Clean Oil Guide

1 μm
Tobacco smoke

100 μm
Grain of salt

3 μm
Bacteria

70 μm
Human hair

8 μm
Coal dust

40 μm
Naked eye visibility

25 μm
Pollen

CJC

Contents

Introduction

Maintenance is the largest single controllable expense in a manufacturing plant. With as many as 80% of all machine failures related to contamination in the oil, pro-active methods are saving industries considerable costs every year.

This booklet offers an introduction to the problems with insufficient oil cleanliness, the causes and the remedy of the problems. All the information presented is generally known and accepted. It was compiled and published by people within the company C.C.JENSEN A/S. We invite you to take advantage of the experience we have gathered over the past 50 years with oil maintenance within various types of applications. The perfect oil cleaning system will control the level of all types of contamination.

For further information, we recommend that you visit www.cjc.dk.

Oil contamination control

The best way to control the oil contamination is to stop the contaminants from entering the system in the first place. This entails making sure that all machine components are clean when installed and that the oil systems are thoroughly flushed before taken into operation. Furthermore the oil system should be as well sealed from the environment as possible with intact seals and gaskets as well as high quality tank breathers including fine particle and moisture retention (desiccant and/or bladder type breathers).

The oil should be pre-filtered before coming in contact with any machine component preferably by continuous filtration in the lube room / storage area or at least when transferred to the machines in operation.

Good oil contamination control also includes maintenance procedures for topping up with oil, replacing parts, taking oil samples etc.

Wear and tear in oil systems
Any machine using oil for power transmission, lubrication or combustion will be affected by the condition of the oil. The oil comes into contact with all components in the system and should be considered very important – as blood is important in the human body.
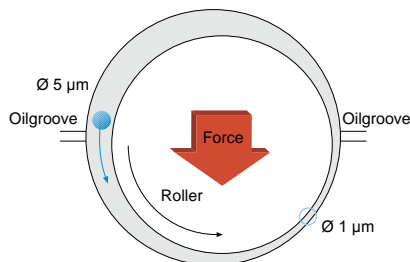

Figure 1:   Lubricating a journal bearing
Source: Västeras PetroleumKemi AB

Particle contamination

Solid particles account for the majority of all failures in an oil system.
The most harmful are clearance size particles of similar size or slightly bigger than the dynamic tolerance between the moving parts in the oil system (figure 1, on page 4).
Dynamic tolerances in an oil system are extremely fine. Figure 2 indicates the finest tolerance found in different types of components.

Dynamic oil film	
Component	**Oil film thickness** μm
Journal, slide and sleeve bearings	0.5-100
Hydraulic cylinders	5-50
Engines, ring/cylinder	0.3-7
Servo and proportional valves	1-3
Gear pumps	0.5-5
Piston pumps	0.5-5
Rolling element bearings / ball bearings	0.1-3
Gears	0.1-1
Dynamic seals	0.05-0.5

Figure 2:   Dynamic oil film

Source: Noria Corporation

1 µm = 1/1000 mm or same size as tobacco smoke.

When tiny abrasive particles such as sand and dust get into the oil system they flow with the oil into critical machine components and are wedged in the fine clearances. This leads to micro cracks being initiated in the surface of e.g. a ball bearing and the load and stress cycles will spread subsurface cracks resulting in degradation of the metal and releasing large spalls (figure 3, on page 6).

1 Oil contamination control

1. Particle trapped
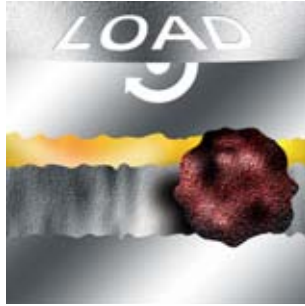
2. Cracking initiated

3. Load & stress crack spreads

4. Surface fails + created particles

Figure 3: Fatigue Wear

Excessive amounts of particles stresses the additive package in the oil. The detergents and dispersants may get depleted if the particle contamination is not taken under control.

How clean the oil needs to be in terms of particle contamination depends on how sensitive the machine components are and how high the penalty for a failure is, i.e. involved costs for replacement parts, downtime cost, safety liability etc.

Recommendations for targeting the required oil cleanliness, see page 17.

Water contamination

Water accounts for a major part of mechanical failures. In some heavily water contaminated oil systems e.g. in the paper industry, water is the predominant cause of failing components.

Water reduces the lubricity of the oil, due to the lower viscosity and poor load capacity of water. When water is exposed to the high pressures found in load zones in e.g. bearings and gears, the water droplets collapse (implode). The resulting micro-jets create micro-pitting in metal surfaces and can even result in metal-to-metal contact when water vapor pushes the oil away momentarily.
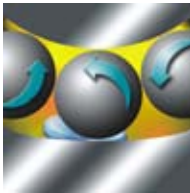
Free hydrogen ions in the water can further worsen the situation, since they migrate into machine components making steel brittle and prone to crack.

Water also results in corrosion and erosion leading to pitting damage (see figure 21 in appendix, page 34).
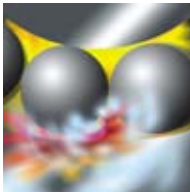
Furthermore, water acts as a catalyst for oil degradation, speeding up the oils tendency to oxidize and form resins, sludge and varnish.
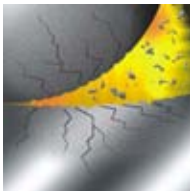
Water can be found in oil as dissolved, emulsified or free water. How much water a specific oil can dissolve or keep suspended in emulsions depends on the base oil, additive package, temperature and pressure. Some oils are designed to keep large amounts of water in suspension e.g. engine lube oils. In order to ensure long oil life and for optimum protection of machine components it is recommended not to have emulsified or free water in oil.

For a typical mineral based oil this means less than 100 ppm of water (0.01%).

Unfortunately many oil analysis reports state water content very inaccurately as "<0.1%", which means less than 1000 ppm. To know the actual water content ask for a Karl Fisher Titration test.

Figure 4:
Micro pitting

Oil degradation

**Oxidation
Sludge
Varnish**

Oil degradation products or soft contaminants are a widespread problem in most industries. They are precursors of deposits often referred to as varnish which are known to cause problems in both hydraulic and lube oil systems.

