible wear particles prior to testing. This is a qualitative test so does not differentiate between a little and a lot of dirt in a sample. It is a good confirmation test to confirm other diagnostic data.





▶ **PQ – Ferrous debris** (10ml) – This is a non-dimensional value indicating the amount of ferrous (i.e. Iron, Steel, Cobalt or Nickel - magnetic) material in the sample. Standard Iron results are performed by ICP (Inductively coupled plasma) and measures particles ideally less than 5 to 10µm (an explanation of the theory of ICP is available in our [Youtube video](#) (minutes 16 to 18)). By comparison the width of a human hair is 80µm. Therefore large ferrous particles that can be seen by eye will be underestimated by ICP. Hence the PQ method detects small and large particles.

	Common Causes	Potential Result	Potential advice
High PQ result compared to Iron ICP result	Abnormal wear processes: <ul style="list-style-type: none"> <li>• Abrasive contaminants</li> <li>• Misalignment</li> <li>• Overloading</li> <li>• Poor lubrication</li> <li>• And many more.</li> </ul>	<ul style="list-style-type: none"> <li>• Machine failure</li> <li>• Reduced component life</li> <li>• Loss of production.</li> </ul>	<ul style="list-style-type: none"> <li>• Further investigation by LFDA (see section further in this guide) to determine route cause of problem.</li> </ul>



# ICP Wear Metals (Source Element guide)

## Lubetrend Analysis Common [Wear Metals](#) (P1 of 2)

Element	Trunk/ Engines	Cross Head Engines System Oil	Gear / Axles	Transmissions	Hydraulics / Turbines	Compressors		
						Centrifugal	Reciprocating	Gear/screw
<b>Aluminium (Al)</b>  Used as Strong and Lightweight with excellent heat dissipation/transfer properties.	Pistons skirt, Thrust Bearings, Turbo Bearings, Main/Rod, Bearings. Dirt (with Silicon), some oil cooler tubing,	Pistons, Turbocharger casing, Fuel (Cat Fines), Bearings, housings.	Pumps, Thrust Washers, Aluminium Casting, Dirt (with Silicon), impellers (retainers / bushings)	Torque converter, Pumps, Thrust Washers, Aluminium Casting, Dirt (with Silicon), some oil cooler tubing.	Bearings, Thrust Plates, Pistons, pump motor housing. Dirt (with Silicon),	Oil rings (older models), Heat exchanger core	Thrust collars & rings, shims and spacers	Sleeve bearing overlay
						Case Casting, Dirt (with Silicon).		
<b>Cadmium (Cd)</b> Good Corrosion Resistant Property alloy plating metal	Environmental Contaminant from combustion fossil fuels, cement production, steel production, phosphate based fertilisers. Alloy Metal,				Bearing Alloy with Aluminium. Environment ingress	Alloy with Aluminium (Bearings), Environmental Contaminant		
<b>Chrome (Cr)</b>  Used for Strength, Hardness and corrosion/erosion resistance. Often plated on steel for additional strength or combined with nickel to form stainless steels for turbine blades, pump rods and valves.	Piston Ring landings, Ring Coatings, Liners, Exhaust Valves, Shaft Plating, Stainless Steel Alloy, Taper Bearings, Piston Crown alloy (with nickel and Molybdenum)	Pistons / Bearings, Piston Rods, Exhaust Valves, Piston rings	Roller/Taper Bearings, Needle Bearings, Shafts	Roller Bearings, Needle Bearings, Shafts	Rods, Cylinders, Gears, Shafts, Pistons		Cams, springs, rods, valves & valve guides	
						Shafts (with Iron), bearing race coating		
<b>Copper (Cu)</b>  It is malleable so can be used for bearings e.g. Can be used sacrificially to wear in to make smooth surfaces. Copper Sulphide can be oil soluble component leaching. Often used as a cage metal for element bearings.	Main/Rod Bearings (Also look for Lead & Tin), Brass (with Zinc) / Bronze (with Tin) Bushings, Leaching (Oil Cooler – 1st 2000 hours). Governor, Wrist pin bushings, Valve train bushings, Thrust washers.	Bearings, Cooler tubing, piston rod glands/bushings (with Tin and lead – Bronze alloy with lead). Stuffing Box.	Bronze (with Copper) Bushings. Cage Metal from Roller Bearings, Leaching (Oil Cooler). Clutches, Steering discs, thrust washers.	Clutch Plates, Brass/ Bronze Bushings (Also Look for Tin and/or Lead & Zinc), Oil Cooler Core Tubing	Bearings, Bushings, Thrust Washers, Oil Cooler Tubing	Bearing Sleeve / Backing, oil rings	Bushes, bearings, backings, valve guides, thrust plates.	Gears. Pumps.
						Roller Bearings, cages, cooler tubing.		
<b>Iron (Fe)</b>  Used as base metal in many components owing to strength. Usually alloyed with Chrome, Aluminium or Nickel to make Steel.	Liners, Valve Train, Gears, Crankshaft, Camshaft, Rods, Oil Pump, Wrist Pins, piston crown.	Piston rod, Liners, Crankshaft, Camshaft, skirt, bearings. Exhaust valve and guide.	Gears, Shafts, Bearings, Cast Iron, housing.	Gears, Disks, Housing, Bearings, Brakes Bands, Shafts	Rods, Cylinders, Gears, Shafts, Pistons, bearings	Roller elements / races. Sleeve bearing.	Cylinder walls, valves, valve guides, springs, rods, cams	Screws, roller elements / races. Sleeve bearing.
						Corrosion, Gears, Shafts, Bearings, Casting, backing.		

## Lubetrend Analysis Common [Wear Metals](#) (P2 of 2)

Element	Diesel/Gas /Petrol Engines	Cross Head Engines System Oil	Gear / Axles	Transmissions	Hydraulics / Turbines	Compressors
<b>Lead (Pb)</b>  Often used for plating bearings as malleable. Often found in wear in process, but can also be a sign of misalignment or corrosion when present.	Main/Rod Bearings, Solder (old machines), Aftermarket Additive, Corrosion.		Cage Metal from Roller Bearings, Oil Cooler Core Tubing	Clutch Plates, Brass/ Bronze Bushings (Also Look for Tin and/or Zinc)	Bearings, Bushings	With Tin (sleeve bearings), without Tin: sealing compounds, lead based paint.
<b>Manganese (Mn)</b>  Improve steel workability at high temperatures and a high tensile strength. Usually below 1.9% to prevent brittleness. However, some alloys e.g. Hadfields contains 12-14%	Steel Alloy Metal in Gears, Some Shafts, Liners.		Steel Alloy Metal in Gears, Some Shafts	Steel Alloy Metal in Gears, Some Shafts	Steel Alloy Metal in Gears, Some Shafts	Steel Alloy Metal in Gears, Some Shafts
<b>Silver (Ag)</b>  Used for heat dissipation and low coefficient of friction. Rarely used owing to cost.	Silver in Wrist Pin Bushings (GM Electro-motive division (EMD) engines), Some Solder from Cooler Core Joints. Bearings.		Solder	Trace Element in some Needle Bearings, Solder form Oil Cooler Core Joints	Solder	Solder
<b>Tin (Sn)</b>  Typically used as a plating material to facilitate wear-in processes.	Bearings (with lead & Copper), Bronze (with Copper) Bushings, Flashing from Pistons, Tin-Lead Solder. Bearing overlay		Bearings, Bushings with Copper and Lead)) Solder from Tin-Lead Solder. Occasional additive	Brass (with Zinc) / Bronze (with Tin) Bushings (Also Look for Tin and/or Lead & Zinc)	Bearings (with Lead & Copper), Bushings, Solder form Tin-Lead Solder	Sleeve Bearings (with Lead and Copper), Bushings, Solder from Tin-Lead Solder, joints.

Note any of the wear metals above may also be contamination in mining, steelworks or any metal working applications.



## Lubetrend Analysis Common [Contamination](#) Elements

Element	Engines	Gear / Axles	Transmissions	Hydraulics / Turbines	Compressors
<b>Lithium (Li)</b>	Lithium Based grease.				
<b>Potassium (K)</b>	Sodium from Salt Water, Spray Wash, Anti-Freeze Inhibitor (Coolant Leak) Additive from Potassium Borate Gear Oil	Sodium from Salt Water, Spray Wash, Anti-Freeze Inhibitor, Additive from potassium Borate Gear Oil	Sodium from Salt Water, Spray Wash, Anti-Freeze Inhibitor (Coolant Leak) Additive from Potassium Borate Gear Oil	Environmental Contaminant from Pot Ash Mining, Water Contaminant, Anti- Freeze Inhibitor	Environmental Contaminant from Pot Ash Mining, Water Contaminant, Anti- Freeze Inhibitor
<b>Silicon (Si)</b>	Dirt (Silica), Silicone form Silicon based Synthetic, Silicone Sealants, Silicates from Anti-Freeze, Siloxanes (Landfill Gas), Silicon anti-foam additive (usually <25ppm)	Dirt (Silica), Silicone form Silicon based Synthetic, Silicone Sealants, Silicates from Anti-Freeze	Dirt (Silica), Silicone form Silicon based Synthetic, Silicone Sealants, Silicates from Anti-Freeze	Dirt (Silica), Silicone form Silicon based Synthetic, Silicone Sealants, Silicates from Anti-Freeze.	Dirt (Silica), Silicone form Silicon based Synthetic, Silicone Sealants, Silicates from Anti-Freeze
<b>Sodium (Na)</b>	Sodium from Salt Water / salt water residue, Spray Wash, Anti-Freeze Inhibitor (Coolant Leak)	Sodium from Salt Water, Spray Wash, Anti-Freeze Inhibitor	Sodium from Salt Water, Spray Wash, Anti-Freeze Inhibitor (Coolant Leak)	Sodium from Salt Water, Spray Wash, Anti-Freeze Inhibitor	Sodium from Salt Water, Spray Wash, Anti-Freeze Inhibitor

## Lubetrend Analysis Common Additive Elements

Element	Engines	Gear / Axles	Transmissions	Hydraulics / Turbines	Compressors
<b>Barium (Ba)</b>	Very old detergent additive with low ash properites (decades old), Not Commonly found in Engine Oils, Contaminant in Drilling Applications	Demulsifying Agent, Additive Common in Compressor Oil, Some Transmission Fluids & Synthetic Gear Oils, Contaminant in Drilling Applications	Very old detergent additive (decades old), Not Commonly found in Gear Oils, Contaminant in Drilling Applications	Demulsifying Agent, Additive Common in Compressor Oil, Some Transmission Fluids & synthetic Gear Oils, Contaminant in Drilling Applications	Demulsifying Agent, Additive Common in Compressor Oil, Some Transmission Fluids & Gear Oils, Contaminant in Drilling Applications for acid retardation
<b>Boron (B)</b>	Additive Common in Engine Oils & Some Gear Oils (synergistic effect with other Anti-wear additives)	Boron Nitride Additive designed for high temperatures anti-friction (up to 900°C) as alternative to MoS <sub>2</sub> , graphite or PTFE. Also found in food grade lubes.	Additive Common in Engine Oils & Some Gear Oils (synergistic effect with other Anti-wear additives)	Additive Common in Engine Oils & Some Gear Oils (synergistic effect with other Anti-wear additives)	Additive Common in Engine Oils & Some Gear Oils (synergistic effect with other Anti-wear additives)
<b>Calcium (Ca)</b>	Detergent/Dispersant Additive, Calcium from Water Contamination, Lime Dust	Detergent/Dispersant Additive, Calcium from Water Contamination, Lime Dust, Engine oil contamination	Detergent/Dispersant Additive, Calcium from Water Contamination, Lime Dust,	Detergent/Dispersant Additive, Calcium from Water Contamination, Lime Dust, Engine oil contamination	Detergent/Dispersant Additive, Calcium from Water Contamination, Lime Dust, Engine oil contamination
<b>Magnesium (Mg)</b>	Detergent/Dispersant Additive, Alloy, Environmental Contaminant, Hard water	Detergent/Dispersant Additive, Alloy, Environmental Contaminant, Engine oil contamination	Detergent/Dispersant Additive, Alloy, Environmental Contaminant	Detergent/Dispersant Additive, Alloy, Environmental Contaminant, Engine oil contamination	Detergent/Dispersant Additive, Alloy, Environmental Contaminant, Engine oil contamination
<b>Phosphorus (P)</b>	Anti-Wear Additive ZDDP (ZincDialkyl-DithioPhosphate), Phosphate Ester, Phosphate Inhibitor found in Coolants	EP Additive, Anti-Wear Additive ZDDP (Zinc-DialkylDithioPhosphate), Phosphate Ester, Phosphate Inhibitor found in Coolants	Anti-Wear Additive ZDDP (ZincDialkyl-DithioPhosphate), Phosphate Ester, Phosphate Inhibitor found in Coolants	Anti-Wear Additive ZDDP (Zinc-DialkylDithioPhosphate), Phosphate Ester, Phosphate Inhibitor found in Coolants	EP Additive, Anti-Wear Additive ZDDP (Zinc-DialkylDithioPhosphate), Phosphate Ester, Phosphate Inhibitor found in Coolants
<b>Zinc (Zn)</b>	Alloy in Brass, Anti-Wear Additive ZDDP, Galvanized Steel from Filter Canisters. If a GM EMD using Silver, then may be a contaminant of incorrect non-zinc free oil.	Alloy in Brass, Anti-Wear Additive ZDDP, Galvanized Steel from Filter Canisters.	Alloy in Brass, Anti-Wear Additive ZDDP, Galvanized Steel from Filter Canisters	Alloy in Brass, Anti-Wear Additive ZDDP, Galvanized Steel from Filter Canisters	Alloy in Brass, Anti-Wear Additive ZDDP, Galvanized Steel from Filter Canisters, piping or sealing compound (without copper). Brass roller bearing cage wear (with copper)

## Lubetrend Analysis [Multi-origin](#) Elements

Element	Engines	Gear / Axles	Transmissions	Hydraulics / Turbines	Compressors
<b>Molybdenum (Mo)</b>  Used for increasing strength of steels at high temperatures. Also alloyed with	Friction Modifier Additive in Oils, Grease Contamination, Molybdates from Some Coolants, Piston Ring plating. Crosshead exhaust valve seat (with Fe), or valve Spindle (with Chrome)	Friction Modifier Additive in Oils, Grease Contamination, Molybdates from Some Coolants	Friction Modifier Additive in Oils, Grease Contamination, Molybdates from Some Coolants	Friction Modifier Additive in Oils, Grease Contamination, Molybdates from Some Coolants. Heat resistance alloy in turbine rotors, boiler tubes (with Vanadium)	Alloy or Plating from Rings, Retainer Pins, Friction Modifier Additive in Oils, Grease Contamination, Molybdates from Some Coolants
<b>Nickel (Ni)</b>  Often alloyed with Iron in e.g. engine guides and valves. Increases strength and erosion resistance. Usually 3 - 4% in connecting, piston and pump rods.	Engine: Alloy in Valves, Crankshaft, guides, Camshaft  System oil: Contaminant in Marine HFO Fuels (with Vanadium), bearings, gears, valves.	Steel Alloy from Bearings, Shafts	Steel Alloy form Bearings, Shafts	Valves, Spools, Shafts, Monel Metal (Ni Cu alloy – 2 : 1 alloy) – turbine blades, pumps.	Shafts, Bearings
<b>Titanium (Ti)</b>  Impingement corrosion & Erosion resistance. Excellent saline water resistance. Alloyed with Cu 2% for increased strength.	Valves, Piston Pins, Bearings, Shafts, Paint or coatings	Shafts, Gears, Bearings, Paint or Coatings	Shafts, Gears, Bearings, Paint or Coatings.	Valves, Piston Pins, Bearings, Shafts, Paint or coatings, turbine blades, heat exchangers	Shafts, Gears, Bearings, Paint or Coatings, heat exchangers
<b>Vanadium (V)</b>  Increases Strength and fatigue resistance and with molybdenum	Alloy Metal, Contaminant in Marine HFO Fuels (with Nickel)	Unlikely wear metal. Possibly contamination	Unlikely wear metal. Possibly contamination	Alloy Metal (turbine blades). Boiler tubes (with Molybdenum)	Alloy Metal (impellor)



The below list is a general guide for additive concentrations in lubricating oils. This list is not definitive and with the recent emergence of Nano-technology and ashless additives that are not metal based the variation between different additive packages formulations will change greatly. The best way to confirm the additive element concentration for your lubricating oil is to send an unused sample for reference to the lab, or contact your lubricant supplier for details. Additive concentrations measured using ICP analysis – picture to left.

## Engines (and ATFs):

- Calcium / Magnesium – Total ~800 to 4000ppm (Can be ~0 in some new very low ash oils)
- Phosphorus and Zinc (ZDDP) – 200 to 1200ppm (can be lower in some ashless oils, or just Phosphorus and <20ppm of Zinc in Zinc free oils)
- Silicon - ~5 to 15ppm
- Molybdenum – 50ppm to 100ppm – only in some oils – see reference oil

## Cylinder Oils

- Calcium 18000 to 25000 (possibly with some Magnesium)
- Phosphorus and Zinc (ZDDP) ~10 to 20ppm

## Gears

- Phosphorus only – 200 to 2000ppm.

## Hydraulic

- Phosphorus and Zinc (ZDDP) – 200 to 600 ppm
- Engine oil formulations on multi-compartment oils.

## Compressors

- Phosphorus and Zinc (ZDDP) – 5 to 40 ppm

## Engine Coolants

- Sodium / Potassium – Approx. 4000 to 9000ppm if 100% concentrate.
- Trace to moderate presence of Silicon, Boron, Phosphorus or Molybdenum dependant on formulation type

## Turbine (Gas / Steam)

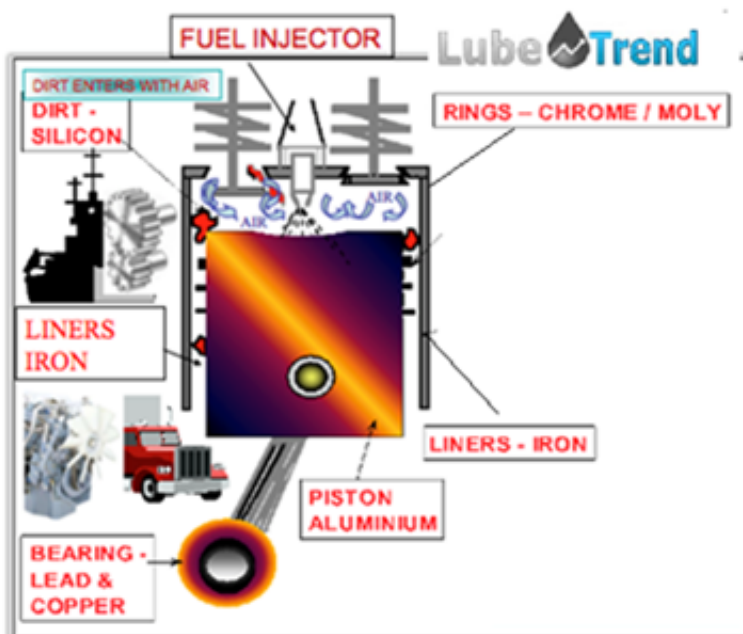
- Mineral oil or group 4 synthetics products typically no metal based additives.
- May occasionally have hydraulic additive package.
- Fire resistant fluids will have phosphorus >2000ppm (typically 9%).



# LubeTrend

## BiteSize Diagnosis Heavy Duty Diesel Engines

### Sources of Engine Wear



Note many elements have multiple sources and limits are just a **general guide only** and should not be used alone as a basis to take action. The best diagnosis can only be obtained with a combination of trending and diagnostic experience. For assistance with reading your reports email

[techservice@alcontrol.com](mailto:techservice@alcontrol.com) or call (+44/0) 1492 574750

### Typical limits

Test	Units	Caution	Serious
Sodium	mg/kg	35	80
Silicon	mg/kg	20	40
Aluminium***	mg/kg	12	20
Chromium***	mg/kg	10	20
Copper***	mg/kg	35*	60*
Iron***	mg/kg	75	100
Lead***	mg/kg	30	40
Tin***	mg/kg	7	15
Molybdenum***	mg/kg	15**	30**
Soot***	%	>2.5%	>3.4%
Water	%	>0.2%	>0.2%
Fuel	%	>2%	>4.5%
Viscosity	mm2/s	>15% of unused	>20% of unused
PQ	-	20	>30

\*Copper may be normal if leaching from copper based components e.g. cooler.

\*\*Molybdenum may be normal as present in some oil additive packages

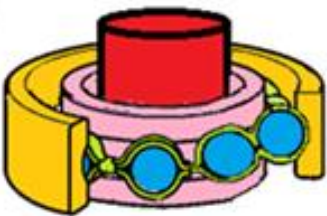
\*\*\* Parameters are assumed to be per 250 oil hours, 6000 miles or 10,000km



## Gear Systems

**Rolling Element**


Inner Race  
Outer Race  
Cage. **Shaft.**



## Typical limits

Test	Units	Caution	Serious
Sodium	mg/kg	20	40
Silicon	mg/kg	40	60
Aluminium***	mg/kg	15	30
Chromium***	mg/kg	5	10
Copper***	mg/kg	20	40
Iron***	mg/kg	200	450
Lead***	mg/kg	10	20
Lithium	mg/kg	-	10
Tin***	mg/kg	10	20
Water	%	>0.24%	>0.6%
Viscosity	mm2/s	>15% of un-used	>20% of un-used
PQ	-	100	200

## Gear Wear Sources



Silicon	Dirt (and Al ), sealant, Sand, Oil additive & Synthetic Fluids
Aluminium	Pumps, White Metal Bearing, Thrust Washers & Torque Converters
Chromium	Roller Bearings, Needle Bearings, Shafts
Copper	Brass/Bronze, Cage Metal in Roller Element Bearings, Phosphorbronze gears
Iron	Gears, Shafts, Bearing, cast iron
Lead	Bushes, Bearings
Tin	Bronze / PhosphorBronze (with Copper), White Metal Bearings, Bushes
Lithium	Grease

\*\*\* Parameters are assumed to be per 500 oil hours, 10,000 miles or 20,000km

Note many elements have multiple sources and limits are just a **general guide only** and should not be used alone as a basis to take action. The best diagnosis can only be obtained with a combination of trending and diagnostic experience. For assistance with reading your reports email [techservice@alcontrol.com](mailto:techservice@alcontrol.com) or call (+44/0) 1492 574750 )

## LubeTrend Bite Size Diagnosis : Hydraulics & Compressors

### Typical limits Compressors

Test	Units	Caution	Serious
Silicon	mg/kg	20	40
Aluminium***	mg/kg	10	15
Chromium***	mg/kg	4	10
Iron***	mg/kg	20	30
Lead***	mg/kg	5	10
Lithium	mg/kg	5	10
Tin***	mg/kg	5	10
Water	%	-	0.15
Viscosity	mm2/s	>15% of un-used	>20% of un-used
PQ	-	20	40

### Typical limits Hydraulics

Test	Units	Caution	Serious
Silicon	mg/kg	20	40
Aluminium***	mg/kg	20	40
Chromium***	mg/kg	4	10
Iron***	mg/kg	25	50
Lead***	mg/kg	5	10
Lithium	mg/kg	-	10
Tin***	mg/kg	5	10
Water	%	-	0.15
Water (Biodegradable / ester based)	%	0.06	0.09
	Mg/kg	600	900
Viscosity	mm2/s	>15% of un-used	>20% of un-used

\*\*\* Parameters are assumed to be per 500 oil hours, 10,000 miles or 20,000km

Note many elements have multiple sources and limits are just a **general guide only** and should not be used alone as a basis to take action. The best diagnosis can only be obtained with a combination of trending and diagnostic experience. For assistance with reading your reports email [techservice@alcontrol.com](mailto:techservice@alcontrol.com) or call (+44/0) 1492 574750 )



## LubeTrend Bite Size Diagnosis : Steam / Gas Turbines

### Typical Routine Turbine (Gas/Steam)

Test	Units	Caution	Serious
Silicon	mg/kg	5	7
Aluminium	mg/kg	5	7
Chromium	mg/kg	-	5
Iron	mg/kg	5	7
Lead	mg/kg	5	7
Lithium	mg/kg	5	7
Tin	mg/kg	5	7
Water (Steam Turbine)	mg/kg	1000	2000
Water (Gas Turbine)	mg/kg	500	1000
Viscosity	mm2/s	Trending (5% to 15% change) dependant on other data	
ISO code	Target cleanliness = 19/17/14		
Acid Number	Mg KOH/g	0.35	0.45

Note many elements have multiple sources and limits are just a **general guide only** and should not be used alone as a basis to take action. Many elements also require trending based on hours in use and some OEM specific limits are also used in the diagnosis. The best diagnosis can only be obtained with a combination of trending and diagnostic experience. For assistance with reading your reports email [techservice@alcontrol.com](mailto:techservice@alcontrol.com) or call (+44/0) 1492 574750 )

### Turbine health Check extra tests

Test	Units	Caution	Serious
RPVOT	Min	75% drop from new oil	100
RULer (Remaining useful life)	%	25	10
Flashpoint	° C	20 drop from new oil	
Water Separability	Must seprate fully within 20 minutes		
Rust Character	-		Fail
Foam (sequence 1)	min	Tendency >450 Stable >10	
Air release	min	10	
Chlorine	mg/kg	100	200
Mineral oil content (in synthetics)	-	Positive (any detected)	
Varnish Number (MPC)	-	30 15 if previous Varnish issues	40

## Bite-size Diagnosis (Transmissions ATFs)

# LubeTrend Bite Size Diagnosis : ATF Transmissions

## Transmission (ATF) Wear Sources

Silicon	Dirt (and Al ), sealant, Sand, Oil additive & Synthetic Fluids
Aluminium	Torque Converters, Pumps, Thrust Washers, Dirt (with silicon)
Chromium	Roller Bearings, needle bearings, Chrome plated shafts
Copper	Clutch plates, Brass/Bronze bushings
Iron	Gears, Disks, Bearings, Brakes.
Lead	Clutch plates, Brass / Bronze bushings
Tin	Brass (with Zinc) / Bronze (with Tin) Bushings (Also Look for Tin and/or Lead & Zinc)
Lithium	Grease

## Typical limits (ATF)

Test	Units	Caution	Serious
Sodium	mg/kg	20	40
Silicon	mg/kg	40	60
Aluminium***	mg/kg	15	30
Chromium***	mg/kg	5	10
Copper***	mg/kg	20	40
Iron***	mg/kg	200	450
Lead***	mg/kg	10	20
Lithium	mg/kg	-	10
Tin***	mg/kg	10	20
Water	%		>0.15
Viscosity	mm2/s	>15% of un-used	>20% of un-used
PQ	-	100	200

\*\*\* Parameters are assumed to be per 500 oil hours, 10,000 miles or 20,000km

Note many elements have multiple sources and limits are just a **general guide only** and should not be used alone as a basis to take action. The best diagnosis can only be obtained with a combination of trending and diagnostic experience. For assistance with reading your reports email [techservice@alcontrol.com](mailto:techservice@alcontrol.com) or call (+44/0) 1492 574750 )

## Bite-size Diagnosis (Cylinder oil Scrape-downs)

# LubeTrend Bite Size Diagnosis : Cylinder Lubrication (Scrapedowns)

Test	Cause Abnormal	Corrective Action
<b>Sodium</b>	Fuel oil source, saline source	Check storage tanks, analyse fuel quality & fuel oil purifier.
<b>Al &amp; Si</b>	Cat fines in fuel, dirt	Check air induction/turbo charger filters, inspect fuel oil purifiers, drain off storage tank debris & analyse fuel
<b>BN</b>	Too High or Low incorrect feed rates. If too High Ash deposits may form & too low means acidic environment.	Match feed rates to fuel sulphur levels (test fuel sulphur), confirm correct Cyl oil in use and confirm stuffing box integrity if low.
<b>Chromium</b>	Ring Wear	Monitor trends & confirm if any abnormal noise, heat or vibration.
<b>Copper</b>	Piston Glands	Monitor trends & confirm if any abnormal noise, heat or vibration.
<b>Iron &amp; Manganese</b>	Corrosion & multiple components. With Manganese suggests liner wear	Monitor trends & submit fuel sample for cat fines testing, confirm BN sufficient.
<b>P + Zn</b>	Increase suggested system oil ingress / wrong oil / wrong sampling point	Inspect stuffing box
<b>Vanadium</b>	Fuel contamination	Reassess injector maintenance. Test fuel oil.
<b>Tin</b>	With copper (piston glands)	Monitor trends & confirm if any abnormal noise, heat or vibration
<b>Soot</b>	Incomplete combustion	Reassess injector maintenance schedule. Test fuel quality.
<b>Water</b>	Humidity, leaks and storage conditions	If rising suspect leak and investigate. If stable check water separators and storage tanks. Test Fuel Quality.
<b>Viscosity High</b>	Incomplete combustion, contaminated fuel, water contamination.	Reassess injector maintenance schedule. Confirm new oil storage conditions Test Fuel Quality.
<b>Viscosity Low</b>	System oil contamination, wrong oil	Inspect stuffing box
<b>PQ</b>	Abnormal wear mode – See Iron	Monitor trends & confirm if any abnormal noise, heat or vibration

## Typical Diagnostics (Limits)

Test	Units	Caution	Serious
<b>Sodium</b>	mg/kg	50	110
<b>Al &amp; Si</b>	mg/kg	20	50
<b>BN</b>	mgKOH/g	<20 or >35	<10
<b>Chromium</b>	mg/kg	25	50
<b>Copper</b>	mg/kg	20	45
<b>Iron</b>	mg/kg	200	450
<b>Lead</b>	mg/kg	20	40
<b>Manganese</b>	mg/kg	20	40
<b>Vanadium</b>	mg/kg	180	320
<b>Tin</b>	mg/kg	20	35
<b>Soot</b>	%	1.5	2
<b>Water</b>	%	0.5	1
<b>Viscosity @ 40°C</b>	mm <sup>2</sup> /s	>315	>400
<b>Viscosity @ 100°C</b>	mm <sup>2</sup> /s	>25	>30
<b>PQ</b>	-	60	100

Note many elements have multiple sources and limits are just a **general guide only** and should not be used alone as a basis to take action. The best diagnosis can only be obtained with a combination of trending and diagnostic experience. For assistance with reading your reports email [techservice@alcontrol.com](mailto:techservice@alcontrol.com) or call (+44/0) 1492 574750 )



## Specialist Lubricant Tests

In addition to routine oil analysis tests there are several specialist tests that are commonly performed as supplementary analysis or as part of an annual machinery health check.



