The Importance of Lube Oil Cleaning

How to improve operational costs and equipment lifetime

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Clean lube oil is key to an effective process

Lube oil is a necessity in many industrial applications, used for lubrication, cooling and anti-corrosion. Equipment need the oil for lubrication of movable machine parts like bearings, gear boxes and similar. With fresh and clean lube oil in the system, the production process can operate at optimal performance.

However, even under the best of circumstances lube oil tends to be contaminated. Particles can enter the system, or are the result of internal wear. Water is another unwanted contamination factor, arising by either external or internal causes.

When the lube oil is contaminated problems will eventually pile up. Contamination changes the oil properties, which will deteriorate and cause equipment problems and production losses. In fact, a substantial part of all machine failures in the manufacturing industry are related to contaminated lube oil, causing high maintenance costs and shortening the lifetime of the equipment.

With that said, clean lube oil is key to an effective production process. And that's what this document is all about. We will show you different techniques to clean lube oil, and highlight their pros and cons. And we will also take a cost perspective, so you can choose the method most suitable to your requirements.

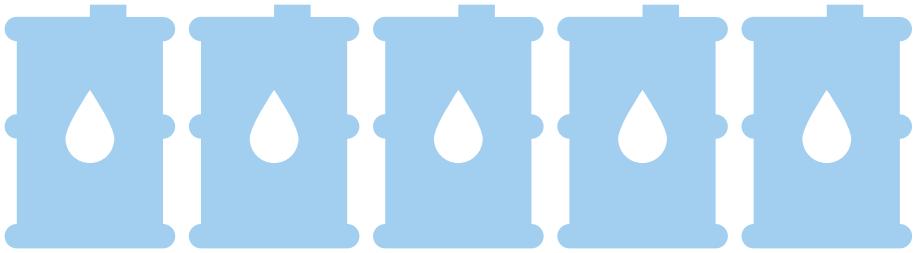
Risks connected to poor lube oil quality

POOR LUBE OIL QUALITY IS GENERALLY CAUSED BY AN UNSATISFACTORY CLEANING PROCESS THAT FAILS TO REMOVE UNWANTED CONTAMINATIONS. CONTAMINATION OF LUBE OIL IS CONNECTED TO SEVERAL RISKS:

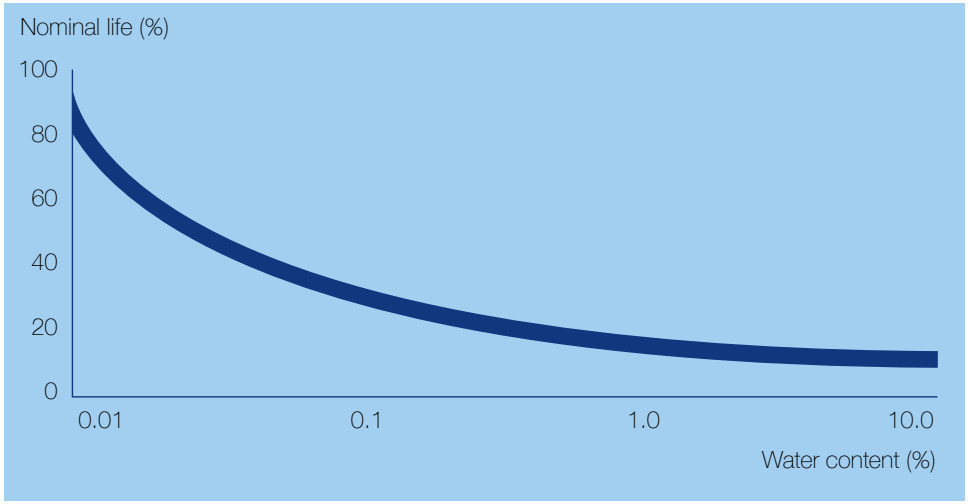
- Chemical degradation
- High oil consumption
- Efficiency losses
- Corrosion
- Friction – wear, noise
- Clogging

All contamination risks have the potential to have costly consequences to your business. A less effective process means lower productivity, and by that, lost revenue. Increased risks of machine wear and machine failure will add to the maintenance costs, as will frequent disposal and replacement of oil. From an environmental perspective, disposal of used oils is more and more unacceptable and often associated with high costs.