When oil degrades due to elevated temperatures, water or chemical contamination e.g. copper, the composition and functional properties of the oil are changed, resulting in the following products being formed:

- Acids
- Polymerized compounds which are dissolved in warm oil (referred to as sludge or resins)
- Varnish precipitating out as deposits on colder machine components

Varnish products are forming a sticky layer on metal surfaces and will easily blog fine tolerances, making e.g. directional control valves seize. Hard particles of all sizes get caught in the sticky layer, creating a sandpaper like, grinding surface which radically speeds up machine wear.

Further consequences of varnish can be ineffective oil coolers, clogged oil passes or inline pressure filters, poor lubrication of bearings etc.

*Figure 5:
Varnish on
valve plunger*

Whether oil degradation products will cause problems in a specific oil system depends on how sensitive the machine components are.

Sludge and varnish can be removed from oil – please see separate section "Oil cleaning methods" at page 20.

Acid contamination

Acid can be found in oil as by-products of oil degradation, combustion of gas or fuel, hydrolysis of Ester-based fluids etc. The amount of acid in oil should be limited, since acid will cause chemical corrosion of machine components and shorten the lifetime of the oil, just to mention a few of the unwanted effects.

Acid number, also referred to as AN or TAN, is measure by titration with a strong base/alkaline and given in amount of potassium hydroxide in milligrams required to neutralize the acid in one gram of oil (mg KOH/g).

Acid numbers should not be allowed to increase more than +0.5 AN higher than that of new oil, and if +1 AN is spotted immediate action is required (i.e. if new oil has 0.5 AN, then 1.0 AN is alert and 1.5 AN is alarm value).

Acid can be neutralized or removed from oil in different ways. The obvious is to use the alkalinity of the oil to neutralize incoming acid. This is done in gas and diesel engine lube oil utilizing high base numbers (BN or TBN).
The rule of thumb is to replace the lube oil if the BN falls below 30% of that of the new lube oil.

Figure 6:
Oil with high AN/TAN
has poor lifetime
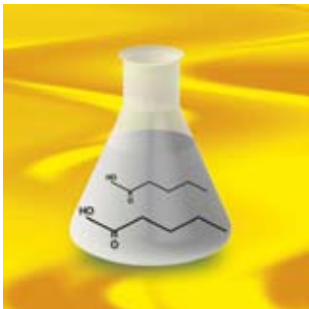
Acid formed by hydrolysis in Ester-based fluids (HFD fluids) used in e.g. turbine control systems, can cause much harm. Acid numbers twenty times higher than that of new oil, which have been seen, result in severe acid corrosion of system components.
In such fluids the acids number can be lowered and maintained using a neutralizing catalyst such as Ion exchange resin, Fullers earth or Aluminum Oxides. C.C.JENSEN has such ion exchange medium in combination fine filters in the portfolio.

2 Oil sampling

Oil sampling

The purpose of oil sampling is to utilize the oil as a messenger telling how the machine is doing. This can prompt pro-active actions in order to achieve the highest level of machine performance and reliability at the lowest possible cost. The initial samples serve to establish benchmarks and to identify the machines with critical levels. The routine sampling is done to document that goals are met and can also provide indications of abnormal wear that needs to be addressed.

The quality of analysis results depends first on correct sampling and handling of the sample, secondly on the quality of the laboratory performing the analysis. The importance of the knowledge about where and how to take a sample is paramount and requires special attention.

Where to take an oil sample

Referring to figure 7, preferably derive the oil from a upwards pointing pipe or bend with turbulent flow to produce a representative sample. Sampling points fitted on the lower perimetre of a pipe tend to allow depositing of particles in the sampling valve.
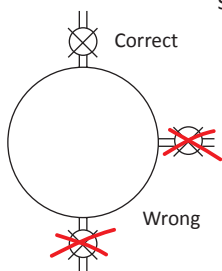
Figure 7:
Pipe cross section
with sampling valves

Source:
Västeras
PetroleumKemi AB

The best place to sample in order to see how machine components are doing, is downstream from the machine before any filtration and before the oil is returned to the system tank. This will show the undiluted result of any wear being created in the machine.

The best guarantee of clean oil in the system is to sample from the most contaminated part of the oil system – the bottom drain of the system tank.

This bottom drain is typically where the offline/kidney lube filtration system is connected, so a satisfying oil analysis result taken from between the pump and the filter housing of an offline filter, is the best guarantee that the oil and the system is clean.

If no offline filter system is installed, a vacuum type sampling pump is a valid option. In such case the sample should be drawn 10 cm (4 inches) off the lowest part of the tank (see page 13).

How to take an oil sample
- between the pump and the offline filter

To take an oil sample, the following is required:
- a certified particle free glass or hard plastic bottle (100-200 mL)
- a cloth
- an open oil container of approx. four litre (one US gallon)

Please read the following instructions carefully before taking the oil sample.

Steps for oil sampling

Ensure the oil system is under stable operation condition
1. Place the oil container beneath the sampling valve
2. Open and close the valve five times and leave it open
3. Flush the pipe by draining one litre (one US quart) into the container
4. Open the sample bottle while keeping the cap in your hand to avoid contaminating it
5. Place the bottle under the oil flow without the pipe touching the sampling valve
6. Fill the bottle to approximately 80%
7. Place the cap on the bottle immediately after taking the sample. Close the sampling valve

All samples must be clearly marked with number, place of sampling, date and oil type/make (see example at page 12)
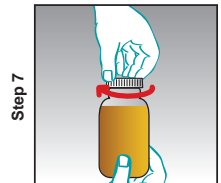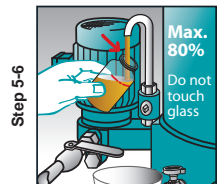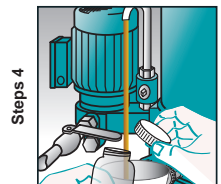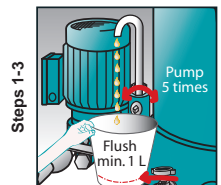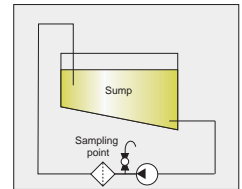
Figure 8:
Oil sampling between the pump and offline filter

2 Oil sampling

Figure 9: CJC™ Oil Sampling Label

Samples should only be collected with the machine operating at normal working temperature. When sampling for particle counting following, the method is very important.

Remember that you can never make a sample any better (cleaner), than the oil in the system, but it is easy to make it worse!

How to take an oil sample
- using a vacuum pump

Follow the instructions that came with the pump kit.
The illustrations below show the CJC™ Oil Sampling Kit.

