Oil Analysis, Filtration and Sampling Process

A research presented to the

Department of Engineers Syndicate

In Partial Fulfillment of

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Abstract

Often, maintenance managers face challenges in making maintenance decisions due to the lack of sufficient and accurate information. It's not uncommon for the current problem to be resolved, but the cause of the problem remains, which is why some types of failures often recur, reducing the equipment availability and generating additional costs. To overcome these challenges, modern maintenance principles are based on the application of the equipment condition monitoring techniques. One of these techniques is used oil analysis also known as lubricant condition monitoring, which yields an insight into the physical and chemical state of the lubricating oil, as well as the condition of the machine elements that come in contact with oil during routine operation. To illustrate the benefits of employing this technique, a case study of asphalt paving machine is presented. In the case study, four basic lubricant parameters (viscosity, water content, solid particulate content and acid number) for the hydraulic system were analysed. The results of the analysis show a sudden increase in the solid particles content, due to which certain maintenance interventions had to be taken to avoid failure of the system and unnecessary maintenance costs. Also, by oil condition monitoring, after two years, maintenance staff received information which is the base for making a decision on the appropriate replacement interval of hydraulic oil.
"Oil Analysis, Filtration and Sampling" is intend to be a comprehensive research material for all technical staff within the group companies and specially for the plant staff, responsible for operational lubrication. It can be used as a guideline to set-up an oil analysis programs in the plant or to review existing analysis programs in regards to their completeness. The research material contains detailed information of recommended oil analysis, condemning limits, contamination ratings and comparisons, filter selection criteria and oil handling.

To outline the main oil analysis methods as used in the cement industry

1. To present the root causes of oil degradation and

2. the limits to respect for proper operation

3. To summarize the main tips and tricks for oil sampling

Table Of Content

Keyword: Cost management, proper usage, failure managment, oil filtration necessity, water content, water impact, sampling.

Introduction

Every year millions of liters of lubricants are prematurely changed in equipment resulting in the disposal of oils, which still have remaining useful life. With the need to maximize the life of the oil to its full potential, but at the same time being cognizant of potential dangers with extended drain intervals, outside contamination and poor maintenance practices, oil analysis should be a corner stone of any maintenance program.

Oil Analysis

1. The first step in setting up an oil analysis program is to select the systems to be monitored
2. Establish the sampling frequency (considering machine

   and oil age – both are moving targets, readjustments required)
3. Determine the cleanliness target of oil sample
4. Ensure proper sampling methods and techniques
5. Ensure a proper evaluation and documentation of sampling results (history and graphical trend analysis are essential parts of the evaluation process)

Oil Sampling Procedure and Frequency

As it is very important that the oil samples for oil analysis are representative, follow the procedure:

1. Critical equipment are normally sampled every six months. If a problem has been observed, sampling becomes more frequent.
2. Sampling is recommended only on reservoirs greater than 100 liter (25 gallon) or due to downtime priorities. There is an economic trade-off between fluid replacement and the costs associated with analysis and fluid reconditioning.

3. Oil reconditioning will be usually done on reservoirs greater than 200 liter (50 gallon) to improve the oil quality (by bypass filtration, centrifuges or vacuum dehydrator). There is an economic trade-off between fluid replacement and the costs associated with analysis and fluid reconditioning.
4. Use only laboratory approved sample bottles – 100% clean
5. Preferably take sample while system is running
6. Take sample from a fixed point, where the oil is moving or flowing
7. If the sample is taken from a valve, flash through the valve with a sufficient quantity (normally at least 500ml).

Methology

Oil Sampling Procedure and Frequency

1. Strictly avoid any pollution from the surroundings to enter the sample
2. Seal the bottle right after the sample have been taken
3. Provide the bottle with following data:

- Company name
- Sample reference number
- Date and time of sample
- System reference e.g. HAC
- Fluid type, ISO VG and supplier
- Sampling location
- Service life of oil.

4. Often the oil sample are analyzed by the supplier, sometimes it is good to change to an independent body.

5. As the analysis is an evaluation of a rather costly product, it can be recommended to asks the supplier for analysis data for a new oil as well as the rejection limits.
6. Fore more details regarding extraction of fluid samples from lines of operating systems see ISO 4021.
7. An analysis of lubricating oil could contain following information:

1. Recommended Analysis for Gear Oil

- IR - Infrared Spectrum
- Appearance / Color
- Viscosity cSt
- TAN – Total Acid Number
- Water Content
- Wear Particle (weight %)
- Trace metal analysis (ppm and size) – optional

2. Recommended Analysis for Hydraulic Oil

- IR – Infrared Spectrum
- Appearance / Color
- Viscosity cSt
- TAN – Total Acid Number
- Water Content
- Wear Particle (weight %)
- Foam
- Trace metal analysis (ppm and size) - optional
- Particle counting - ISO 4406 (optional)

Frequently Damages due to Contamination

Different types of contamination affect the oil in different ways- but one thing is sure, they all shortened the lifetime of the equipment and the oil.

Type of contamination:	**Cause:**
Dust (Si, Ca, etc.)	Increased wear – reduction of lifetime of equipment
Metal particles	Wear (micro-pitting) – increased wear
Water	Reduction of lubricity, lifetime of oil and corrosion
Acid	Rust and corrosion
Soot	Deposit, which is plugging filters and oil passages
Fuel dilution	Reduction of lubricity
Oxidation	Lacquer on piston and liner, fastened piston rings

Frequently Damages due to Contamination

Investigation on 2000 bearing damages showing, that the most frequently cause of damage was dirt.

Percentage:	**Cause of damage:**
45 %	Dirt in bearings
15 %	Misalignment in bearings
10 %	Wrong assembly of bearings
10 %	Overload
10 %	Lack of lubricants
5 %	Rust and corrosion
5 %	Other reasons incl. wrong lubrication rec.

Wear Metals Warning Limits

Element	Warning Limits	Remarks
Iron (FE)	> 100 ppm	Indicate worn crankshafts, valves, cylinder liners, bearings
Chromium (Cr)	> 5 ppm	Indicates worn piston rings, bearings or contamination by antifreeze
Copper (Cu)	> 20 ppm	Indicate worn bearings and bushings
TIN (Sn)	> 10 ppm	Indicate worn bearings and bushings
Aluminum (Al)	> 20 ppm (> 80 ppm Alu. Block Engine)	Indicate worn piston or engine block
Lead (Pb)	> 20 ppm	Indicate worn bearing. Where leaded gasoline used, results are meaningless.
Boron (B)	> 20 ppm	Indicate antifreeze leak. Some engine oils contain a boron dispersant additive.
Silicone (Si)	> 20 ppm	Indicate presence of dust or sand. May also due to high level of silicone anti-foam.
Magnesium (Mg), Calcium (Ca), Barium (Ba), Sodium (Na), Phosohorus (P), Zinc (Zn)		These elements may be part of the additive package. They remain in the oil and do not deplete.