**Air release** (250ml) is a test where air is blown through a lubricating fluid at a set temperature and pressure. The release of the 'trapped' air bubbles within the fluid is measured until no additional gas escapes. The time it takes to reach this point is called the air release and time is measured in minutes.

Tested On: Hydraulics, Compressors, Steam and Gas Turbines

Diagnostic significance: The air release should be as low as possible. Contamination and oxidation products can increase the air release time. Air is a poor lubricant and so if air is likely to become trapped for long periods in the lubricant the lubricant becomes less effective. In hydraulic applications the entrainment of air in a system poses many risks:-

1. Air can be compressed and this can lead to potential uncontrolled movement in machinery.
2. Air when compressed becomes very hot and can actually lead to thermal breakdown of the oil surrounding the bubbles. The principle is very similar to the combustion process in a diesel engine but instead of a hydrocarbon fuel being passed into air and then compressed, air is passed into a hydrocarbon fluid and then compressed.

Typical Diagnostic limit: 5 to 20. Typically ~10 minutes

**Asphaltenes** (25ml) are high molecular weight chemicals found in crude oil, but concentrated in residual fuel oils. They are typically found in a solid form and the term *Asphaltenes* derives from their asphalt / bitumen like properties.

Tested On: Marine Engines, Heavy Fuel or Petroleum products

Diagnostic significance: Asphaltenes can form solid precipitates in pipelines and reservoirs causing blockages. In addition, in marine applications these particles can cause abrasive wear to components, hence it is important to analyse on all marine engines using heavy fuel oils.

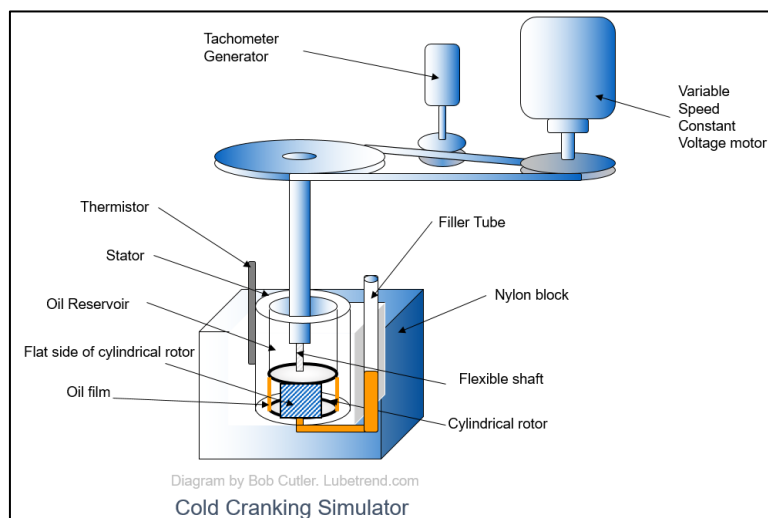
Typical Diagnostic limit: Typically flagged at ~0.5% in engine oil depending on engine type and size.

**Colour** (5ml) is a simple test where the colour of the fluid is compared to set standards of a given scale from 1 to 8 with increasing darkness.

Tested On: Usually Steam and Gas Turbines. However, any lubricant sample can potentially benefit from this test.

Diagnostic significance: As an oil oxidises the colour will begin to darken/change and a colour change can often be one of the first indicators of early oxidation. The absolute colour is not significant, but the trend compared to previous samples is measured. Increasing darkness usually indicates other investigative tests should be performed such as Acid Number and antioxidant testing by RULER or RPVOT. Colour change may not always be significant as a small increase in acid number can still cause a noticeable change in colour, hence it should only be used in conjunction with other analysis data and not as the sole diagnostic flag.

**Cold Cranking Simulator** (120ml) (**Winter Grade Viscosities**) – Certain engine SAE lubricant grades have multiple grades denoted with a 'W' in the name e.g. 15W40, 5W30, 0W20 etc. W = Winter and denotes the viscosity grade at a low temperature. A 15W40 for instance is a SAE 15 grade oil with a viscosity improver additive that means when the temperature reaches 100°C it acts like a SAE 40 oil. This allows for improved efficiency and fuel economy at lower temperatures. To confirm the fluid performs correctly at cold temperatures a cold-crank simulation is run where a piston is rotated within a static cylinder through the oil at very low temperatures (as low as -35°C) to simulate cold cranking. A variation on this method exists called the **mini-rotary viscometer (MRV)** (25ml), which measures the cold pumping viscosity instead of cranking viscosity which is usually performed as part of specification testing.






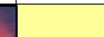








Tested On: Engine oils used in conjunction with viscosity at 100°C and other tests. This is tested on all new products and any dispute resolution to confirm the grade used in warranty cases.

Diagnostic significance & Diagnostic limits: This is a specification testing limit set to ASTM 5293.

SAE Grade	Crank Temp (°C) (CCS)	Max Cold cranking Viscosity (mPa.S) - CCS	Pump Temp (°C) (MRV)	Max Cold Pumping Viscosity (mPa.S) - MRV
0W	-35	6200	-40	60 000
5W	30	6600	-35	60 000
10W	-25	7000	-30	60 000
15W	-20	7000	-25	60 000
20W	-15	9500	-15	60 000
25W	-10	13000		

**Copper Corrosion** (60ml) is a test where a finely polished and degreased copper strip is submerged in the sample fluid at a set temperature and duration. The tarnish / corrosion of the strip is determined using a reference of corrosion standards such as the below. The corrosion level is determined in an ascending scale from 1 to 4 each broken into between 2 and 5 letter categories.

Lubetrend Copper Corrosion Chart											
Slight Tarnish		Moderate Tarnish					Dark Tarnish		Corrosion		
1A	1B	2A	2B	2C	2D	2E	3A	3B	4A	4B	4C
											

Tested On: Any Mineral oil lubricant; typically turbines.

Diagnostic significance: Many lubricating systems use copper in e.g. coolers and connecting tubing as well as components such as bushes and bearings. Corrosion to these parts of a system can ultimately reduce the life of the equipment. It is usually used for compatibility testing of oil for suitability for systems containing copper. Reasons for increased copper corrosion are usually owing to contamination with high sulphur containing compounds or lubricating oils that increase the formation of copper-sulphur tarnish compounds.

Typical Diagnostic limit: 2A on turbine applications. On fuel systems Slight Tarnish (1A and 1B) are maximum allowed.

**Chlorine content** (25ml) can be analysed by different methods, but the result is reported in ppm.

Tested On: Gas engines and Turbines

Diagnostic significance: In Gas engines, Chlorine is an important indicator of gas quality, especially on landfill gas applications. Chlorine compounds are contained in several household products such as bleach that commonly end up at landfill. When chlorine enters the combustion chamber in which fuel and air form water and carbon dioxide the reaction can lead to the formation of chlorine based acids such as hydrochloric acid. These acids lead to corrosion of components of the engine and ultimately reduce machine life.

In turbine applications chlorine is measured typically in Fire Resistant Fluids (Phosphate Esters). Chlorine can be a left over product from lubricant manufacturing process or from the use of chlorinated solvents when cleaning components. Chlorine under high temperatures (such as in steam turbines) results in generation of chloride ions that can lead to erosion of servo valves.

Typical Diagnostic limit: Varies dependent on engine OEMs. Commonly ~1000ppm on gas engines. Typical limits for turbine applications are ~100ppm.

**Cloud point, Pour point, CFPP, Channel point** (60ml) – This is the point at which a fuel or low temperature lubricant form a wax causing clouding and eventually stop pouring. The cloud point is the point at which the fluid begins to crystallise. The pour point is considered the point 3°C above the temperature at which the fluid did not pour for 5 seconds when the test tube is tipped on its side. The channel point is considered the point at which a channel can be formed in a lubricating fluid and it does not instantly fill in the gap

behind an object passing through it. A CFPP (Cold-Filter Plugging Point) is used on fuels where fuel is passed through a special filter at low temperature eventually causing it to block (Plugging Point) – this is used in conjunction with a cloud point to determine the temperature at which a fuel could possibly begin to cause filter blockages.

Tested On: Predominantly fuels, but any low viscosity fluid can be tested.

Diagnostic significance & Typical Diagnostic limit: On certain fuels there are legislative limits used around the world for fuels depending on climate conditions. In lubricating systems, a cloud, pour or channel point value higher than the lowest temperature the machinery will be operating means the fluid may:

- Block filters with wax deposits (primarily on fuels)
- Be difficult or impossible to pump fuels or lubricants
- Result in wear as the points where a channel in the fluid is left (e.g. gear teeth passing through the lubricant) will have direct metal to metal contact.

**Evaporation Loss (Noack) (75ml)** – There are several alternative methods for this test, but the principle of the method includes heating the fluid to a high temperature and measuring the percentage mass loss of the sample after a set period of time.

Tested On: In service Engines and hydraulics, but usually any new lubricants too.

Diagnostic significance: A low result is ideal and a high result suggests the oil will thicken over time as the lighter fractions of the lubricant evaporate off at high temperature. This results in reduced useful life of the oil. Causes of a high result can be blends of light and heavy base oils or contamination/top-up with another product with a different boiling profile to the rest of the lubricant. If a recently changed oil or new oil shows a high value then please consult your lubricant supplier for advice.

Typical Diagnostic limit: Varies dependent on machine OEMs and lubricant suppliers recommendations, but typically a result of 14% or greater would be seen as high. On engine specifications ACEA 2012 A1, B1, A3, B3, B4, C1, C2, C3, E4, E6, E7 and E9 the result must be less than or equal to 13%. ACEA 2012 C4 has a maximum limit of no greater than 11%.

**Foaming** (400ml) is a common test (ASTM D892) performed on lubricating oils to determine their tendency to foam. Air is pumped through a porous stone (similar to an air stone used in household aquariums) to produce many fine bubbles. The process is split into 3 sequences – usually Sequence 1 is sufficient for most applications, but some applications require sequences 2 and 3 as well. In High temperature applications such as engines and transmissions there is a separate method for foaming often referred to as sequence 4.

- **Sequence 1** – Air is pumped through the stone into the oil for 5 minutes at 24°C.
- **Sequence 2** – Air is pumped through the stone into the oil for 5 minutes at 93.5°C.
- **Sequence 3** – Perform sequence 2 first and then sequence 1.
- **Sequence 4** – (ASTM D6082) This is a different method to standard foaming 3 sequences and is specific for engine and transmission oils. The analysis is performed at 150°C.

The result obtained on each sequence is quoted in millilitres of foam at the end of the test called the tendency to foam. Some of this foam will then collapse over time and at 10 minutes the foam is measured again. This foam still present at 10 minutes is called stable foam. The result is expressed in tendency/stable e.g. 20/0 where there is 20ml of tendency to foam, but it had all collapsed before 10 minutes (0) leaving no stable foam.

Tested On: In service Turbines, gears, hydraulic oils and any new oil products. Sequence 4 is tested on engine/transmission applications.

Diagnostic significance: Foam is a poor lubricant. Additives such as detergent in the oil clean oxidation and sooty deposits, whilst anti-foam additives (typically silicone oil based) collapse foam bubbles. Imbalance in these additives can lead to foaming in a system. Stable foam is worse than foam tendency as it does not quickly collapse and enter load bearing zones such as bearings causing metal to metal contact and wear. Foam in general can cause leakage of oil from the surface by increasing the volume in the system and it is possible to have systems overflow with foam filling an entire room.

Typical Diagnostic limit: New oils typically have limits of <50ml tendency and 0ml stable foam, whilst in use applications tend to allow higher tendency up to 450ml and up to 10ml of stable foam.

**Flash point (open (100ml) and closed (100ml)) and firepoint.** Flashpoint and fire-point are important tests when determining safety of certain systems. It may come as a surprise that no liquid burns and it is in fact the vapours just above the liquid that actually burn. Hence performing a closed cup flashpoint (i.e. with a lid on the container the flashpoint is lower because the vapours are allowed to collect. Closed flashpoints are usually most important in systems where the vessel is closed such as fuel tanks and when transporting fluids. Open cup flashpoints are usually slightly higher because there is no lid to the container and the gases can escape, hence a higher temperature is needed for sufficient vapour to collect above the fluid to cause a flash. A flash is when a flame is placed just above the liquid the vapours ignite and then go out quickly



in a 'flash'. If you continue heating the fluid past the open flash point, to a point at which the vapour ignites and stays lit because the fluid is at sufficiently high a temperature for more vapours to be produced to fuel the flame, then this is termed the fire point.



**Tested On:** Any product that has a Material Safety Data Sheet. Nearly every product has this as a new oil batch test and these are important safety tests. However, in condition monitoring it is mostly used in engines to detect fuel dilution, petroleum product drilling/mining equipment and seal oils to detect contaminating petroleum products such as natural gas, and in heat transfer / metal quenching systems to determine if product is safe for continued use.

**Diagnostic significance & Typical Diagnostic limit:** The limits used are often application specific and involve analysing the trends. However, diesel fuels closed flashpoints need to be over 56°C, whilst lubricating oils need to be over 200°C. In heat transfer systems the comparison of the gap between the open and closed flashpoint is important as it determines when the oil has degraded to a point in which small light end fractions of the oil have collected as a vapour in the system and run a significant fire risk.

**HTHS (High Temperature High Shear) Viscosity** (100ml) - this is a relatively new oil specification test used to determine how well oils perform under extreme conditions e.g. where the temperature and friction is highest. Low HTHS oils give the best fuel economy as the oil is thinner and provides less energy to rotate the bearing shaft, but provides least protection against wear.



A high HTHS oil gives the best wear protection, but a poorer fuel efficiency. A table of the ACEA-2012 specification requirements is listed below. Traditionally, the test is performed at 150°C, but some of the newer fuel efficiency testbed

testing now measures at 100°C as well.

Lubetrend Summary of ACEA 2012 HTHS data												
Test	A1 / B1	A3/B3	A3 / B4	A5 / B5	C1	C2	C3	C4	E4	E6	E7	E9
Viscosity at 150°C and 106 s <sup>-1</sup> shear rate (mPa.s)	≥ 2.9 and ≤ 3.5; On XW20 ≥ 2.6	≥ 3.5		≥ 2.9 & ≤ 3.5	≥ 2.9		≥ 3.5		≥ 3.5			

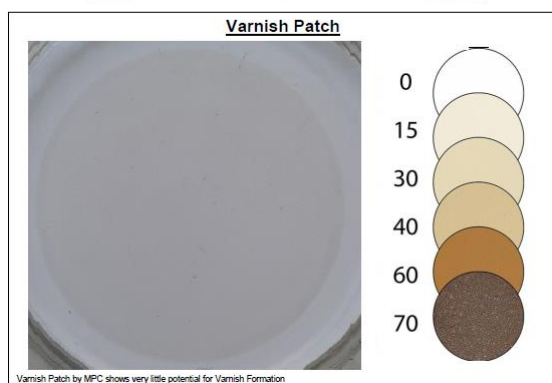
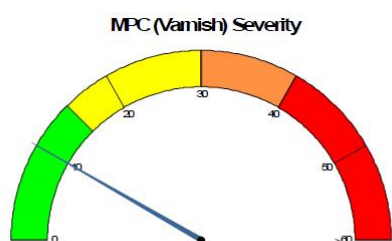
**Mineral oil content** (35ml)– This detects mineral oil contamination in fire resistant fluids (FRF) such as phosphate esters.

Tested On: Non-mineral oil (group 5) products, usually FRF phosphate esters.

Diagnostic significance & Typical Diagnostic limit: The significance of this test is it confirms contamination / topup of a lube oil system with an incorrect fluid. If a system is designed to be mineral oil free for safety reasons due to operating temperatures etc, then contamination with mineral oil product can depress the flashpoint if at significant quantities. Additionally, as mineral oil will not easily mix with synthetic products then this can lead to blocked filters as they attempt to remove the contaminating product.

**MPC Varnish test** (70ml) is a method for determining the tendency of an oil to varnish. Varnish is a build-up of oxidation products in a system and can coat components, block valves and filters and cause reduction in heat loss through oil cooler pathways. Overall, varnish is very difficult to remove without specialist filtration equipment or chemical cleaning/flushing once it forms and so the ideal situation is to avoid varnish build up and prevent it occurring in the first place. Hence the importance of monitoring MPC Varnish potential on a regular basis as part of an annual or biannual health check of the system. After an initial incubation period of up to 3 days, the MPC method involves a

filtration with solvent through a 0.45 micron filter patch. The result is read using a colour spectro-photometer sensor to accurately determine the colour and hence level of varnish (i.e. the insoluble oil degradation products) in the sample.



Tested On: Hydraulics, Compressors, Steam turbines and Gas turbines.

Diagnostic significance & Typical Diagnostic limit: Below is an example of the varnish report graph. Serious is considered >40. <15 is considered normal. 15 and 30 are the two choices of caution limit popularly used depending on whether there is a previous varnish problem or based on OEM recommendations.

**RPVOT** (75ml)/ **RULER** (10ml)– These tests measure the oxidation stability or concentration of antioxidants in a lubricant and hence it's remaining life. RPVOT (Rotating Pressure Vessel Oxidation Test) submits a sample of the lubricant to high pressure, high temperature (150°C), pure oxygen and water with a copper catalyst to promote oxidation and measures the time in minutes

for the oil to absorb 25% of the available oxygen (i.e. when the anti-oxidants in the oil are spent). The way this is achieved is during the process the oil absorbs oxygen once the anti-oxidants are spent and the pressure in the vessel drops. Oils in relatively good condition can take several days of running time to process if they have high RPVOT values. An advantage of the RULER (Remaining Useful Life) is that rather than oxidising the oil to indirectly measure how much anti-oxidant is remaining, the RULER directly measures how much is remaining making the test quicker. However, the disadvantage is that a reference oil is always required for comparison. Therefore:

- RULER is ideal when a fast turnaround is required and a reference oil of the unused oil can be provided for comparison.
- RPVOT is ideal when a reference oil of the unused oil cannot be obtained, or the oil in the system is unknown.

Tested On: Large circulating oil systems such as steam and gas turbines, Paper machines etc where the oil is likely to be in use for several years and a single oil change is a very large cost.

Diagnostic significance: The significance of the test is to allow a business to plan for oil changes, which can sometimes take several days to perform and require sometimes months of notice before implementing.

Typical Diagnostic limit: 75% drop in value from reference oil or 75% drop from first sample if no ref oil available. Serious limits are typical 90% drop from ref oil / first sample or on RPVOT <100 minutes remaining. This is a guide only, as customers may start planning for oil changes / consulting their oil supplier for advise much earlier than these limits so a plan can be made for corrective action.

**Rust Prevention (300ml)** – This test involved submitting polished steel rods to a bath of 300ml of sample with 10% water content at 60°C for several hours. The steel rods are visually inspected evaluated for any evidence of corrosion, in which case any evidence would be considered a fail. The method is by default run with distilled water – (ASTM D665 method A), but can be performed with synthetic sea water on request where applicable (ASTM D665 method B).

Tested On: Steam turbines typically with high risk of water ingress into the system

Diagnostic significance: This is performed typically as part of an annual Turbine Health Check, but should be added on every sample when there is either evidence of poor water Separability of the fluid, or repeated evidence of water ingress into the system. If on an annual assessment the rust protection is poor (i.e. a fail) then water content should be monitored closely on future samples.

**Sulphated Ash and SAPS (Sulphated Ash Phosphorus & Sulphur) (30ml)**– In engines the lubricant coats the liner and rings to provide a fluid film between these and the piston. The piston rings function is to separate the combustion chamber from the lube oil, but no system is perfect and small quantities of lube oil over time come into contact with combustion gases and

enter the combustion chamber. Lube oil when heated will burn to form the gases carbon dioxide and water as does the fuel, but the metal additives such as Calcium, Magnesium and Zinc which are important engine oil additives will form an ash rather than a gas. This ash has two related issues.

- (1) It will be blown out of the exhaust and hence cause environmental pollution. These contribute to the particulates often measured when determining tax implications on cars and trucks.
- (2) The ash remains hot even after the compression stroke has ended and can cause pre-ignition when the piston is not at top-dead-centre.

Tested On: SAPS on Engine oils and Sulphated Ash only on greases.

Diagnostic significance: This is important when confirming the correct specification of oil has been used. Sulphated ash is important for the particulate emissions standards, but this is part of the larger SAPS standards. The Phosphorus and Sulphur are important because these are catalytic converter poisons, leading to increased exhaust emissions. Lubetrend have worked heavily with several Truck and agricultural OEMs researching this issue. Equally, the Sulphur promotes Sulphur Oxides (SO<sub>x</sub>), which form acid rain. Therefore, the SAPS standards monitor the particulate emissions (sulphated ash), and exhaust emissions (Sulphur and Phosphorus) Lubricant manufacturers in low SAPS oils use ashless additives as substitutes.

Typical Diagnostic limit - A table of ACEA specification limits is listed below.

Lubetrend Summary of ACEA 2012 SAPS data												
Test	A1 / B1	A3/B3	A3 / B4	A5 / B5	C1	C2	C3	C4	E4	E6	E7	E9
Min Base Number (mg KOH/g)	8		10	8			6		12	7	9	7
Max Sulphur (ppm)					2000	3000	3000	2000		3000		4000
Phosphorus (ppm)					≤500	≤900	≥ 700 & ≤ 900	≤900		≤800		≤1200
Sulphated ash (%)	≤1.3	≥ 0.9 & ≤1.5	≥ 1.0 & ≤1.6	≤ 1.6	≤ 0.5	≤ 0.8		≤ 0.5	2	1	2	1

**Water Separability (120ml)–** There are 3 or 4 main methods to choose from when determining an oil's tendency to mix and separate from each other with the principle of timing how long the fluids take to separate. Some methods simply time the separation, whilst others measure the level of emulsion in the fluid too. Lubetrend recommends the ASTM D1401 method in which 40ml of the fluid and 40ml of water are heated to 50°C and mixed using a high speed agitator for 5 minutes until a milky emulsion is formed. The sample is then timed every 5 minutes to determine the level of separation, if at 1 hour the fluid has not separated then the test is stopped and the values are reported to the client. The result is quoted as ml of oil – ml of water – ml of emulsion (time in minutes to reach this point), e.g. 40-40-0 (5) means the oil fully



separated in 5 minutes, whereas 30-10-40 (60) means there is 30ml of water, 10 ml of water and 40 ml of water at the 60 minute mark. As mentioned there are other methods e.g. IP19, so please contact us if you would prefer we use a different method on your samples.

Tested On: Turbines, but also any product where the separation of water and oil needs to be measured.

Diagnostic significance & Typical diagnostic limit: This is particularly useful in conjunction with monitoring water content and rust characteristics of the oil. A typical diagnostic limit is set as the oil does not fully separate within 20 minutes. If water in the system cannot be removed, then it is critical to implement measures to reduce water ingress into the system.





## Electrical Oils Specific Testing

Electrical oils have a different set of analyses compared to lubricating oils. Additionally electrical oils have two diagnoses as both the fluid and the dissolved gases are analysed to give a complete overview of the transformer condition.

The tests performed on these samples are typically performed every 6 months to 1 year depending on voltage (see "when to sample"). If a cautionary fault is identified then the sampling interval should be halved (i.e. twice as often), and if a serious fault is identified immediate resampling should be performed to confirm.