Vacuum pump
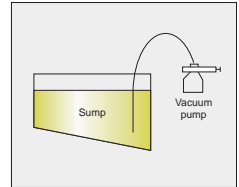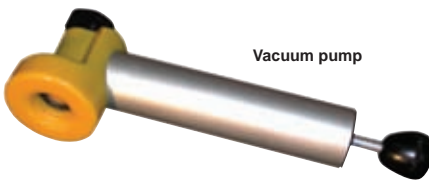
Steps for oil sampling

1. Cut a suitable piece of tube off the roll. **Use new tube every time.** Push the tube into the pump head. Always flush tube with 2 L oil before taking the sample
2. Fit the bottle by screwing it unto the pump head
3. Create a vacuum in the bottle by a few pump strokes, and fill the bottle to approximately 80%
4. Close the lid

Lower the free end of the plastic tube to 10 cm (4 inches) above the lowest part of the tank, in the center of the tank. **Be careful not to let the tube touch the walls or the bottom of the reservoir.**
Strapping the sample tube to a rod may help to position the tube. Utilizing a fixed pitot tube installed one third above the tank bottom can also be recommended.
When you have sealed the bottle, make sure that the label is filled in with all the information as per example on page 12.

Sump — Vacuum pump

Step 1

Step 2

Step 3
Max. 80%

Step 4
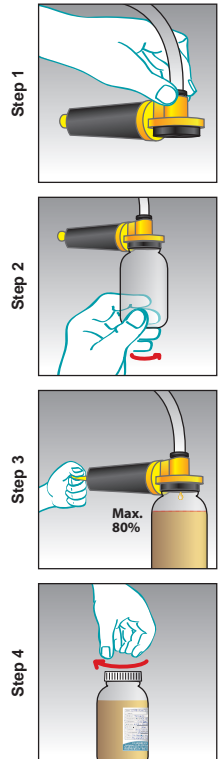
Figure 10:
Oil sampling
with a vacuum pump

3 Oil sample analysis

Oil sample analysis

As a minimum, an oil analysis should include:

- a particle count
- viscosity
- water content in ppm
- acidity level (TAN)

In oil systems prone to varnish problems e.g. gas turbines and hydraulic control systems, it is recommended to do a varnish test. Methods are described on page 18.

If the oil additive content is of interest, a spectral analysis should be included (AES or ICP). The trend is of highest importance, so it is vital to have a baseline showing the additive package in the new oil.

It is recommended that the initial tests are performed by an independent laboratory with expert knowledge on lubricants.

The Millipore membranes show oil degradation if a 0.45 µm cellulose membrane is utilized.

ISO 11/10/6   **ISO 18/17/15**

ISO 13/12/7   **ISO 20/18/13**

ISO 15/13/8   **ISO 24/23/20**
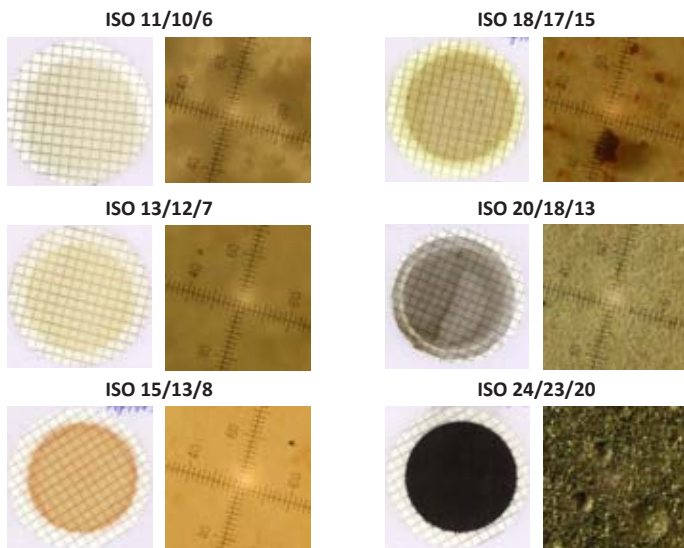
Figure 11: Test membranes and microscopic photographs of various contamination levels

ISO Standards

The ISO 4406/1999. Method for coding the level of contamination by solid particles, was introduced to facilitate comparisons in particle counting, using automatic particle counters. Here particles are counted in size 4/6/14 μm.

ISO 4407/1999 is describing particle counting using a microscope (particle sizes 2/5/15 μm).

For example a typical sample from new bulk oil, contains in every 100 mL of oil as follows:

450,000 particles	≥ 4 micron
120,000 particles	≥ 6 micron
14,000 particles	≥ 14 micron

In the ISO classification table (on the right), this oil sample has a contamination class of 19/17/14.

Some laboratories give the particle counting per millilitre in stead of per 100 millilitre (mostly USA).

Number of particles per 100 ml fluid after their size ranges		
More than	**Till**	**ISO Class**
8,000,000	16,000,000	24
4,000,000	8,000,000	23
2,000,000	4,000,000	22
1,000,000	2,000,000	21
500,000	1,000,000	20
250,000	**500,000**	**19**
130,000	250,000	18
64,000	**130,000**	**17**
32,000	64,000	16
16,000	32,000	15
8,000	**16,000**	**14**
4,000	8,000	13
2,000	4,000	12
1,000	2,000	11
500	1,000	10
250	500	9
130	250	8
64	130	7
32	64	6

*Figure 12: Contamination classes according to the
ISO 4406/1999 standard*

AS / NAS Classes

The American standard NAS 1638 has been changed to AS4059 (issue E), which is considered to be a significant advance because it presents data in terms of cumulative counts (>X μm) rather than interval mode (X-Y μm), introduces a cleaner (Class 000,) and extends the size range to smaller sizes (>4 μm) for increased sensitivity.

Correlation tables are available to compare ISO with AS/NAS or other methods of particle counting.