And, in the long run, with poor lube oil quality the equipment lifetime will decrease, rising the need for costly investments. Important to know is that even very small increases in contamination levels have severe impact on the lifetime of machine components and systems.



Life time of bearing as function of the water content in the oil



Conversion from percent to parts per million (ppm):
0.01% = 100 ppm
10% = 100.000 ppm

Different types of lube oil contamination

IS IT POSSIBLE TO TOTALLY AVOID CONTAMINATION OF THE LUBE OIL?
THE SHORT ANSWER IS NO

Even if you make sure that machine components are clean before installing them, and that seals are secured, contamination is a problem you should be prepared to deal with.

When looking closer into the oil we can see two types of contaminants: particles and water. Small particles like sand or dust tend to find their way into even the most enclosed systems, and water can emerge due to condensation or intrusion.

Sources of contamination

Built in contaminants

- Cylinders, fluids, hydraulic motors, hoses and pipes, pumps, reservoirs, valves, etc.

Generated contaminants

- Assembly of system
- Break-in of system
- Operation of system
- Fluid breakdown

External ingression

- Reservoir breathing
- Bearing seals
- Cylinder and rod seals
- Component seals

Contaminants introduced during maintenance

- Disassembly/assembly
- Make-up oil

Particle contamination

PARTICLES CONTAMINATING THE LUBE OIL IS A COMMON CAUSE TO EQUIPMENT FAILURE. THEY CAN COME FROM SEVERAL SOURCES: WEAR FROM METAL, PLASTIC AND RUBBER COMPONENTS, PAINT FLAKES, AND AIRBORNE DUST.

Even brand new oil, if stored improperly, can be a source of particulates. If the lube oil is left untreated the particles will cause wear and clog equipment, and also change the properties of the oil.

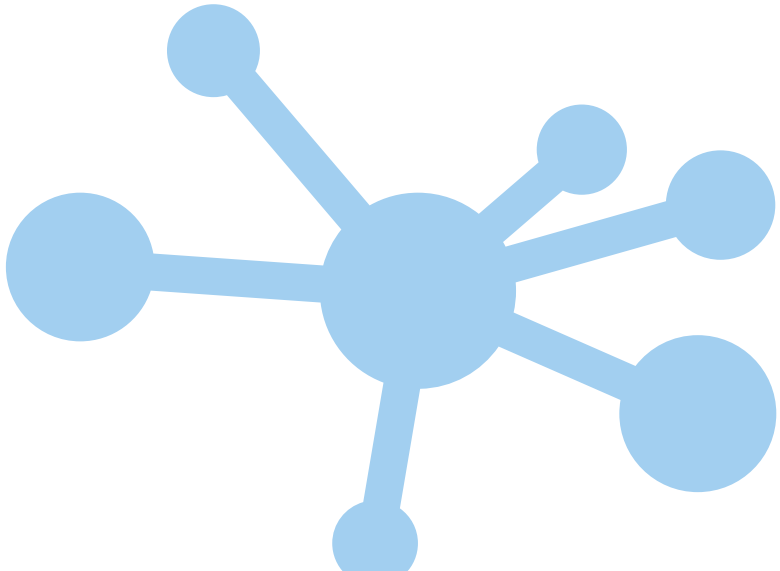
The particles that contaminate the lube oil can vary in size, type and shape from process to process. They are measured in µm, where 1 µm is 1/1000 mm. As an example, a bacteria could be around 3 µm, coal dust 8 µm, salt 100 µm and a grain of sand as large as 1-2 mm.

The oil films in an engine or bearing are very thin, and ports and other passages are narrow. Depending on the size of the solid particles, they impair on the systems functionality in different ways. If they are trapped in a fine clearance, like in a bearing, they can cause micro cracks on the surface. With continuous system load these cracks can spread and degrade the metal surface until it starts to fall apart.

Particles may also change the properties of the lube oil additives. If the lube oil quality does not meet the required equipment standards, there is another potential risk of malfunction.