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Tests, Warning and Condemning Limits

Test	Caution	Critical	Remarks
IR Infrared Analysis			Addresses lube chemistry and degradation process – must be compared to new oil
Viscosity Test cSt 40 °C (mm²/s) DIN 51562 or ASTM D445	± 10%	± 15 %	Change versus the new oil viscosity. It will increase when aged.
TAN - Total Acid No. (mg KOH/g) DIN 51588 or ASTM D974		1.0 increase from new oil	Acid no. is proportional with the degree of degradation. Trending important.
Wear Particle (weight %) DIN 51592		>0.08 %	Note: Fresh oil is not clean oil and must be filtrated during re-filling
Wear Particle Analysis Direct Read (DR) Ferrography or Spectrochemical Analysis (SMA)		Limits see next page	Normally together with a microscopic evaluation to determine size, composition and wear type of particle
Water (weight %) DIN 51582 or ASTM D1744, D95	> 0.05 %	0.1 % Hydraulic Oil 1.0 % Gear Oil	Most accurate is Karl Fischer (ppm) or distillation test. Excessive water is the second most destructive contaminant.
Flash Point °C DIN 51794 or ASTM D 92	± 15%	± 20 %	Lowest limit should be 160 °C
Density 15 °C (g/cm³) DIN 51757		< 2 %	
Foam (ml) DIN 51566 or ASTM D 892	No Foam	No Foam	Mainly used for hydraulic oils.
Air Entrainment (min. with 50 °C) DIN 51381	< 5 min.	< 8 min.	Mainly used for hydraulic and gear oils

Test	Caution	Critical	Remarks
Demulsibility ASTM D 1401	< 30 min Complete separation	< 45 min	Test time for specified test for oil-water emulsion to break
Corrosion Test DIN 51355, DIN 51585, ASTM D 130		Failed	Non corrosiveness is not to be confused with rust inhibiting.
Pour Point DIN 51597			Pour point is 3ºC above the temp. to which normally the product maintains fluidity.
Ash Content ASTM D 582, ASTM D874			Since some detergents are metallic salts or compounds, the percentage of ash has been considered to have a relationship to detergence.
RBOT – Rotary Bomb Oxidation Test ASTM D 2272	< 50 %	< 25 %	Change versus the new oil. Test mainly designed for turbine oils.
Fuel Dilution		3 %	
FZG Test DIN 51345		< 12	Mainly CLP, HLP, HK Oil. Special Test DIN 51354 A.276/50 for extreme heavy load condition
Four Ball Test ASTM D 2266, ASSTM D 2596 (EP Test)		Depend on	To determine the relative wear preventing properties of lube under boundary condition.
Timken Load Test			For extreme pressure properties. Measures the maximum load that can be carried without scoring.

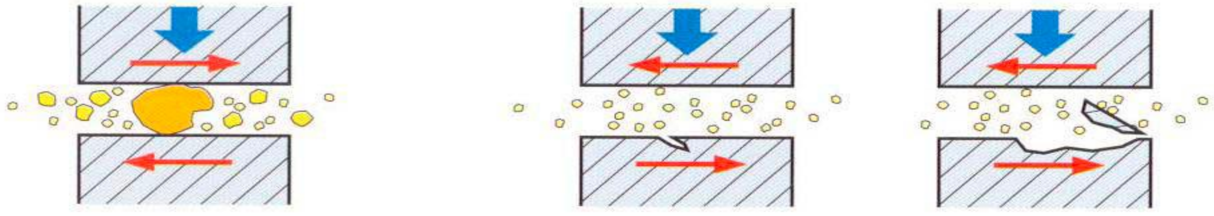
Visual Check of Water in Oil

Amount of water, ppm:	Appearance of oil:
0	Bright and clear
100	Trace of translucent haze
200	Slight translucent haze
250	Translucent haze
500	Opaque haze
1000	Opaque haze with slight water drop out

1 ppm = 1ml pro 1000 liter or 1000 ppm = 0.1 %

Wear Causes

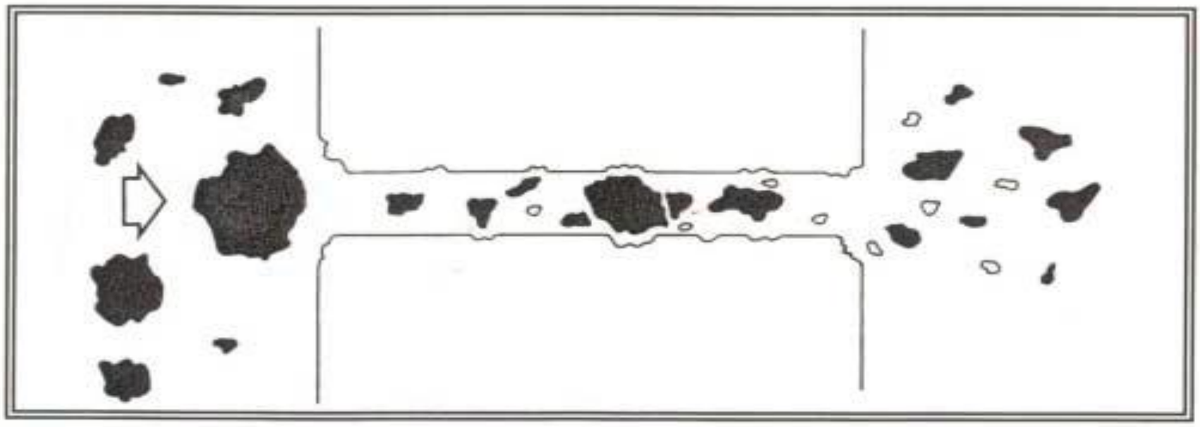
1. Wear caused by local overload (fatique stress) of the surface.
2. The particle will introduce a microcrack in – or right under the oil surface.
3. The crack will increase in size, and finally the oil pressed into the crack will create the micro pitting – and more particles.
4. Wear caused by erosion, when particles hits the metal surface with high velocity. The impulses will loosen particles. The phenomena is most actual when there is turbulent oil flow.



Mechanical Pollution

The dust and metal particles (mechanical pollution - particle contamination) comes from three sources:

1. Build-in pollution from fabrication or erection (cylinders, hoses, fittings, pipes, pumps, valves etc.)
2. Wear from operating conditions e.g. poor housekeeping
3. Service pollution, when a lubricating system is opened (for repairs, inspections, oil services etc.)



Impact of Water and Catalysation to Service Life

Beside the wear caused by solid particles, the material of contamination particles and their catalytic ability have also a major impact to the service life of oil. The chart is indicating that for instant Cupper has a much higher catalytic impact compare to Ferro. In addition to water, the service life of oil will be reduced to a minimum of the original specified life time.

Water	catalytic converter	operating hours	neutralization no. after test
without	with	>3500	0.17*
without	Ferro	>3500	0.65*
without	Cupper	3000	0.89*
with	Without	>3500	0.90*
with	Ferro	400	8.10*
with	Cupper	100	---