Size	Maximum contamination limits (Particles/100 mL)				
ISO 4402 *	>1 μm	>5 μm	>15 μm	>25 μm	>50 μm
ISO 11171 **	>4 μm(c)	>6 μm(c)	>14 μm(c)	>21 μm(c)	>38 μm(c)
SIze Code	A	B	C	D	E
Class 000	195	76	14	3	1
Class 00	390	152	27	5	1
Class 0	780	304	54	10	2
Class 1	1,560	609	109	20	4
Class 2	3,120	1,220	217	39	7
Class 3	6,520	2,430	432	76	13
Class 4	12,500	4,860	864	152	26
Class 5	25,000	9,730	1,730	306	53
Class 6	50,000	19,500	3,460	612	106
Class 7	100,000	38,900	6,920	1,220	212
Class 8	200,000	77,900	13,900	2,450	424
Class 9	400,000	156,000	27,700	4,900	848
Class 10	800,000	311,000	55,400	9,800	1,700
Class 11	1,600,000	623,000	111,000	19,600	3,390
Class 12	3,200,000	1,250,000	222,000	39,200	6,780

*   ISO 4402 or Optical Microscope.
     Particle size based on longest dimension
** ISO 11171 or Electron Microscope.
     Particle size based on projected area equivalent diameter

Figure 13: AS4059 Cleanliness Coding System

Evaluation of particle count and machine lifetime

In figure 20, on page 34 you can find the Life Extension Table. The table describes the expected increase in lifetime when the oil cleanliness is improved. Each quadrant represents a machine type:

- top left quadrant is for hydraulic components and diesel engines
- top right quadrant is for rolling element bearings
- lower left quadrant is for machines incorporating journal bearings e.g. turbines and turbos
- lower right quadrant is for gear boxes and other components not covered by other quadrants

If, for example, the current oil cleanliness in a gear box is found to be ISO 22/20/17 and the oil is cleaned to an ISO cleanliness code of 16/14/11, it can be expected that the lifetime of the gear is prolonged 2.5 times. For every oil-filled system, a cleanliness goal should be specified. This is the basic requirement to ensure reliability at the lowest possible price.

Figure 14 & 15 show the recommended ISO cleanliness levels in hydraulic, lube oil and gear systems. New oil is typical contaminated with particles to ISO 19/17/14.

ISO Code	Description	Suitable for	Dirt/year
ISO 14/12/10	Very clean oil	All oil systems	8.5 kg *
ISO 16/14/11	Clean oil	Servo & high pressure hydraulics	17 kg *
ISO 17/15/12	Light contaminated oil	Standard hydraulic & lube oil systems	34 kg *
ISO 19/17/14	New oil	Medium to low pressure systems	140 kg *
ISO 22/20/17	Very contaminated oil	Not suitable for oil systems	> 589 kg *

Figure 14: Contamination guide for **hydraulic** and **lube oil** systems

ISO Code	Description	Suitable for	Improvement factor	Dirt/year
ISO 14/12/10	Very clean oil	All oil systems	200%	8.5 kg *
ISO 16/14/11	Clean oil	Critical gear systems	150%	17 kg *
ISO 17/15/12	Light contaminated oil	Standard gear systems	100%	34 kg *
ISO 19/17/14	New oil	Non critical gear systems	75 %	140 kg *
ISO 22/20/17	Very contaminated oil	Not suitable for gear systems	50%	> 589 kg *

Figure 15: Contamination guide for **gear oil** systems

*) The amount of dirt passing the pump per year, if the oil passes with a capacity of 200 ltr/min, 8 hours a day, 230 working days per year

3 Oil sample analysis

Analysis methods and frequencies

Before establishing a trend, it is important to have a baseline sample of the fresh new oil. This will be used as reference for later comparison e.g. verifying if the additive package is still intact.

In the implementation phase of a condition monitoring system, analyses must be made frequently, at least every three months, but even better once per month in order to establish a trend.
A useful trend consists of minimum eight progressive samples taking from the same oil system under the same operating conditions.

Every oil system should have a log where analysis results are registered. The logbook must also contain information about oil type, oil changes, break-downs, targeted ISO cleanliness code and oil analysis results.

Testing for varnish

Many types of oil analysis can indicate the oil being degraded e.g. acid number (TAN), viscosity increase and FTIR, but at C.C.JENSEN we have found that the two following tests give a very detailed picture of the varnish problem:

1. Millipore patch test or colorimetric patch test (MPC) shows sludge/resin/varnish present in the oil by dis-colorization of the white cellulose patch. This indicates oil degradation products, also dissolved in the oil, which may or may not result in varnish on machine components (depending on the oil temperature). The darker the color and the higher the number (typically up to 100) the more the oil is prone to form varnish deposits.

2. Ultra Centrifuge test (UC) uses centrifugal force to extract the sludge and varnish precursors, driving them to the bottom of the test tube. The density/size of the concentrated material is then compared to a visual sediment-rating scale giving a number of 1 – 8 (8 being the worst).

The UC test shows the actual varnish and insoluble contaminants in the oil. Any oil degradation seen in this test will result in varnish as deposits on system components.
The UC test is not recommended for oil highly contaminated with particles, because it masks the result, nor for Ester or Glycol based fluids, since specific gravity plays a role in the UC test.
UC and MPC tests are very useful tools to trigger an action e.g. install a filter or change the oil.

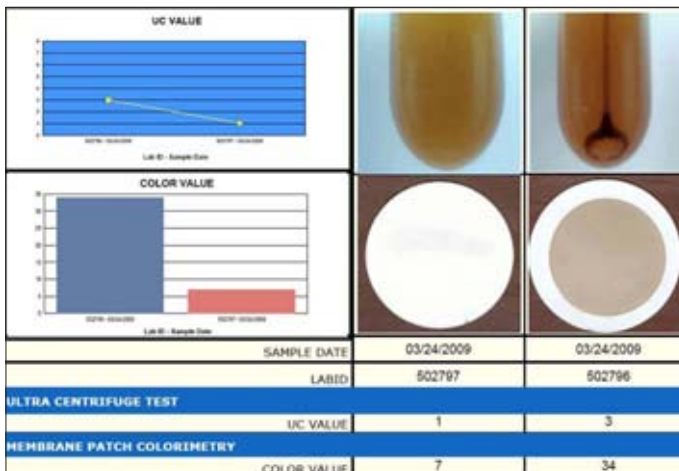|		
SAMPLE DATE	03/24/2009	03/24/2009
LABID	502797	502796
ULTRA CENTRIFUGE TEST		
UC VALUE	1	3
MEMBRANE PATCH COLORIMETRY		
COLOR VALUE	7	34

Figure 16: UC Analysis and MPC Test Result

Oil cleaning methods

Several oil cleaning methods are available:

Method	Cleaning action
Cellulose based offline filter	Reduces the content of solid particles, water and oil degradation products
Glass fibre based pressure filter	Reduces the content of solid particles
Electrostatic filter	Reduces the content of solid particles, and oil degradation products
Centrifugal separator	Reduces the content of solid particles with a density higher than that of oil as well as water
Vacuum filter	Reduces the content of air and water

Figure 17: Oil cleaning methods

All the above technologies are commercially available. However the glass fibre based pressure filter and the cellulose based offline filter, are often preferred due to their superior efficiency and economy. Both of these oil filter techniques work best under constant conditions, i.e. steady flow and pressure.