Particle Size	Effects on Equipment
Particles > Gap	Particles do not fit into gaps. Particles can block orifices and ports, jam moving parts, and lodge inside valves and lock them.
Particles = Gap	Particles fit into gaps where they scratch surfaces, sausing abrasive wear and surface fatigue. Particles are broken into fragments and are work hardened.
Particles < Gap	Individual particles pass through gaps. Particles cause erosive wear and form deposits of silt which can block gaps.
Particles of all sizes	Noise, vibration, loss of reliability, breakdowns, shorter service intervals and equipment lifetime, and catalysis of base oil oxidation (leads to sludge, varnish, shorter lubricant lifetime).

Source: Noria Corporation



Water contamination

ALL OILS CONTAIN WATER, TO A CERTAIN DEGREE. BUT WHEN WATER CONTAMINATES THE LUBE OIL THROUGH LEAKAGES AND CONDENSATION, AND THE LEVELS RISE, THIS CAN CAUSE SEVERE PROBLEMS. FOR SOME, LIKE THE PULP AND PAPER INDUSTRY, WATER IS THE PRIMARY CAUSE OF BEARING FAILURE.

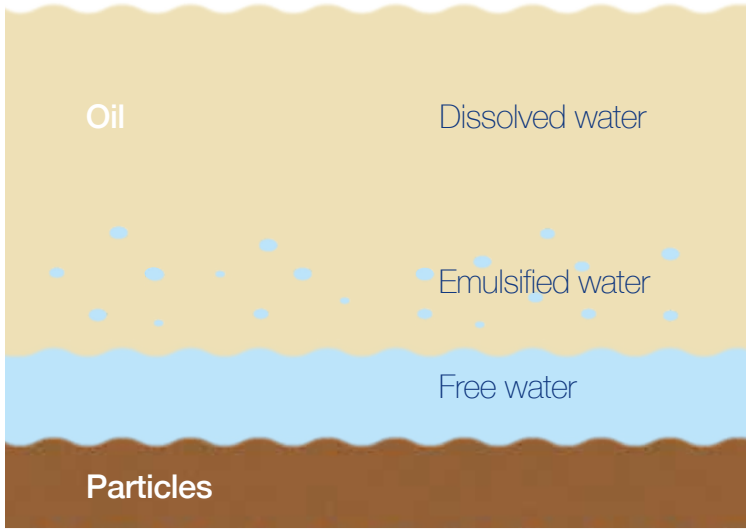
Water has a lower viscosity than lube oil and reduces the lubricative properties. Trapped in bearings and gears, water droplets can implode under the pressure and cause micro cracks. There is even the risk of metal-to-metal contact when the lube oil is pushed away by water. Water contamination has several negative effects on oil properties and overall system performance:

- creation of high-viscosity emulsions, which have a damaging effect on valves and pumps
- oxidation of oils and additives which creates hard particles
- reduction of oil viscosity and lubricity
- reduction of bearing lifetime
- corrosion

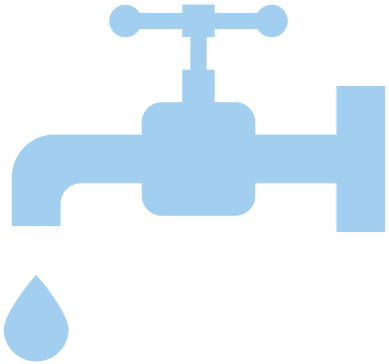
Types of water contamination

Water contamination can be of three types:

- Dissolved water – water molecules dispersed one-by-one
- Emulsified water – water dispersed as small droplets
- Free water – water that settles to the tank bottom



Common methods to clean lube oil



THERE ARE SEVERAL DIFFERENT METHODS TO CLEAN LUBE OIL FROM CONTAMINANTS.

In this document we describe and compare the common, and widely applicable methods, Filter, Coalescer and Centrifugal Separator. The methods come with their pros and cons, and recommended usage depends on the application and the contamination challenges.

Filter is used to remove particles from lube oil. If water contamination is also a problem, the filter needs a complementary Coalescer module. Centrifugal Separation removes particles and water in a single operation.

