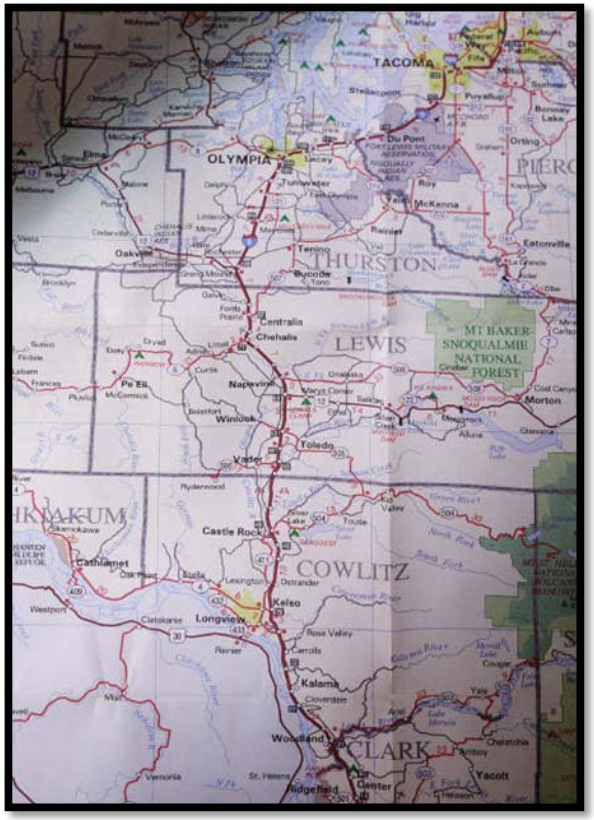


The Roadmap to Effective Contamination Control in Wind Turbines

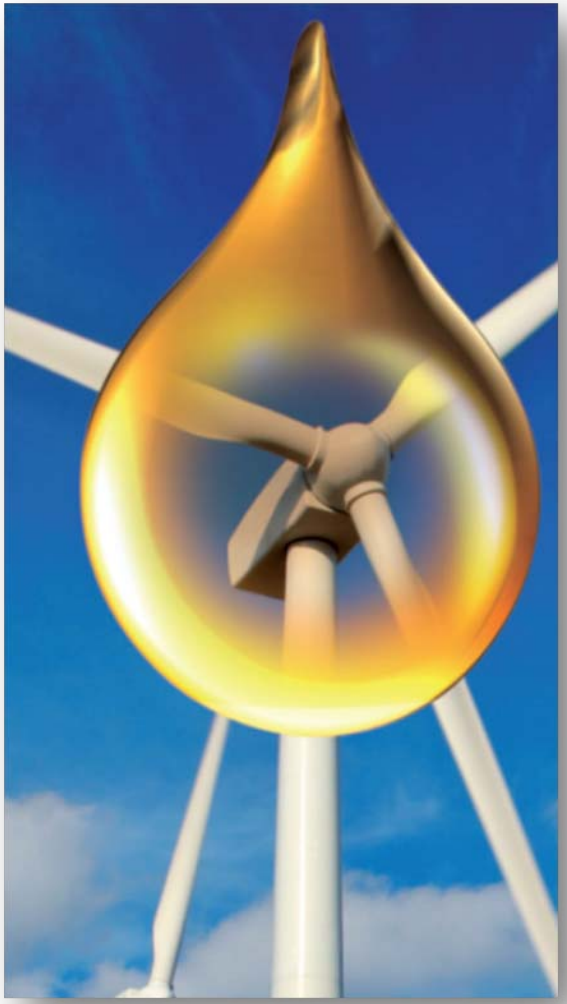
2009 Wind Turbine Condition Monitoring Workshop

Session IV) Lubricant Conditioning and Monitoring

What is the most important component in a wind turbine?

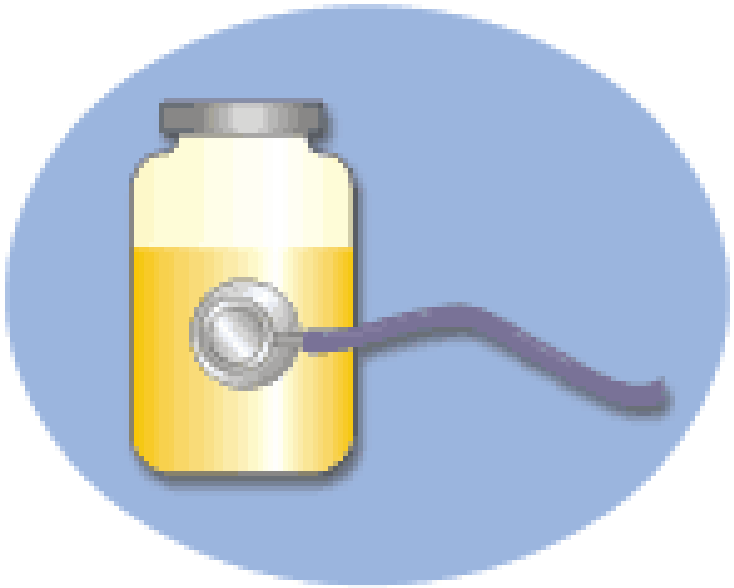
LUBRICANT FUNCTIONS

Friction Control > separates moving surfaces
Wear Control > reduces abrasive wear
Corrosion Control > protects surfaces
Temperature Control > transfers heat
Power Transmission > transmits force (hydraulics)
Contamination Control > transports contaminants