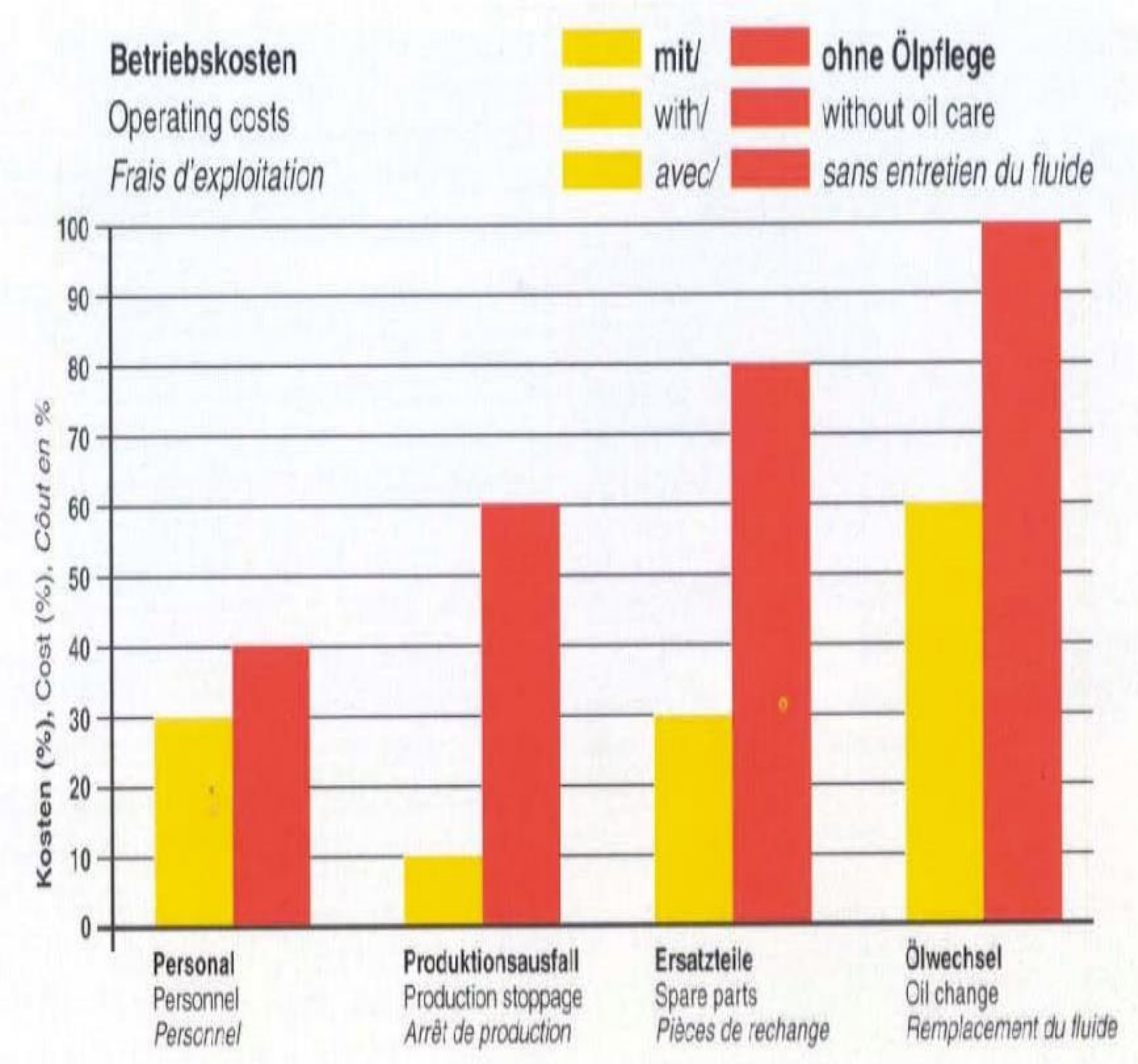
* Above mentioned neutralization no. is representative for turbine oil only – new oil n_z 0.17

Handling of Oil

1. Handling of oil is focused on 205 litre barrels and drums
2. Best storage of barrels is in-door in a clean, vented and fire proof room
3. Storage out-door requires water proof cover
4. Barrels must always be stored horizontal, as the thermal expansion will suck water through even sealed plugs.
5. First-in, first out policy should be adopted.
6. Under the barrel tap should be a waste tray.
7. Keep surface clean especially around the taps, as greased surfaces (and open oil/grease barrels) collects dust.
8. Barrels should be lifted /moved only with sufficient equipment/tools.
9. High viscosity oils need to be above 10ºC before used
10. Heavy additivated oil are quite toxic and must be handled with care.
11. Wear rubber gloves.

12. Reject the old oil according to the instructions of local authorities.

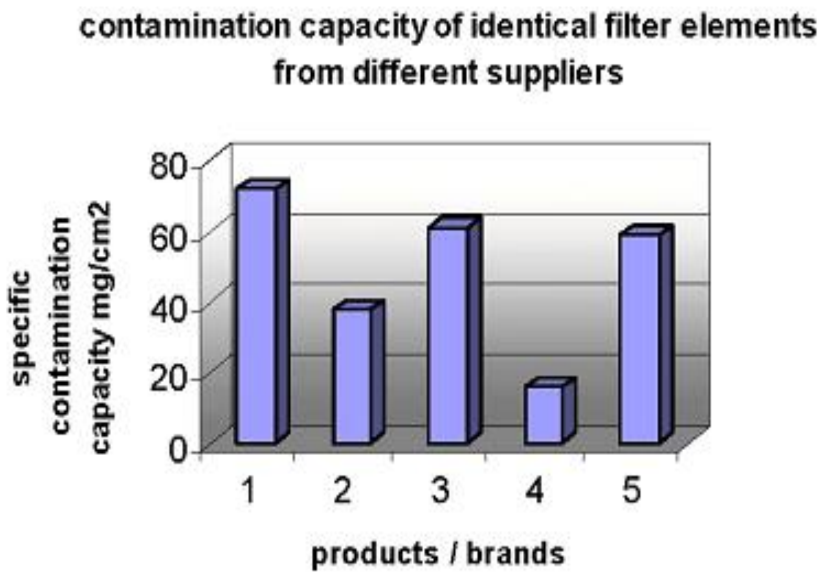
Cost Reduction with Oil Care



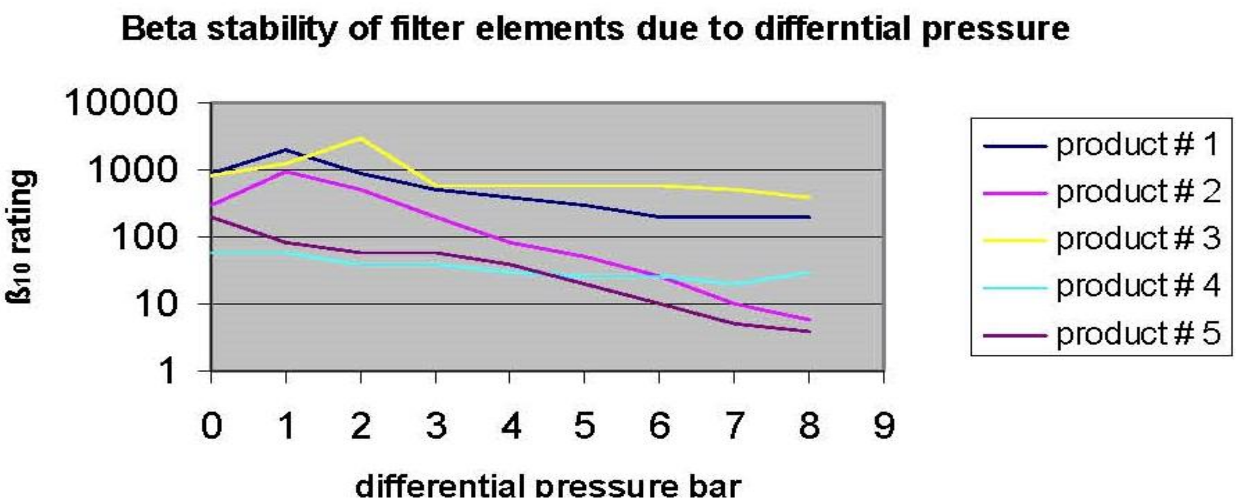
Selection Criteria for Filter Elements

To ensure the best return of investment of your filter elements following characteristics should be considered:

1. Differential pressure sustainability
2. Specific contamination capacity

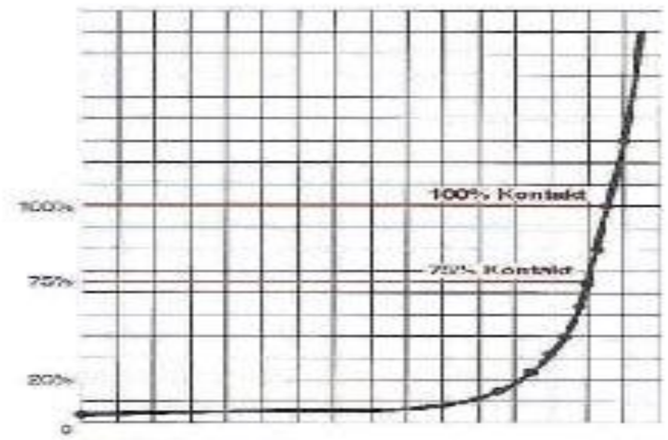


Differential pressure 3.5 bar



Differential Pressure due to Contamination Capacity

The oil cleanness will always be a compromise of "what is necessary to obtain the specified life time and the cost" (pressure drop across the elements, filter dirt capacity etc.)



Filter Rating

Previous and elder filter ratings are based on different supplier experiences and internal tests. Since the introduction of Beta (***ß***) ratings under consideration of the differential pressure, it is possible to compare products of different suppliers and their filter ratings. There are two classification on filter ratings:

1. Nominal filter rating
2. Absolute filter rating (highly preferred)

Nominal filter rating: There is no useful ***ßx*** rating determent. That means for the user: even with the right filter element, only a part of the contamination will be filtered. For example: Selecting an filter element with ***ß10*** =??? means filtration of 10 µm particles. But the retention rate is not defined and might be only 50% what means that the efficiency drops dramatically.

Absolute filter rating: Only with a ***ßx*** = 100 or a retention capacity of 99%, the filter rating will be called ***"absolute retention rate"***.

Filter Rating

For example: The ***ß10*** **= 100** ensures a filtration with 99% retention rate of the selected particle size of 10 µm.

ßx = 2 50.00% efficiency or retention capacity (nominal)

ßx = 20 95.00 % efficiency or retention capacity (nominal)

ßx = 75 98.67 % efficiency or retention capacity (nominal)

***ßx* = 100 99.00 %** efficiency or **retention capacity (absolute)**

ßx = 1000 99.90 % efficiency or retention capacity (absolute)

The reduction factor ßx defines the ratio between the number of particles (of size or bigger than x) before and after the filter element. X is indicating the max. Particle size in µm.

Therefore, we highly recommend to use only the absolute filter rating.

Recommended Degrees of Purity and Filter Level

Typical demands to components		Recommended maximum contamination		New (fresh) oil is not necessary clean oil !!! Typical range of contamination for fresh oil is approx. NAS 1638 - # 9		
ISO 4406	NAS 1638	ISO 4406	NAS 1638	Pressure	Typical systems	Filtration $ß_x$ (100 (absolute)
12/9	3	12/9	3	0-600 bar	Silt sensitive systems with very high demands for reliability of operation. Laboratories – space travel – airplanes – control systems	1-3 µm
15/12	6	14/11	5	0-400 bar	Servo systems, great accuracy, high pressure, long lifetime. Certain airplanes – tool machines – certain plastic machines – servo hydraulic systems - robots	3-5 µm
16/13	7	15/12	6	0-300 bar	Proportionate systems – flow regulation. Fast adjustable pumps. Hydrostatic systems – roller bearings - production machines in general - universal hydraulic systems	5–10 µm
18/15	9	16/13	7	0-250 bar	Ordinary directional valve – adjustable pumps – planetary gear drives – conventional mobile hydraulics	5-15 µm
18/15	9	17/14	8	0-250 bar	Components as above used in systems in which reliability and lifetime are not decisive parameters.	10-15 µm
18/15	9	18/15	9	0-150 bar	Medium pressure systems in which some operations stops are acceptable – cylindrical gear drives – heavy duty hydraulics	15-25 µm
19/16	10	19/16	10	0-100 bar	Medium pressure systems in which components are specially designed for high contamination – heavy duty machinery	20-30 µm
20/17	11	20/17	11	0-60 bar	Low pressure systems as for instance winches with separate hydraulics for remote control and large tolerances – mining industry	25-40 µm
21/18	12	21/18	12	0-40 bar	Low pressure systems with directly manually operated valves – mining industry	40-50 µm

Comparison of Different Filter Design

Design of filter element	Advantage	Disadvantage
Pressure filter	Filtration takes place direct before the critical component. This ensures the required cleanness of oil	Expensive filter housing and elements. Difficult filter element design because of the high differential pressure ability. No protection of pump elements.
Return line filter	Filtration of the entire return line lubrication. No contamination of tank reservoir. Low price elements and filter housings. Large element size due to low pressure requirements.	High grade equipment like servo valves must be protected with an additional pressure filter element. Installation of bypass valve required Elements with low differential pressure stability can be destroyed due to mass pulsation.
Bypass filter	Constant filtration, independent of operation condition. Optimum exploitation of contamination capacity of filter element. Low costs filter housing and elements. Easy supplementary installation possible. Good	High grade equipment like servo valves must be protected with an additional pressure filter element. Due to the ad pump, higher energy consumption of system. Higher capital expenditure required. For cyclical contamination extended bypass filtration required.
Suction filter	Filtration of liquid / oil due to the suction (flow rate) of pump.	Finest filtration not possible. Not easy to clean. Protection of pump regarding under pressure absolute necessary.

Comparison of Different Contamination Ratings

ISO DIS 4406 / Cetop RP 70 H: The contamination rate of oil is defined with two numbers, represented by a code.The code 17/14 for instant is indicating a specific number of particles > 5µm and > 15µm due to 100 ml test sample (nowadays three numbers like 21/17/14 for > 2 µm, > 5µm and > 15µm) .

NAS 1638: Maximum number of contamination particles are determines in regards to their seize on 100ml test sample. Details see next page.

MIL STD 1246 A: The Norm has almost no acceptance any more within the industrie and will be used only in very specific cases.

SAE 749 D: Due to the relative low number of particles (9 particles to 580 particles/ml), the classification has been replaced by NAS 1638 (1971).