Feature comparison

	Disc stack centrifuge	Filter	Coalescer
Particles & water separation?	yes	no	no
Particle removal	yes	yes	no
Free water removed	yes	no	yes
Emulsified water removed	limited	no	limited
Dissolved water removed	no	no	no
Capital cost	high	low	low
Operating cost	low	high	high
Total cost of ownership	low	high	high

Filter for cleaning lube oil

A COMMON METHOD TO DEAL WITH LUBE OIL CONTAMINATION IS TO USE A FILTER MODULE. THIS TECHNIQUE IS SIMPLE WITH FEW MOVING PARTS, AND COMES WITH A COMPARABLY LOW INITIAL INVESTMENT COST.

There are several competing filter techniques, but this document focuses on the widely used cartridge filter.

The cartridge filter is used to remove solid particles from lube oil. This mechanical filter catches all particles larger than the selected mesh size, and lets the lube oil pass through. Over time the cleaning efficiency will decrease as the trapped particles clog the filter, which needs to be replaced and properly disposed.

A filter can only handle two phases at once, liquid-solid or liquid-liquid. If the lube oil is contaminated with both particles and water, you will need an additional coalescer module to remove the water. Their efficiency is highest with fairly clean oils having little or no solids and less than 1% water.

Coaleser for cleaning lube oil

If the lube oil also contains water, a coalescer can be used to remove it, often in a combination where the coalescer module follows the filter module. This is a common two step operation to remove both solids and water from the lube oil.

When the lube oil flows through a screen in the coalescer, fine dispersions of water are retained. When another droplet comes in contact with the first one, they join forming a larger droplet. This is repeated numerous times until a large enough drop is formed, and because of its size is forced towards the discharge and ends up in a water sump.

A coalescer operates at optimal efficiency when the oil's viscocity is low, and the oil is clean without any solids contamination.

Centrifugal Separator for cleaning lube oil

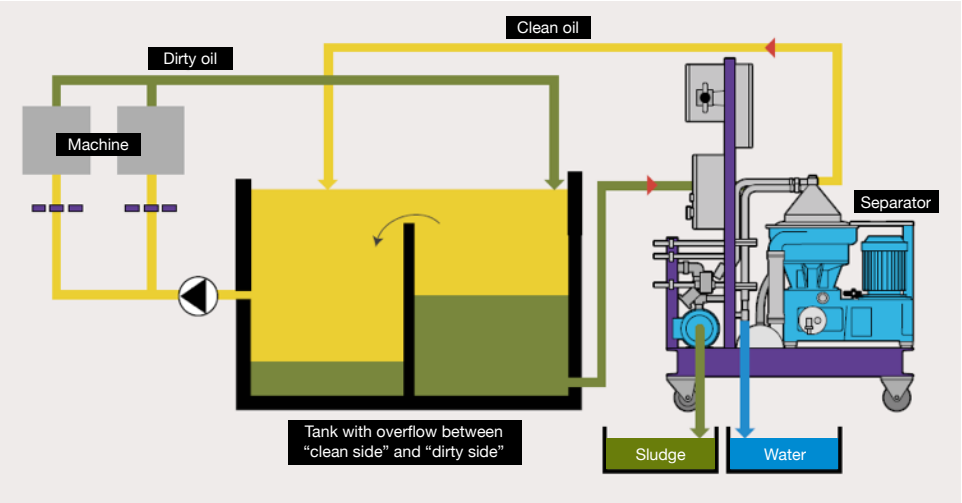
A CENTRIFUGAL SEPARATOR CAN BE USED TO REMOVE PARTICLES AND WATER IN A SINGLE OPERATION. IN A SEPARATOR PARTICLES AND WATER ARE SEPARATED FROM THE LUBE OIL BY THE USE OF CENTRIFUGAL FORCE.

The contaminants are forced outwards to be dispatched as sludge and water. At the same time, the clean lube oil is continuously recirculated back to the production process.

Centrifugal separators are widely known for their highly efficient lube oil cleaning abilities, and for their consistent and reliable performance. Also they require minimal maintenance and attendance, which have a positive effect on both process uptime and running costs.

Integration of a centrifugal separator is simple since no modifications to existing systems are required. The separator module is installed in a bypass loop and is not interfering with the production. It has the benefit of a small footprint, and optional mobility to service other production units within the premises.