Your Oil is Talking…

Are You Listening?



Understanding the role of Lubrication, Contamination Control and Condition Monitoring is key to a modern maintenance strategy.

To get the most reliability out of a Wind Turbine, understanding the fundamentals is essential!

The Importance of Clean Oil and it's Impact on Reliability Has Been Known for Decades

"Replacing 40-25µm filters by units rated at 3µm absolute is to be recommended for gearboxes. Such action should lead to improved reliability, longer periods between overhaul, cheaper overhauls, and consequent reductions in ownership costs. Times between oil changes, where relevant, should be substantially increased." [1]

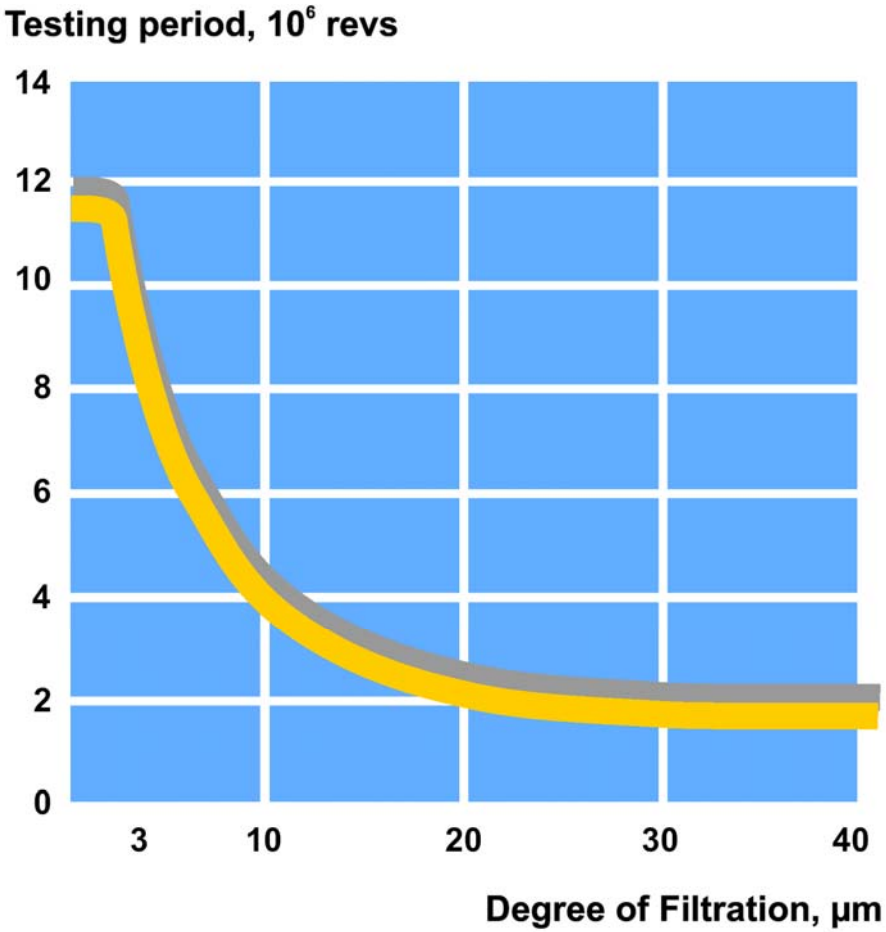
1979
The Influence of Filtration on Rolling Element Bearing Life
Source:
R. Bhachu, R. Sayles, and P.B. Macpherson

Macpherson Curve

Bearing life is increased by a factor of six when upgrading to a 3 µm filter [1]