The cellulose based depth filter is often placed in a separate offline circuit also called kidney loop filtration, and with such stable conditions, it retains the majority of contaminants found in the oil. The glass fibre based pressure filter could be installed in an oil cooling circuit or as a full-flow "last chance" filter upstream of the oil system.

Filter types
The best method for capturing and retaining fine particles as well as water and varnish is by installing an offline filter. An offline filter should operate continuously, circulating the oil volume in the system many times per day. With a low pressure and low flow rates a dense filter medium with very fine filtration can be selected (< 3 micron filtration).

The cellulose based offline filter is like a maze where the oil passes through several layers of cellulose. The largest particles are retained on the surface of the filter insert whereas the smaller particles enter the filter insert and are retained within the filter material, this ensures a high dirt holding capacity. This type of

filter can also be installed in a by-pass circuit, throttling the pressure of the system pump. Using a cellulose based offline filter also enables removal of water, by absorption or coalescing, and removal of oil degradation products such as sludge/ varnish from the oil.

Varnish can be removed from oil systems through the detergent/dispersant additives in the oil, but the oil needs to be clean from particles, water and sludge before the additives are free to do the varnish cleaning job. Since sludge and varnish precipitate out of cold oil, typically between 10 - 40°C (50 - 100°F), cooling the oil in the offline filtration circuit combined with a cellulose based depth filter is highly effective.

The CJC™ Offline Filters removes oil degradation products such as sludge and varnish through polar attraction to the filter medium. A combination of adsorption and absorption fills each cellulose fibre with oil degradation products until the insert completely is saturated. The CJC™ Filter Inserts can hold up to 4 kgs (8 lbs) of varnish depending on type.

Conventional inline pressure filters are typically glass fibre based, because they need to operate under high pressure and high flow conditions, while creating as little restriction as possible. The filter element is pleated in order to increase the surface area and reduce the pressure drop.

Since they are installed after the main system pump, they often live a tough life with cyclic flows and many stops and starts, which is very harmful for the efficiency of any filter. Capturing and retaining fine silt particles is therefore very difficult, which is why most of these inline filters have a rating of 10 – 30 micron. However, many already captured particles will be released again when the filter is exposed to pressure shocks at stop/start.
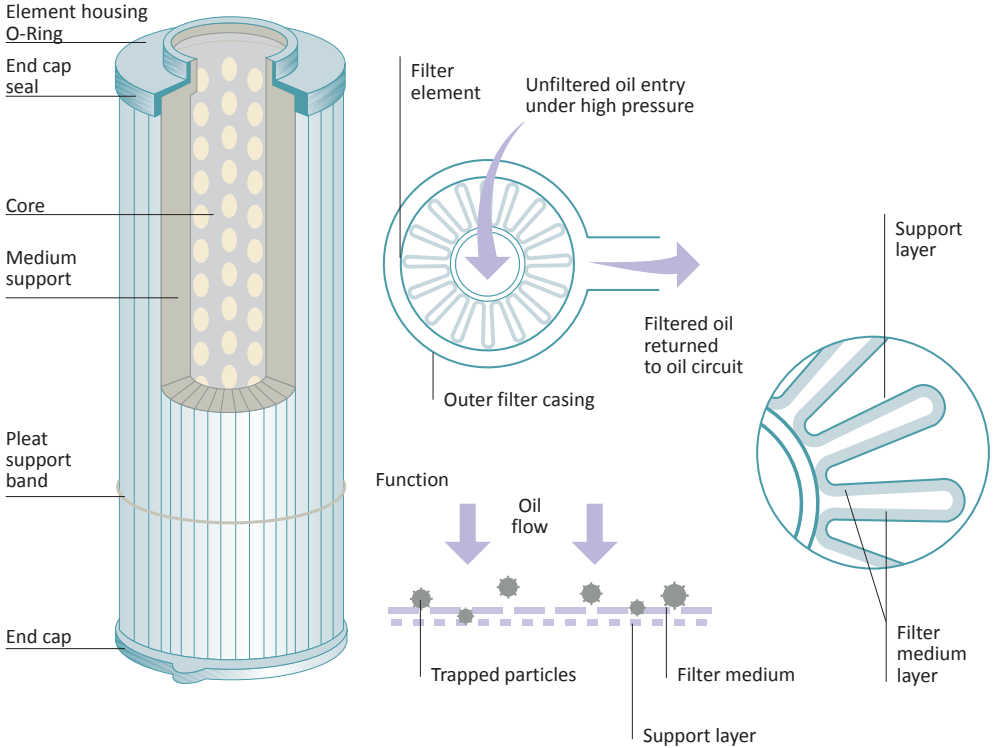
The glass fibre based pressure filter is capable of removing solid particles only – and due to the relatively small filter depth and volume, it has a restricted dirt holding capacity.

Modern oil systems often combine the two cleaning systems, where the offline filter removes the contamination and the inline pressure filter serves as security or "last chance" filter before critical components.

4 Oil cleaning methods

Glass fibre based pressure filter

Element housing O-Ring

End cap seal

Core

Medium support

Pleat support band

End cap

Filter element

Unfiltered oil entry under high pressure

Outer filter casing

Filtered oil returned to oil circuit

Support layer

Filter medium layer

Function

Oil flow

Trapped particles

Filter medium

Support layer

Pressure filters have a limited dirt holding capacity, usually between 1 and 100 grams, which results in filter element replacement at short intervals in order to ensure efficient filtration.

Typical filtration rating on inline pressure filters are 5 – 50 micron.

Conventional glass fibre based inline pressure filters do not absorb water, nor retain oil degradation products such as sludge and varnish.