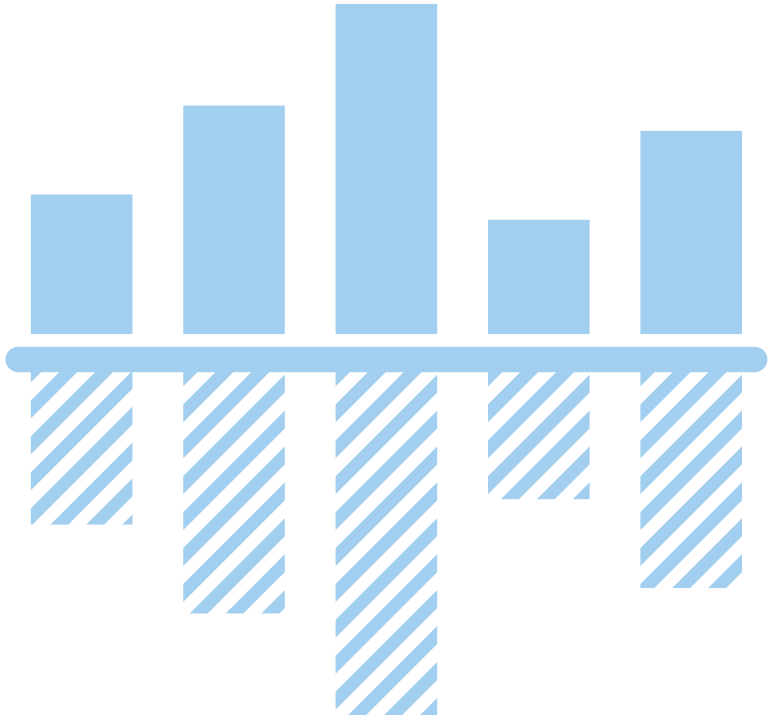
The separator works continuously, independent of the existing installation.



Two different separator operation types are available:
Manual separators (Emmie modules, OCM modules): Sludge collection inside the separator with manual removal.
Automatic separators (Flex modules): Sludge discharge automatically.

How does Filter and Coalescer compare with Centrifugal Separators?

THE DIFFERENT TECHNOLOGIES COME WITH ADVANTAGES AND DISADVANTAGES. WITH THIS SIDE BY SIDE COMPARISON IT IS EASY TO SEE THE DIFFERENCES.



Centrifugal Separator	Cartridge Filter
ADVANTAGES • Choice between automatic/manual removal of solids • Continuous water removal • Efficient solids handling – limited disposal costs • Solids removal* 100% removed: 10 µm and above 90% removed: 5 µm to 10 µm 70% removed: 3 µm to 5 µm *Valid for non-oil soluble particles and solids with a density ≥ 2000 kg/m^3 • Beta-value is always constant • HSS distinguish between additives and contaminants • HSS operates normally in by-pass for continuous operation • Low operation costs • Completely flexible, no filter mesh has to be selected or changed DISADVANTAGES • High investment costs • Solids with a density below 2000 kg/m^3 are not removed	ADVANTAGES • Low investment costs • Particles larger than mesh size are removed DISADVANTAGES • Manual change of filter elements • No water removal • Complete filter cartridge has to be disposed • Particle removal only down to 3 µm • Beta-value declines by time • Water can effect additives, which influence TAN (Total Acid Number) • Compensate high viscosity with bigger mesh (max 60-200 cSt) • Filters normally in full-flow when only in operation • High operation costs

Centrifugal Separator	Coalescer
ADVANTAGES • Handles also high-viscosity fluids • Relative high solids-handling capacity (especially for self-cleaning separators) • Separation efficiency is not depending on the presence of surfactant DISADVANTAGES • Because of high speed separation sound is typically 64-75 db(A) for the separators on the OCM modules	ADVANTAGES • Low sound emission, due to no moving parts DISADVANTAGES • Coalescers functions best with low-viscosity fluids; as the viscosity increases efficiency decreases. • No solids-handling ability; only small amounts of solids are required to clog the coalescer. Coalescers work best on clean solids-free fluids. • Coalescers cannot be used if surfactants are present. Surfactants are contaminants or additives which lowers the interfacial tension, which means that the water droplets do not coalesce.