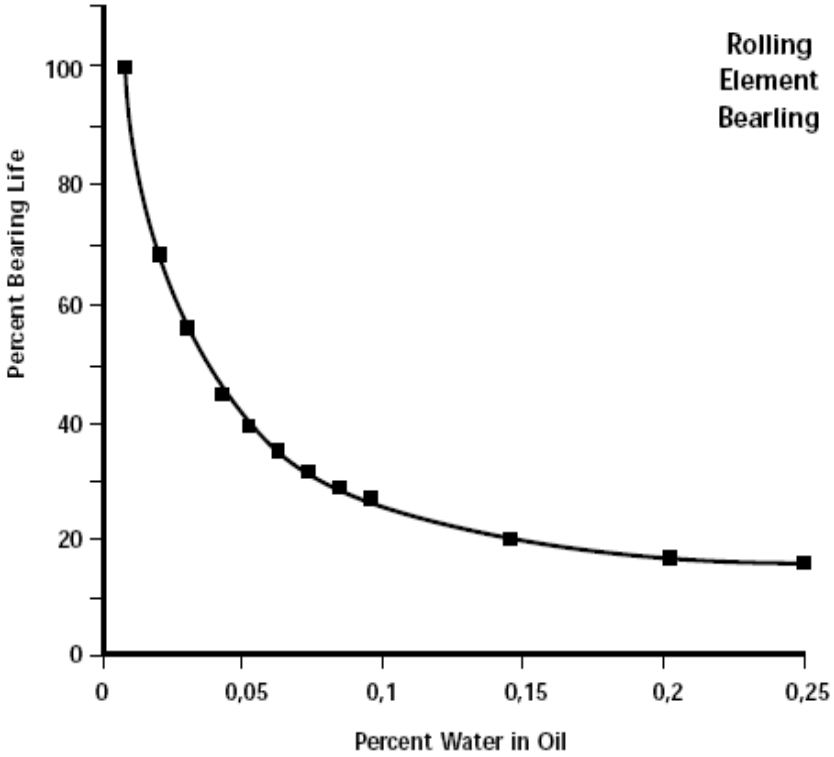
Addressing the cause, the effect is eliminated.

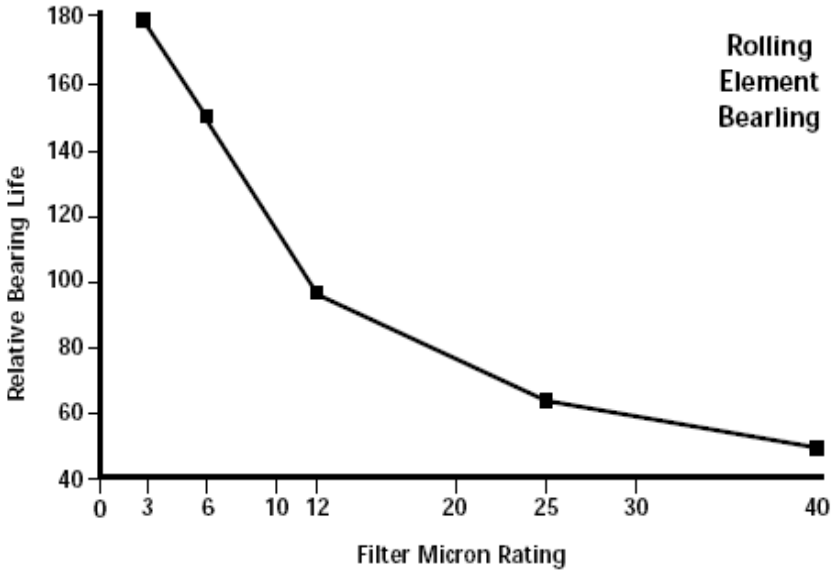
To increase service life and reliability, the wear rate must be slowed down and contaminants controlled.