ISO DIS 4406 oder Cetop RP 70 H	Partikel pro ml > 10 µm	ACFTD Feststoff-gehalt mg/l	MILSTD 1246 A (1967)	NAS 1638 (1964)	SAE 749 D (1963)
26/23	140000	1000			
25/23	85000		1000		
23/20	14000	100	700		
21/18	4500			12	
20/18	2400		500		
20/17	2300			11	
20/16	1400	10			
19/16	1200			10	
18/15	580			9	6
17/14	280		300	8	5
16/13	140	1		7	4
15/12	70			6	3
14/12	40		200		
14/11	35			5	2
13/10	14	0,1		4	1
12/9	9			3	0
18/8	5			2	
10/8	3		100		
10/7	2,3			1	
10/6	1,4	0,01			
9/6	1,2			0	
8/5	0,6			00	
7/5	0,3		50		
6/3	0,14	0,001			
5/2	0,04		25		

Contamination Rating due to ISO 4406

Adopt the new ISO 4406 standard with 3 digit code; increase 1st digit by one level: (2 / 5 / 15 µm) compare to the previous ISO with 2 digit code (5 / 15 µm)

Klasse	5-15 µm	15-25 µm	25-50 µm	50-100 µm	> 100 µm
00	125	22	4	1	0
0	250	44	8	2	0
1	500	89	16	3	1
2	1000	178	32	6	1
3	2000	356	63	11	2
4	4000	712	126	22	4
5	8000	1425	253	45	8
6	16000	2850	506	90	16
7	32000	5700	1012	180	32
8	64000	11400	2025	360	64
9	128000	22800	4050	720	128
10	256000	45600	8100	1440	256
11	512000	91200	16200	2880	512
12	1024000	182400	32400	5760	1024

Contamination Rating due to NAS 1638

Maximum number of particles in 100 ml hydraulic oil

Klasse	5-15 µm	15-25 µm	25-50 µm	50-100 µm	> 100 µm
00	125	22	4	1	0
0	250	44	8	2	0
1	500	89	16	3	1
2	1000	178	32	6	1
3	2000	356	63	11	2
4	4000	712	126	22	4
5	8000	1425	253	45	8
6	16000	2850	506	90	16
7	32000	5700	1012	180	32
8	64000	11400	2025	360	64
9	128000	22800	4050	720	128
10	256000	45600	8100	1440	256
11	512000	91200	16200	2880	512
12	1024000	182400	32400	5760	1024

Typical Tolerances / Clearances of quipment

Limits for internal clearances without load prior to mounting		Tolerance / gap (µm)
Servo valve	Control nozzle Deflector plate Piston / sleeve	130 – 150 18 – 63 1 - 4
Gear pump	Gear – side plate Gear - housing	0.5 – 5 0.5 - 5
Piston pump	Piston – cylinder (radial) Valve plate - cylinder	5 – 40 0.5 - 50
Vane pump	Vane tip Vane side	0.5 – 2 5 - 13
Ball Bearings C3	Max. Internal clearance, bore Ø 50 / 100 / 200 mm Elasto-hydrodynamic lubricant film thickness	43 / 66 / 132 0.60
Spherical Roller Bearings C3	Max. Internal clearance, bore Ø 50 / 100 / 200 mm Elasto-hydrodynamic lubricant film thickness	90 / 160 / 290 0.65
Sleeve bearings	Between liner and shaft e.g. Kiln roller bearing journal Ø approx. 500 mm	30 - 40
Gear Drive	Between gear mesh (min. 2 x Ra) to avoid boundary friction. Elasto-hydrodynamic film thickness approx.	1 – 2 (normal gear drives) 6 – 10 (open gear drives) 1.37

Mobile Filtration Units

Example of mobile pump unit with large filter element, suitable for filtration or pump transfer.

Bypass filtration possible with 40 l/min and 5 to 40 μm elements for water or oil filtration.

1. Filtration during filling
2. Commissioning flushing
3. Continuous off-line filtration
4. Water extraction

Note: New (fresh) oil is **not clean** and should be filtrated before commissioning !!!

Element Performance and Cost Comparison

1. Especially due to the high costs of water absorption filter elements, cost trade-offs should be examined before filtering.
2. Look at the costs associated with the different filters, the media, and the maintenance costs. Then calculate the total cost per unit volume of water removed by an element.
3. Also, consider the reduction in solid contaminants that will be gained with the water absorption filter.
4. Look always for the best cost / performance balance.

Note: Many water absorption filter also remove solid particles.

Tank Breather Filter

The biggest culprit for letting dirt enter your system is the air breather. Most systems come with a standard paper media breather with a rating of about 40µm or sometimes a simple wire mesh with 200µm. This means that the smaller, more destructive particles e.g. fine dust, are able to get into the system very easily. Therefore, the simplest and most efficient way to improve the reliability of the equipment is to check and if required re-install suitable tank breathers.

Note: Size Range of Fine Dust is from <1 to 80µm - Particle Technology Inc. PTI 5-80 per SAE JI858

Filtration in micron: 3, 10……µm

Oil Analysis and Sampling made simple

Objective

1. To outline the main oil analysis methods as used in the cement industry
2. To present the root causes of oil degradation and the limits to respect for proper operation
3. To summarize the main tips and tricks for oil sampling