Total Cost of Ownership

CHOOSING BETWEEN DIFFERENT TECHNOLOGIES COMES DOWN TO ESSENTIALLY TWO QUESTIONS. PERFORMANCE AND COST.

Since performance is tightly connected to machine wear and the need for maintenance, these factors must be taken into account when calculating the total cost of ownership.

Investment

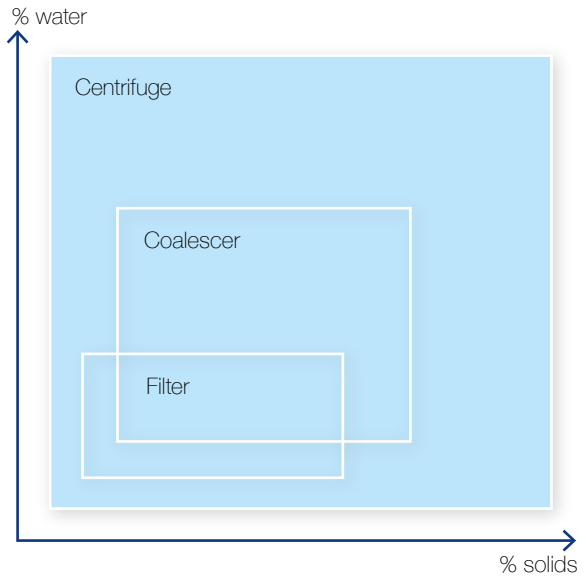
A filter solution comes with the advantage of a low initial investment compared to a centrifugal separator.

Maintenance costs

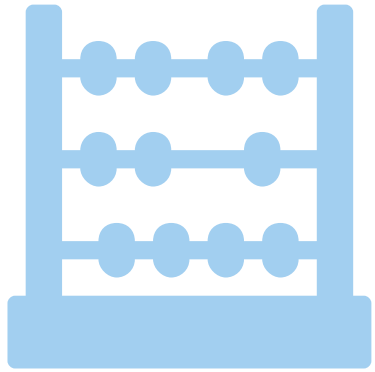
A centrifugal separator requires minimal maintenance and spare parts. Filter technology needs continuous service, causing additional cost for filter element replacements, man hours and costs for downtime/production loss. The cost for disposing used filter cartridges is also a factor to consider. The practical issues of spare part availability is an aggravating factor on remote locations.

Operating performance

Filter, Coalescer and Centrifugal Separators are designed do the same job, clean the lube oil from contaminants, but operate within different ranges as shown in the chart. The performance of the lube oil cleaning process has a direct effect on process reliability and equipment lifetime. Cleaner lube oil equals more uptime and longer equipment lifetime.



Particles effect on machine life



DEPENDING ON THE APPLICATION THERE ARE DIFFERENT LIFETIME EFFECTS FROM THE PARTICLE CONTAMINATION OF THE EQUIPMENT. THE ISO CLEANLINESS CODE 4406:1999 CAN BE TAKEN TO VIEW THE SOLID PARTICLE EFFECT ON MACHINE LIFE.

If expected machinery lifetime of a diesel engine at a cleanliness level of ISO 4406 16/14/11 (top row) is 8 years, and the current continuous oil cleanliness is 21/19/16 (column to the left), then the expected machinery lifetime would be reduced by a factor 4 for hydraulic and diesel engines applications which means 2 years. Would the particle count instead be 15/13/10, the expected lifetime would be increased by a factor 5, to 10 years.