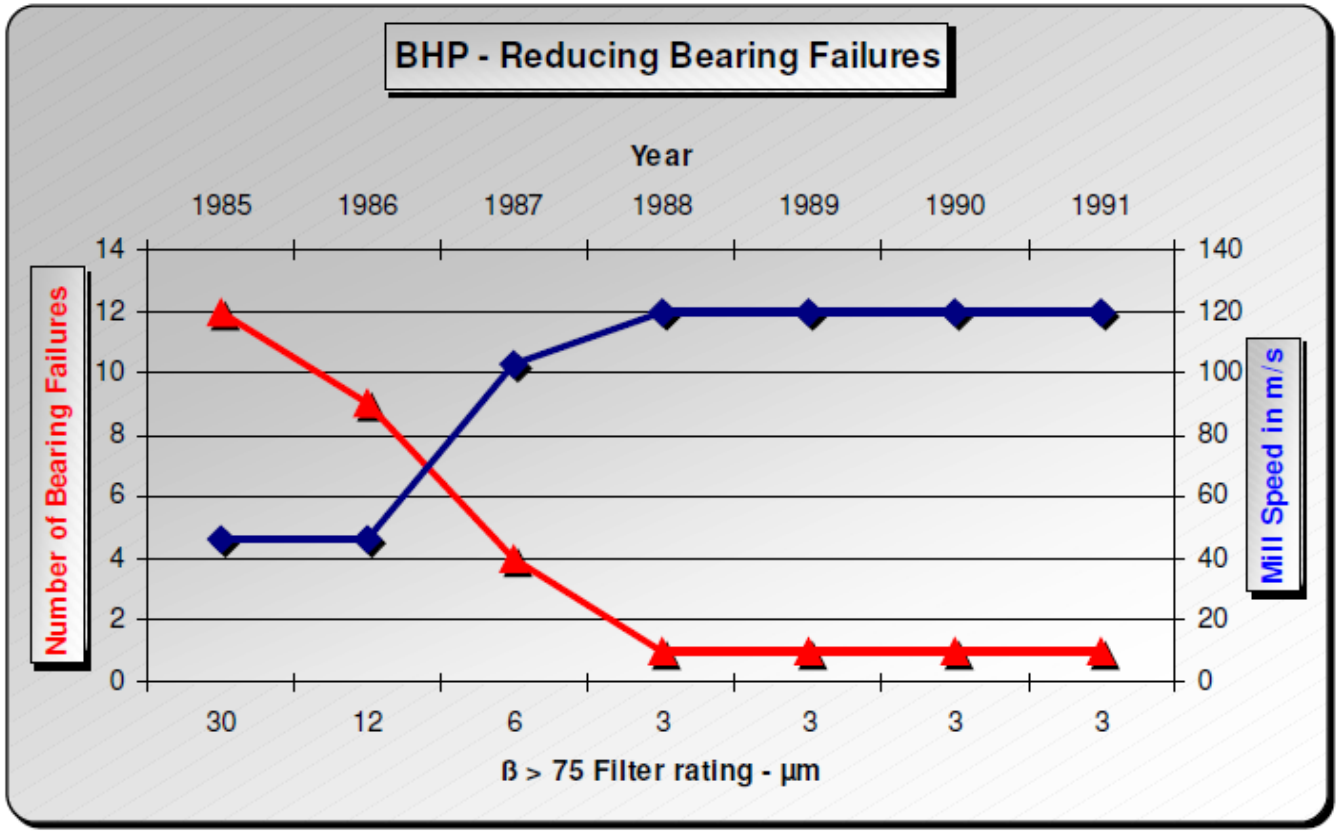
Contamination Kills Bearings

"If the full bearing life potential is to be attained, it is necessary that the lubricant used has maximum cleanliness." SKF [2]





BHP Billiton



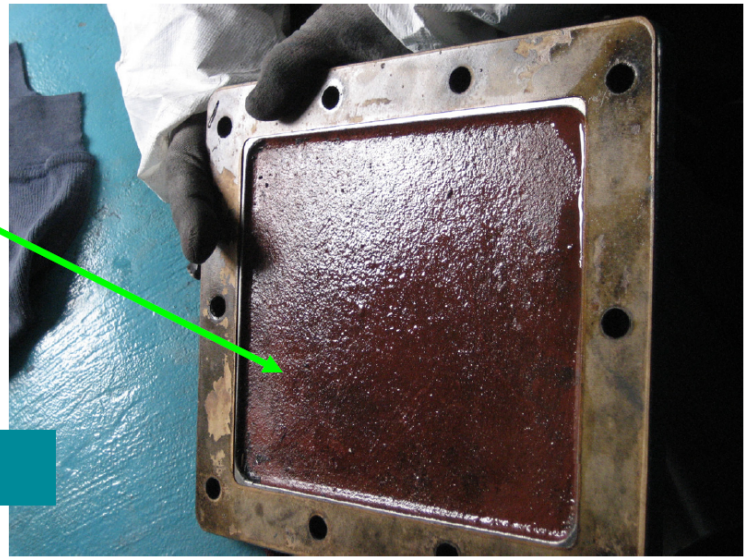
Reduced bearing failures improved productivity [3]

Know Your Enemy

Particles | Water | Varnish

Know Your Enemy - Varnish

Example of varnish on Internal parts (surfaces) in the gearbox



THE RELIABILITY CHALLENGE

QUESTION: Can a wind turbine gearbox reach it's full reliability potential with a 10 micron filter only and little to no water or varnish removal?

What Research Teaches: For optimum life and reliability of gears, bearings and lubricants a 3 micron filter must be employed. Furthermore, removing moisture and varnish with a suitable media will increase lifetime further.

Challenge: The fact remains that many modern wind turbines come equipped with no better than 10 micron filters and little to no water or varnish removal capacity.