The fluid has three main functions (1) to separate the electrical contacts acting as an electrical insulator, (2) dissipate heat within the transformer and (3) to provide arc quenching for switchgear operation.

This section assumes the reader has a basic knowledge of the electrical function and significance of transformer, switch-gear and tap-changer system. It also assumes the reader is familiar with terms such as arcing and sparking. If so you can skip the grey box below and move onto the next page. However, if you do not have an electrical background and are not familiar with these terms please read the grey box below before proceeding.

### ***Not an electrical engineer? A simple overview of some of the terms used***

- **Transformer (oil insulated)** is simply two copper coils (windings), with the windings usually having different number of turns, wrapped in a specialist paper and submerged in an electrical insulating fluid to allow a step up or down in voltage via electromagnetic induction.
- **Switchgear** is used for important safety requirements; e.g. isolation and circuit protection (overload and short circuit). Oil emerged switchgears composes of electrical disconnect switches, fuses and circuit breakers either individually or in combinations to isolate and protect electrical equipment.
- **Tap Changer** is a system to allow voltage regulation by a connection point selecting variable number of turns.
- **Spark** is when the insulating fluid or air breaks down to allow electrons to jump the gap between the conductors, temporarily discharging the charge that led to the potential. Most people will be familiar with a static spark when touching a surface that has built a static charge or for example a petrol/gas engine spark plug.
- **Arcing** is similar to a spark, but is where the fluid or air between the conductors remains ionized meaning that electrons can continue to jump the gap even at voltages lower than the original breakdown voltage.
- **Floating Potential** - Most people are familiar with a circuit being grounded or earthed for safety. In contrast, a floating potential is where the circuit is not earthed/grounded, which presents a safety concern within the system.

Please note these terms are referencing solely their use in relation to electrical oil / DGA analysis and some of these terms have additional / more detailed definitions and uses for physicists describing electrical circuits.

# Routine Electrical Oil Testing

The following table summarises some of the routine electrical oil limits used typically by an electrical oil laboratory.

Fluid condition Electrical fluid limits						
Test Name	TC	TB	TA	TO	TS	TP
Full Name	Category C Transformer (<72.5kV)	Category B Transformer (>72.5kV to <170kV)	Category A Transformer (>170kV to <400kV)	Category O Transformer (>400kV)	Switchgear	Tapchanger
Dielectric Breakdown (kV) – Min (Non-Ester based synthetics)	30	40	50	50	Use TC, TB, TA or TO limit	Use TC, TB, TA or TO limit
Dielectric Breakdown (kV) – Min (Ester based synthetics)	45	45	50	50	Use TC, TB, TA or TO limit	Use TC, TB, TA or TO limit
Water / moisture (ppm) - max (Non-ester based synthetics)	30 (caution) 40 (serious)	20 (caution) 30 (serious)	10 (caution) 20 (serious)	10 (caution) 20 (serious)	Use TC, TB, TA or TO limit	Use TC, TB, TA or TO limit
Water / moisture (ppm) – max (Ester based synthetics)	400 (Serious if breakdown impaired)	400 (Serious if breakdown impaired)	400 (Serious if breakdown impaired)	400 (Serious if breakdown impaired)	Use TC, TB, TA or TO limit	Use TC, TB, TA or TO limit
Acidity (mg KOH/g) – max (Non-ester based synthetics)	0.1 (caution), 0.3 (serious)	0.1 (caution), 0.15 (serious)	0.1 (caution), 0.15 (serious)	0.1 (caution), 0.15 (serious)	0.07	Use TC, TB, TA or TO limit
Acidity (mg KOH/g) – max (Ester based synthetics)	2.0 (serious)	2.0 (serious)	2.0 (serious)	2.0 (serious)	Use TC, TB, TA or TO limit	Use TC, TB, TA or TO limit
Colour – max ASTM Colour - Max	LIGHT 2	LIGHT 2	LIGHT 2	LIGHT 2	LIGHT 2	LIGHT 2
Contamination - Max	LIGHT	LIGHT	LIGHT	LIGHT	NIL	LIGHT
Particle count (ISO code) Max	20/18/15 (caution)	20/18/15 (caution)	20/18/15 (caution)	20/18/15 (caution)	20/18/15 (serious)	20/18/15 (caution)
Total Furans (FFA) and individual FFA counts – Max	1	1	1	1	1	1 (if paper used)
Est. Degree of Polymerisation (DP) - Min	Caution <600 or <50% of new oil value. Serious <300	Caution <600 or <50% of new oil value. Serious <300	Caution <600 or <50% of new oil value. Serious <300	Caution <600 or <50% of new oil value. Serious <300	Caution <600 or <50% of new oil value. Serious <300	Caution <600 or <50% of new oil value. Serious <300 (if paper used)
Interfacial Tension (IFT mN/m) - Min	Caution (28) Serious (22 or 18 dependent on trends)	Caution (28) Serious (22 or 18 dependent on trends)	Caution (28) Serious (22 or 18 dependent on trends)	Caution (28) Serious (22 or 18 dependent on trends)	Caution (28) Serious (22 or 18 dependent on trends)	Caution (28) Serious (22 or 18 dependent on trends)
Power Factor @ 90°C - Max	1	1	0.2	0.2	Use TC, TB, TA or TO limit	Use TC, TB, TA or TO limit
Dielectric Dissipation Factor (DDF) / Tan Delta @ 90°C - Max	0.1 (caution) 0.5 (serious)	0.1 (caution) 0.5 (serious)	0.1 (caution) 0.5 (serious)	0.1 (caution) 0.5 (serious)	0.1 (caution) 0.5 (serious)	0.1 (caution) 0.5 (serious)
Resistivity at 90°C Giga ohms metres - Min	3 (caution) 0.2 (serious)	3 (caution) 0.2 (serious)	10 (caution) 3 (serious)	10 (caution) 3 (serious)	Use TC, TB, TA or TO limit	Use TC, TB, TA or TO limit
Corrosive Sulphur - Max	Non corrosive	Non corrosive	Non corrosive	Non corrosive	Non corrosive	Non corrosive
Flash Point (OC) Max % Drop from new oil / first sample	10%	10%	10%	10%	10%	10%

These are LubeTrend general guidelines. Note Trending may be used by the lab to over-rule these general limits. Additional electrical oil diagnosis information sources are available from: BS EN60422:2013.

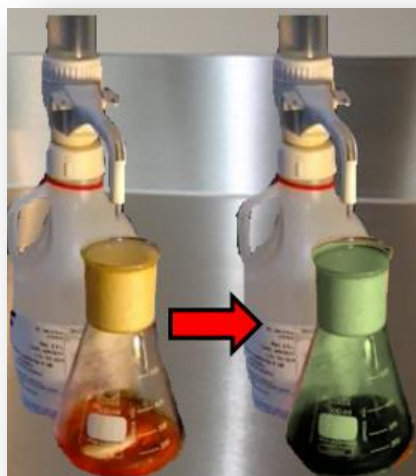
**Dielectric breakdown** (250ml) – of the two main functions of the insulating fluid, one of them is to provide an electrical insulation. The dielectric breakdown is the voltage at which the insulator no longer prevents an electrical discharge across (arrowed red to right) two electrical contacts submerged into the fluid. The method involves submerging the two electrical contacts in the fluid and gradually increasing the voltage until the insulating properties are overcome termed the breakdown voltage. The test is repeated several times and an average breakdown voltage is obtained.



Diagnostic significance: Presence of contamination such as long fibres, water, dirt and oxidation products can all contribute a low dielectric breakdown. The breakdown voltage is an excellent overall indicator of contamination in the fluid as the contaminants will have conducting properties.

**Moisture** – This is a measure of the water in the sample. The maximum allowable content of water/moisture in electrical oil is much less than a lubricated system. This is owing to the significance of water in hindering the ability of the insulating oil to perform its function in being an electrical insulator. Owing to the difference in solubility of water in the insulating fluid at very low concentrations temperature becomes far more significant to determine the water content. This is often referred to as a temperature adjusted water. Temperature adjusted water takes into consideration the temperature of the water measured in the laboratory as well as the temperature of the oil at time of sampling provided by the sampler to adjust the laboratory measured water to the water measured in a transformer.

Diagnostic significance: Presence of water contamination can contribute to increased oxidation and contribute to a low dielectric breakdown. Water can enter the transformer via atmospheric air through a breather, or through degradation of the cellulose paper insulation. Water can also contribute to paper insulation breakdown as the water breaks down the paper insulation.



**Acidity** – Excessive temperature and the presence of oxygen in air causes the oil to oxidise forming organic acids. This is accelerated in the presence of metallic catalysts such as the metallic windings. Acidity is measured by titration with an alkali using a coloured indicator to identify the concentration of alkali needed to neutralise the acid changing the indicator from orange to green as identified to the left.

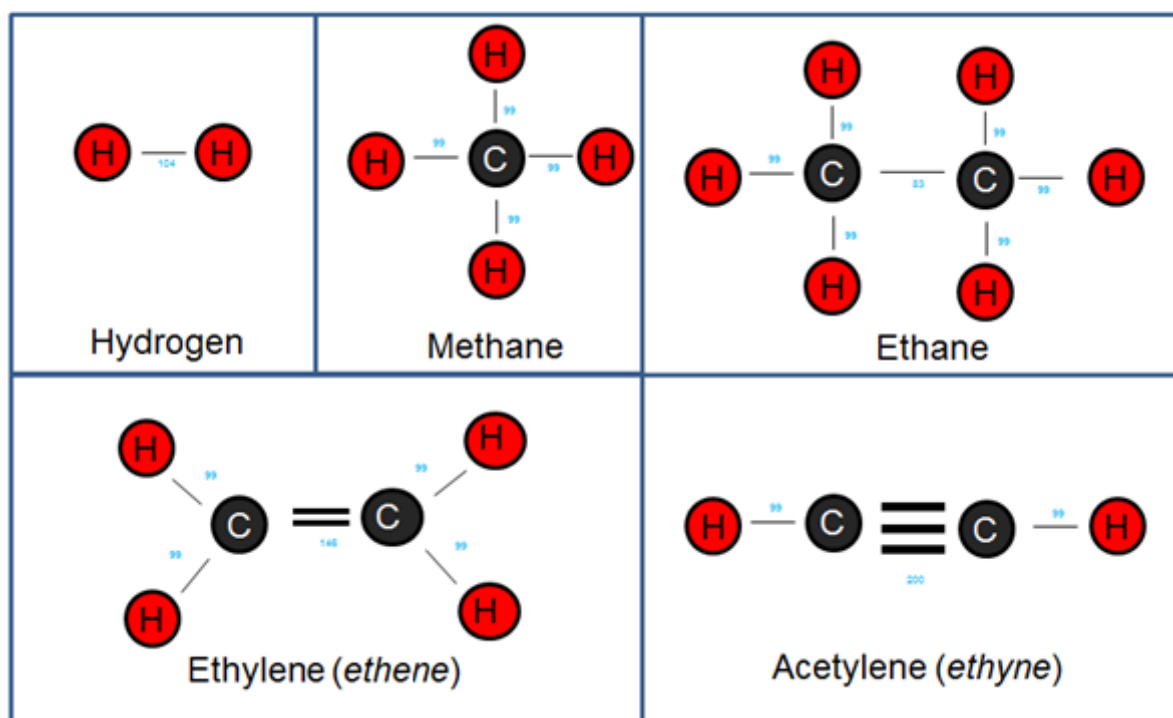
Diagnostic significance: Acidity build up can lead to varnish formation and catalyse the

breakdown of cellulose within the paper insulation. Acid products can increase the solubility of the moisture in the oil.

**Particle count** – Details of the ISO particle count are covered in “Tests on lubetrend report – particle count”. Particles can accumulate in the system from wear metals and corrosion metals from oil pump bearings where fitted. However, particles matter can also be in the form of carbon. Carbon particles form at temperatures  $>500^{\circ}\text{C}$  and can be caused by localised overheating in on-load tap changer diverter switches that end up entering the bulk oil tank contaminating the oil-immersed parts of the transformer.

## Dissolved Gas Analysis (DGA)

Dissolved gas analysis is the study of fault gases in transformer oil to predict transformer faults. This is different to the fluid condition analysis as it specifically identifies the condition of the electrical system and the faults within it. DGA analysis can predict fault gases up to 4 years in advance of a failure meaning significant plans can be made to take corrective action on the system.



**DGA Fault gases structure** with relative bond energies in average bond dissociation enthalpies in kcal per mole in blue. The more serious fault gases have larger structures / more double bonds. The order of severity of fault gases is Hydrogen < methane < ethane < ethylene < acetylene, i.e. hydrogen is the least serious and acetylene is the most serious.

In tap changers the concentrations of gases are usually much higher owing to the nature of the repeated changing contacts causing high temperature sparking. However, in tap changers the fault gas for carbon monoxide is usually lower owing to less/no paper insulation present.



Typical Fault Gas alarm limits					
Test Name	Example Fault type	Temperature Range	Transformers	Switchgears	TapChanger
Hydrogen (ppm)	Arcing corona / start-up	Low (100 °C to 300 °C)	100	100	4000+
Methane (ppm)	Sparking	Low (100 °C to 300 °C)	100	100	2000
Ethane (ppm)	Local overheating	Mid (300 °C to 700 °C)	100	100	4000
Ethylene (ppm)	Severe overheating	High (>700 °C)	30	30	2000
Acetylene (ppm)	Arcing	High (>700 °C)	12	12	4000
Carbon Monoxide (ppm)	Paper insulation / severe overloading	n/a	500	500	100

Note Trending may be used by the lab to over-rule these general limits.

**Ratios Methods** (80ml) - Although, the method of determining faults by DGA includes alarm limits in fault detection, it is the ratio of the gases to one another that determines the fault diagnosis. There are many different methods each with their own merits for use in electrical oil diagnosis. Examples of which include:

- Rogers Ratios
- Duval's Triangle
- IEC Ratios
- IEEE Conditions
- Key Gases

All of these methods above are used by the LubeTrend laboratory in electrical fault diagnosis, but our default diagnostic method is the Rogers ratios method followed by Duval's triangle where confirmation is needed.

***Did you know the inventor of Rogers Ratios worked for Lubetrend?***

The reason our default method is the Rogers' ratios is Ron Rogers who invented the system and was one of the first to publish a method for DGA Ratios fault gas interpretation, worked for our laboratory in 1980s to 1990s and trained our diagnosticians in this method of interpretation. Some of our diagnosticians were personally trained by Ron Rogers, whilst the remainder (including myself) were trained by Ken Lewis who spent most of his early career learning electrical oil diagnostics at the side of Ron Rogers at our laboratory.

## Specialist Tests (Electrical Oils)

**Elemental Analysis (15ml)** – This is useful in identifying dissolved wear metals in the oils. Unlike lubricating oils there are very little or no detectable elements in the sample other than sulphur (or silicon in silicone based fluids) from the base oil in new oil.

**Diagnostic significance:** The most common metals dissolved in the oil are iron with either copper or aluminium depending on the alloy used in the coils. However, there are many metals that may appear in the sample. Some example sources are below.

Typical Metals found in electrical oils	
Test Name	Example source
Iron (ppm)	Alloys used in coil construction (usually with copper or Aluminium), or Debris from sampling valve when not flushed correctly.
Copper (ppm)	Alloys used in coil construction, bearing pump shaft / impeller wear in pumps (where fitted to cool transformer) or Debris from sampling valve when not flushed correctly. Copper from corrosive sulphur presence.
Aluminium (ppm)	Alloys used in coil construction and bearing pump shaft / impeller wear in pumps (where fitted to cool transformer).
Lead (ppm)	Brazes, Solders, lead based paint and bearing pump shaft / impeller wear in pumps (where fitted to cool transformer).
Zinc (ppm)	Plating, brazes, solders, bearing pump shaft / impeller wear in pumps (where fitted to cool transformer) or Debris from sampling valve when not flushed correctly.
Silicon (ppm)	Silicone fluids, Silicone grease, caulking sealant, Environmental Dirt (with Aluminium), damaged / overheated gaskets
Silver (ppm)	Bearing pump shaft / impeller wear in pumps (where fitted to cool transformer)
Tin (ppm)	Bearing pump shaft / impeller wear in pumps (where fitted to cool transformer), or Debris from sampling valve when not flushed correctly.

**Corrosive Sulphur (60ml), DBDS (100ml) and Passivators (100ml)** – Sulphur containing compounds (organo-sulphur compounds) exist in mineral oil based products as it is part of crude oil. Generally, as the oil is treated to make the different base stocks the reactive sulphur compounds are removed. However, poor refining or contamination can lead to reactive sulphur compounds that at high temperatures (e.g. at switching equipment) can attack copper electrical contacts. The corrosion can include the formation of copper-sulphur compounds e.g. copper (I) sulphide ( $\text{Cu}_2\text{S}$ ) – known to mineralogists as Chalcocite (from the Greek *khalkos* meaning copper). This  $\text{Cu}_2\text{S}$  deposition into the paper insulation can lead to a drastic drop in insulating properties of the paper and lead to overall equipment failure. Presence of Dibenzy disulphide (DBDS), commonly used as an anti-oxidant in rubbers, stabilisers and as a silicone oil additive can also lead to  $\text{Cu}_2\text{S}$  deposition at relatively normal operating temperatures. Metal passivators such as tolyltriazole derivatives (~100ppm) are used to inhibit the chemical reactions between copper and sulphur within the insulating fluid.

**Diagnostic significance:** This is particularly important to monitor where the equipment is paper insulated, at equipment running at high temperatures with low oxygen (e.g. where gas blankets are used) or where unvarnished / coated copper is used within the system. Additionally any measurement of low passivator content within the oil should automatically schedule a corrosive sulphur measurement.

**Density (15ml)** – This is useful for type of fluid determination (mineral vs synthetic fluids). It tends to be used in cold climate situations where water freezing within the transformer can lead to sufficient density reduction that it floats on top of the fluid rather than the other way round. This can cause problems with electrical circuits when it melts.

**Dielectric Dissipation Factor – DDF - (aka TAN Delta) (65ml), Power Factor (PF) (65ml) and Resistivity (65ml)** – DDF is a measure of how dielectric strength is dissipated as heat. Another measurement is Power factor, which is the same test as DDF, except the measurement phase angle is different when calculating the value. With both DDF and PF, a low value means very little is lost as heat, but a high value suggests it is being lost as heat, typically owing to contamination. Resistivity measures the resistance of the fluid to conduct. Oil is naturally a poor conductor and it is the contamination within the fluid that increases conductivity and hence reduces resistivity. It is different to dielectric breakdown that rather than measuring the uncontrolled breakdown of the insulation leading to an arc or spark, it allows monitoring of the resistance drop and current flow caused by contaminants in the fluid.

*Diagnostic significance:* With contamination increase resistivity and dielectric breakdown would both be expected to decrease, whilst DDF and PF increase.

**Flash point (120ml)**– This is usually used where safety regulations require this test on the fluid. The predominant cause of a low flash point is contamination with solvent, but also in very serious accumulation of fault gases from extensive sparking discharges. Hence, this naturally compliments DGA (see above) analysis that detects and identifies these fault gases.

**Furans (FFA) and Est. Degree of Polymerisation (DP) (60ml)**– Furans, or Furfuraldehyde (FFA) occur upon thermal degradation of paper insulation. It is an excellent indicator of the condition of the paper insulation within the transformer. A high result suggests the paper insulation is in a poor condition. The paper insulation is made of cellulose, which is a long chain of glucose (sugar) molecules that forms the structure we are familiar with as paper. Estimated Degree of Polymerisation (DP) provides an estimate of the average chain length (i.e. how many glucose molecules make up a cellulose chain). New paper will typically have a value between 1000 and 1500, but as it dries this will reduce to between 900 and 1200 in the new transformer. If the paper is intact then the DP will remain steady near the new transformer value. However, as the paper insulation degrades the chains will break and the average chain length (est. DP) will decrease leading to a reduction in DP. A low DP suggests the paper insulation is in poor condition.

Diagnostic significance: FFA can be broken down into its constituents to identify the failure type.

Symbol	Full Name	Failure Type
5H2F	5-hydroxymethyl -2-furaldehyde	Oxidation
2FOL	2-Furfurol	High Moisture
2FAL	2-Furaldehyde	Overheating / old faults (lasts a long time). Used for Est. DP.
2ACF	2-acetylfurn	Rare – lightning Strikes.
5M2F	5-methyl-2-furaldehyde	Local Severe overheating

Levels of 5H2F can increase in the presence of high oxygen – e.g. if system is free breathing and does not have a gaseous blanket. This is only traditionally observed on Kraft rather than thermally upgraded paper in the system.

The oil to paper ratio – typically 20:1 should be taken into consideration when accessing the severity of the furans present with the value becoming more significant the higher the ratio becomes.

**InterFacial Tension (IFT)** – (50ml) – This can be oil-water or oil-air. Most commonly used for electrical oils is the oil-water IFT. A high interfacial tension suggests the oil and water separation is being maintained at the interfacial surface. This is because the oil is non-polar whilst the water is polar meaning the surfaces are separated.

Diagnostic significance: When the oil becomes oxidised or sludges the oxidised products (which are polar) lead to a reduction in the IFT. Equally incompatibility of two fluids, or contamination (e.g. water/dirt etc) added to the electrical oil system will also lead to a reduction in IFT. Overall it is an excellent tool in confirming overall deterioration of the fluid. A high IFT helps maintaining oil seals, so IFT should also be added to a suite if there is excessive or sudden leakage from the system.

**OQIN (Oil Quality Index) / Myers Number** (65ml) – This uses the interfacial tension divided by the acidity or acid number data to determine the overall oil condition.

OQIN Index	Classification
300-1500	Good Oils
271-600	Proposition A oils
160-318	Marginal Oils
45-159	Bad Oils
22-4	Very Bad Oils
9-21	Extremely Bad Oils

**Polychlorinated biphenyls (PCBs)** (20ml) – PCBs were discovered in the mid 1800s as a by-product of coal tar, which a few decades later was successfully synthesised in a laboratory. The non-flammable properties were used widely in the 1920s and 1930s. Over the following decades papers were

published identifying PCBs as a toxin (owing to its high chlorine content) and in the 1970s it began to be officially recognised as such with its use being limited entirely to 'closed' systems such as transformers. Its use began to be restricted and eventually banned in the 1980s onwards, but each country has its own regulations for handling, transport and disposal.

*Diagnostic significance:* Limits used for regulations and transport as they are based on government regulations are subject to change, but typical maximum limits are 50ppm (caution) and 500ppm (serious). It is advisable to confirm the regulations in your local authority for disposal of PCBs.

This is predominantly important for when changing transformer oils and hence wishing to dispose of the old oil. However any electrical system built prior to 2000 should be monitored regularly owing to the likelihood of PCB content / contamination.

**For more information see your local government environmental / safety regulations e.g. <http://www.hse.gov.uk> or [http://www.doeni.gov.uk/niea/ann\\_reg\\_ofpcbholders\\_guidance\\_web.pdf](http://www.doeni.gov.uk/niea/ann_reg_ofpcbholders_guidance_web.pdf)**

**Pour Point** (45ml)– This is predominantly used where the electrical oil is likely to be in very cold climates. It is commonly combined with a viscosity test as they help provide information on the oils ability to flow.

**Viscosity** (30ml)– This is a test performed as standard on lubricating oils, but tends to be a none-standard test on electrical oils. This is because the viscosity dictates how easily the fluid will flow through convection fins, as part of the transformer cooling system in the transformer to dissipate heat. Only under extreme conditions of excessive oxidation would a change (increase) in viscosity be significant.



## Fuel Testing – Why Test fuel?

Apart from mandatory regulations requiring fuel testing, there are several additional reasons to do regular fuel analysis to keep your machinery protected and reduce fuel costs.

**Reduce fuel costs:** Monitoring fuel condition and quality means that combustion of the fuel is efficient and there is reduced damage to the injectors to cause excess fuel dosing. Both of these help save money on fuel consumption costs.

**Protect engine & fuel system.** Fuel quality and condition impacts your engine significantly. For example it can be linked to:

- Injector wear & seizing.
- Fuel wash and upper cylinder wear.
- Excess soot generation and engine gelling.
- Fuel filter plugging / blocking.
- Lube oil additive depletion.

*Case Study 1: (Marine) – An off-specification fuel was used in a container ship in place of the correct specification of fuel. The fuel in the bunker was predominantly the correct fuel, but there was approximately 5% to 8% contamination with a different specification fuel/solvent. The root source of this contamination was not found, but the insurance claim after the dry-dock replacement of the failed part was for 1.9 Million Euros to repair the engine damage.*

*Case Study 2: (Marine) – After bunkering with a heavy fuel oil an insurance claim of 550000 EURO was placed to repair the 8 cylinder liners required replacing due the presence of contamination with Cat Fines in the fuel oil (used during the refining process of the fuel) .*

**Environmental impact & Safety:** Since fuel is combusted, this has significant environmental implications surrounding air quality and emissions as well as safety regulations regarding flashpoints during transportation.

**Specification, Taxation & Warranty:** Engine OEMs need consistency in the products being used as fuel so that their machinery can be designed to run safely and efficiently at all times. Finally, since fuel is an expensive and taxable commodity in most regions, it is also important to confirm what is being purchased meets the specification criteria required so the correct price and tax can be applied to the product at the point of sale and delivery.

Overall, a fuel health check determines if your fuel is fit for use and whether it requires purification, addition of additional additives / biocides or simply needs purging from your machinery system.

# Diesel Fuel Testing – Routine Testing

**Note** – Fuel regulations are constantly changing and also vary by country. The threshold values used in this document are based on latest information as of point of writing based on UK regulations, but if in doubt some limits may be outdated please contact the laboratory (+44 (0) 1492 574750) / [techservice@alcontrol.com](mailto:techservice@alcontrol.com) if you have any questions. Additionally, ask for if there have been any updates to this guide to reflect any new regulation limit changes.

Much of the testing is performed to confirm the fuel meets specification at the point of the refinery. There are often complex transportation and supplier chains before the product finally meets the client and the product can be held in bulk storage where contamination can occur over time. Hence, in addition to the standard refinery testing to specification that is performed there are additional places where fuel testing can be performed.

- **Specification testing** - testing to full standard specification of fuel – commonly a mandatory requirement. Examples include:
  - **Point of sale to client** – confirmation product meets requirement at point of delivery.
  - **Periodic spot checks** – usually annual, especially on critical pieces of equipment, or where more than one fuel type is used on site to confirm no cross-contamination.
- **Condition Testing** - confirmation fuel has not been contaminated during bulk storage. These are generally more condensed suites to look for contamination such as dirt, water and microbes. Examples include:
  - **Bulk storage tank checks** to confirm no water, dirt or microbial growth. Usually performed 3 monthly, or post tank cleaning. Bulk tank testing is usually performed in two locations:
    - **Bottom of tank** – To identify sediment, water and sludges that require drain off.
    - **Centre of tank** – to identify overall condition of the bulk of the tank.
- **Warranty Testing** - confirmation correct fuel has been used in the machinery for warranty purposes. This is commonly requested by OEMs to confirm if a failed machine is covered by warranty and if the warranty has been invalidated by mis-fuelling. Examples include:
  - **Any machine failures** where suspected fuel faults.
  - **Suspected mis-fuelling** e.g. Petrol in diesel.