Cellulose based offline filter
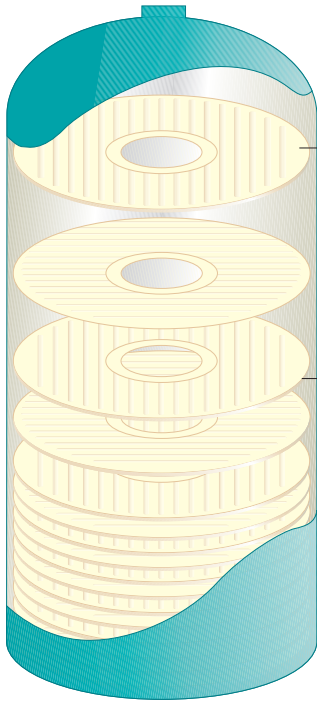
Filter Insert
Made of corrugated wood cellulose discs rotated at 90°
to the next and bonded together. This gives a series
of connected surfaces with corrugations running north-
south and east-west.
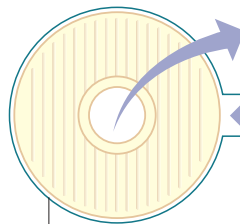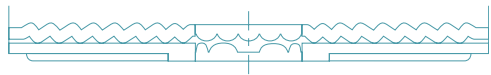
Filtered oil returned
to the oil circuit

Unfiltered oil enters
under pressure

Filter housing

Function

Particles pass
through the
filter maze until
they are trapped
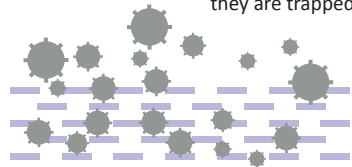
The CJC™ Offline Filter has a large dirt holding capa-
city of approximately 4 L solids, up to 2 L of water
and 4 L oil degradation products (varnish). The CJC™
Offline Filters typically only need replacing every 12
months.

The CJC™ Offline Filter will filter effectively down to
3 µm absolute and remove water and oil degrada-
tion products (oxidation products, resin, sludge and
varnish) from the oil, continuously cleaning machine
components and the whole oil system.

Basic filtration definitions

Nominal filtration ratings are estimated values, indicating a particulate size range at which the filter is claimed to remove a given percentage. There is no standard for this, so consequently, different products/makes cannot be compared. Operating pressure and concentration of contaminants will affect the retention efficiency of filters with nominal rating.

Absolute filtration ratings describe the pore size, indicating the largest size of particle which can pass through the filter. The filter needs to apply to a standard test method intended for filter usage. The rating of a cellulose based offline filter is often 3 μm absolute or less. The rating of a glass fibre based pressure filter varies according to the requirements of the system component(s) to be protected.

Beta values describe filter efficiencies at given particle sizes. The value is written ßx, where the "x" represents the particle size in question and ß ("beta") is the efficiency e.g. ß3 = 200, which means that one out of 200 particles of 3 micron in size will pass through the filter (0.5% passes through and 99.5% are retained in one pass). In order to find the Beta value a standardized "Multipass test ISO 16889" is used, and the Beta value is calculated by the following formula.

$$\text{ßx} = \frac{\text{number of particles upstream} > x\ (N_U)}{\text{number of particles downstream} > x\ (N_D)}$$

Figure 18: Multipass test
Source: ISO Standards
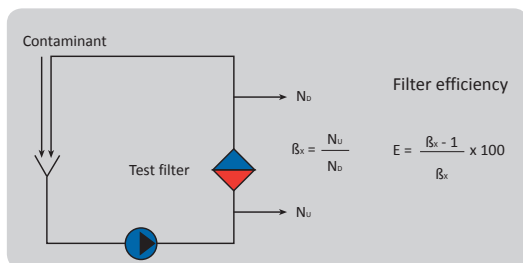
This Multipass test is performed under controlled laboratory conditions and does not take into account some of the challenges an inline pressure filter will see in most oil systems, such as air bubbles, vibrations, pressure pulses from stop-start etc.

Dirt holding capacity is the quantity of contamination retained by the filter insert when the saturation pressure is reached. This is measured in weight or volume. How much oil contamination a filter insert is capable of retaining is of highest importance for the cost of operating over a period of time. While most conventional pleated pressure filter inserts can retain less than hundred grams of dirt (<0.2 lbs), they may be fairly inexpensive to replace. However, if the cost of removing 1 kg or pound of oil contamination is calculated, these conventional pressure filter inserts will suddenly appear quite expensive.

A good quality cellulose based offline filter insert can retain up to several kgs/lbs of dirt, so even though the purchase price is higher, the calculated cost for removing one kg or pound of contamination will be considerable lower than that of a pleated pressure filter insert, giving lower lifetime costs.

The cost of removing 1 kg or lb of dirt

$$\frac{\text{Cost of filter insert in your currency}}{\text{Dirt holding capacity in kg or lbs}} = \text{cost for removing 1 kg or lbs of dirt}$$

	Example 1	Example 2
Filter type	Glass fiber based pressure filter insert	Cellulose based offline filter insert
Cost of element/insert	€ 35 / $ 50	€ 200 / $ 300
Dirt holding capacity	0.085 kg / 0.18 lbs	4 kg / 8 lbs
Cost per kg/lb removed dirt	**€ 412 / $ 278**	**€ 50 / $ 40**

The filter by-pass valve is a safety device which reduces the pressure when the pressure drop over the filter gets too high. It eliminates the filtration function by by-passing the full flow filter which means the oil flow then completely or partially passes by - and not through - the filter. A leaking by-pass valve has a devastating effect on the filter efficiency value. (Figure 19).
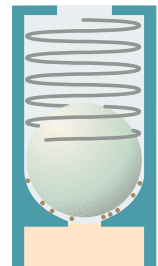
*Figure 19:
By-pass valve*

Installation methods

Full-flow filtration

The total system flow passes through the filter.
Only pressure filter elements are applicable here.

Offline filtration

An installation method where the filtration unit operates
in a separate kidney loop circuit, enabling the use of dense
filter inserts.