How "Clean" Is Clean Oil? [4]

Table 17 -- Lubricant cleanliness

Source of oil sample	Required cleanliness per ISO 4406
Oil added into gearbox at any location	–/14/11
Bulk oil from gearbox after factory test at the gearbox manufacturer's facility	–/15/12
Bulk oil from gearbox after having been in service 24 to 72 hours after commissioning of the WTGS (pressure fed systems only)	–/15/12
Bulk oil from gearbox sampled per the operating and maintenance manual (pressure fed systems only) (see 6.7)	–/16/13

Clean Oil – Step 1:

Filter "New" oil to ISO -/14/11 with a filter cart or skid [5]

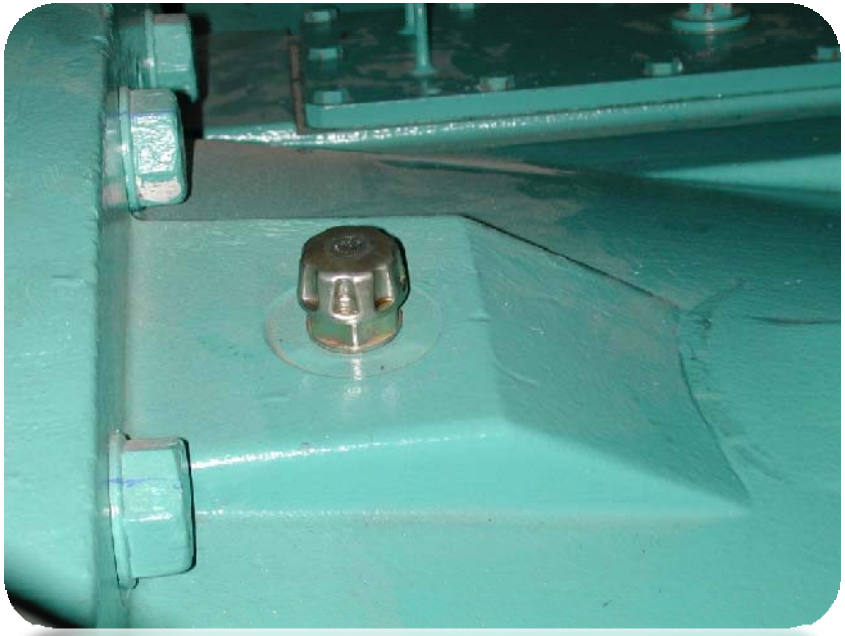
DID YOU KNOW…

The average cleanliness level of new oil in bulk tanks, drums and totes is anywhere from ISO 20/17 to ISO 23/20! Adding this oil to a gearbox will introduce millions of fresh contaminants

Clean Oil – Step 2:
Minimize Ingression [5]

- Install high quality breathers and seals
- Add oil with a portable filter using quick connect fittings
- Use clean containers with pre-filtered oil for top-ups