Solids particles effect on machine life

Amount of solid particles (ISO 4406)	Expected cleaniliness level (ISO 4406)																					
	21/19/16		20/18/15		19/17/14		18/16/13		17/15/12		16/14/11		15/13/10		14/12/9		13/11/8		12/10/7	
24/22/19	2 1,8	1,6 1,3	3 2,3	2 1,7	4 3	2,5 2	6 3,5	3 2,5	7 4,5	3,5 3	8 5,5	4 3,5	>10 7	5 4	>10 8	6 5	>10 10	7 5,5	>10 >10	>10 8,5
23/21/18	1,5 1,5	1,5 1,3	2 1,8	1,7 1,4	3 2,2	2 1,6	4 3	2,5 2	5 3,5	3 2,5	7 4,5	3,5 3	9 5	4 3,5	>10 7	5 4	>10 9	7 5,5	>10 10	10 8
22/20/17	1,3 1,2	1,2 1,05	1,6 1,5	1,5 1,3	2 1,8	1,7 1,4	3 2,3	2 1,7	4 3	2,5 2	5 3,5	3 2,5	7 5	4 3	9 6	5 4	>10 8	7 5,5	>10 10	9 7
21/19/16			1,3 1,2	1,2 1,1	1,6 1,5	1,5 1,3	2 1,8	1,7 1,5	3 2,2	2 1,7	4 3	2,5 2	5 3,5	2,5 2,5	7 5	4 3,5	9 7	6 4,5	>10 9	8 6
20/18/15					1,3 1,2	1,2 1,1	1,6 1,5	1,5 1,3	2 1,8	1,7 1,5	3 2,3	2 1,7	4 3	2,5 2	5 3,5	3 2,5	7 5,5	4,6 3,7	>10 9	6 5
19/18/17							1,3 1,2	1,2 1,1	1,6 1,5	1,5 1,3	2 1,8	1,7 1,5	3 2,3	2 1,7	4 3	2,5 2	6 4	3 2,5	>10 8	5 3,5
18/17/16									1,3 1,2	1,2 1,1	1,6 1,5	1,5 1,3	2 1,8	1,7 1,5	3 2,3	2 1,8	4 3,7	3,5 2	8 6	4 3,5
17/16/15			Hydraulics and Diesel Engines		Rolling Element Bearings						1,3 1,2	1,2 1,1	1,6 1,5	1,5 1,4	2 1,8	1,7 1,5	3 2,3	2 1,8	6 4,5	2,5 2,2
16/15/14			Journal Bearings and Turbo Machinery		Gear Boxes and others								1,3 1,2	1,3 1,1	1,6 1,6	1,6 1,4	2 1,9	1,8 1,5	4 3	2 1,8
15/13/10															1,4 1,2	1,2 1,1	1,8 1,6	1,5 1,3	2,5 2	1,8 1,6

This chart is an estimate of prolonged lifetime of machinery as an effect of clean oil.

Source: Noria Corporation

No of particles per milliliter		
Range code	More than	Up to/including
24	80 000	160 000
23	40 000	80 000
22	20 000	40 000
21	10 000	20 000
20	5 000	10 000
19	2 500	5 000
18	1 300	2 500
17	640	1 300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2,5	5
8	1,3	2,5
7	0,64	1,3
6	0,32	0,64

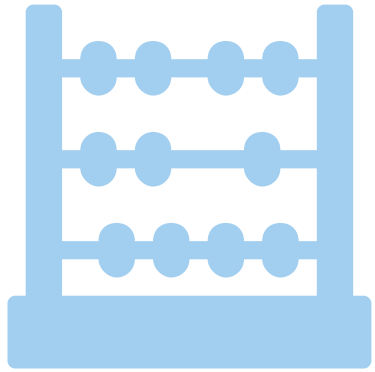
Source: Table ISO Cleanliness Code 4406:1999

EXAMPLE:
Suppose oil with following particles count:
No. of particles > 4 µm: 9 800 (=> range 20)
No. of particles > 6 µm: 470 (=> range 16)
No. of particles > 14 µm: 34 (=> range 12)
Hence contamination level 20/16/12

For centrifuges below can be taken to calculate the solid reduction:
100% of particles removed with size 10 µm and above
90% of particles removed with size 5 µm to 10 µm
70% of particles removed with size 3 µm to 5 µm

(Valid for non-oil soluble particles and solids with a density ≥ 2000 kg/m^3)

Water level effect on machine life



IF THE EXPECTED LIFETIME OF SOME MACHINERY IS 5 YEARS AT 2500 PPM OF WATER, AND THE WATER IN OIL WAS REDUCED TO 625 PPM THE LIFETIME WOULD EXTEND BY A FACTOR OF 2, YIELDING AN EXPECTED LIFETIME OF 10 YEARS.