**Elemental Analysis** - See our [YouTube video](#) (minutes 16 to 18) for principles of how this test is performed.

*Diagnostic significance:* This is usually used to test for presence of lubricating oil contamination (calcium, Magnesium, Phosphorus or Zinc), as well as Iron corrosion in bulk storage tanks and the sulphur is within specification. In marine applications Vanadium and Nickel are also good indicators of cross contamination with heavy fuel oil products.

### **Elemental Analysis – Sulphur (30ml)**

This is the most commonly monitored fuel property on diesel across all industries. This is because regulations have continuously lowered the level of allowable sulphur to be used owing to its environmental implications and its link to emission gases causing acid rain. Additionally, sulphur in the presence of water (produced in the combustion process) forms sulphuric acid – battery acid, which means more acidic by-products causing corrosion to engine parts (see earlier sections “Tests on Lubetrend report” - Acid number and Base number). Finally, sulphur in the form of active sulphur can lead to corrosion of injection system components (see copper corrosion). This has meant that, for example, some fuel regulations have reduced sulphur content from 1000ppm to as low as 10ppm over the space of a decade.

Sulphur maximum limits are also variable by industry and application with a fuel acceptable for off-highway standby generators not acceptable for combustion in a road operating vehicle. In addition, in the marine industry bunkering in one location with different regulations for fuel, can mean although the sulphur is acceptable in one location, it cannot be burnt in another location – hence the need to monitor every batch of fuel, even if the fuel met specification at point of sale. One of the problems in lowering the sulphur is that despite its obvious disadvantages, sulphur is an excellent lubricant and so the constant lowering of sulphur content causes headaches for both OEMs in operating more fuel efficient fuel injection rail systems with tighter tolerances as well as fuel suppliers in supplying fuel with sufficient lubricity properties to prevent injectors seizing.

### **Water Content (20ml)**

Water is a poor lubricant, causes corrosion, promotes microbial growth and also is not combustible, so its content needs to be tightly monitored to ensure efficient operation of the machinery. It additionally is not taxable, so in transport chains its content needs to be monitored closely to determine if 50000L of bulk delivery fuel is indeed that or if 500L of it are water for instance. In a market where exceptionally large quantities of bulk fuel storage fuel are bought and sold each day, and profit margins in the industries buying the fuel are quite small, any additional expense that should not be incurred can have a big impact on the businesses involved.

*Diagnostic significance:* The cause of water is usually due to fuel storage conditions in that tanks ‘breathe’ – i.e. the air temperature in the day and night changes meaning there is a constant circulation of air – usually through breathers – into the tank. At night this cool air condenses on tank walls and

over time there can be a large build-up of water content in the storage tanks. Additionally, tanks tend to be drained or pumped from the bottom meaning if the tank has not been disturbed for a long time water sinks to the bottom of the tank because water is denser than fuel. This means that even low water contents overall, are found in high concentrations when drawing from the tank bottom.

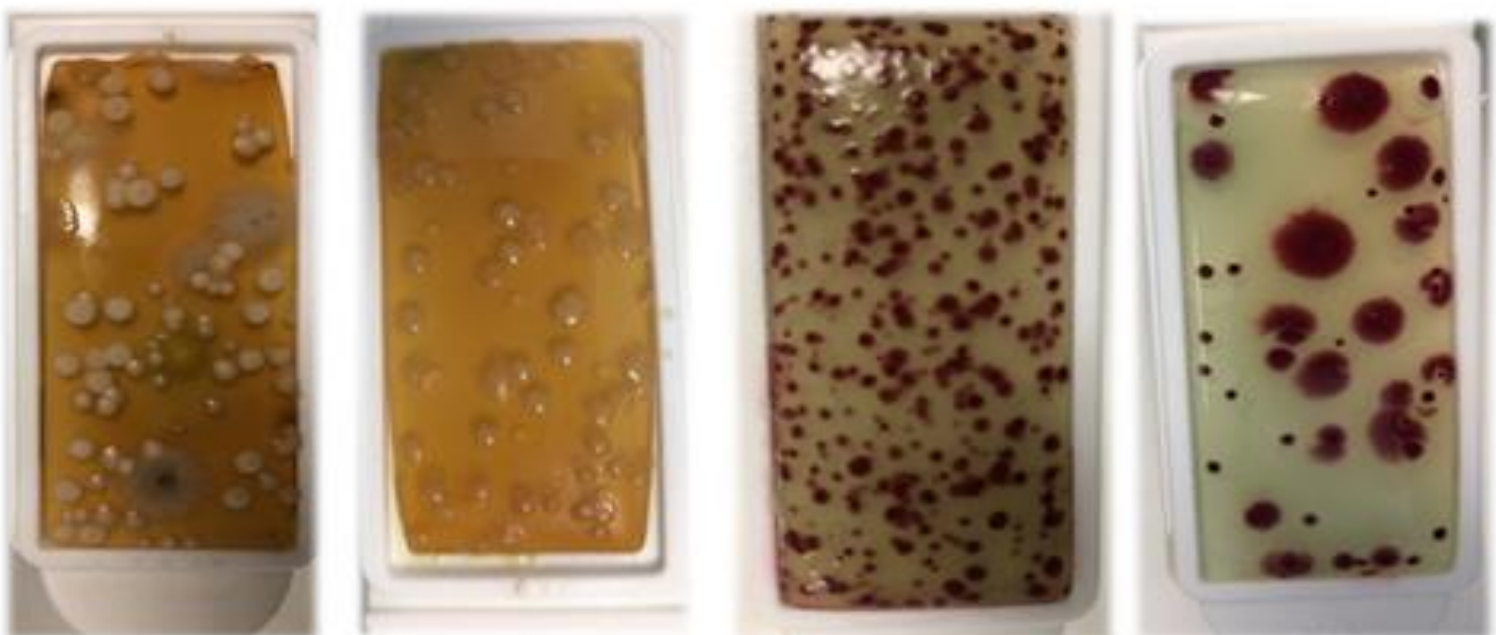
### **Cleanliness – Sediment or ISO cleanliness (30ml)**

The most common failure type of a fuel sample when testing to fuel specification is due to environmental contamination such as dirt. Dirt is usually removed by the fuel filtration systems, but the tolerances and pressures of injector rails means that it is not practical to have filtration at sizes smaller than the tolerances of the injectors meaning very small particulate matter may pass through and cause injector seizing or scoring. For this reason it is important to keep the fuel exceptionally clean owing to the fine tolerances of the parts in use.

Cleanliness can be measured by ISO cleanliness code routinely (see “tests on lubetrend report – contamination section to explain more about ISO codes”). However, as part of specification testing it is usually measured by gravimetric filtration where a filter patch (usually 0.8µm pore size depending on method used) is weighed before and after filtering a set volume of fuel to determine the weight of the insoluble contamination.

### **Microbial Growth (10ml)**

Microbial growth is usually only present when water is also present in the system as all known cellular life requires liquid water to thrive. Hence, minimising water content is an excellent way of reducing microbial growth. The reason microbial growth is so important is that they tend to get filtered out by the filtration system in addition to water and the filters act as an excellent breeding ground for microbial growth. This growth can completely block filters meaning insufficient fuel reaches the injector rail and the engine stops.



**Fungi**

**Bacteria**



There are two main ways of detecting microbial growth. One is to measure as a culture, where the microbes are incubated for sometimes several days or even weeks to identify the number that grow per volume, termed Colony Forming units (CFU/ml). This is useful for determining the microbe type e.g. bacteria/fungi or yeast/mould so that a suitable biocide may be used. However, please note local regulations vary on the use of biocides in fuel systems – so please check with your local authority if you can use them. The use of tank cleaning services where the tanks are flushed and cleaned is becoming more common – in these cases the particular organism is not as significant and the speed of testing becomes more relevant. In these situations, fast turnaround test kits are quite popular. These can produce results in just a few hours of microbial activity by biochemistry as opposed to microbiology. cATP looks at the presence of life by life-presence confirming biochemical reactions as opposed to culturing and growth. The testing is usually more expensive than performing standard culture methods, but does give a faster result, which in critical equipment is usually something that is worth the extra cost.

## Fuel (Diesel) – Specialist / Specification Testing

**Ash** (20ml)– In method IP4 (ASTM D482) a measured weight of sample is burned in a crucible until ash and carbon are the only remaining products. The residue is then heated in a high temperature furnace at 775°C to remove the carbon, leaving only the ash. Upon cooling the ash is weighed to give the percentage ash of the total product.

*Diagnostic significance:* The ash can come from lubricating oil, metallic deposits / cat fines or solids such as dirt and rust. This measures the amount of ash forming material to identify if combustion will produce unacceptable deposits affecting both cylinder wear rates (as these are abrasive) as well as particulate emissions. The Abrasive ash content contribute to fuel pump, piston, ring and injector wear and can ultimately lead to an upper cylinder and engine failure if severe.

**Calculated Cetane Index** (150ml)– This is used as an alternative to expensive actual engine test-bed testing on a single cylinder comparing performance with blends of n-hexadecane (straight chains) and alpha-methylnaphthalene / heptamethylnonane (non-straight chains of carbons). The method looks at Density/API Gravity and the mid-boiling point of the fuel to give an estimated Cetane Value, termed the cetane index.

*Diagnostic significance:* The test is used to identify the level of contamination with non-straight chain hydrocarbons and aromatic products, with the higher the value indicating lower aromatics / double bonds, meaning less energy will be required to break these bonds, a shorter ignition delay a more efficient combustion process. This is an excellent test to use on diesel fuel and is used similarly to octane rating on petrol fuels as a diagnostic tool for ignition delay problems. Ignition delay is where there is a prolonged delay between time of injection and combustion, leading to a rapid rise in pressure due to the accumulation of fuel before combustion. This rise in pressure can cause an



audible knocking sound, and caused increased stress on bearings and liners from this vibration. This is a test that is very unlikely to fail routinely as the refining processes in manufacturing diesel are usually excellent. Hence it is usually contamination with another product that is the cause of low cetane indices.

**Carbon / Micro-Carbon residue (10% bottom)** (10ml)– This method looks at the tendency of the fuel without additives to form carbon deposits.

*Diagnostic significance:* This shows the tendency of the fuel to cause 'coking' of the engine. The deposits left behind may form heat insulated hot spots and high stress cracking. Additionally, the hot spots can lead to deposit formation in injectors (blocking / scoring the injectors) and potential pre-ignition.

**Copper corrosion** (35ml) – See "Specialist Lubricant Tests" for details of this test, which are also performed on lube oils.

*Diagnostic significance:* This is only likely to be abnormal if contaminated with another product with high sulphur. Its importance is on its effects and tendency to corrode copper parts of the fuel system.

**Cloud Point, Pour Point and CFPP** (45ml) – See "Specialist Lubricant Tests" for details of this test, which are also performed on lube oils. One particular issue with fuels is when the fuel gets to low temperatures the system does not normally heat the fluid above atmospheric temperature (as in a lube system). This means wax crystals may not dissolve after forming even when temperatures return to above the cloud point are reached as the crystals require additional energy to re-dissolve above the cloud point. Wax is difficult to dissolve as it is a good insulator as well.

*Diagnostic significance:* Their significance is really in its ability to be pumped and block the fuel filters and exposed fuel lines at cold temperatures due to precipitation of wax causing restrictions in flow. Pour point is particularly useful to identify the lowest temperature the fuel can be pumped between bunkers and tankers etc. Pour point can also be used to determine the effectiveness of pour point improver additives, which help inhibit wax precipitation.

**Distillation Testing** (120ml)– The distillation heats up and boils the fuel to determine the volatility and different fractions within the fuel mix. This is important as volatility effects fuel economy, soot formation / engine deposits, exhaust emissions and overall power output.

*Diagnostic significance:* This is only likely to be abnormal if contaminated with another product. A low initial boiling point (IBP) suggests contamination with a higher volatile fluid. A high 10% recovered temperature can cause difficulties with starting the engine as the fuel is not volatile enough to ignite or the time taken to achieve operating temperature may be extended, meaning longer warm-up time. A high 50% recovered temperature can lead to smoking issues as excessive incomplete combustion. A high 90% recovered temperature increases the risk of engine deposits and fuel dilution as the fuel is not reaching the desired temperatures to completely combust.

**Density** (15ml) – The density of the fuel is an important physical property of the oil like viscosity.

Diagnostic significance: The causes of a high viscosity can be contamination with denser products such as biofuel (FAME), whilst low density can be contamination with less dense solvents or products such as petrol.

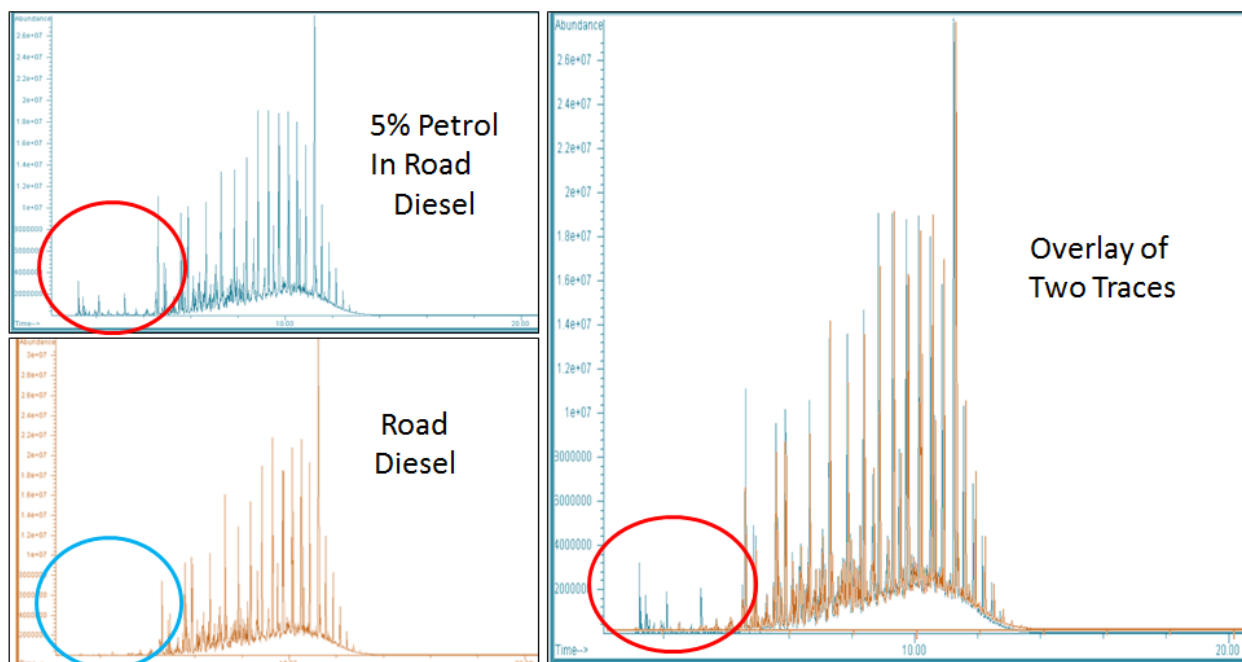
**Flashpoint** (110ml)- See “Specialist Lubricant Tests” for details of this test, which are also performed on lube oils.

Diagnostic significance: The significance is in the safety for transportation (closed cup/mini-flash) where the vapour collects above the sample in the headspace of the container and can flash to form a fire. Maximum storage temperatures are usually a minimum 10°C less than the flashpoint.

**FAME (total) – Fatty Acid Methyl Ester – Biofuel** (25ml) – As diesel is not a renewable fuel source, renewable sources such as rapeseed or palm oil derived fuels are now being introduced into diesel fuel blends to give a renewable source to the fuel. The amount that can be used differs by country and OEM ability to run the fuel type, but UK regulation is max 7% for EN590 specification, but parts of Europe use 20%, 80% or even 100% biofuel blends.

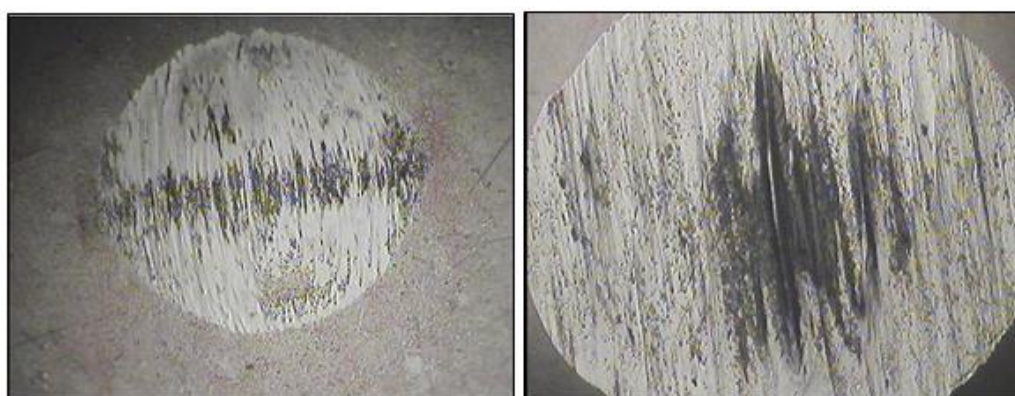
**Gas Chromatography / Mass Spectroscopy (GCMS)** (20ml) – Diesel, mineral oil, petrol or heavy fuel oil are not a single molecule throughout and are actually a mixture of various lengths of carbon chains to give an overall blended product. Hence no two samples of diesel will be exactly the same and there can be slight variations depending on crude oil used. Gas Chromatography/Mass Spectroscopy methods use different column types to separate a mixture of chemicals such as diesel into their individual components based on properties such as mass or charge of the molecules. Similar to filter paper chromatography that most people will be familiar with, the individual components are separated out so that comparisons can be made.

Diagnostic significance: There is no specification testing that requires GCMS. However, it is an excellent tool in identifying problems otherwise not detected by specification testing, or identifying the root cause of a specification failure. For instance a low flash point, density and viscosity on the specification may point to a low flash point product contaminating the fuel, but GCMS is required to identify what that contaminant may be. A classic example of mis-fuelling with petrol into a diesel tank is shown below.



**GCMS Use in identifying Petrol in diesel.** Bottom Left shows typical road diesel purchased from local fuel station. Top left shows road diesel with 5% petrol contamination. The right hand trace shows the overlay of both traces. In each case the ringed area is the point of interest on this trace when identifying the petrol contamination.

**Lubricity** (20ml) – The lubricity of a diesel fuel can affect the engine components such as fuel injection pumps. The most common method used to determine lubricity is the high-frequency reciprocating rig (HFRR) method. In this method a vibrating non-rotating steel ball loaded with a specified mass, is lowered onto a disk submerged in the test fuel at a set temperature and time period. At the end of the test the wear scars on the ball are measured x100 magnification to determine the length of the scar in microns ( $\mu\text{m}$ ), with  $<250\mu\text{m}$  being good,  $>600\mu\text{m}$  being bad and the target being set usually at a maximum of  $460\mu\text{m}$ .



**Lubricity Wear scar images (both at same magnification).** Left the sample had a scar size of  $394\mu\text{m}$  (pass), whilst the scar on the right was  $685\mu\text{m}$  (fail).

**Diagnostic significance:** A high result suggests the fuel not only fails specification, but injectors are more likely to seize and overall component life is expected to decrease.

**Oxidation Stability (Accelerated)** – (600ml) – Traditional oxidation stability testing involves testing over methods up to 24 weeks, which, apart from research purposes, is not practical for the time constraints and turnaround times required for specification confirmation and condition monitoring. Hence, most labs use accelerated methods for determining oxidation stability e.g. ASTM D2274 in which a fixed volume of fuel is bubbled with oxygen at a specific rate and temperature. The total filterable and adhesive insolubles formed during the test as measured in kg/m<sup>3</sup>.

Diagnostic significance: Even if, at point of testing, your fuel passed specification, over time the fuel ages and becomes contaminated. The level of which is determined by the several variables including age of fuel, storage conditions and local environment. If tanks are not fully drained, contaminated or aged fuel can accelerate the oxidation of fresh fuel when topped up. Causes of high oxidation stability can be because the sample has been stored in a tank with high sediment and water, which can lead to fuel darkening, blocked filters and lacquering. Once the contamination is removed, the fuel may not be fully stable, in which fuel anti-oxidant additives may be used to improve the oxidation stability of the fuel.

**Viscosity** (10ml) (see “tests on a LubeTrend report – Fluid condition” for more explanation on viscosity testing principles.) The viscosity is important to ensure effective flow of the fluid through injection nozzles, fuel lines and orifices.



Diagnostic significance: The viscosity is an important physical property. Causes for high viscosity include: too high biofuel, lubricating oil or heavy fuel oil contamination, whilst too low viscosity can be caused by solvent or petrol contamination.

# Fuel (Diesel) – Typical Specification Limits used

Limits based on EN590: 2009 for Road vehicles / coastal vessels, BS2869: 2010 for off-road highway vehicles and stationary applications, and ISO 8217 for marine applications (none-costal). Regulations change by country, so consult your local authorities to for regional differences.

		Road (EN590: 2009)		Offroad (BS2869: 2010)				Marine (ISO 8217: 2010)							
		Automotive		Off-road mobile		Off-road Stationary		DMX		DMA		DMZ		DMB	
Test	Units	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Viscosity @ 40C	mm <sup>2</sup> /s	2.0	4.5	2.0	5.0	1.5	5.0	1.4	5.5	2.0	6.0	3.0	6.0	2.0	11.0
Density @ 15C	Kg/m <sup>3</sup>	820	845	820		820					890		890		900
Calc. Cetane Index	-	46		45			45	45		40		40		35	
Carbon residue (10% bot.)	%		0.3		0.3		0.3								0.3
Dist. Recovery @ 250C	%		65		65		65								
Dist. Recovery @ 350C	%	85		85		85									
95% recovered at	°C		360												
Flash Point (closed)	°C	55		56		56		43		60		60		60	
Sulphur	mg/kg		10		10 (at Manufacture) 20 (at distribution)		1000		10000		15000		15000		20000
Ash content	%		0.01		0.01		0.01		0.01		0.01		0.01		0
Water content	mg/kg		200		200		200								3000
Contamination/Sediment	mg/kg		24		24		24								
Oxidation Stability	g/m <sup>3</sup>		25		25		25		25		25		25		25
Copper corrosion (3h @ 50C)	rating		1		1		1								
FAME	%		7 (in UK)		7 (in UK)		7 (in UK)								
Lubricity wear scar at 60C	µm		460		460		460								
CFPP			-4 (UK Mar to Nov) -12 (UK Nov to Mar)		-4 (UK Mar to Nov) -12 (UK Nov to Mar)										
Pour point	°C										-6 (winter) 0 (Summer)		-6 (winter) 0 (Summer)		0 (winter) 6 (Summer)
Cloud point	°C								-16						
Strong Acid number	mgKOH/g				None		None								
Hydrogen Sulphide	mg/kg								2		2		2		2
Acid Number	mgKOH/g								0.5		0.5		0.5		0.5
Sediment (hot oil filtration)	%														0.1
Appearance	-							Clear & Bright							



## Engine Coolant Analysis

Engines convert only  $\sim 1/3$  of the energy from fuel combustion into kinetic energy to move the crankshaft. This leaves over  $2/3$  of the energy as heat through the exhaust ( $1/3$ ) and conduction through the engine block ( $1/3$ ). Water is not the ideal coolant because it boils at a reasonably low temperature compared to the engine temperatures and freezes during winter in all but the warmest of climates. Engine coolants (anti-freeze) have a high boiling point and low freezing point using mixtures of glycol (ethylene or propylene), corrosion inhibitor additives and deionised water.

Ethylene glycol is the most extensively used glycol, but with progressively strict environmental / toxicity requirements and the increased use of biofuels in which propylene glycol is a waste product of manufacture, propylene glycol is now becoming popular. These formulation types are built to specific OEM requirements. Mixing coolant types is not recommended and can compromise coolant condition, reducing its effective life and protecting properties on the engine.

With the emissions regulations tightening, there is a tendency for engines to run hotter; a potential problem when typical aluminium alloys are difficult to protect in high heat with traditional coolant technologies. This has led to Extended Life Coolants (ELCs) to combat the greater demands on the cooling systems. These deliver much of the functionality of Supplementary Coolant Additives (SCAs) to achieve by using Organic Acid Technology (OATs) additives. This increasing dependence on reliable coolant technology for efficient and reliable engine performance has also increased the demand for engine coolant sampling to compliment the already well established lube oil sampling programmes of customers.

### **Start your coolant programme by sending an unused reference sample.**

Before starting your coolant analysis programme, owing to the vast differences in coolant additive technologies on the market, it is advisable to send references of all coolants in use with their product datasheets before starting your programme so that a baseline reference can be obtained of which additive package is in use. Furthermore confirm with the laboratory whether the filters in use contain SCA additives so that correct recommendations can be made if additives are low, and can identify the source of problems e.g if a pre-charged SCA filter has been accidentally used with an ELC coolant.

**Appearance, Clarity and Colour** - Part of the engine coolant assessment begins at sampling with a brief visual inspection of the sample, which can be performed both by the laboratory and sampler. Appearance photographs can also be included on your Lubetrend report on request – click contact us at [lubetrend.com](http://lubetrend.com) for details.

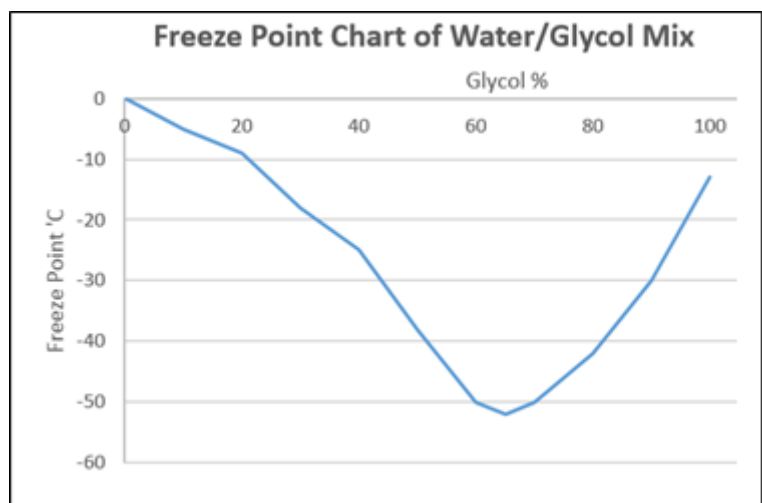
**Diagnostic Significance:** The visual inspection looks for clear and bright coolant with no hazy or opaque appearance, which could suggest degraded / contaminated or incompatible coolant mixes. Engine coolants tend to be brightly coloured and should stay roughly the same colour as when first taken from the coolant container. A change in colour or browning in colour can suggest mixing of coolants, coolant degradation or contamination.