Breathers

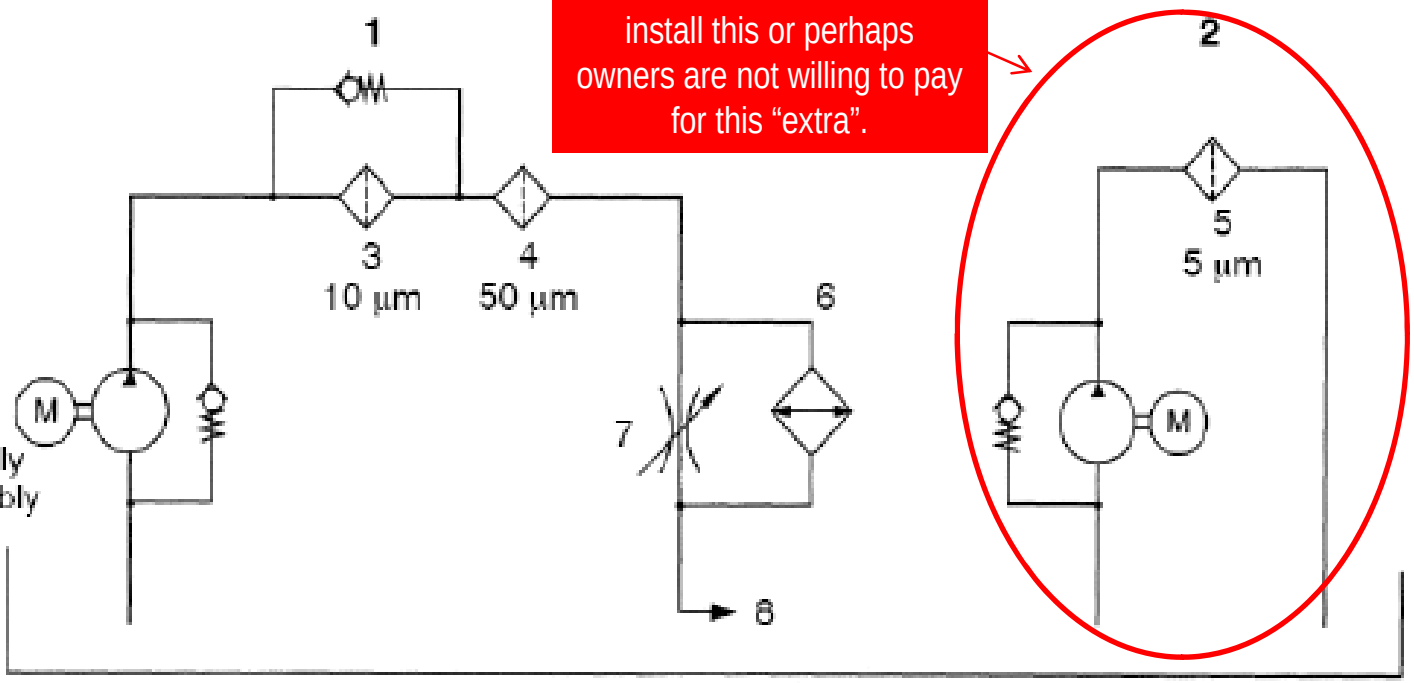


Old School

High Quality Desiccant Type

Clean Oil – Steps 3 & 4:
Configuration of Filtration System [4]

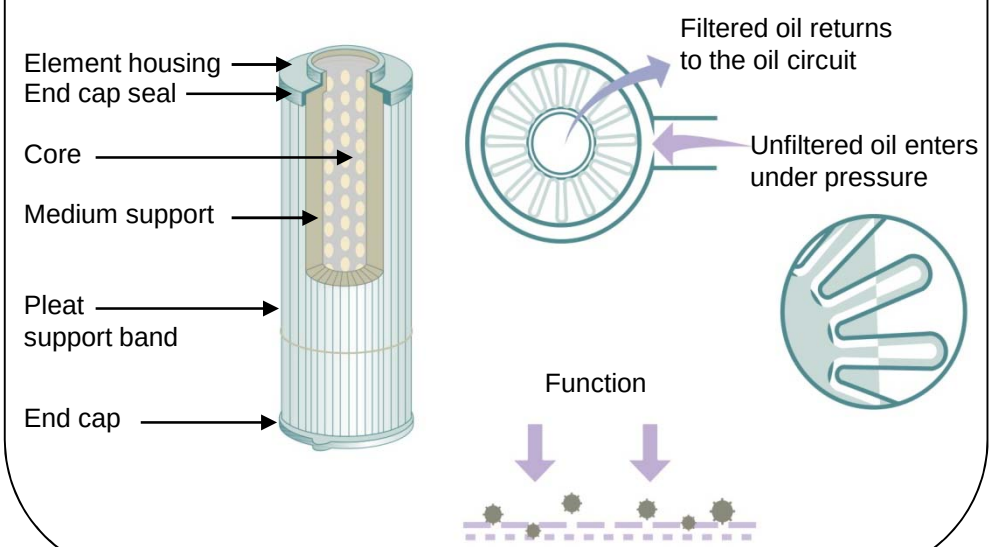
Some OEM's choose not to install this or perhaps owners are not willing to pay for this "extra".



Key
1 Inline filter assembly
2 Offline filter assembly
3 Inline filter
4 Pressure strainer
5 Offline filter
6 Cooler
7 Thermo bypass valve
8 To the lubrication sys-