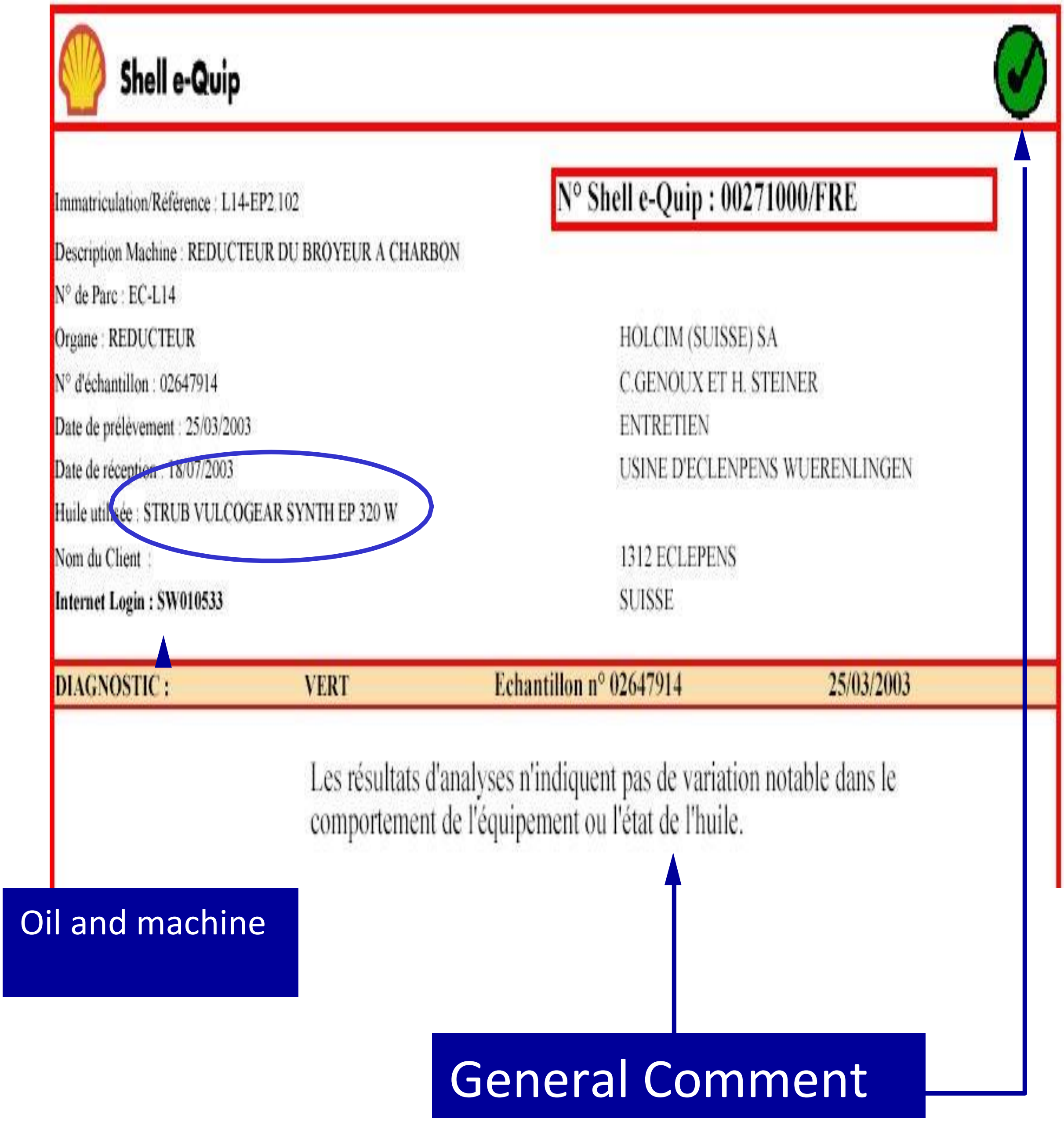
Agenda

1. Main tests used for cement equipment (not engines)

- Viscosity
- Water content
- TAN
- Foam
- Flash point

- Elemental spectroscopy
- Ferrous density
- Particle count

2. Tips and tricks for oil sampling


Shell e-Quip

Immatriculation/Référence : L14-EP2.102

N° Shell e-Quip : 00271000/FRE

Description Machine : REDUCTEUR DU BROYEUR A CHARBON

N° de Parc : EC-L14

Organe : REDUCTEUR

N° d'échantillon : 02647914

Date de prélèvement : 25/03/2003

Date de réception : 18/07/2003

Huile utilisée : STRUB VULCOGEAR SYNTH EP 320 W

Nom du Client :

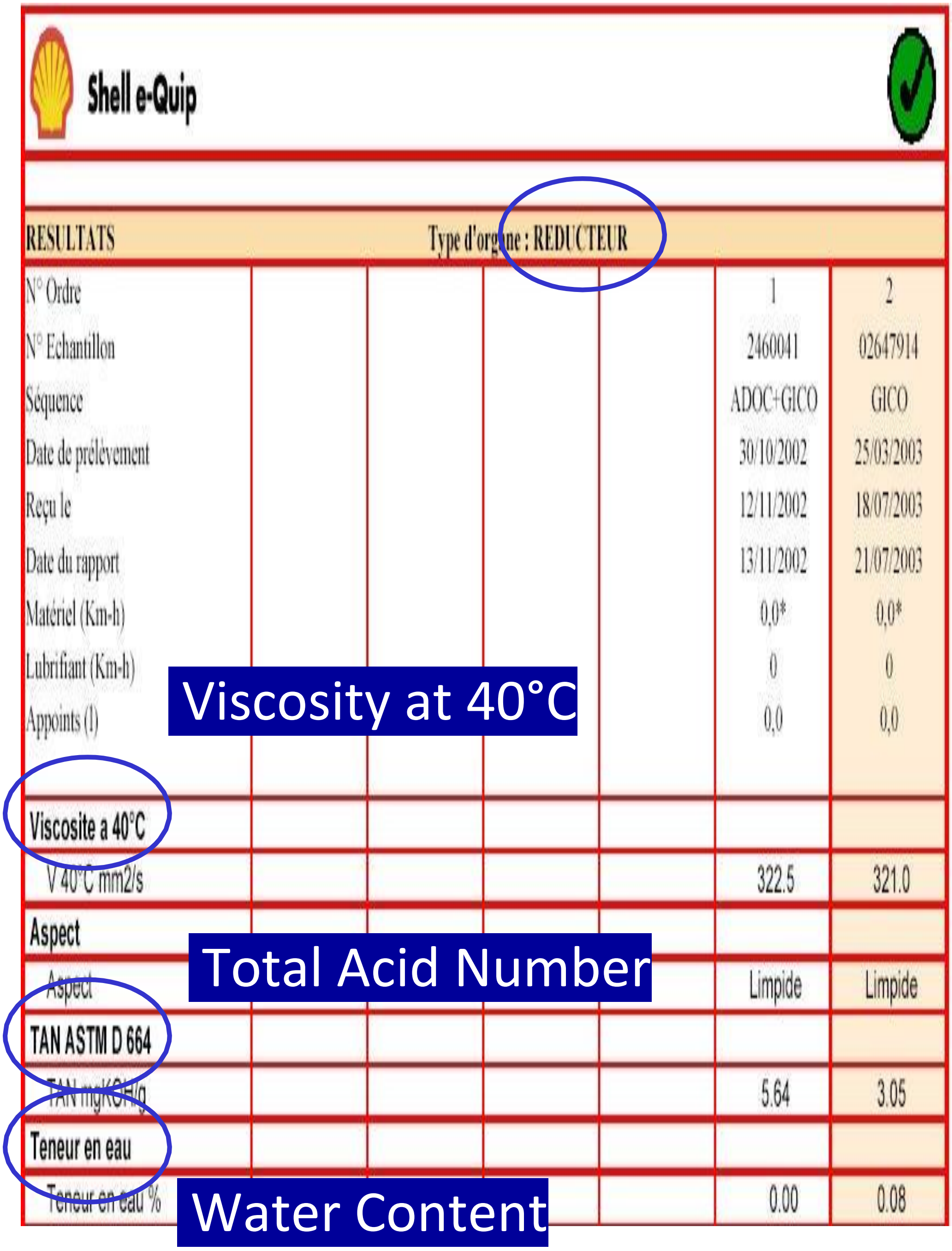
Internet Login : SW010533

HOLCIM (SUISSE) SA
C.GENOUX ET H. STEINER
ENTRETIEN
USINE D'ECLENPENS WUERENLINGEN

1312 ECLEPENS
SUISSE

DIAGNOSTIC :	VERT	Echantillon n° 02647914	25/03/2003

Les résultats d'analyses n'indiquent pas de variation notable dans le comportement de l'équipement ou l'état de l'huile.



RESULTATS				Type d'organe : REDUCTEUR		
N° Ordre					1	2
N° Echantillon					2460041	02647914
Séquence					ADOC+GICO	GICO
Date de prélèvement					30/10/2002	25/03/2003
Reçu le					12/11/2002	18/07/2003
Date du rapport					13/11/2002	21/07/2003
Matériel (Km-h)					0,0*	0,0*
Lubrifiant (Km-h)					0	0
Appoints (l)					0,0	0,0
Viscosite a 40°C						
V 40°C mm2/s					322.5	321.0
Aspect						
Aspect					Limpide	Limpide
TAN ASTM D 664						
TAN mgKOH/g					5.64	3.05
Teneur en eau						
Teneur en eau %					0.00	0.08

Elemental spectroscopy

Spectrometrie						
Phosphore %					.04	.03
Zinc %					.00	.00
Calcium %					.00	.00
Barium %					.00	.00
Magnesium ppm					0	0
Aluminium ppm					0	0
Fer ppm					2	2
Chrome ppm					0	0
Molybdene ppm					0	0
Cuivre ppm					9	6
Plomb ppm					0	0
Etain ppm					1	1
Silicium ppm					0	2
Sodium ppm					0	0
Bore ppm					1	1
Vanadium ppm					0	0
Soufre %					.01	.00
Nickel ppm					0	0
Argent ppm					0	0
Titane ppm					0	0

Viscosity

1. Viscosity at 40°C

1- Unit : mm2/s = cSt

2- Definition : Measurement of oil resistance to flow at one temperature

3- Method of measurement : Viscometry

4- Alarm : -5%, +10%

5- Limit : -10%, +20%

Limit	Motor Oil	Industrial Oil	Industrial Oil Heavy service
Critical (upper)	+ 20%	+ 10%	+ 7%
Caution (upper)	+ 10%	+ 5%	+ 4%
Caution (lower)	- 5%	- 5%	- 5%
Critical (lower)	- 10%	- 10%	- 10%