If the lifetime was expected to be 5 years at 225 ppm water in the oil, and current water level in oil was 2500 ppm the lifetime of the machinery would be lowered to one year and three months.

Moisture level effect on machine life

Current level of moisture, ppm	Machine life extension by factor								
	2	3	4	5	6	7	8	9	10
50 000	12 500	6 500	4 500	3 125	2 500	2 000	1 500	1 000	782
25 000	6 250	3 250	2 250	1 563	1 250	1 000	750	500	391
10 000	2 500	1 300	900	625	500	400	300	200	
5 000	1 250	650	450	313	250	200			
2 500	625	325	225						
1 000	250								

This chart is an estimate of the prolonged lifetime of machinery as an effect of clean oil.

Source: Noria Corporation

Conclusion

WHEN SUMMING ALL RELEVANT FACTORS THE CENTRIFUGAL SEPARATOR COMES OUT AS THE SUSTAINABLE SOLUTION WHEN CALCULATING TOTAL COST OF OWNERSHIP IN LUBE OIL CLEANING.

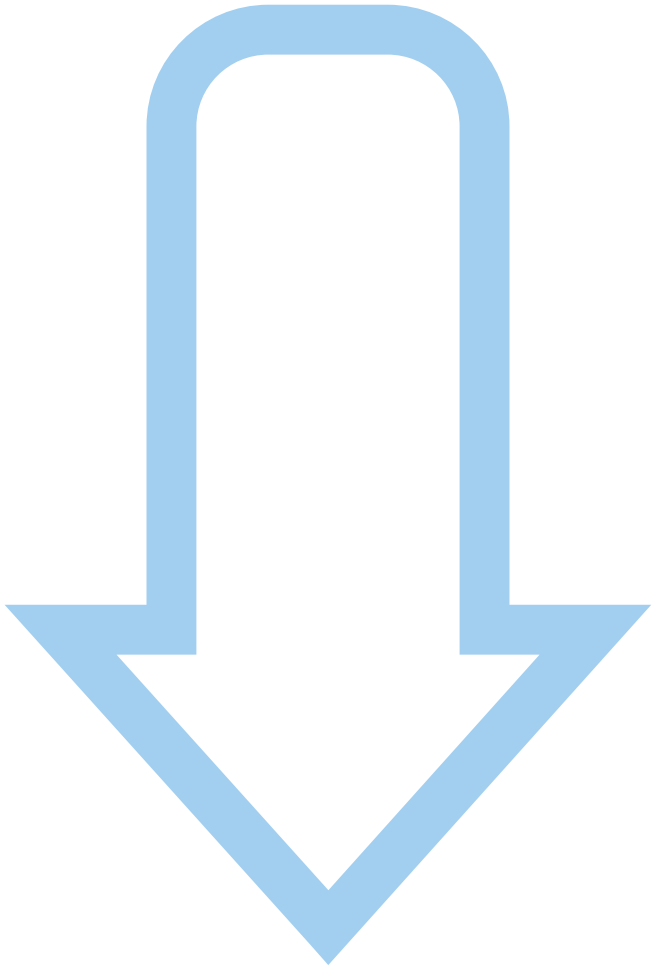
With its low operational costs, and excellent performance, it will provide smooth and hassle-free operations and prolonged lifetime of your equipment. In that context, investing in a Centrifugal Separator is a relatively small cost with substantial benefits.

Centrifugal separator reduced downtime with 90%

WHEN UTILIZING PROACTIVE OIL MAINTENANCE NUMEROUS BENEFITS HAVE BEEN DISCOVERED. AT THE WEYERHAEUSER FLINT RIVER OPERATIONS MILL THESE BENEFITS WERE RECORDED, AND THE MOST OUTSTANDING ONE WAS THE IMPROVED UPTIME.

By handling lube oil contamination with a centrifugal separator, downtime was reduced by 90%.

Another important consideration is the worst case scenario for downtime. Production planners and managers must prepare for the worst case to occur. By implementing proactive maintenance, the worst case scenario for downtime caused by hydraulic systems dropped from almost 14 hours/month to just over 3 hours/month. In addition to reducing downtime, repair costs at Weyerhaeuser Flint River have been reduced by 74% with the deployment of proactive maintenance.



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