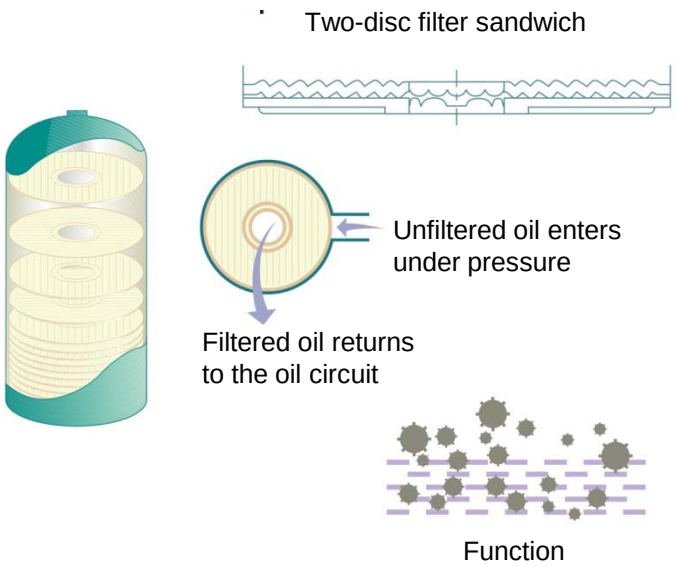
Surface Filtration

Typical Surface Filter for Inline Filters



Depth Filtration

Typical Depth Filter for Offline Filters



Clean Oil – Step 3:
Inline Filters

Typically Installed in Cooling Circuit
High Flow – Low Surface Area

Typically 10µm

Clean Oil – Step 3:
Inline Filters

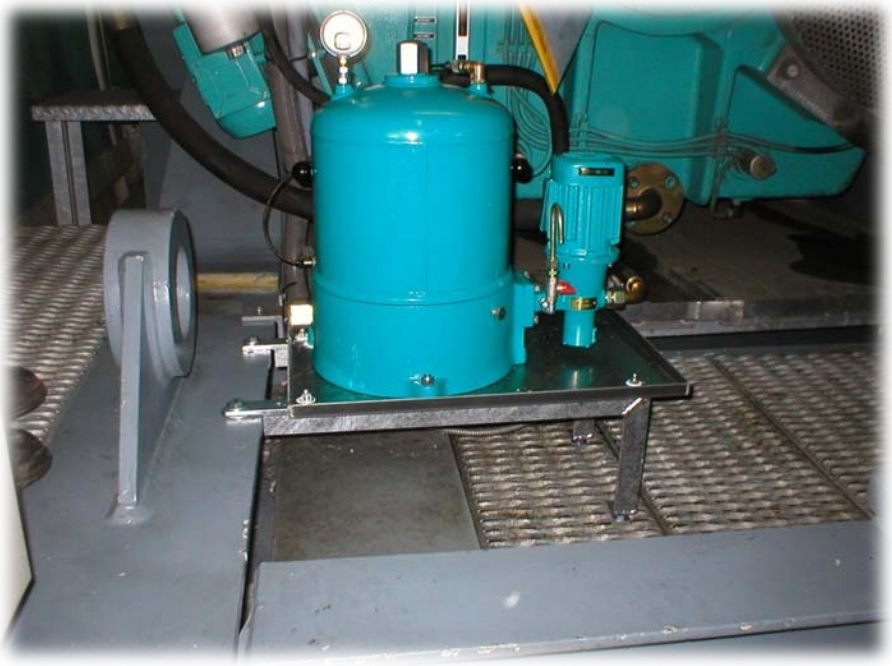
Advantages

- ✓ Fine filtration possible (down to 10 micron)
- ✓ Protects the system from large debris
- ✓ Full flow filtration before sensitive components (safety!)
- ✓ Can be adapted for condition monitoring

Disadvantages

- ✗ Expensive in operation (frequent replacement of expensive fine filtration elements)
- ✗ Energy consuming (large pressure drop = wasted energy)
- ✗ Low efficiency under cyclic flow conditions
- ✗ Low surface area
- ✗ Little to no water and varnish removal capacity
- ✗ Effective with system flow only

Clean Oil – Step 4:
Offline Filters



Low Flow – High Surface Area

Typically 3µm
Removes Particles, Water, and Varnish

Clean Oil – Step 4:
Offline Filters

Advantages

- ✓ Very fine filtration possible (3 micron and lower)
- ✓ Large dirt holding capacity (depth filtration)
- ✓ Low total operational costs
- ✓ Water absorption possible
- ✓ Removal of soft particles (varnish)
- ✓ Continuous operation possible
- ✓ Independent of main system operation (constant efficiency)
- ✓ Improves operational conditions for all other system filters
- ✓ Can be adapted for condition monitoring

Disadvantages

- ✗ Relatively costly investment
- ✗ No component protection in the event of sudden break-downs

A Danish Perspective…

Danish Wind Turbine Owners' Association

DANMARKS VINDMØLLEFORENING

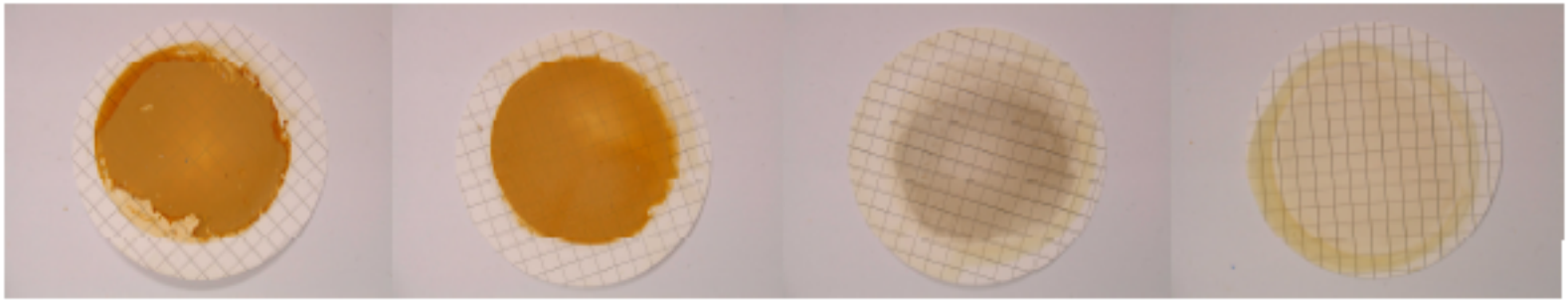
Mr. Strange Skriver
Chief Technical Advisor