6- Norms : DIN 51588, ASTM D974 (D-445)

7- Root cause of variations:

- Increase :
  - Molecular changes : Oxidation, loss by evaporation (high running temperature)
  - Contamination : water (emulsions), air trapped in the oil, glycol, mixed with higher viscosity grade oil, soot and other solid particles (formation of coal and insoluble oxides)
- Decrease :
  - Molecular changes : Thermal rupture of the molecules, Thinning of Viscosity Index improvers due to shear

- Contamination : Fuel, cooling additives, solvents, mixed with lower viscosity grade oil

8- Consequence :
  - High viscosity :
    - Increase of temperature, oxidation, sludge, varnish
    - Cavitation
    - Inadequate lubrication of bearings (poor lubricating film formation)
    - Oil whirl
    - Increase of energy consumption
    - Poor anti-foam and anti-emulsion characteristics
    - Low pumpability at low temperature
  - Low viscosity :
    - Loss of lubricating film, high wear
    - High mechanical friction, loss of energy, high temperature, oxidation
    - Internal and external leakages
    - Higher sensitivity to contamination with solid particles

Water Content

1- Unit : % or ppm (0.1%=1000ppm)

2- Definition : Water content as concentration of the 'total' water (free or dissolved) in the oil

3- Method of measurement : Karl Fischer test, distillation

4- Alarm : >0.05

5- Limit : 0.1 for Hydraulic, 1 for Gears

6- Norms : DIN 51582, ASTM D1744

7- Root cause : Cooling system leakage, low operation temperatures, ineffective steam extraction, condensation in the reservoir

8- Consequence : Corrosion, oil load carrying capacity reduction, degradation of additives (precipitation leading to filter plugging)

TAN

1- Total Acid Number
2- Unit : mg KOH/g
3- Definition : Total acid concentration of the oil, Number of mg of KOH (Potassium Hydroxide) required to neutralize 1 gram of oil
4- Method of measurement : Titration
5- Critical limit : 1 TAN increase compared to the initial value
6- Caution limit : 0.2 – 0.5 TAN
7- An oil with high anti-wear additives has 0.6 to 1.5 TAN. Slow increase over long period is normal, rapid change is alarming
8- Norms : DIN 51588, ASTM D974
9- Root cause : Oil degradation (oxidation is usually characterised by an increase of acidity), oxidation is due to high operation temperatures, overload, cooling system problems, inadequate lubricant
10- Consequence : Corrosion, high viscosity. The risk of corrosion is increased with water

FOAM

1- Definition : Accumulation of air bubbles on the surface. It occurs when pressure is reduced on an oil containing air
2- Method : Foam test
3- Limits : No foam
4- Norms : DIN 51566, ASTM D 892
5- Root cause : Leaky suction lines, low fluid level, improper system design, churning gears
6- Consequence : Reduced lubricating film strength, erratic behaviour of hydraulic systems, cavitation, quick oxidation of the oil, very dangerous for hydraulic circuits

Flash Point

1- Definition : Identifies the lowest temperature under barometric pressure (760 mm Hg) to which the vapors above the surface of a sample ignite when exposed to a source of ignition

2- Limits : +/- 15%

3- Lowest limit : 160 ºC

4- Norms : DIN 51582, ASTM D 92

5- Root cause : presence of volatile molecules from fuel and other flammable contaminants

6- Consequence : Fuel or chemical dilution diminishes the lubricant effectiveness and can cause fire or explosion hazard

Elemental spectroscopy

1- Unit : ppm
2- Definition : Quantifies the presence of dissolved and some undissolved inorganic materials in the oil
3- Root cause : Machine wear, ingress of contamination, depletion of additive elements

- Examples :

a. Increase of Silicon and Aluminium suggests dirt increase
b. Increase of Sodium and Boron may signal the ingestion of glycol-based coolant
c. Calcium and Magnesium are often signs of hard water ingestion
d. Zinc and Phosphorous are common in anti wear additives
e. Chromium : Wear of piston rings, bearings
f. Copper, Tin : Wear of bearings and bushing

Some limits :

	Wear	Contamination	Additive
Iron (Fe)	100ppm		
Copper (Cu)	20ppm		
Chromium (Cr)	5ppm		
Tin (Sn)	10ppm		
Aluminium (Al)	20ppm		
Lead (Pb)	20ppm		
Silicon (Si)		20ppm	
Sodium (Na)			
Boron (B)		20ppm	
Calcium (Ca)			-10% - -20%
Magnésium (Mg)			
Zinc (Zn)			-15% - -30%
Phosphorous (P)			
Molybdenum (Mo)			
Potassium (K)			

- Caution limits should consider 50% of the values shown above

Ferrous density

1- Definition : Concentration of ferrous debris (large ferrous particles > 5 microns)
2- Root cause : Load changes caused by increased load, eccentric load due to unbalance or misalignment, insufficient lubrication, contamination (particles, water, air, solvents, etc), fatigue, wear

Analytical ferrography

1- Test performed in special cases when ferrous density is high
2- Definition : Analysis of debris deposited onto a ferrogram slide or filtergram membrane : particle morphology, color, size, reflectivity, edge

detail, … in order to determine their origin :

- Normal wear, debris of gears, debris of bearing, particles of rust, non metallic particles, …

3- Root cause : Load changes caused by increased load, eccentric load due to unbalance or misalignment, insufficient lubrication, contamination (particles, water, air, solvents, etc), fatigue, wear

Particle Count

1- Definition : Number of particles in specified size range per fluid volume (ml or 100ml). It is also expressed in terms of ISO 4406 (Cleanliness code): particle concentration and distribution

Number of particules / 100 ml :					**ISO Code**
5 - 15µm	**15 - 25µm**	**25 - 50µm**	**50 - 100µm**	**>100µm**	
...	...	...	...	...	...
4000	712	126	22	4	15/13/10
8000	1425	253	45	8	16/14/11
16000	2850	506	90	16	17/15/12
32000	5700	1012	180	32	18/16/13
64000	11400	2025	360	64	19/17/14
...	...	...	...	...	...

2- Method : manually (optical microscopy) or automatically (optical particle counter)

3- Root cause of particle count increase : Dirt ingestion (seals, breathers, …), filter failure (full, in bypass), generated wear

4- Some limits :

Applicati on	Contamination level
High pressure hydraulic system (>200bar)	ISO 15/13/10
Low pressure hydraulic system	ISO 16/14/11
Turbines	ISO 16/14/11
Rotative machine, variable speed or high load	ISO 17/15/12
Rotative machine, constant speed and low load	ISO 18/16/13
Gears	ISO 19/17/14
Engine	ISO 17/15/12

Agenda

1- Main tests used for cement equipment (not engines)
   - Viscosity
   - Water content
   - TAN
   - Foam
   - Flash point
   - Elemental spectroscopy
   - Ferrous density
   - Particle count
2- Tips and tricks for oil sampling

Oil sampling : First questions

1- How critical is the system for the operation ?
2- What are the goals of the analysis :
   - Troubleshooting, contamination analysis
   - Controlling oil condition

- Determining oil change intervals: cost optimisation

3- What is the volume of lubricant ? If the objective of the analysis is optimising lubrication cost, then we recommend 100 litters are a minimal volume
4- How long has this lubricant historically lasted ?