**Appearance – Visible Debris** – This is the most common abnormal flag for engine coolants and so deemed its own section. The samples as part of the appearance inspection identify any deposits, debris or sediment in the sample.

**Diagnostic Significance:** The sample should preferably have no visible debris, but in practice this is not always possible even with excellent sampling procedures. It is important to distinguish between 1 or 2 insignificant dirt particles that occurred at sampling compared to the more serious sediment caused by additive drop out, rust, hard water soap deposits, etc. These deposits can suggest corrosion to oil cooler/radiator or water pumps or poor coolant mixing with tap water. Further, evidence of emulsification or a visible floating hydrocarbon layer suggests evidence of fuel or oil, which could indicate either poor sampling, poor coolant storage or a leak between oil and coolant systems. This can be confirmed by sampling oil for the presence of coolant contamination and pressure checking the coolant system.

**Glycol Concentration & Freeze Point** – Glycol concentration is one of the major factors for both maintaining a sufficiently low freeze point for cold winter climate as well as maintaining a high boiling point to ensure the fluid does not boil at operating temperatures.

**Diagnostic significance:** This level is unlikely to change due to a machinery fault and a too high or too low concentration is typically owing to operator error in topping up with either too high or low concentrated mix. Hence, why it is often recommended to top-up with pre-mixed coolant where available to safeguard this does not occur. The protection of the engine is maintained by having an optimum level of glycol for operation, but too much glycol can also lead to a decreased effectiveness in maintaining a low freeze point (see chart to right), which shows that for an example product above 60% glycol, the effectiveness starts to decrease. This is because water is required for efficient heat transfer to the coolant mix.



**Typical Diagnostic Limits:**

Glycol – Low typically <40% and high >60%. However, a common manufacturer recommendation is to have at least 33% and some pre-mix coolant solutions with OEM approval are supplied at 20%. Therefore, it is best to consult your engine manufacturer or coolant supplier if they have any bespoke recommendations for your equipment.

Freeze Point – This depends on environmental conditions and is usually country specific. E.g. arctic areas would require a lower freezing point than desert areas.

**pH** – This indicates the acidity (low pH) or alkalinity (high pH) tendency of the coolant.

*Diagnostic significance:* Too high or too low a pH can lead to metal corrosion in the coolant system. The usual reasons for a pH change are either coolant degradation or contamination with another product.

Causes of low pH include:

- Air leaks
- Combustion gas leaks (usually pH <7)
- Improper coolant levels maintained in system
- Low additives if mixing own SCAs (conventional coolant)
- Electrical grounding issues (note changes in odour)

Causes of high pH include:

- High additives if mixing own SCAs or mixing ELC coolant with SCAs; possibly by SCA filter
- Mixed coolants
- Contamination with an alkali water based product

*Typical Diagnostic Limits:*

Conventional coolants – Min 8.5 to Max 11.0

Extended life coolants – Min 7.5 to Max 9.5

**Total Dissolved Solids (TDS)** - This is a measure of the total dissolved cations, anions and organic compounds dissolved within the sample.

*Diagnostic significance:* A high value can indicate either contamination with the system such as hard water components, or over-dosing with SCA additives. A typical maximum value is <20000 ppm. At high values the clarity of the product will start to become hazy too.

Possible Actions to take when high include confirming if using deionised water and check if SCA filter is overdosing system.

**Reserve Alkalinity** - This measures the ability of a coolant to neutralise acids e.g. glycol breakdown products or via exhaust gas leaks into the system. The rate of deterioration can indicate the severity of a fault and also be used to predict a coolant change.

*Diagnostic significance:* Too low a value and the protection of the coolant system may be impaired.

**Conductivity** - This is the total measure of electrically charged particles (anions and cations) within the system. The higher the number, the higher the

contamination within the system because the particles make it easier for the fluid to conduct electricity.

**Diagnostic significance:** A high value can indicate either contamination with the system, e.g. hard water or over-dosing with SCA additives.

**Total Hardness** - This is the sum of total calcium and magnesium hardness within the system.

**Diagnostic significance:** Any hardness is an indicator of potential poor water quality and deionised water should always be used when producing coolant mixes. A typical limit maximum would be 85ppm.

**Ion Chromatography (IC)** - This looks at the negatively charged particles not normally detected by traditional coolant testing methods. This detects contaminants, inhibitors and degradation acids caused by air leaks, hot spots, electrolysis and general overheating.

Anion	Coolant Breakdown	Max limit			
Glycolate	Stage 3 breakdown product of Glycol (see Glycol breakdown products). Associated with overheating or hot spots. As Acid increases pH drops and iron corrosion is likely.	Caution : 1000ppm Serious: 2500ppm			
Oxalates	Stage 5 breakdown product of Glycol (see Glycol breakdown products)				
Formate	Stage 6 breakdown product of Glycol (see Glycol breakdown products)				
Anion	Contamination & Corrosion	Max limit			
Bromide	Bromide based solder corrosion in copper based radiators.	Serious: 110PPM			
Chloride	Contaminant from tap or sea water ingress. Can lead to hydrochloric acid formation, pH drop and deterioration in coolant condition.				
Sulphates	Usually indicates hard-water soaps e.g. tap water calcium sulphates that form scale in the system under alkali conditions, or can form sulphuric acid under acidic conditions.	Serious: 300ppm			
Anion	Additive	TL	TH	H	OAT
Molybdate	In addition to Nitrite another common SCA additive used.	SCA	SCA	Y SCA	Y
Phosphates	pH buffer to provide iron corrosion protection. Over-dosing the system leads to sediment deposition and plugged cooler / radiator. These cannot be used with aluminium based systems. May also be from left over cleaning agents if radiator recently cleaned.	Y	Y	Y	N
Nitrates	Sometimes a coolant additive, but an increase associated with a nitrite decrease suggests either an air leak or an electrical short in the system causing electrolysis based breakdown.	YY	YY	Y	Y
Nitrites	Nitrites are traditionally an anti-corrosion and anti-cavitation coolant additives to protect coat copper, iron and aluminium – particularly sleeves. Usually found in older technology systems as this additive can rapidly degrade to nitrates by oxidation and air leaks leading to SCA addition requirement. In ELC the products are usually nitrite free or hybrid formulations, using Organic Acid Technology (OAT) to get extended life. This is why the information on which product is in use is essential for diagnosing.	Y SCA	YY SCA	Y/N SCA	N
		New coolant >1200ppm. >350ppm when Nitrite/Molybdate SCA mix used.			<30ppm if nitrite free.

TL = Traditional Light Duty Coolant. TH = Traditional Heavy duty coolant. H = Hybrid coolants. OAT = Organic Acid Technology / ELC (Extended Life Coolants). SCA = Found when SCA (Supplementary Coolant Additives) used. Y = typically used. N = Not typically used. YY = Almost always used. NN = Almost Never Used. Y/N = Depends on product if used.

## Glycol breakdown products

Glycol based coolants have to endure extreme temperatures within the engine and dissipate this heat through the radiator. Eventually, the glycol breaks down and degrades to different chemical compounds. There are several stages to this process. An example with ethylene glycol is shown below, but the process is similar with other glycol types. The process includes

Lubetrend Stages of Glycol Breakdown under high temperature oxidation.							
Stage	1	2	3	4	5	6	7
Name	Ethylene Glycol	Glycoaldehyde	Glycolic acid	Glyoxylic acid	Oxalic Acid	Formic Acid	Carbon Dioxide & Water
Structural breakdown	<p>The diagram illustrates the chemical transformation of ethylene glycol through seven stages of oxidation. Stage 1 shows Ethylene Glycol (CH<sub>2</sub>OH-CH<sub>2</sub>OH) undergoing 'Acid formation (pH drop)' with the loss of H<sub>2</sub> to become Glycoaldehyde (HC=O-CH<sub>2</sub>OH). Stage 2 shows Glycoaldehyde undergoing 'Removal of Alkalis (pH drop)' with the addition of OH<sup>-</sup> to become Glycolic acid (Glycolate) (COOH-CH<sub>2</sub>OH). Stage 3 shows Glycolic acid undergoing 'Acid formation (pH drop)' with the loss of H<sub>2</sub> to become Glyoxylic acid. Stage 4 shows Glyoxylic acid undergoing 'Removal of Alkalis (pH drop)' with the addition of OH<sup>-</sup> to become Oxalic acid (Oxolate) (COOH-COOH). Stage 5 shows Oxalic acid undergoing 'Removal of Alkalis (pH drop)' with the addition of OH<sup>-</sup> to become Formic acid. Stage 6 shows Formic acid undergoing 'Removal of Alkalis (pH drop)' with the addition of OH<sup>-</sup> to produce 2 molecules of Formic acid (labeled as Dicarboxylic Acid formation). Stage 7 shows the final decomposition of 2 molecules of Formic acid into CO<sub>2</sub> and H<sub>2</sub>O.</p>						

**Elemental Analysis (ICP)** - This is a commonly used tool for determining elements in samples by heating the sample in a plasma flame and measuring the wavelengths of light emitted as they cool (further details available in our [YouTube Video](#) minutes 16 to 18).

**Corrosion Types Definitions** - To understand the types of corrosion listed in the corrosion metals, some terms require defining.

- **Whole System or Uniform Corrosion** - A general corrosion of the entire surface metal which is not localised. Typically caused by drops in pH, poor coolant or water condition. Variations on this are sometimes called **crevice corrosion**, which occur in specific parts of the system with little or blocked flow e.g. under gasket, clamps, washers or in small cracks where the coolant forms an acidic microenvironment.
- **Pitting** - Often termed **porous liner**, or **cavitation**. Caused by the formation and collapse of air bubbles (termed condensation nuclei). Usually caused by vibration of system causing vapour bubbles to implode, low coolant pressure, slight imperfections on the surface wall either at manufacturing or by deposition of hard-water soaps / coolant additives.
- **Wear** - sometimes called **erosion**, in which abrasive particles in the coolant wear the coolant system walls.
- **Galvanic corrosion** - This is where two metals in contact with the coolant forms an electrical cell leading to breakdown of one of these metals either due to a manufacturing fault or poor coolant choice.
- **Electrolysis** - This usually occurs when an electrical system fault ends up being grounded by the cooling system, which is essentially an electrolyte and can leads to severe breakdown of coolant systems, particularly in aluminium based systems.



Element	Corrosion Metals	Max Limit			
Aluminium (Al)	Uniform corrosion or wear/erosion from high coolant particulate content. Sources include radiators (if Aluminium based), thermostats, heat exchanges and coolers.	Caution: 10 Serious: 15			
Copper (Cu)	Uniform corrosion or wear/erosion from high coolant particulate content. Sources include radiators (if Copper based), heat exchanges or coolers, and any brass components such as tubes.	Caution: 10 Serious: 20			
Iron (Fe)	Predominantly associated with cylinder liners, but can technically be anywhere in the coolant system as most components have some iron composition.	Caution: 25 Serious: 50			
Lead (Pb)	Typically corrosion to copper alloys in tube-header joints often giving the classic internal solder joint white deposit termed "solder bloom", which leads to blockage of radiator tubes and passages, reducing their ability to remove heat and causing overheating failures.	Caution: 25 Serious: 35			
Silver (Ag)	Rarely seen, but can sometimes be used when repairing problem solder joints owing to its increased durability. Hence, corrosion of this solder suggests a severe corrosion process or points to the maintenance performed previously has not resolved the previous solder corrosion fault.	Caution: 25 Serious: 35			
Tin (Sn)	Commonly seen with copper in bronze, or with lead in tin-lead solder.	Caution: 10 Serious: 20			
Zinc (Zn)	Seen with copper for bass components (radiator, heat exchanger or oil cooler), but also used sacrificially in marine applications as a Zinc anode to prevent corrosion by saline water.	Caution: 25 Serious: 35			
Element	Contamination Elements				
Calcium (Ca)	Usually associated with tap water or poor water quality. These can lead to scale formation within the coolant system when coolant comes into contact with hottest surfaces such as heat exchangers. In addition to causing blockage, scale is also an insulator and so reduces heat exchange through the cooling system.				
Magnesium (Mg)	See Calcium. Usually found ~1/2 the value of the calcium figure. If higher this can be presence of magnesium chloride de-icer pellet ingress used on road surfaces. In marine applications, combined with a chloride increase, the cause may be sea water ingress. In agricultural applications, top-up with contaminated containers or air leaks can lead to magnesium containing fertiliser ingress.				
Element	Additive	TL	TH	H	OAT
Sodium (Na)	Corrosion inhibitor and carrier for other metals. Typically seen in European Formulations.	YY	YY	YY	YY
Potassium (K)	Corrosion inhibitor and carrier for other metals. Typically seen in North American Formulations.				
Silicon (Si)	Aluminium corrosion inhibitor and as an antifoam additive. Traditionally this additive has been used, but on newer engines that require ELCs, the pathways are so small that deposition of the additive can occur leading to system blockage. Silicon can also be a contaminant in the form of sand or dirt.	YY	YY	N	NN
Phosphorus (P)	Seen in the form of phosphate (see phosphate)	Y	Y	Y	N
Boron (B)	Seen in the form of Borate for general iron protection and pH management.	Y	Y	N	NN
Molybdenum (Mo)	See Molybdate.	SCA	SCA	Y SCA	Y

**SCA Number** – This is used when calculating the amount of supplementary coolant additives (Nitrite and Molybdate) within the system so that there is sufficient protection against liner pitting and scaling.

Typical Diagnostic Limits. Values <1.2 require additional charge of SCA additive if system is suitable for their use, whilst values >3.0 units per gallon suggest that the system is over-charged with SCA additive.

# **Section 3 - Lubrication Fundamentals & Investigative Analysis.**

# What is a lubricant?

A lubricant has several valuable functions within machinery. These are:

**Lubrication and Friction Control** – The key lubricant property generally accepted is to separate two contacting and moving surfaces thus preventing metal to metal contact. Failure of this function will lead to abnormal wear.



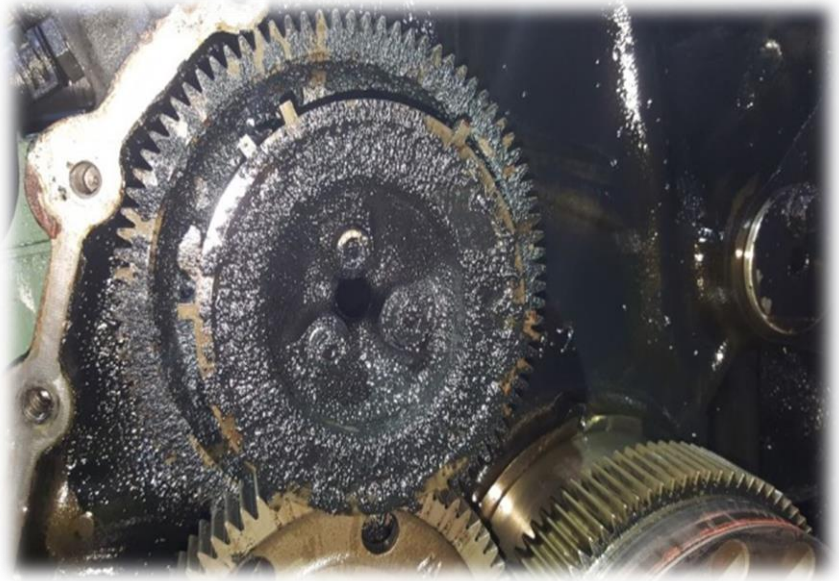
**Corrosion Control** – air and moisture can lead to rusting, whilst acids generated by combustion can lead to strong acidic corrosion. Lubricants must therefore reduce the potential of corrosion through the use of anti-rust additives, particularly the alkaline additives - often referred to as Base Number). Failure of this function will lead to corrosion and rusting of key components and eventually wear within the system.

**Sealing** – Lubricants form a Liquid seal between components, such as rings and liners to help prevent combustion gases entering the crankcase. Oils are also designed to control the amount of seal swelling to prevent oil leaks, while grease forms a more viscous seal barrier to help prevent dirt and water ingress. Failure of any form of sealing can lead to leaks or contamination ingress both of which can ultimately lead to abnormal wear.

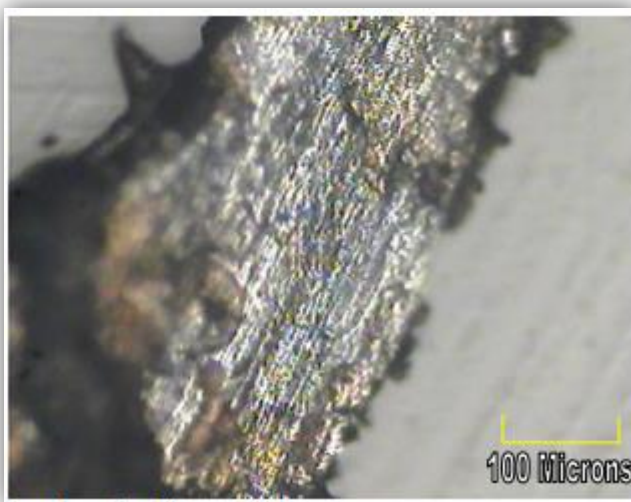
**Cooling and temperature control** – Oils circulate through working areas of a machine operating under high loads, high temperatures or extreme environmental conditions, transferring this generated heat to the oil; in turn the oil is cooled by the coolers/radiators. Inefficient cooling leads to oxidation, visibly evident when an oil is heavily oxidised, creating varnish deposits and sludge, which may collect in the coolers, leading to undesirable insulation of the system and even more inadequate cooling, and overheating of the system. The increased temperature will initially lower the lubricant's viscosity (as oils become thinner when heated) and potentially allow metal to metal contact. The increased temperature will eventually lead to thickening (increase in viscosity) of the oil, as it oxidises to form sticky polymers.



**Clean** – Oils possess the ability through additives, to remove contamination from the component surfaces and suspend it in solution (i.e. if using detergent and dispersant based formulations), or simply transport this insoluble material to the filters, which is designed to remove these contaminants. The inability of the lubricant to suspend particulates, dirt, sludge and oily deposits, within the lubricant will lead to abnormal wear and inadequate cooling of the system.



**Transmission of power** – The purpose of the fluid in hydraulic systems is to transmit force (power) and therefore motion from one part of the system to another. Failures of the fluid to transmit power by any type of particulate contamination and varnish will block valves. Ingress of entrained air will lead to loss of power or uncontrolled and unsafe hydraulic movements, which must be avoided at all times.



**Protect (wear, but also see corrosion control above)** – Lubricants are compounded with numerous additives including those designed to protect bearing metal surfaces by forming a barrier layer, termed the shear mix layer or boundary lubrication layer. These coatings also help protect against corrosion by acting as metal deactivators, simply by providing a surface coat, to isolate the metal surface from contact with corrosive acids, air and water.



## Groups of lubricants

Using the term lubricant is generally better than using the term oil, as not all lubricants are oil based, but the industry still uses the terms interchangeably when describing lubricants. When talking about oil we generally mean mineral oil, which is still the base fluid of the vast majority of lubricants used in industry. Mineral oil is derived from crude oil and is a mixture of many types of molecules, which together produce all the petroleum based products in use today. These products include petrol (gasoline), diesel (gas oil), lubricant base stocks and indeed cosmetics, through to viscous materials such as tarmac / asphalt. Of all the crude oil extracted from the earth's crust, only about 1% can be used as lubricant feed stock, compared to about 44% to make petrol (gasoline).



Lubricants are grouped into 5 different base stock classifications GI to GV, based on their method of manufacture or refining process.

Many of the natural properties of mineral oil, such as its sulphur and unsaturation content, are excellent lubricant properties. Sulphur however is very corrosive to copper alloys and unsaturation means the oil contains double bonds (i.e. some of the carbon-carbon bonds within the oil molecules are double bonds instead of single bonds), which makes them susceptible to attack by oxygen. Unfortunately, unsaturated oils limit the life of the oil and are likely to rapidly deteriorate over time, meaning oil changes may prove to be too often to be practical for most operations. Mineral oils may also contain aromatic molecules making them excellent solvents to dissolve oxidised sludge and varnishes produced in used oil, but are considered carcinogenic and must be removed or reduced to a very low concentration.

Therefore, the base oil must be treated to remove the sulphur, aromatics and its unsaturated components. This means the base oil will be more resistant to oxidation, hence last longer, but will still lack vital lubricant qualities; so lubricant manufacturers must use special chemical additives to give the lubricant its desirable properties.

The initial process to refine oils focussed on clay and acid treating and in 1930s included solvent extraction techniques too. Today such base oils fall into Group I. These oils tends to be used where long life of oils are not required and where regular oil changes are acceptable and lubricant cost is a major concern.



Hydro-treating, developed in the 1960, is where the oil is brought into contact with hydrogen gas, heat and specific catalysts to force hydrogen atoms into the oil molecule to remove the unstable unsaturated properties of the base oil. As the technology improved it led to hydrocracking, which uses higher temperatures and pressures and specific catalysts to break and then reshape the base oil molecules to form more stable and desirable molecular properties - leading to group 2 oils.

Catalytic and solvent de-waxing in the 1970s to 1990s and wax hydro-isomeration allowed for alternatives to cracking straight chain molecules to create branched molecules and the development of Group III base oils with comparable properties (High VI, low pour point & high oxidation resistance) to the entirely synthetic base oils of group IV. In some countries Group III oils are considered synthetic, following an advertising watchdog decision between two organisations over whether a highly refined mineral oil can be termed synthetic. Although Group III oils are not synthetic in the true sense of the word, their properties are comparable with those of group IV oils. Nevertheless, this ruling is only recognised in some countries and many OEMs still prefer to recognise true synthetics Group IV oils as their recommendations for approved oils as opposed Group III oils.

PAOs (Polyalphaolefins) are synthetic lubricants manufactured from small molecules to make larger molecules and because they are synthetic, the purity is excellent with good oxidation resistance, low pour points and incredibly high Viscosity index values. These base oils tend to be the premium products used in the marketplace. However, Group III and Group IV oils require special additive packages to provide all the desirable properties present in Group I and II base stocks, none of the bad characteristics, but possess excellent lubricating and longevity properties required for the modern industrial world. That is, Groups III and IV must also have excellent oxidation stability so less likely to oxidise. Yet when they do, the varnish formed will not dissolve in the base stock and simply deposit on the machine components - creating major problems. Hence these high grade base oils must use excellent anti-oxidant additives to prevent or at least significantly reduce the onset of oxidation and varnish formation.

Group V oils are essentially the miscellaneous synthetics category that includes all other types of base oils, including biodegradable, Esters, Polyglycols and fire resistant phosphate esters.

The table below summaries the categories of base oils.

Base Stock Classification				
Group	Saturates % mass	Sulphur and saturates required for classification	Sulphur % mass	Typical VI before VI improvers added
I	<90	One required	$\geq 0.03$	80 – 119
II	$\geq 90$	Both required	$\leq 0.03$	80 – 119
III	$\geq 90$	Both required	$\leq 0.03$	$\geq 120$
IV	All polyalphaolefins (PAO) synthetics			$> 120$
V	All other synthetics e.g. PAG, Esters and vegetable oils			Varies – can be as high as 200+

Once the base oil has been chosen for an application, additives are added to impart or enhance desirable properties of the oil, or remove undesirable properties of the base stock. Some common additive functions and examples are listed below.

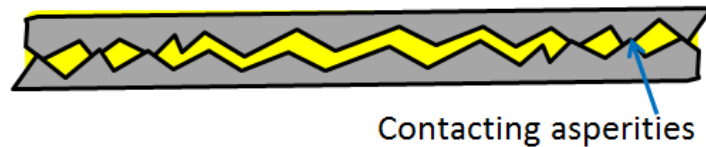
## Common Additive Types, functions and testing

To understand the reason why certain analyses are performed it helps to understand the properties the lubricant requires and the additive that is being tested. The table below lists some common additive groups, their function, a couple examples and the method of testing for them.

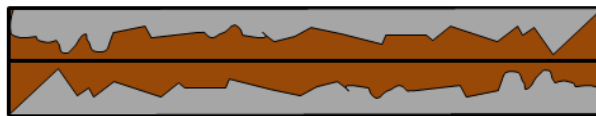
Additive Group	Function	Examples	Analysed by
<b>Anti-wear &amp; Friction Modifiers</b>	Chemically react with metal surface to form a stronger and more durable film with lower shear strength than the original metal, thereby reducing wear. Friction modifiers act similar, but do not chemically react and usually coat either as polar layer that attracts to metal surfaces, or as planar layers such as graphite that slip past each other rather than the two metal surfaces.	AW: ZDDP, sulfurized isobutylene (SIB / EP). Additional organic sulphur and chlorine compounds. Organic fatty acids and amides, lard oil, artificial sperm whale oil, high-molecular-weight organic phosphorus and phosphoric acid esters, graphite and molybdenum disulphide.	Elemental analysis, FTIR & Lubricity
<b>Anti-foam</b>	Prevent lubricant from forming a stable foam. Reduce surface tension to speed collapse of foam hence reducing foam stability rather than tendency.	Silicone oils	Elemental analysis, Foaming Characteristics (foams if too little additive), air release (air becomes trapped if too much additive).
<b>Antioxidants</b>	React with oxidative free radicals to prevent oxidation of the lubricant.	hindered phenols, aromatic amines	TAN (indirect), RPVOT (indirect), RULER (direct), FTIR (direct)
<b>Corrosion &amp; Rust Inhibitors</b>	Prevent corrosion and rusting of metal parts by competing with reactive polar molecules such as acids etc that could corrode the component.	Zinc dithiophosphates, metal phenolates, calcium/magnesium sulfonates and amines	copper corrosion, rusting characteristics, FTIR
<b>Detergents &amp; Dispersants</b>	Remove desposits from surfaces and neutralise acid/oxidation products (detergent). The Dispersant consist of a polar surface that attracts water, acids and any sludge particles connected to a non-polar oil loving tail. Surface tension physics results in a micelle forming with the contamination, soot and oxidation products in the middle with the non-polar tails outwards soluble in the oil. The Michelles repel each other keeping the disperancy properties.	Metal phenolates, phosphonates and sulfonates (usually sodium, magnesium or calcium). Alkylsuccinimides,	dispersancy, soot, FTIR and TBN
<b>Metal Deactivators</b>	Metals are usually excellent catalysts for reactions such as oxidation and deterioration of lubricants. Metal deactivators coat the metal surfaces reducing this effect and hence allowing the lubricant to last for longer.	See Anti-wear additives and Anti-oxidant additives as they usually perform a dual function in assisting with this process.	RPVOT, RULER, TAN, Elemental, FTIR
<b>Pour Depressants</b>	Reduce oil ability to form waxes that crystallise out at low temperatures so the oil can be used at lower temperatures before waxing.	Alkylated naphthenic products, polymethacrylates and phenolic polymers, (usually only required when basestock is not inherently naphthenic and is a paraffinic promoting likelihood of waxes)	Pour point, cloud point, channel point, Cold Filter Plug Point (CFPP), Cold Crank Simulator, Mini-Rotary Viscometer.
<b>Viscosity Improvers</b>	Reduce the drop in viscosity with temperature increase. Polymers expand with increasing temperature to give resistance to flow and artificial viscosity.	Polymers of olefins such as Polyisobutylene (PIB). methacrylates, dienes or alkylated styrenes. Note high molecular weight polymers give the best VI improvement, but are more susceptible to shear, so a compromise on chain length has to be made to maintain the VI in use.	Viscosity index, High Temperature High Shear (HTHS), Cold Crank Simulator, Mini-Rotary Viscometer.