Contaminants can pass the filter when by-pass valves cannot close completely after they have opened.
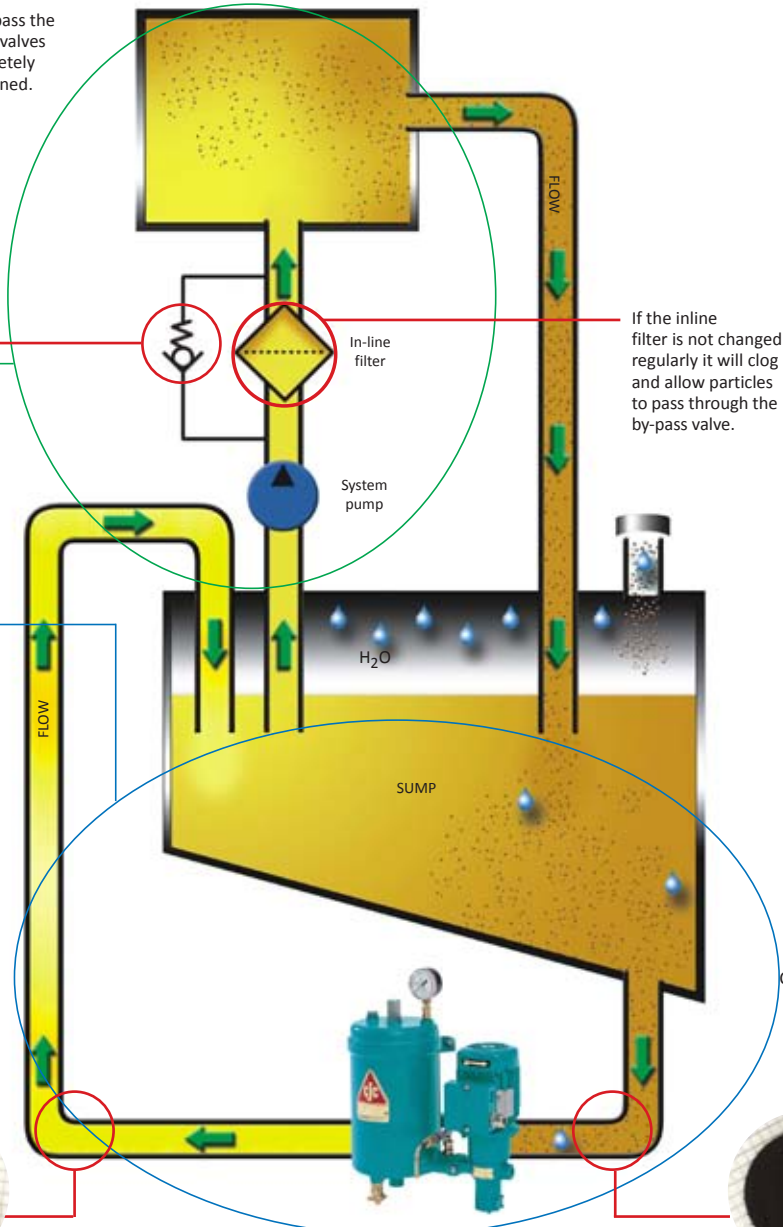
If the inline filter is not changed regularly it will clog and allow particles to pass through the by-pass valve.

In-line filter

System pump

H_2O

FLOW

FLOW

SUMP

Contaminated Millipore membrane. Sample taken before offline filtration.

Millipore membrane. Sample taken after offline filtration.

Offline filter

Economy

Before investing in a filtration system, a cost benefit study should be carried out. The involved costs can be divided into two groups:

- **Purchase costs:** costs directly related to the purchase of a filtration system, i.e. purchase price and installation costs.
- **Operational costs:** costs for keeping the filtration system unit in operation, i.e. replacement of filter inserts, energy consumption and repairs.

Purchase Costs + Operational Costs = Total Investment

The total investment has to be lower than the savings obtained through clean oil.

- **Savings:** the reductions in maintenance costs, the minimizing of lost production hours, prolonged service intervals, longer oil lifetime, extended component life, etc.

In most applications the **payback period or the Return Of Investment** for a CJC™ Offline Filter is typically from a few weeks up to some month, but rarely more than one year. In industries where any downtime is very costly e.g. steel production, the payback period can be a few hours. This means that if the improved oil condition leads to e.g. just 3 hours of additional production, the filtration system has paid for itself. Because the operation cost of the filter solution also plays a role in the total investment, it is relevant to look at how much oil contamination the filter is capable of retaining – the so-called dirt holding capacity.

Most conventional pressure filters can retain less than hundred grams of dirt (less than 0.2 lbs), so they will need to be replaced more often than a good quality cellulose based offline filter capable of retaining several kg or lbs of dirt.

The cost of removing 1 kg (or pound) of dirt from the oil is a good factor for comparing different filter makes and help to find the lowest cost of ownership (the total investment).
See the calculation of the cost for removing 1 lb dirt on page 25.

Ordering a filtration system

In the quote for a filtration system from any supplier the following should be included:

- Operational costs of the filter over a period of min. 5 years (power, filter inserts, spares etc.)
- Obtainable fluid system cleanliness level (e.g. ISO 17/15/12 and 200 ppm water)
- Control procedure confirming that the cleanliness level has been achieved (e.g. oil samples)

Offline filter sizing
When sizing an offline filter the following basic information about the oil system should be specified:

- Oil volume in the system (tank volume)
- Oil type (ISO VG)
- Oil temperature: Normal operation and minimum temperatures (ambient)
- Oil contamination problem:
  - particles
  - oil degradation products, sludge and varnish
  - water (ingress or accumulated)
- Type of application (indoor/clean, outdoor/dirty, severe ingress etc.)
- Machine operating hours per day
- Available power supply

This information will help your local distributor to size the correct CJC™ Filter for your oil system.

Aside from continuous filtration of the oil in machines, drums or bulk tanks, the CJC™ Offline Filters can also be utilized for filling and topping up with oil, thus ensuring that only clean oil enters the system.

CJC™ Oil Maintenance Systems

CJC™ HDU Fine Filter
- Dry oil with limited water content (accumulated over time)
- Hydraulic, lube and gear oils – also Glycols or Ester based fluids
- Retains particles and varnish
- Water removal by absorption (free, emulsified and some dissolved water)
- Reduce acidity level utilizing ion exchange inserts

CJC™ PTU Filter Separator
- Water contaminated oil and diesel
- Hydraulic, lube and gear oils – up to ISO VG 150
- Retains particles and varnish
- Free water is removed by separation (coalescing)
- Suitable for oil with good demulsibility (not engine oil, Ester based fluids etc.)

CJC™ Desorbers
- Water contaminated oil – even with strong emulsions
- Hydraulic, lube and gear oils – up to ISO VG 1000 (depending on Desorber type)
- Removes both free, emulsified and dissolved water
- Suitable for most oils even engine oil, paper machine oil etc.

CJC™ Desorbers do not retain particles and varnish, thus a separate CJC™ HDU Fine Filter is recommended.