Oil sampling : selection of the sampling point

1- After filter : determines what the machine gets
2- Before filter :
    - Tells you the condition of the lubricant
    - Allows to determine the 'baseline' contaminant level
    - Coupled with a sample after filter, gives evaluation of the filter efficiency
3- Reservoir :
    - Mid-level: machine condition, coupled with return line, may give an indication of the reservoir efficiency
    - Return-line: component wear, system generated contaminants
    - Drain: not representative, allows to analyse the reservoir sludge
4- Gearbox : as close as possible to the gearset, using a vaccum pump and a minimess sample port with tube extension (installed at the drain, keep the end of the tube at least 5cm away from any static or dynamic surface)

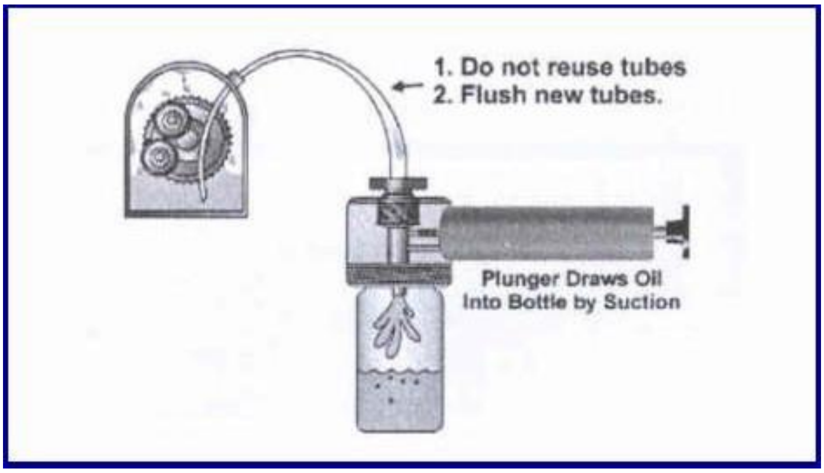
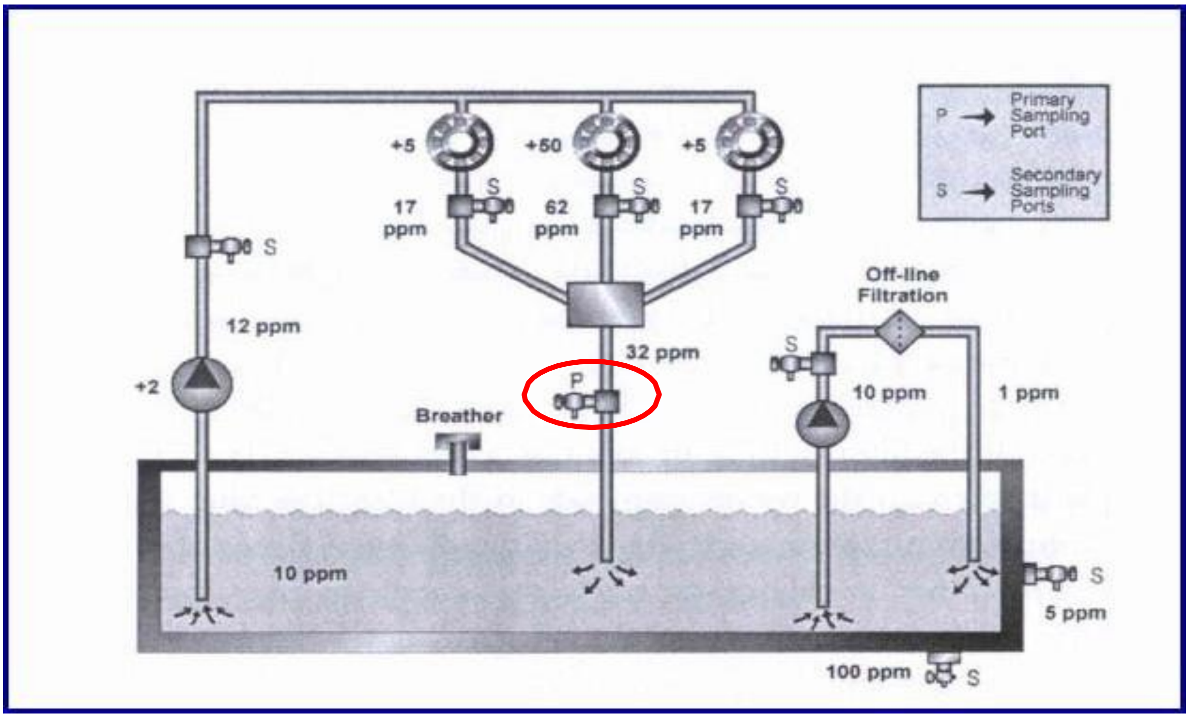



Figure 4-6 - Minimess Sampling Valve

5- Hydraulic unit : Return line, before the filter



Oil sampling : 'Keys' for obtaining a good sample

1- The system should be in operation
2- Select proper sample point that allows a representative sample :
    - Clean hose or valve
    - Area of turbulent flow
    - Mid-level of a reservoir
3- Use a clean device to draw sample
4- Use clean, proper sized and particle free bottles
5- Flush, purge the proper amount of fluid before taking a sample

Oil sampling : Safety considerations

1- What is the system pressure
2- How hot is the fluid
3- What kind of access do I have to the sample port
4- Is the area dirty
5- Is it safe to take the sample while the equipment is in operation

Results

1- Once taken, sample should be tested as soon asreasonably possible (after several weeks the sample is no longer representative). 1 week is a reasonable maximum before testing
2- Appearance and color give a first idea about changes taking place : the oil should be clear and bright with no visible water or sediment
3- It is recommended to have new oils tested to establish baselines
4- Procedures help ensure that samples are taken the same way every time
5- Do not take samples immediately after having added oil to the machine
6- Oxidation limits the life of lubricants. At some point a lubricant will degrade, from acids, loose lubrication abilities and deposit sludge and varnish. At temperatures above 70 ºC, mineral oils begin to oxidize.

Each increase of 10 ºC cuts the service life in half.

7- Antiwear, antiscuff, antifoam and anticorrosion additives can be depleted if the gears are repeatedly subjected to conditions requiring reaction of the additives.
8- In many cases contamination requires an oil change long before the oil oxidizes. Filters should help to prevent abrasion, polishing, micro-pitting and macro-pitting. An often heard complaint:
“A fine filter will clog easily.” The response is: ”Good. That means the filter is necessary and doing its job.”
9- The best filters will do little good if they are not properly maintained.
10- Make sure all pipe fittings are properly tightened; besides leakage, loose fittings allow airborne dust to be sucked into the system.
11- Promptly replace worn seals and hoses; if not done, the effects are the same as loose fittings.
12- Practice good housekeeping when a system is opened for maintenance; prevent contamination of replacement components.
13- Inspect filter indicators to make sure they are working.
14- Ensure commissioning flushing – it is an essential part to avoid initial damages on new equipment.

Conclusion

If we can successfully identify contamination in the systems, we have:

1. A better chance of eliminating the root cause.
2. The key to effective contamination control comes in three parts.
3. Identification of the contamination or potential for contamination
4. Prevention of occurrence for contamination ingression
5. Removal of contamination
6. The approach to control contamination will ensure that we maintain not only lubricant reliability.
7. An effective contamination control strategy implemented into the maintenance program will benefit the entire mandate, to improve equipment condition and availability and will help finally to reduce the specific actual costs of cement.

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