## Lubrication methods

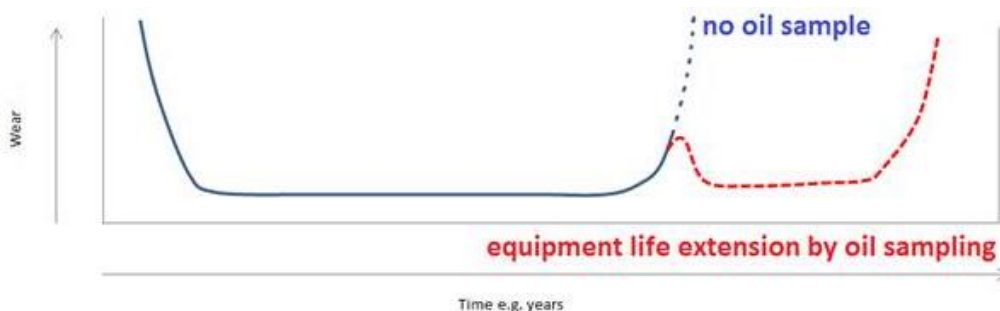
**Wear-In and Boundary lubrication** – Even the most apparently looking smooth surface of a bearing is actually quite rough, showing high and low peaks when seen under the microscope. These surfaces actually contact each other in a rotating journal bearing during the “wear-in” period, causing the asperities to either bend flat or brake off to create “wear-in” debris.



The resulting worn surfaces react with anti-wear additives e.g. ZDDP or Extreme Pressure sulphur based compounds, to form a toughened surface called the boundary lubrication layer (coloured brown below). If the lubrication film (coloured yellow above) should fail to separate the surface, boundary lubrication is the last line of defence to prevent metal to metal contact and severe wear.



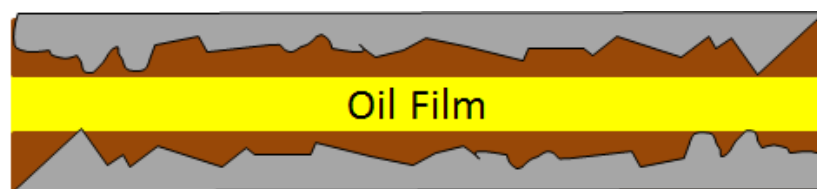
The wear-in process, to create boundary lubrication, occurs very early in the life of the machine. In the example graph below, the level of wear is high in the early stages of the machine life, which rapidly decreases as the wear-in process completes, to leave relatively smooth mating surfaces - allowing full fluid film lubrication to form between the two mating components (see below). There is naturally a high correlation between wear and the likelihood of machine failure, so there is a high risk of failure at the start of any equipment life. This may prove to be manufacturing faults or poor installation practices etc.; once these problems have been resolved, the normal wear-in process can begin and these wear problems decrease. Then the machine enters the steady state or random region; a period where problems are likely to occur only as a result of random problems, such as dirt contamination, insufficient lubrication or lack of maintenance etc.



**No oil Sample means no early failures detected or corrective actions in place (blue). Early failures detected and corrected by oil sampling (red)**

The above wear curve graph, often called a bath tub curve, shows the pattern of wear in a newly installed machine or engine. The rate of wear begins relatively high until the shearmix layer is formed, when the wear rate becomes relatively low and steady, unless a random event creates a problem, which will most likely lead to an expensive failure. Otherwise, the graph shows the machine components (e.g. bearings) will start to wear out due to their age and normal use. Oil Analysis is one of the best techniques available to detect the random events likely to cause a failure, such as contamination, poor quality maintenance or wrong lubricant etc. Indeed regular Oil analysis programmes are frequently reported as helping extend the expected life of a machine, by simply detecting these random problems before abnormal wear occurs.

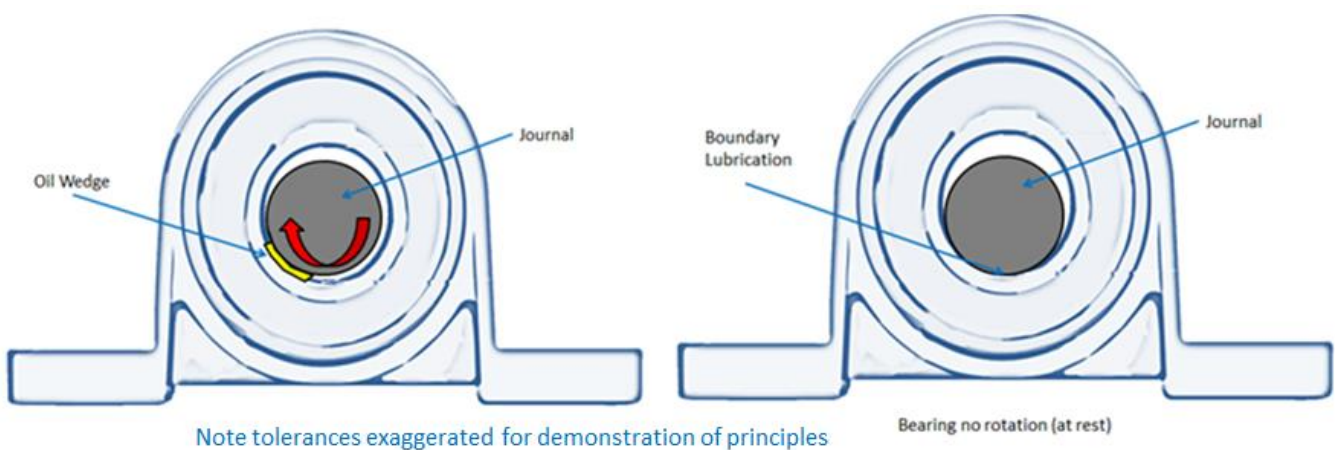
**Full fluid film** – This is the lubrication type that springs to mind when describing lubrication; where two contacting surfaces are separated by a full film of lubricant. Typically after any asperities (surface imperfections shown as peaks on the pictures below) have already broken off and reacted with additives during the normal wear-in process to produce the essential smooth and toughened boundary lubrication layer.



Note - within full fluid film lubrication systems there are subcategories: Hydrodynamic, Hydrostatic or Elastohydrodynamic. (See later)

**Mixed film** – this is in-between Full-fluid film and Boundary lubrication where there is some fluid film separating the majority of the asperities, but where there is also some boundary lubrication at certain points. These situations tend to be temporary scenarios and eventually become either boundary or full fluid film.

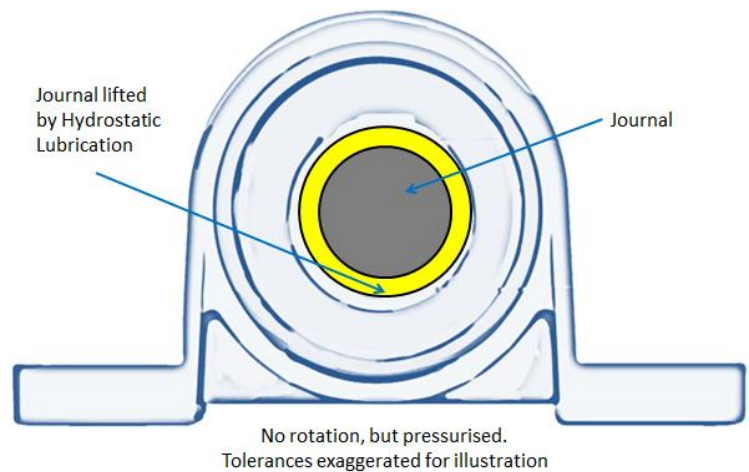
**Hydrodynamic lubrication** is where a rotating bearing produces the centrifugal forces leading to a wedge of oil collecting just ahead of the load zone, enabling the journal to ride the oil wedge around the bearing and separating the two surfaces of the bearing. When the bearing comes to rest and oil is squeezed or drains out allowing the two surfaces to touch again.



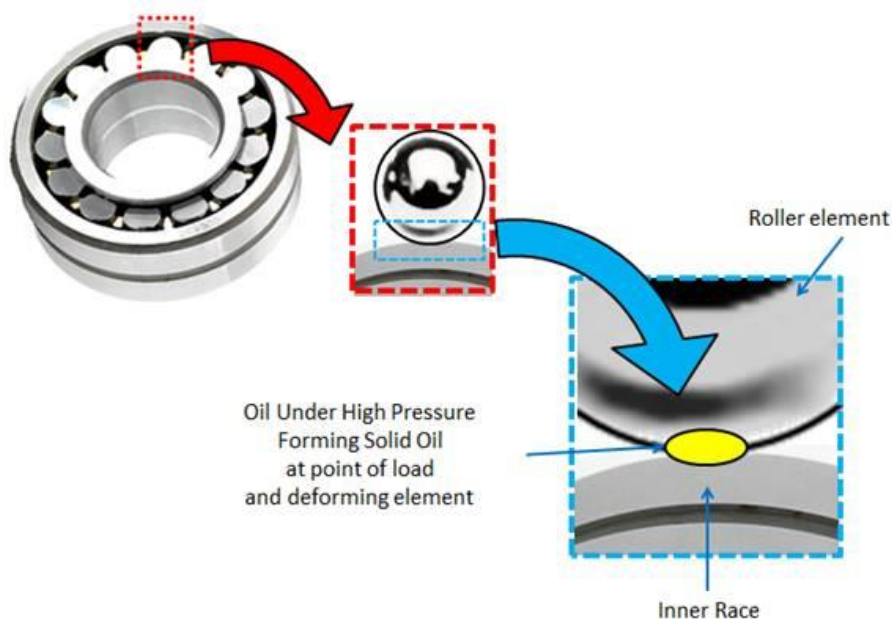
Then when the bearing starts to move again the lubrication temporarily relies only on the boundary lubrication layer. However, when starting up and before getting to operational speed sliding wear can and does occur. It is at this stage most bearing wear occurs.

### Hydrostatic Lubrication –

Under extreme loads, boundary lubrication alone is insufficient to protect the bearing surfaces. So before the shaft starts to rotate a film of oil is pumped into the bearing to lift and separate the mating surfaces. Thereafter as the shaft rotates Hydrodynamic lubrication comes into play.





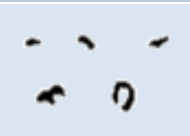

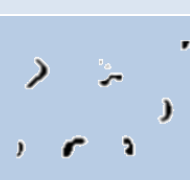




**Elastohydrodynamic Lubrication –** In systems such as roller bearings the point of contact is  $<1$  micron between the two opposing curved surfaces. In this exceptionally small area - the load can be between 200,000 psi and 500,000 psi - causing the oil in this small area to become solid. The bearing element surface deforms around this oil similar to how a tyre deforms to the shape of the road. This constant deformation of the surface, which springs back into its original shape as the load moves to the next section of the bearing during normal rotation, relies on the bearing material being "elastic". Eventually this repeated bending action will cause the material to work-harden, become brittle and fail through fatigue wear. Simultaneously, dirt contamination within this local small area will only exasperate the problem, the dirt itself promoting work hardening of the bearing metal too and both situations will eventually lead to fatigue wear and component failure.





## Wear Modes & Identification

One of the most common questions asked when discussing a red actionable report with a client, is “can you tell me more how this happened.” When there are obvious contamination sources such as dirt, water or the wrong oil in use then this is easily spotted on the oil analysis reports. However, sometimes, the flag may just be one wear metal increasing – such as iron, which is the most common element found in lots of components. This makes identifying the source of the iron wear difficult and often further lab or field testing analysis is required to investigate the cause. One additional investigation that is possible is analysis of the wear type on actionable high particle count or wear reports. This can be included in your test suite as standard to perform on all actionable reports if required – just ask the lab for more details. This is performed by a technique called Laser-Net Fines where the particle counter analyses not only by laser to determine ISO code, but an optical camera also scans the flow of fluid at the same time and uses image recognition software to identify larger (>20µm) particles and the wear type occurring. A contour of each of the particles identified is then placed on the report and categorised into its particle type. The overall percentage of each wear type is tabulated, together with the percentage of the abnormally sized particles identified compared to the smaller particles to identify the significance of the particles detected to provide a holistic view of the overall equipment condition.

Wear Type	Cause	Micrograph	LNF
Normal Rubbing Wear	Normal operation of machinery that produces the stable wear level expected for the machinery once the wear in process is complete.		Particles not pictured during scan as normal size
Non-Metallic debris	Typically spent oil additives, soot, wear to non-metallic components and contaminants such as dirt.		
Cutting/Abrasive wear	When circulating / surface projections wear away softer surfaces, usually when a contaminant such as dirt enters between two contacting surfaces shaving off surface material resulting in long, thin and curved wear particles		
Fatigue wear	Associated with roller/element bearings and gear systems is where cyclic or repeated stresses lead to cracking, spalling or pitting to component surfaces. Particles are usually approximately equal width and height with no set shape		
Sliding/adhesive wear	Occurs when lube film does not fully separate two moving surfaces & contact occurs. Low level small particles <15µm are considered normal rubbing wear, but larger particles are generated due to excess load, speed or temperature.		

**Abnormal Size** – This test as part of the Lubetrend LNF report identifying what percentage of the particles analysed are abnormally sized. A low value suggests that although a few larger particles are present the majority of the particles are of a normal size and the wear levels should just be monitored for any increasing trend in abnormal size, PQ or wear metal values. A high value suggests the particles are predominantly large particles suggesting (if the sample is representative of the bulk of the system) that there is an abnormal wear mechanism developing in the system and this should be investigated further.

## Fourier Transform Infra-Red (FTIR) Spectra Analysis

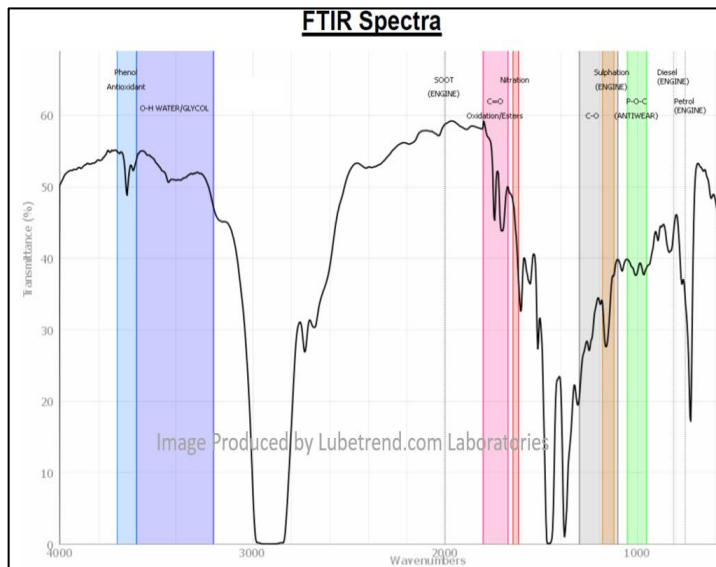


FTIR is a commonly performed test on lubricating oils. It is usually used on engine oils to determine parameters such as soot, oxidation, glycol, fuel etc. Further, FTIR is an exceptionally powerful and its benefits go much beyond those

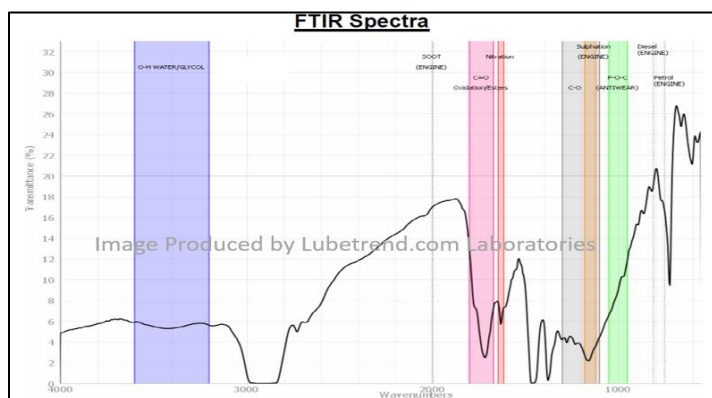
traditional routine parameter tests. Much as the elemental analysis can tell you much about the inorganic chemistry of metals such as Calcium, Phosphorus and Zinc in the oil, the FTIR analysis analyses the organic part of the fluid to identify sulphonates, fuels and esters which are important components of lubricant chemistry. More importantly, comparison of both the elemental and FTIR trace data of two products can be used to confirm if two products are indeed the same, useful for confirming the source of contamination in a system or confirming the correct fluid was used.

FTIR works on the principle of passing infra-red light of various wavelengths through a cell containing the sample and measuring the amount of light that passes through (transmittance) or the absorbance (that amount of infra-red light absorbed by the Lubricant molecules at that wavelength). Traditionally values from FTIR are expressed in Absorbance when looking at data points. For instance an OEM limit of 20 Abs/cm for oxidation would be based on Absorbance, but when viewing FTIR Spectra they are typically showed in transmittance. This may seem a bit confusing at first, but in simplicity this means an absorbance peak is a transmittance trough on the graph. So note when referring to a peak in this guide the spectra actually points down.

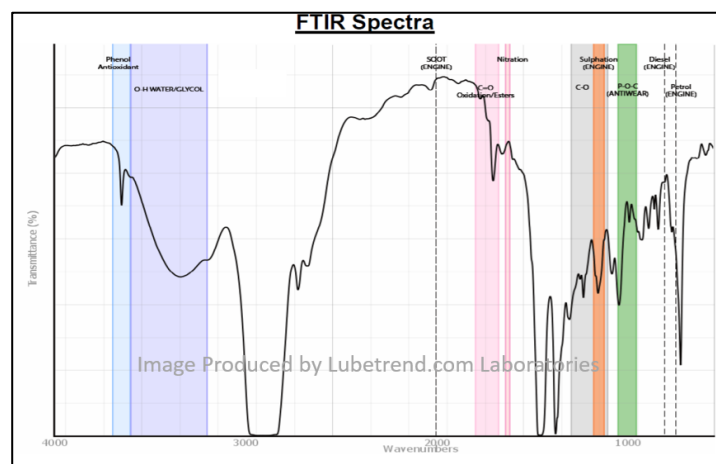
FTIR analysis is a Chemistry discipline that does take time to master and an in-depth analysis of the subject goes far beyond the realm of this guide, but the basic principles required to understand your lubricant analysis report are fairly straight forward, especially when the trace is labelled and have a reference for comparison. Some example FTIR traces are shown below.



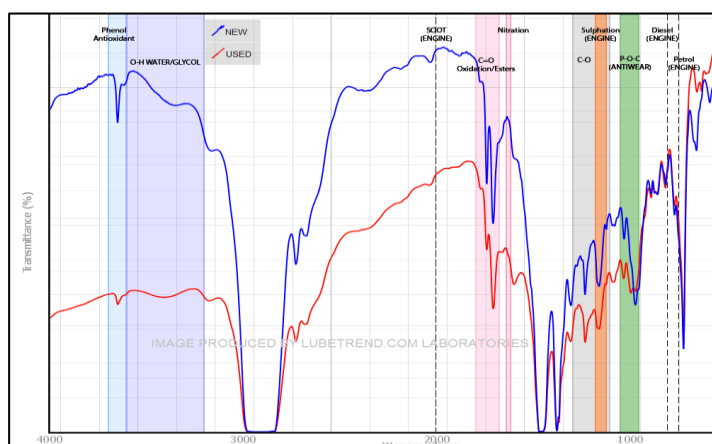
**FTIR New Lubricant** – To left is an FTIR Trace of a new lubricant. Note x-axis goes from large to small. To the left are the higher wavelengths ( $>1500\text{ cm}^{-1}$ ) consistent with basic functional groups such as OH coming from **Water, Glycol** or **phenol** anti-oxidant additives, and carbonyl peak consistent with **oxidation**, ester additives, biofuel contamination etc. The big broad peak C-H Stretch between  $2850$  and  $3000\text{ cm}^{-1}$  can largely be ignored as this is simply telling the reader that the sample being analysed has a lot of carbon to hydrogen bonds, which is expected in any hydrocarbon based lubricant. These regions are roughly the same in most products and are mainly used to identify if the oil looks relatively new (see the **phenol antioxidant peak**), and look for e.g. **oxidation** or **nitration** peaks. To the right ( $500$  to  $1500\text{ cm}^{-1}$ ) is the fingerprint region which is used for more specific identification of the lubricant and is used to identify one product from another.



**FTIR Used Lubricant** - The trace below has a lot of absorbance with very little transmittance, which is consistent with a spent, dark and sooty oil.



**FTIR with Water contamination** - The trace below is of a relatively new lubricant (note the **phenol peak**), which has developed a water ingress issue. This sample was taken from a relatively low oil hour piece of equipment with a coolant leak (note the OH broad peak)



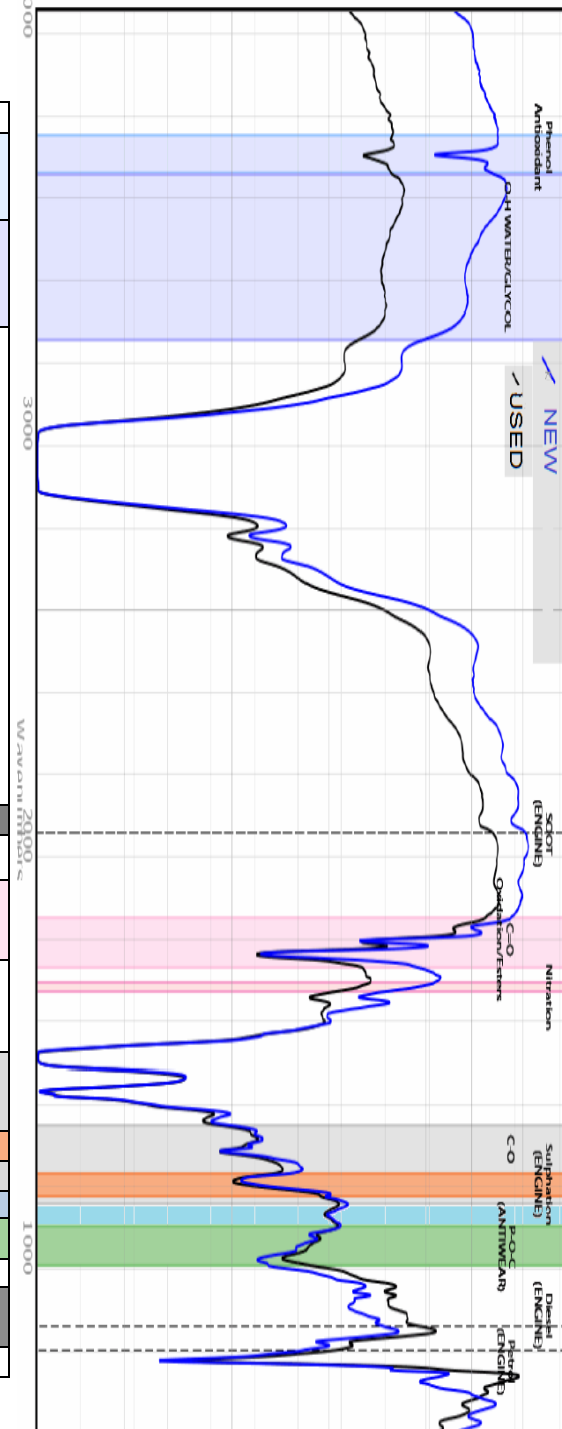
**Traces comparison** - Traces can be overlaid onto each other to compare **unused reference** vs **used oil**. This can be provided if the client provides unused reference oil for comparison. The trace below is an oxidised oil vs the new oil.