CJC™ Varnish Removal Unit
- Dry oil with limited water content
- Retains varnish very effectively
- Suitable for systems with servere varnish production e.g. gas turbines

Handling of oil and oil systems

New oil in containers
- New oil should be considered contaminated until a sample has been analyzed
- Oils containing additives that are not necessary for the application are to be considered contaminated
- New oil should always be introduced to the system via a filter, preferably a 3 μm absolute filter
- Do not mix oils without previously investigating compatibility
- Keep lubricating products in closed containers to avoid ingress of contaminants

Oil in the system
- Observe the oil regularly during operation in order to discover any sudden appearance of water, air or other contaminants. Using fresh oil as a reference may be helpful
- Check the oil after machine malfunctions or other incidents which might affect the oil
- Always observe maximum cleanliness and accuracy during sampling
- Systems should be sealed as much as possible. All permanent openings should be equipped with venting filters (preferably desiccant breathers). All systems should be equipped with permanent filter installations
- When changing the oil, the tank and the system should be emptied completely and the tank should be cleaned manually of settlings, sludge etc. (this can be avoided by installing CJC™ Offline Filters)
- When replacing seals, only oil-resistant materials should be used. Compatibility with the oil should be checked.
- Never apply new additives without consulting the oil supplier/consultant. Ask for written confirmation of the measures to be taken
- Always use independent analysis resources with high quality control and repeatability

11 Recommendations for buying oil

Recommendations for buying oil

When buying oil in bulk, buyers have a right to set specific certified requirements to ensure the quality.
Below find some examples of requirements and test for the quality of the oil, emphasizing oil cleanliness.

Oil test certificates and test sampling
The results of an oil test of the batch should be presented to the buyer. A sample should be taken during the filling of the first batch. Samples should be marked with the trademark, batch number and size of the consignment. The oil should be analyzed by an independent laboratory and the analysis should include the data described in the oil analysis section of this booklet.

Claims
If the oil supplied does not fulfill requirements, returning the consignment might be considered. If the problem can be corrected, new samples must be approved. The supplier must pay all costs, including machinery failure and downtime.

Sampling of new oil

Samples must be drawn from each manufactured batch. The analysed sample must be a representative sample of the manufactured batch. Test records must be available for the buyer for at least five years.

An analysis certificate must be delivered together with the ordered oil and include at least the following items:

- Visual inspection
- Viscosity @ 40°C
- Density
- Total Acid Number of finished product
- Air bubble separation time
- Contaminants, gravimetric or ISO cleanliness code

For wind turbine oils, foaming at 50°C could be included.

The oil must be delivered by tanker trucks, epoxy-painted drums or 20-litre cans. The buyer must indicate the type of container for each individual case. The container must be of first class quality and the type generally used in the oil trade. The container must be marked with the buyer's trade description, the suppliers trade designation, net content and a continuous manufacturing batch number.

Appendix

LET – Cleanliness Level — ISO Codes, Complete

Source: Noria Corp.

Current Machine Cleanliness (ISO Code)	Expected Cleanliness level (ISO Code)									
	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 1.6 / 1.8 1.3	3 2 / 2.3 1.7	4 2.5 / 3 2	6 3 / 3.5 2.5	7 3.5 / 4.5 3	8 4 / 5.5 3.5	>10 5 / 7 4	>10 6 / 8 5	>10 7 / 10 5.5	>10 >10 / >10 8.5
23/21/18	1.5 1.5 / 1.5 1.3	2 1.7 / 1.8 1.4	3 2 / 2.2 1.6	4 2.5 / 3 2	5 3 / 3.5 2.5	7 3.5 / 4.5 3	9 4 / 5 3.5	>10 5 / 7 4	>10 7 / 9 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 1.7 / 1.8 1.4	3 2 / 2.3 1.7	4 2.5 / 3 2	5 3 / 3.5 2.5	7 4 / 5 3	9 5 / 6 4	>10 7 / 8 5.5	>10 9 / 10 7
21/19/16		1.3 1.2 / 1.2 1.1	1.6 1.5 / 1.5 1.3	2 1.7 / 1.8 1.5	3 2 / 2.2 1.7	4 2.5 / 3 2	5 3 / 3.5 2.5	7 4 / 5 3.5	9 6 / 7 4.5	>10 8 / 9 6
20/18/15			1.3 1.2 / 1.2 1.1	1.6 1.5 / 1.5 1.3	2 1.7 / 1.8 1.5	3 2 / 2.3 1.7	4 2.5 / 3 2	5 3 / 3.5 2.5	7 4.6 / 5.5 3.7	>10 6 / 8 5
19/17/14				1.3 1.2 / 1.2 1.1	1.6 1.5 / 1.5 1.3	2 1.7 / 1.8 1.5	3 2 / 2.3 1.7	4 2.5 / 3 2	6 3 / 4 2.5	8 5 / 6 3.5
18/16/13	*Hydraulics and Diesel Engines*	*Rolling Element Bearings*		1.3 1.2 / 1.2 1.1	1.6 1.5 / 1.5 1.3	2 1.7 / 1.8 1.5	3 2 / 2.3 1.8	4 3.5 / 3.7 3	6 4 / 4.5 3.5	
17/15/12					1.3 1.2 / 1.2 1.1	1.6 1.5 / 1.5 1.4	2 1.7 / 1.8 1.5	3 2 / 2.3 1.8	4 2.5 / 3 2.2	
16/14/11	*Journal Bearings and Turbo Machinery*	*Gear Boxes and others*				1.3 1.3 / 1.3 1.2	1.6 1.6 / 1.6 1.4	2 1.8 / 1.9 1.5	3 2 / 2.3 1.8	
15/13/10							1.4 1.2 / 1.2 1.1	1.8 1.5 / 1.6 1.3	2.5 1.8 / 2 1.6	

Figure 20: Life Extension Table, cleanliness level

LEM - MOISTURE Level

Source: Noria Corp.

Current Moisture Level, ppm	Life Extension 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	156
5,000	1,250	650	450	313	250	200	150	100	78
2,500	625	325	225	156	125	100	75	50	39
1,000	250	130	90	63	50	40	30	20	16
500	125	65	45	31	25	20	15	10	8
260	63	33	23	16	13	10	8	5	4
100	25	13	9	6	5	4	3	2	2

1% water = 10,000 ppm. ● Estimated life extension for mechanical systems utilizing mineral-based fluids.

Example: By reducing average fluid moisture levels from 2500 ppm to 156 ppm, machine life (MTBF) is extended by a factor of 5.

Figure 21: Life Extension Method, moisture level

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