Parameter	Spectra Wavelength (cm <sup>-1</sup> )	Interferences
Phenol Anti-oxidant	3650 (mineral) or 3540 (When organic Ester additives – sometimes used as method of determining oxidation when organic esters present.)	Water / Glycol
Water / Glycol	General JOAP (3150 to 3500) Usually: 3400 (mineral oil) (Also Glycol) Usually: 3625 (Organic Ester)	Glycol

## Reading a Lubetrend FTIR Trace Summary



Soot	2000	Particle size, sample darkness
Oxidation	Mineral - 1710 (DIN) or 1670 to 1800 (JOAP) – usually ~ 1700	Carbonyl containing additives e.g. VI improvers (1739), Succinimide Dispersants (1773 or 1704), esters etc
Nitration	1600 to 1650 (JOAP) or 1630 (DIN)	various
Various Additives	Aromatic Amine Anti-oxidant 1515, 1310 & 743 Detergent Carbonate 1495 Succinimide Dispersant 1367	various
	Silicone oil antifoam 1290 to 1240 Succinimide Dispersant 1230 Sulfonate Detergent 1169 and 1158	various
Sulphation	1120-1180 (JOAP). Usually ~1150	Additives e.g. EP (1112), corrosion inhibitors
EP Antiwear	Sulphurised isobutylene (SIB) / EP (1112)	Sulphation.
Glycol	1020 to 1100 (JOAP), Usually 1040 to 1080	Glycol degradation level (see coolant analysis)
ZDDP Anti-wear	JOAP 960 to 1025, usually ~970 (P-O-C)	Fuel, base stock aromatics & dirt.
Detergent	Carbonate 869	SIB/Extreme Pressure (EP) – (815 and 893)
Diesel	800 or 805 to 815 (JOAP)	Fuel blend and degree of fuel weathering.
Petrol	745 to 755 usually ~750	Kerosene (795 to 815), EP/SIB (815).
ZDDP Anti-wear	655 (P=S)	various





## Lubetrend Filter Debris Analysis (LFDA)



OIL FILTERS are designed to capture:

- Wear metals
- Solid debris
- Water
- Spent Additives

Hence show historical evidence of wear patterns & contamination –

Making them a valuable receptacle of information to perform Root Cause Analyses (aka Machine Post Mortems) through Analytical Ferrography

Standard Filter Analysis programmes detect stages of component failure through Standard Analytical Ferrography providing valuable information concerning:

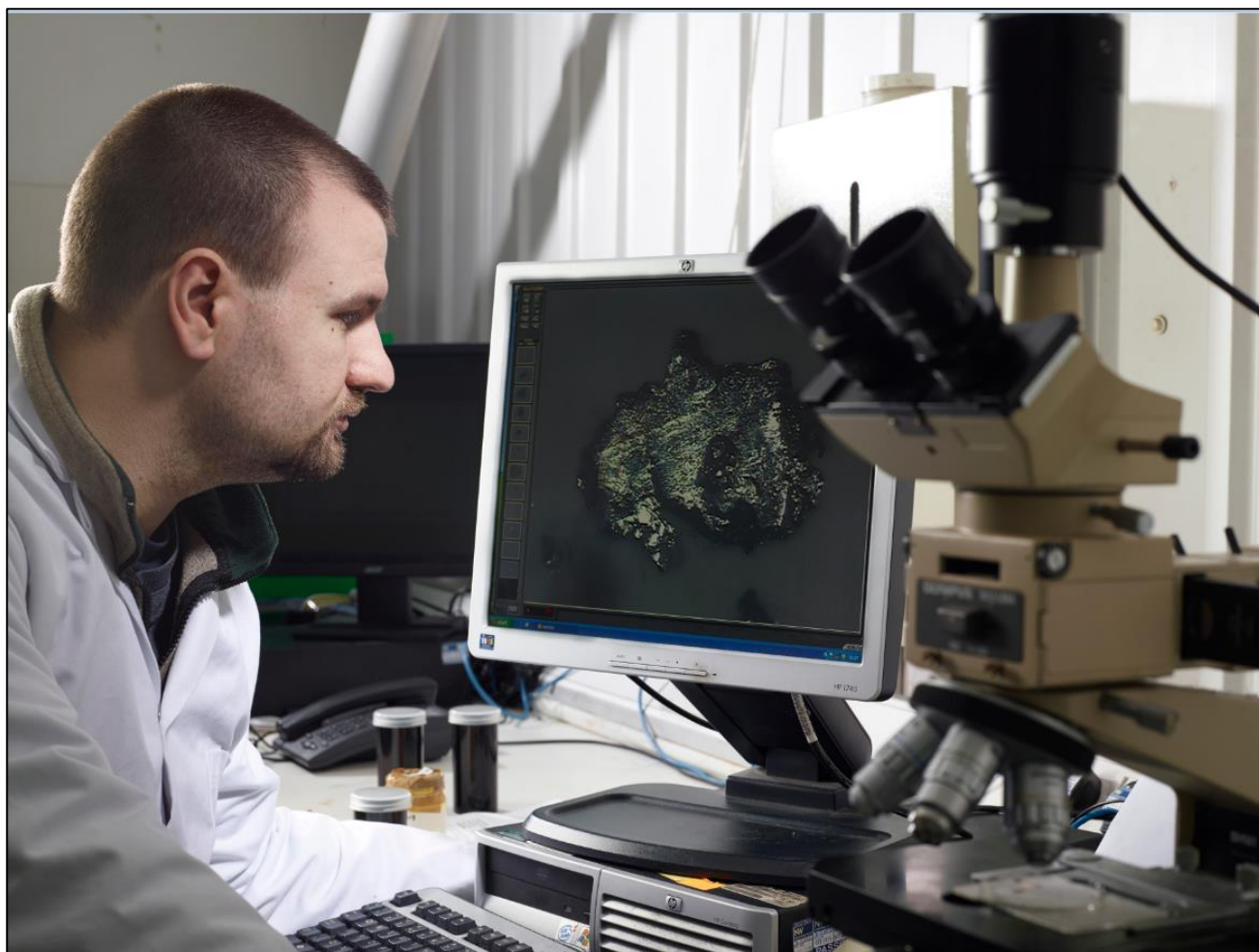
- Early Stages of abnormal wear
- Large Wear particles - indicative of serious wear
- Small Wear particles - by Fine filtration preventing detection by regular Condition Monitoring atomic emission spectroscopy
- Wear mechanisms & Failure Modes
- Root Cause Analysis – but not organic material contamination





However, the Lubetrend Filter Debris Analysis (LFDA) Programme is a full Root Cause Analysis programme including Standard Ferrography **and far more**. Indeed Alcontrol trains customers and their competition in the art and techniques of Standard Ferrography, through their accredited British Institute of Non-Destructive Testing (BINDT) courses, held within their impressive, well equipped Lubricant Condition Monitoring Laboratories.





Ferrography is a proven technique to identify the mode of failure by studying the morphology (shapes & texture) of the wear debris found in a used oil filter, offered by many laboratories. However, the Alcontrol Full Filter Analysis programme is far more - it recognises Filters also show evidence of both organic & inorganic debris leading to failure modes not evident by standard Ferrography techniques alone.

Lubetrend recognises and understands that filters rarely fail owing to wear debris alone – but recognises filters block due to minute inorganic particles, immiscible fluids, oxidised oil debris, spent additives compounds and insoluble organic chemical contaminants not miscible with lubricants, which together with normal wear debris and environmental dirt, blind the filter medium pores, causing the demand for repeated early filter changes and potentially complete machine failure.

The Alcontrol Filter Analysis Programme (LFDA) includes both Analytical Ferrography and their specially designed Chemical analysis programme to identify chemical species found in most used filters.

Staffed by highly motivated oil chemists and diagnosticians with decades of experience in oil analysis and lubricant formulations, the Alcontrol Filter Analysis Programme (LFDA) is able to identify the chemical structure of organic and inorganic materials present in filters - using Atomic Emission & FTIR spectroscopy, XRF, Laser Net Fines (LNF), Microscopy, Gas Chromatography and wet chemical techniques.



Then Alcontrol reports this valuable diagnostic and prognostic information in clear - user friendly terms - giving recommendations & advice on what action to take to overcome the problems identified by (LFDA).

 <p><b>Microscopic Debris Analysis</b></p>	<p><b>LubeTrend Bite Size Diagnosis</b></p>	
 <p><b>Blueing</b></p> <p>Blue tinting to metal. Seen in high temperature / extreme friction situations. Often seen on edges of sliding wear particles.</p>	 <p><b>Abrasive Cutting Wear</b></p> <p>Long (15 to &gt;100 micron) , thin and curved particle caused by abrasive wear from misalignment leading to one surface cutting the other, or from contamination (e.g. dirt/grit) between the surfaces cutting like a lathe tool.</p>	<p><b>Normal Rubbing Wear</b></p> <p>&lt;15 microns in size.</p>  <p><b>Environmental dirt / grit</b></p> <p>Various shapes and sizes, black in colour.</p>
 <p>Arrows direction of sliding wear.</p>	<p><b>Adhesive Sliding Wear</b></p> <p>Particles &gt;15 micron to several mm with grooves across surface of particle down to breakdown of lubricant film leading to metal to metal contact. Usually caused by overloading, oil starvation, fuel wash or poor lubrication.</p>	<p><b>Fatigue Wear chunk</b></p> <p>Large (15 to 200 microns) particles approximately same width and height (1/10<sup>th</sup> depth) with "island like" appearance. Caused in rolling contact situations in gears and bearings by repeated impact and work-hardening of metal. Lubricant film usually intact and no metal to metal contact.</p>
<p>Photos supplied by ALcontrol Laboratories . To find out about investigative failure analysis on oil, fuel or filters, our field engineer training courses, or to discuss an analysis report email <a href="mailto:techservice@alcontrol.com">techservice@alcontrol.com</a> or call (+44/0) 1492 574750</p>		

# **Section 4 – Common Symptoms & Corrective Actions**

## Why a section on corrective actions?

Although this guide mentions many corrective actions and additional tests that can be performed, clients often request more advice on the potential corrective actions to take following a red flagged report.

We are of course only too please to help, but one very important thing to bear in mind is that one single report should never be used as the basis to replace or even stop a machine - a second sample should be sent to confirm the findings. Indeed, the best advice any one can receive - is to consider other investigative and non-destructive inspection methods to confirm the findings of the analysis before making costly decisions. All the potential actions are optional and the comments made are generic for this book and not necessarily designed for your specific and unique circumstances - so also consider asking your OEM, filter company or lube Oil Company for advice and please contact this lab for help before taking any expensive actions.

## Dirty Oil – An Introduction

This condition may exhibit no signs of an impending problem within the system, but if this condition (dirt in the oil) is leading to severe cutting wear or fatigue wear then abnormal noise, heat and vibration may also be evident within the system. If so, it suggests the oil cleanliness is having an impact on the condition of the system. In this case, oil analysis is the best method for early detection of fluid cleanliness, helping to reduce the chances of this problem leading to abnormal wear in the system.

Many studies have been performed by equipment manufacturers and filtration companies to demonstrate that cleaner oil can extend the life and reliability of equipment. This is because cleaner oil leads to less abrasive wear, hence longer component life.

To reduce contamination, such as environmental dirt in the system the best solution is to try preventing it getting there in the first place.

A visual inspection of your sample can be a starting point - any visual dirt or debris in your oil sample suggests there may be a cleanliness issue with your equipment that needs addressing.



## Dirty Oil - Prevention

All systems breathe, which means that air, which contains dirt and water can and will enter the system during normal machine use, unless there is something to stop it. So if your system involves a bulk storage tank, then consider fitting air filters on breathers to combat dirt ingress and desiccants to remove water.

Systems such as engines or compressors are normally fitted with air filtration to prevent dirt ingress. Hence a visual inspection of air filters and trunking joints at the next planned maintenance or offline shutdown period is crucial in reducing dirt ingress into the system.



When new parts or components are fitted or new machines installed on your site the system should be flushed with clean oil to remove any build-debris or casting sand likely to cause wear on start-up. This procedure is an important fact to discuss with your OEM and lube supplier prior to the very first start-up. Additionally, when new oil is delivered, even with the cleanliest and strictest quality control procedures in place, there is always room for improvement. So especially for expensive, critical machines or large oil volume systems it is often worthwhile pre-filtering the oil before it enters the system. Your lube oil or filtration supplier will be able to give advice, on the most cost effective solution for your equipment.

If the system is pressurised then it is recommended to monitoring the pressure of the system and noting any pressure changes. A drop in pressure may indicate a leak (sight glass drops can confirm this) or significant increase - indicating filter blocking. A laboratory particle count test may confirm this possibility and may in turn suggest seals or pipe connections as a potential source of contamination in the system.

Acoustics monitoring is often a useful way to identify leaks within pressurised systems (particularly air leaks). Likewise inexpensive options, such as the manufacturers approved soap-based fluids, which if placed on the outside of

suspected areas of leaks, foaming will indicate a leaking seal etc. Again, dirt ingress may cause a pressure increase, but if the pressure gets too high within the system or across the filter, the by-pass valve may trip - meaning contamination is no longer being removed, but at least unfiltered lubricant is reaching vital components; a much better option than no lubrication.

If the system is fitted with a drain tap, then it is possible to first allow the oil to stand and settle for a period, then running off a small volume of oil until the oil clarity improves; thus removing some of the sludge or sediment collecting at the bottom of lube oil systems.

The most common cause of a flagged contamination result on a report is poor sampling and not an indication of true contamination of the system. If it is suspected this is the cause of the contamination - then please see our advice on "how to take a good sample" shown in the previous sections.

## Dirty Oil – Removal

When discussing oil cleanliness it is not possible to have zero particles present, even if using the best filters available, so there is always room for improvement. This is why contamination control should be considered an ever improving target and not a fixed cleanliness level, claimed will cause no wear. The cleaner the oil - the better the expected component life, but also with each improvement the more difficult it gets to improve further. Hence it is often a balance of working towards best component life against what can be achieved for a given at a sensible cost. Target cleanliness levels should only be set if it is realistic and achievable for your given equipment and working environment i.e. don't set yourself unreasonable NASA cleanliness levels if your equipment is working in quarries for example, excavating rocks and earth all day. Your filtration supplier and equipment manufacturer will be able to assist you in finding the ideal balance.

The choice when it comes to handling dirty oil often comes down to three options:

- **Change it** – This is often the best approach where oil changes are relatively inexpensive or the practicalities of filtration make this a too costly solution. Changing the oil may also be the best approach if there are other factors, other than dirt affecting the oil, which cannot be completely resolved by filtration, such as viscosity changes or spent additives, leading to loss of key lubricant properties.
- **Filter it** – usually the best approach if the contamination is particulate or the system is large. Oil changes may prove too costly, because the price of oil or waste handling is too expensive and the oil is otherwise in good condition. Or, of course, if shutdown is not a commercial option at the time dirt ingress is detected, then the filtration option is best.

- **Leave it** – Stricter and stricter cleanliness targets will eventually reach a point where it is impossible to achieve further significant benefits from additional cleaning. This point may be the ideal cleanliness level achievable at an acceptable cost, but the system should be closely monitored thereafter for signs of an increase in abnormal wear. This may also be the approach if the equipment is at the end of its expected life and plans to replace the equipment have been agreed. In any event “leave it” should be the practice, if waiting for a resample result to confirm the original result..

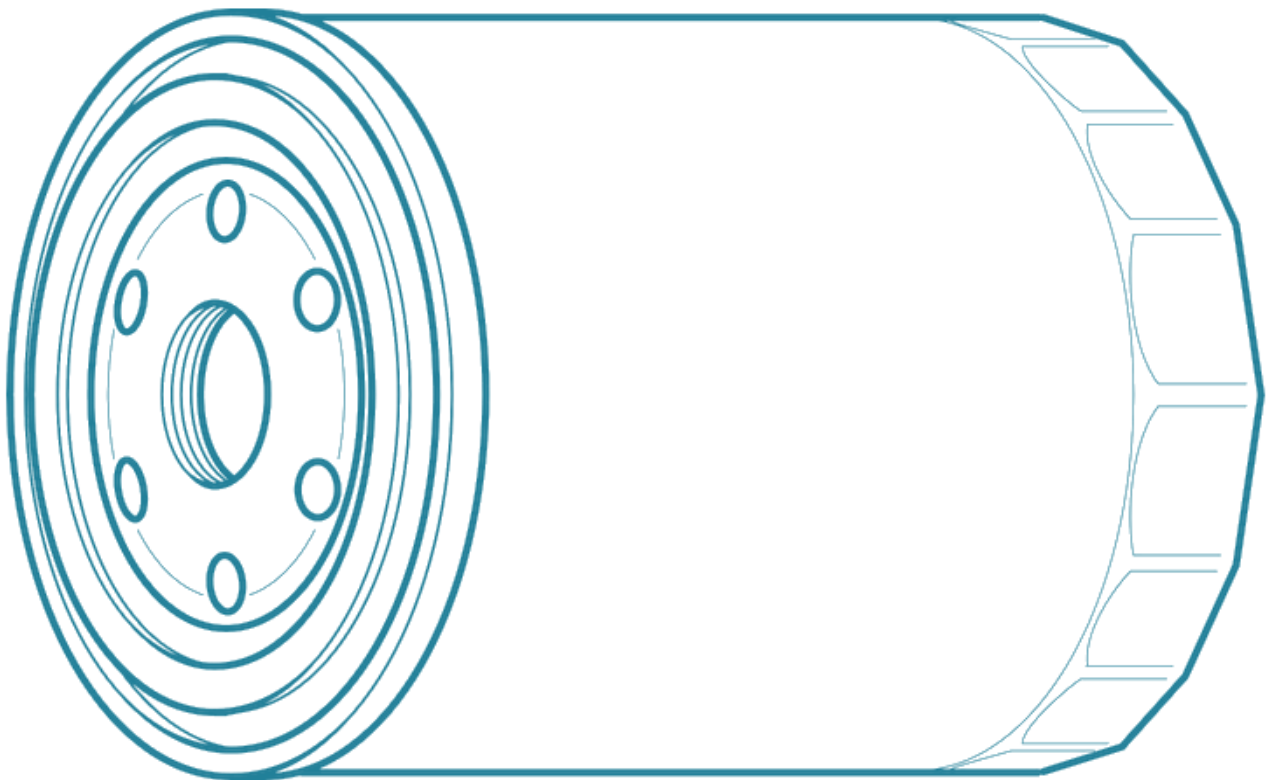
When changing oil on large systems, it is always wise to have the oil tested before and after changing and indeed when changing supplier or product types to ensure that the fluids are compatible – the lubricant supplier should be able to provide all this information and give advice if flushing the system is necessary.

When considering filtration there are usually two distinct methods:

1. **Conventional full flow Inline filtration** – Inline filtration is the typical filtration systems adopted, usually using filters with pleated designs to give a high surface area to maximise filter efficiency and reduce pressure drop across the filter. These may be single filters, or part of a series of filters throughout a system. They are often under high pressure, operate at fast flow rates and be installed after the main system pumps. These high pressures, stop/starts, cyclic conditions mean they generally struggle to be efficient at removing particles. They are usually between 5 and 30 micron ratings and designed to catch large solid particles. In modern systems these are often combined with off-line filters that do the majority of the cleaning and then the in-line filtration is just a “last chance” filter to catch anything before it reaches the critical components. The groups of in-line filters can be grouped further into:
  - **Pressure inline filter** – as described above, are generally fitted after the pump and before components.
  - **Suction Filters** – Designed to reduce wear to the pump, so are generally coarse filters 25+ micron (to reduce risk of cavitation) fitted before the pump/booster pump to remove large particles.
  - **Return line filter** – these filters remove any contamination or wear particles from components upstream of the filter and returns clean oil to the reservoir tank. When assessing wear levels it is important the sampling points is before this filter otherwise wear metals cannot be accurately determined.
  - **Combination Suction Boost Return line filters** – These are often used as return line filters where space requirements for a main oil tank is at a premium and smaller tanks are used and when the pump requires finely pre-filtered oil, which otherwise would risk of cavitation with other filtration options.
2. **Offline Filtration** – These are often called filter caddies, or kidney filters in so much they work offline away from the system and able to filter at less than full system pressure with slower flow rates. The ratings tend to be relatively small, ranging from 0.1 to 5 micron ratings. Unlike traditional filters these tend to have higher capacity for holding dirt and although more expensive than standard inline filters, they benefit by requiring less frequent changes. There is

a simple calculation available, which is the cost of removing 'x' amount of dirt. Typically this may take the form of cost of removing 1kg of dirt = cost of filter insert / dirt holding capacity. This can enable comparisons to be made between two or more products. However, additional features - such as efficiency and beta ratio ratings and material type should also be considered when selecting which filter to buy.

When fitting any filtration, lubricant delivery or storage system to improve oil cleanliness – it will prove a major expensive investment. Hence it is important when planning any of these systems, to take regular oil samples before and then after implementation to truly establish the benefit of the new equipment. Often on-line particle counters, which may be part of the new filtration system, will probably show an improvement after installation. Nevertheless, unless the filter supplier or the machine owners use an independent ISO 17025 accredited laboratory to verify these findings, the results may not stand up to scrutiny. Hence it is recommended to use independent laboratories, who participate in regular round robin analyses, to ensure the values being obtained are true cleanliness levels and have no bias towards any one set of data. This is because differences between instruments and methods of measuring particles can result in significant particle count variations.

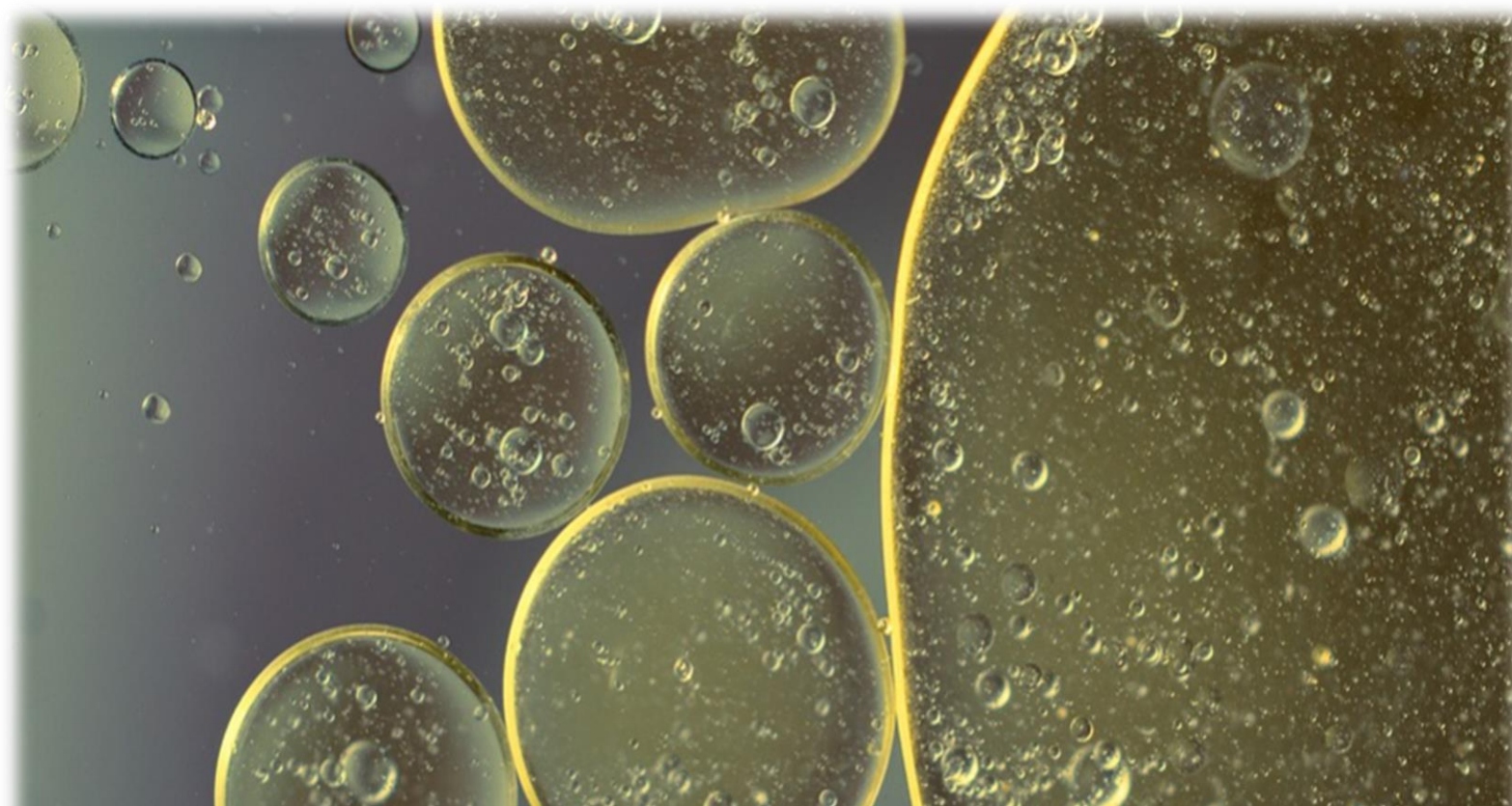




## Water in oil – An Introduction

Water is a poor lubricant and does not mix readily with oil, leading to inefficient lubrication between mating surfaces. Water also promotes corrosion (rust) within the system. In addition, high temperature environments will boil off at the component contact points, leading to a temporary loss of all lubrication, whilst the impact of these explosions, as the water boils, may lead to pinhole corrosion. Water has the additional property of damaging the oil additives designed to protect the machinery; this is often termed hydrolysis. Water also has the ability to wash out the additives, leaving insufficient to protect the machinery. Finally, water contamination in hydraulic systems or in brakes can boil under these conditions to cause loss of power, uncontrolled hydraulic movement or brakes failure.

Testing for water contamination starts at the point of taking the oil sample. If there is visible water present in the sample, evident by a cloudy or milky appearance or settled to the bottom of the sample bottle, then there is a strong chance of water contamination is present, which will show in the lab report.





## Water in Oil - Prevention

Prevention of water ingress, as all contamination, is usually better than removal.

If the system is free breathing, consider using a desiccant breather to remove water vapour (wet air) before it enters the system. Additionally, when using a desiccant breather the desiccant should be replaced on condition rather than simply time based. So send regular desiccant samples to a laboratory capable of monitoring desiccants to confirm condition.

Any visible fumes or vapours emanating from the machinery may condense onto a cold metal surface. These fumes could potentially indicate the system has water ingress, which should be confirmed by submitting an oil sample.

If the main tank has a drain tap then it is advised to regularly drain small volumes of oil from the system until it runs clear to remove any sludge, sediment and water collecting at the bottom of the tank. Likewise when inspecting the top tank hatch of a system that normally runs hot, and shows signs of water droplets or rust on the top surface, then this suggests water is boiling off from the system and condensing on the cold tank top surface, eventually dripping down into the system again. Note: when inspecting sight glasses any increase in volume may be linked to water ingress.

If the system is using a synthetic polyglycol (PAG) oil, then these products have a natural affinity for water and are able to absorb water vapour from the air; such fluids are termed hygroscopic. Consequently, it is important to never half fill an oil sample bottle to send to the lab, but fill to within 10 millimetres of the top. Large air volumes above sensitive samples may give a high erroneous result. However, while water contamination remains undesirable and difficult to remove, polyglycol products can cope with water much better than mineral oil based products.

When examining cellulose based oil filters, a wavy appearance suggests water contamination; in which case it is advised to consult the filter supplier for additional actions how to remove the water.

If using IBCs, drain off any sediment and water from the bottom before drawing from this container and follow the same procedures as above to reduce the likelihood of water ingress. Note: Always store barrels on their side and under a shelter; this keeps an oil surface next to the bung, reducing the likelihood of air circulation and water ingress through natural breathing of the barrels.

Wherever possible, attempt to get equipment up to full operating temperatures as often as possible to help drive off any water. This is particularly true for large, slow or medium speed marine engines, with cooling systems designed to cope with the engine running at high load. Such systems at low speed tend to over-cool the engine liners. This means water vapour from the combustion processes, condense on the cylinder walls rather than being expelled together

with the combustion gases - leading to corrosion of the system (termed cold corrosion).

When submitting samples from systems with additional cooling fluids, such as cooling waters or anti-freeze engine coolants, it is advised to submit a sample of these fluids for analysis. This practice is also useful to (1) rule these out as the source of any contamination and (2) confirm they are in good condition to effectively cool and prevent corrosion in the system

## Water in Oil – Removal

The first point to establish when water has been found in the oil - is the ability of the oil to separate from the water. If the oil shows poor water shedding ability then it is unlikely to be easily removed.

Similar to actions to remove dirt ingress the options are to:

- a) Change the oil,
- b) Filter the oil or
- c) Leave the oil.

Changing the lubricant contaminated with water is recommended for small systems, especially if grossly contaminated with water, even if the water easily separates from the oil. This is because the water may have damaged the oil additives and further, most engine formulations emulsify the water, making filtration a difficult and expensive option.

The table below shows the different types of water contamination and their prevention/removal:

	Water Contamination Management strategy							
	Gravity & Drain	Coalescing	Centrifuge	Absorbent	Vacuum	Dry Breather	Active Venting	Hot oil filtration / hot oil purifier
Use / Application	Remove	Removal	Removal	Removal	Removal	Prevention	Prevent & Remove	Remove
Water Type								
Gross Free (visible)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Moderate Free (visible)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Emulsion	Some	Some	Some	Yes	Yes	Yes	Yes	Yes
Dissolved	No	No	No	No	Yes	Yes	Yes	Yes

Simple methods to remove water such as the “gravity and drain” system, which amounts to regularly allowing the oil to stand for a period, then simply draining off the water - come under prevention. It catches the problem early and prevents subsequent wear.

Systems using hot oil filtration or oil purifiers, then increasing the temperature of the purifier to ~95°C (or maximum your manufacture of the filter and equipment recommends if 95 is too high) to remove the water. Active venting

has been classed as both prevention and a removal method as it is used as a removal method to remove water, but once fitted it then turns to a preventative solution for keeping water content low.

If you are using hot oil filtration or oil purifiers, then increasing the temperature of the purifier to  $\sim 95^{\circ}\text{C}$  (or maximum your manufacture of the filter and equipment recommends if 95 is too high) will help remove the water. Active venting has been classed as both prevention and a removal method as it is used as a removal method to remove water, but once fitted it then turns to a preventative solution for keeping water content low.

## Foaming issues - Introduction

All liquids foam to some extent when agitated, especially if they contain a surfactant (soap material), which can have two effects.

**Cosmetic Foam** – This is the term used to describe air bubbles in the lubricant that produce foam that floats to the surface of the lube oil tank. Its interaction with moving parts is limited, so has little effect on the cause of wear. However, it is an alarm warning to the machinery operator there is an issue with the lubricant's ability to suppress foam. Cosmetic foam can also be very severe and even spill over the sides of tank onto floors causing safety and environmental waste spillage problems.

**Circulating Foam** – If the foam is being drawn into circulation of the system so foam (air and Liquid) rather than liquid lubricant alone is being fed to moving parts - this can lead to a serious problem, likely to cause excessive wear to bearings and gears, as foam is a very poor lubricant, unable to carry load. Note: Foam in hydraulic systems will prevent the machinery to operate safely.

## Foaming issues – Identify the cause

Any circulating or excessive cosmetic foam should be addressed at the first available opportunity by sending a sample of the lubricant to a suitable laboratory to measure the extent of foaming compared to the lubricant's specification. This will identify the level of tendency to form foam and the stability of the foam once produced.

**Tendency** of foaming is a measure the amount of foam the lubricant is likely to produce in service if agitated with air. The Foam in this test is likely to and should collapse quickly once the agitation stops. Unless there is an excessive level of tendency to Foam then there should be no observable cosmetic foam problems. Generally, manufacturers quote on their product data sheets the foaming tendency levels to be expected and if there is a cosmetic foam issue, the oil supplier may be able to provide an anti-foam additive solution to the problem.

**Stable foam** – Stable foam is very serious and unless the lubricant is designed for special applications, even with high detergents lubricants, there should never be any stable foam in a system.



If observing high Foam tendency, the first step should be to check the new oil baseline is for the product in use - available from the manufactures datasheets. If this is not available then it is essential for the operator to send a unused reference sample from an IBC or new oil barrel.

All reputable lubricant brands will have undergone years of test-bed testing to confirm that the new lubricants provide the best lubrication properties to components before going on sale. If the new oil barrel / IBC value for tendency is close to the product datasheet value then it is very unlikely any observed excessive foam in the system is as a result of the lubricant, and is usually caused by contamination. If contamination is suspected a full 1L oil sample should be sent to the laboratory for a system health check analysis to investigate the problem and identify the cause of the foaming.

Note the laboratory may ask for samples of potential contaminants or products on site, which can be discussed by telephone or indeed agree to a site visit to help resolve the problem.

If on the other hand, the value of foam comes out considerably higher on the new barrel/IBC sample than the product datasheet state, then the next step should be to take a second sample to rule out bad sampling of the IBC or barrel. The laboratory can give advice on best practice for sampling to assist the operator if required. Confirmation of high Foam tendency and/or stability should be reported to the lubricant supplier, which will of course wish to carry out further tests.

## Foaming issues – Correcting

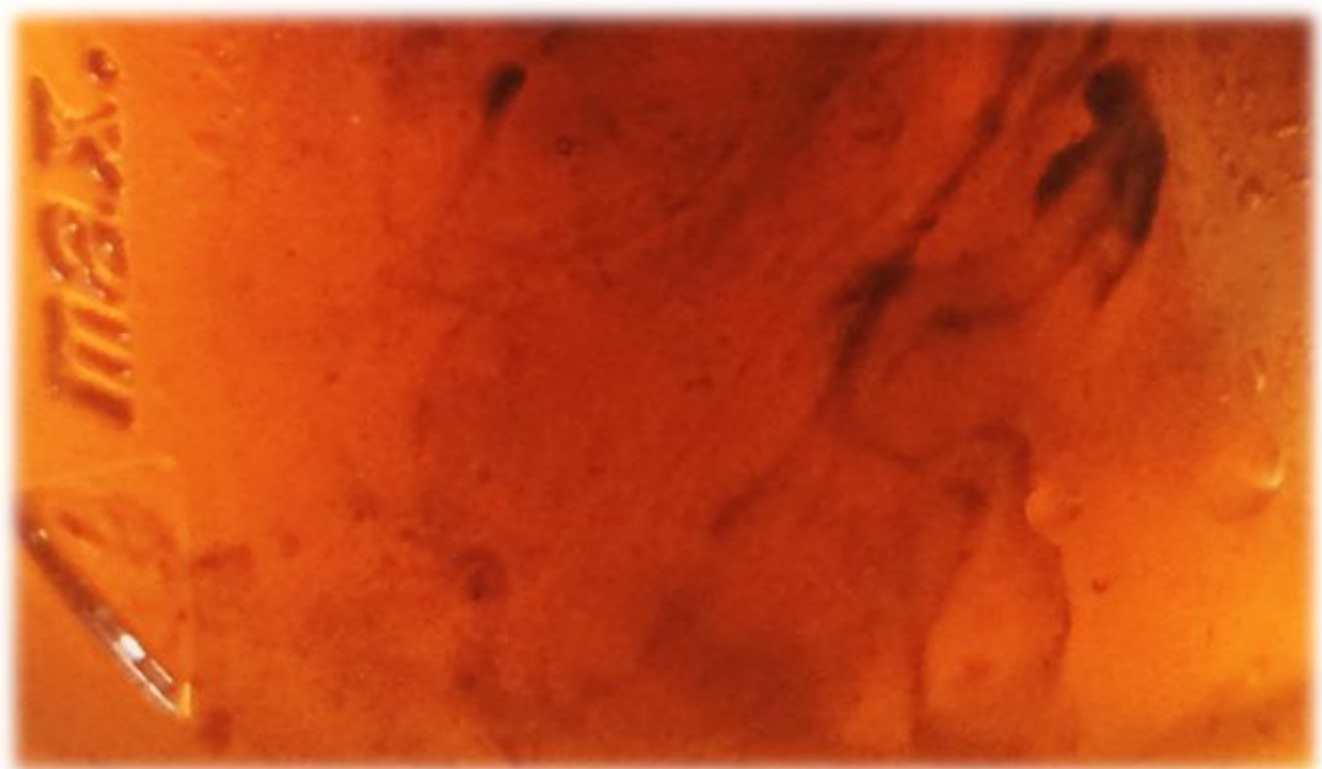
Depending on the cause of the foaming the issue may be solvable by filtration to remove contaminants. However, sometimes the issue may be mixing incompatible oil; then the solution could be a full drain, flush and fluid change to remove the contamination, which can be expensive and of course the last resort.

Ideally it may be just the addition of an anti-foam additive to the system help reduce the problem, but under no circumstances should this be done without first consulting the lubricant manufacturer. Over-dosing with antifoam can exasperate the problem or lead to other issues such as air release issues, which can cause more problems than small amounts of cosmetic foam.

In some cases low level cosmetic foam with a slightly raised tendency, but no stable foam may be something the machinery operator chooses to live with and just closely monitors the machine system for wear. To help with this choice, it is recommended the operator submits oil filters regularly for wear debris analysis to confirm the foam is not leading to any abnormal wear processes within the system

## Changing Oil Types - Mixing Wrong Oils - Intro

At some point all lubricated systems require an oil change either because the oil has come to the end of its useful life or has become contaminated.

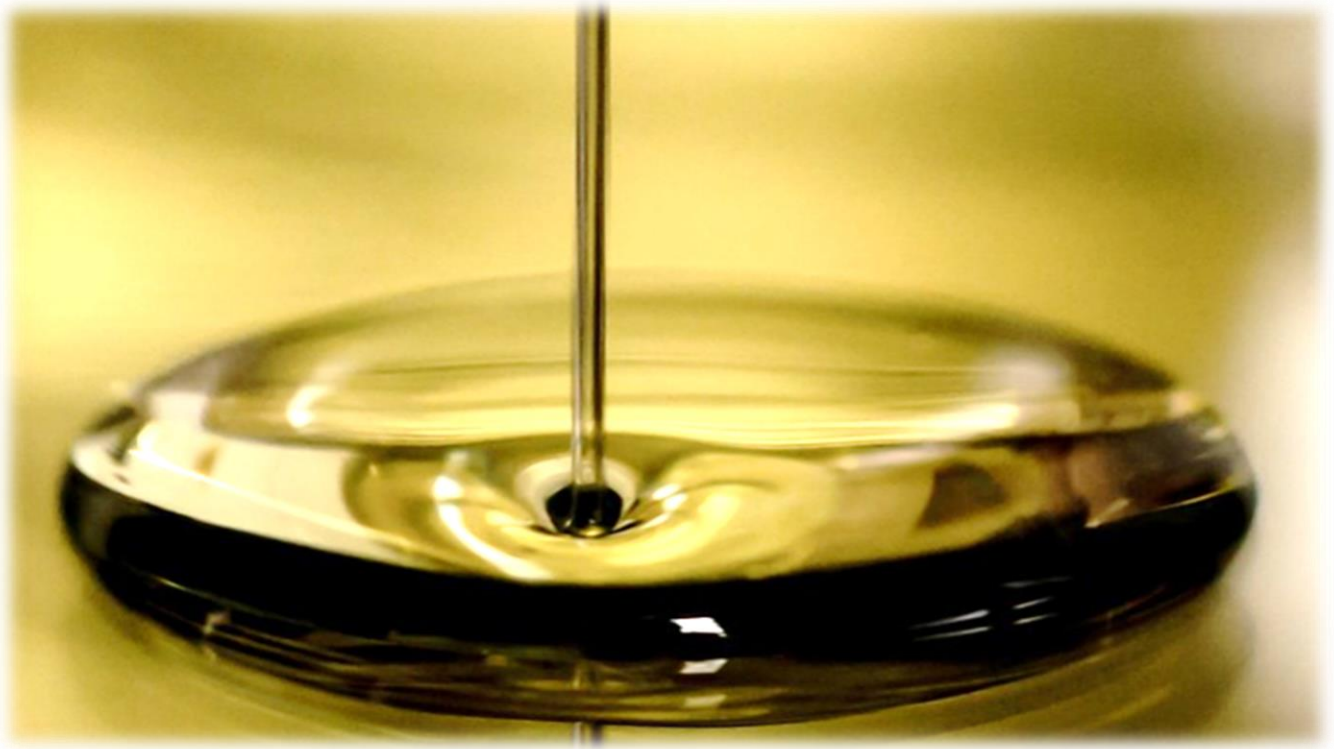




When performing oil changes - suppliers and product types may change - as business decisions are made as to which lubricants to use, based on performance testing and cost of the lubricant.

Therefore, throughout the life of the machine it is possible that several different brands of products have been used. Equally, in large oil filled systems performing an oil change may cost thousands of pounds, hence the decision is often made to use the new lubricant supply as top-up until the previous oil has effectively been removed. This means mixing of two products - often the source of many problems. The oil thereafter is never actually the new or old product and room for reasons the problem lies with the "other" oil. This approach is ok to have, as long as the individuals making the decision to mix the oils have fully researched the compatibility of the two oils and not only with the latest product

## Changing Oils - Is an oil change really needed?



The first thing to establish when changing oil is the reason for the change.

If it is just time based then this may be wasteful exercise, as oil should only be changed based on condition, unless the oil change is part of the warranty of the machine manufacturer.

If the volume of the oil makes the oil change an expensive exercise or indeed if downtime is not currently convenient, it is best to ensure any oil report recommendation to change the oil, has been confirmed by a second sample report. Please note an oil report is based on the sample received and problems such as incorrect submission information, sampling when the machine was not at operating temperature, drawing from the bottom of a storage tank or dirt entering the sample bottle when sampling etc. - a second sample is much cheaper than an unnecessary oil change. It is also worth establishing if, contamination is the problem it can be removed by other methods such as filtration or draining bottoms of tanks etc., which may be prove to be a far more suitable alternative.

If changing the oil is based on a fluid condition alone, such as poor water separation properties, which prevents simple settling of water and draining, or poor anti-rusting characteristics indicate loss of anti-rust protection – risking corrosion wear if water entered the system, then it may be worth introducing a stricter monitoring programme. This can help extend life of the oil, allowing an oil change to take place at a more convenient time, possible during an annual shutdown period and promote corrective procedures to reduce water ingress such as employing desiccant breathers etc. Finally, it is worth establishing if the oil change is just masking an underlining problem, such as a fuel or coolant leak, which should be addressed asap.

## **Changing Oils – Using compatible oils**

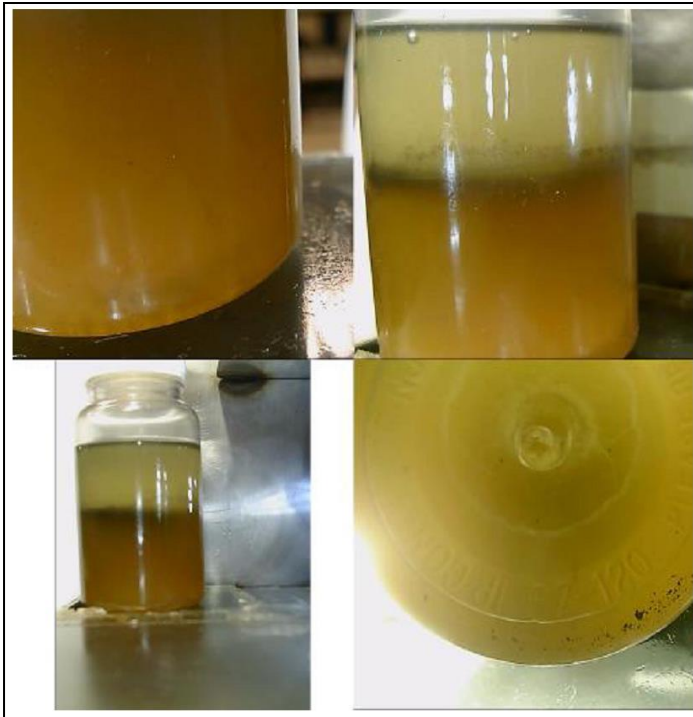
When changing products that are compatible, it is worth noting switching from a group 1 to a group 3 product; does not mean a 50% change of oil will give properties of the mix half way between those of the two products. This is also true when simply partially changing the same oil for fresh oil. The facts suggest the oil mixture will default to the worst scenario, so if the current product lasts 6 weeks and the new oil lasts 1 year, the properties and life of the oil mixture will be much closer to 6 weeks than the half way point between the two predicted remaining life. This is because the relationship between top-up and life of the oil is not linear; oxidation promotes more oxidation. Hence it is worth considering the benefits of the short term lower expenditure against an overall larger spend at that time. Insomuch much of the value and useful life of the new oil added will be lost, as a total oil change will soon be necessary. Note this cost comparison assumes the only factor at work is oxidation and the machinery conditions are identical in both scenarios.

## **Changing Oils – Using incompatible oils**

When changing oils that are known to be incompatible, it is always worth discussing with the lubricant manufacturer how clean the oil change must be, as there is always the risk some of the previous lubricant remaining. The steps to achieve this level of cleanliness should always be costed before making the

final decision to switch to a lubricant that is not compatible with the current lubricants in use.

The practicalities should also be considered such as does this mean all systems will be changed at once, or will some systems be running on one type of oil and some run on different oil? If all is to be changes at once, then this could be a large demand on resources and so needs careful planning. For example you may need to decide the cost of disposing of the unused barrels of the old product.



Equally if the plan is to phase in the lubricant switchover, then steps to prevent cross contamination e.g. separate oil fill containers, storage, labelling, sampling equipment etc. Training must be paramount. The team must know what oil should go in which machine, even despite these preventative measures there is nothing to stop human error leading to cross contamination of the products. See example picture on the left where the customer had separate warehouses for the two oil types, believing they had designed a system that was impossible to cross contaminate the products, yet they still

managed to mix a mineral and synthetic product in quite considerable quantities.

The process of making the change is not just simply draining one oil and replacing with the new one in applications like this, but requires repeat flushing to remove the contaminating fluid. There are several options and there is no universal best option for making changes such as this, but your OEM or lube oil supplier should be able to assist in picking the most practical and cost effective option.

**Drain as much out as you can and then fill with the new oil** – This is by far the cheapest option adopted by many operators, but often leads to scenarios in the above picture. This is an approach that should not be adopted if the oils are incompatible, however, the cost of solvent/flushing oils often make cost conscious engineers tempted by this option.

**Use a solvent or flushing oil** (usually a lower viscosity version of the current product or an OEM approved cleaning solution) to remove the majority of the old oil and hence make removing the old oil easier when introducing the new product. These solvents can often be quite expensive, so it is often worth asking the lube oil supplier to include in the quotation for switching to their

new product an additional line on the quotation to include the costs of flushing liquids.

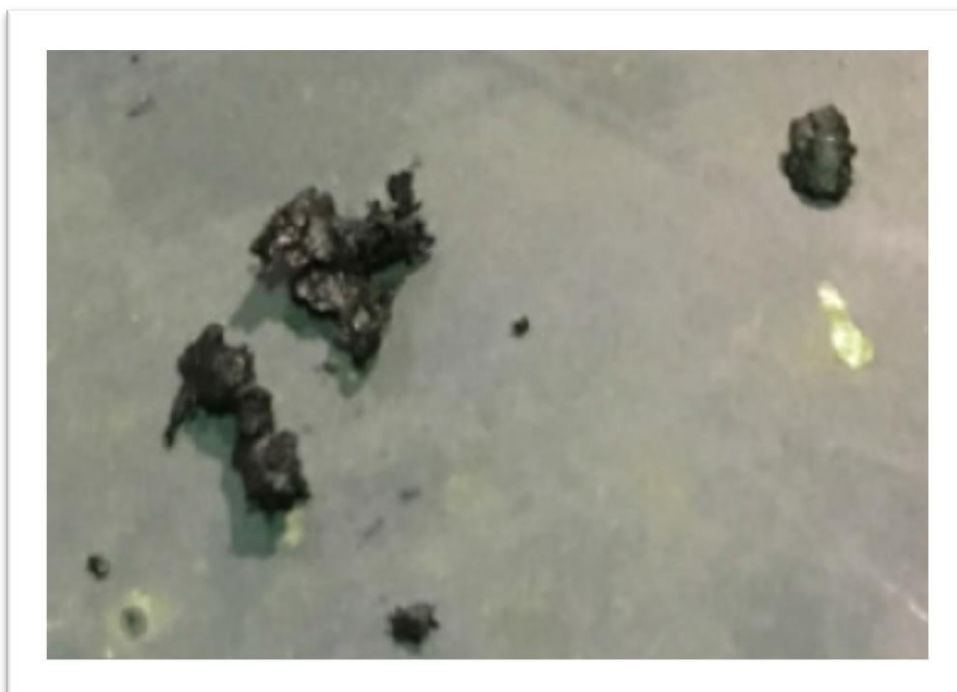
**Flush with the new product** – This approach uses cleaning out the empty system with the new product to remove traces of the old product, draining and refilling again. Again, it is worth costing this exercise before making the decision to switch.

**Solvent/flushing oil followed by flush with new product** – This gives a very thorough cleaning of the system, but is the most expensive option. Hence the importance of establishing the degree to which the oils can be mixed without causing problems by checking with your oil supplier. The cleaner the requirements, the more heavily flushed the system will require. As a very general rule of thumb, 90% can be removed with 1 flush, 99% with 2 flushes and 3 flushes removes up to 99.9% in perfect conditions.

## Changing Incompatible Oils – Check seal compatibilities

Before the final decision is made to switch lubricant types it is advisable to ask the laboratory and/or oil supplier to carry out a seal compatibility test to check the impact of the new oil on the machine seals i.e. a seal swell test. If expecting at the end a 1.5% mix of the old product in the new product and the operating temperature is 45°C the lab can simulate these conditions and create these mixes to establish if the seals are likely to change as result. Ideally an unused spare seal material should be submitted as part of the testing to confirm compatibility.

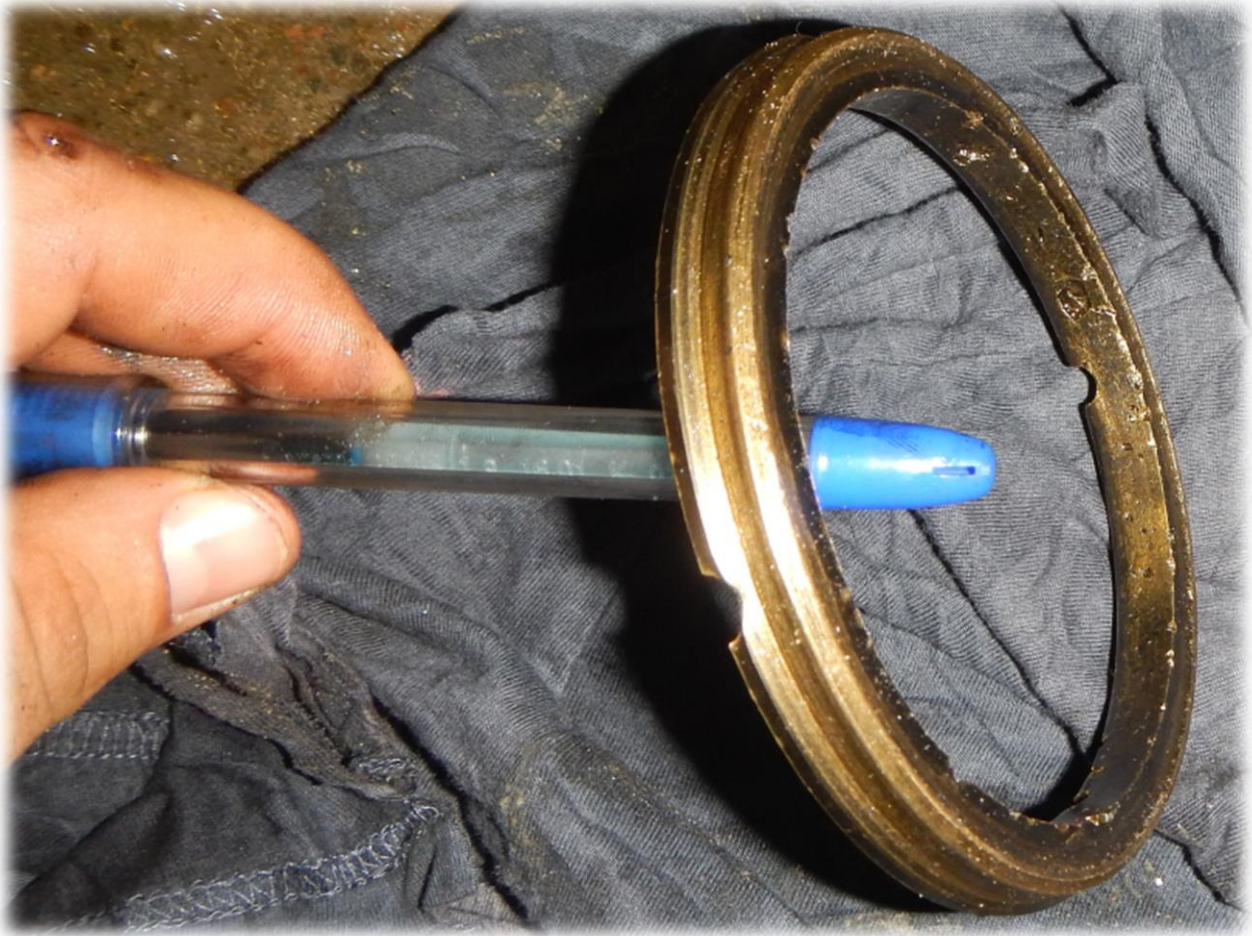
A picture is below of material from seal damaged by incompatible oil.





## Abnormal Noise, Heat, Vibration or high Wear metals

Any abnormal noise, heat or vibration should instigate sending an oil sample to establish the cause of the problem (unless another NDT technique suggests immediate stopping of the machine to prevent catastrophic failure). If the analysis result is time critical it may be worth contacting the lab to discuss your options for urgent analysis.



Whether the oil report or another investigation suggests a high wear process it is worth establishing the cause in a methodical manner. On smaller systems the cause may be quite easy to spot as there are only a limited number of components involved, but a wear debris analysis can aid in identifying potential contaminants and wear modes to narrow this down further.

On larger systems there can be multiple points of failure, and so this is where if taking from one primary sampling point it may be worth taking from additional secondary sampling points close to components but before any filters. These samples will reveal the highest concentration of wear metals and hence the likely source of the wear and failing component.





Likewise, if the system has filtration, then much of the wear in the system is likely to get trapped in the filter, rather than remain in circulation, hence submitting the filter for analysis is an excellent way to detect the root cause of a problem. Filters concentrate the wear metals and contamination in one place, helping to assist the root cause analysis procedures.

**Note: It is never advised to make a costly shutdown or component replacement on the back of one single oil analysis report. It is best practice to build a trend and ideally use confirmation tests to confirm oil analysis findings (such as abnormal noise, heat, oil volumes, top-ups, pressures, filter replacements etc)**

## Training Courses (ISO 18436 certification)

If you have enjoyed this introductory guide and would be interested in attending one of our formal training courses please let us know at [techservice@alcontrol.com](mailto:techservice@alcontrol.com)



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- Input of laboratory data into spreadsheets/database
- Maintain Oil analysis program/database
- Undertake basic machine inspections/audits
- Demonstrate basic quality knowledge in accordance with laboratory practises (ISO 17025)

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- Management Reporting
- Operate & Identify wear debris particle instruments
- Preparation of reports & corrective actions on machines condition
- Manage & Trend analysis databases
- Use of other CM Techniques (VA, Thermography)

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## Coming soon in next version of this guide

If you would like to offer suggestions for other topics to cover in the next version of this guide click contact us at [www.lubetrend.com](http://www.lubetrend.com)

**These pages are for additional notes**

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