"It is agreed upon that cleaning the oil is of vital importance for bearing life… I will advise all wind turbine owners with turbines ranging above 550 kW to install an offline filter system. The sooner the better!" [6]

Clean Oil – Step 4:
Offline Filters Remove Varnish

Clean Oil – Step 4:
Offline Filters Remove Varnish

Before	24 after	7 days	1 month
ISO 21/19/16	ISO 21/19/16	ISO 18/16/12	ISO 16/14/11



Millipore membranes of gear-oil from a 750 kW wind turbine

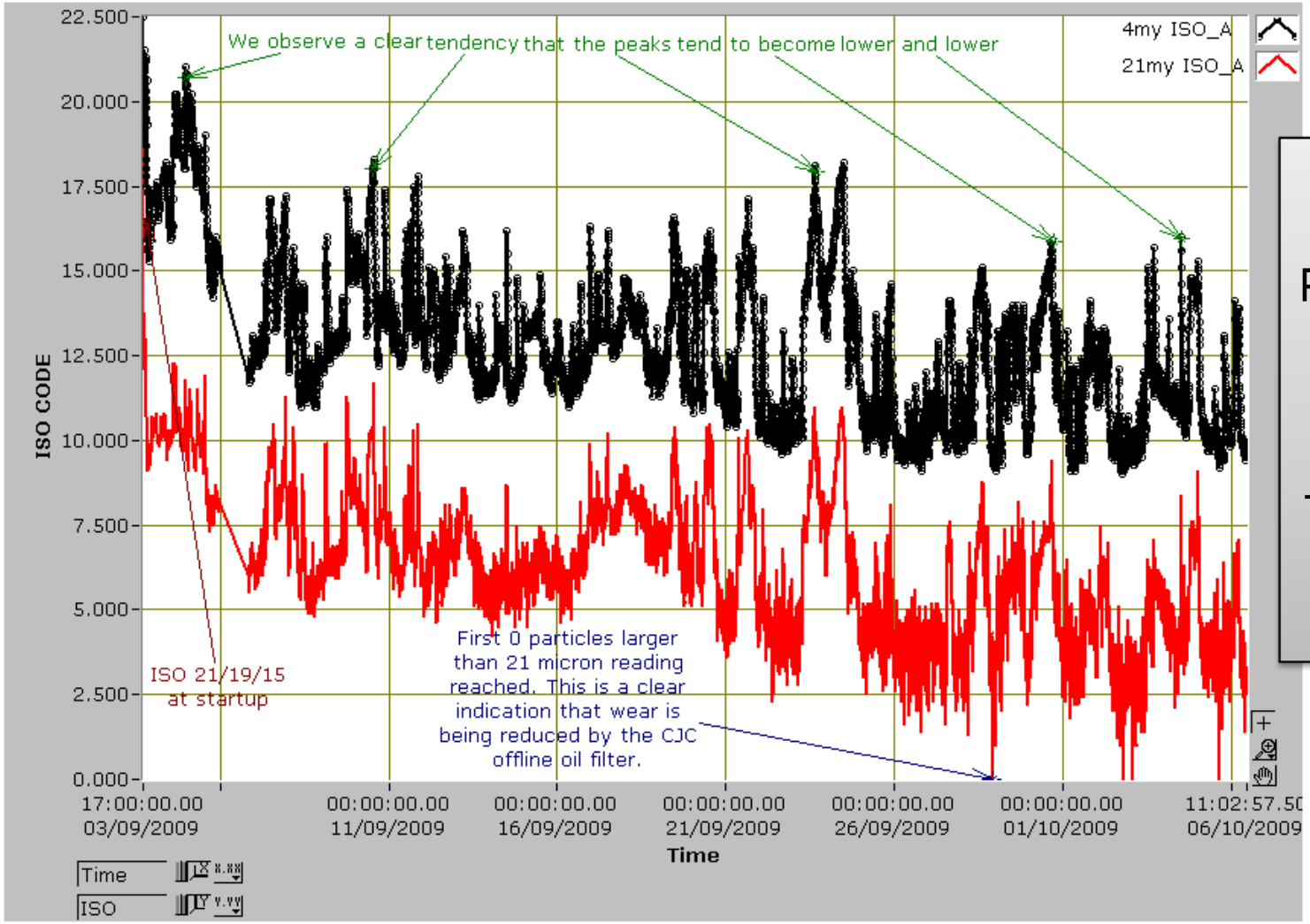
Clean Oil – Step 5: *Condition Monitoring*

Offline Filter fitted with Particle Counter

Advantages:

- Oil cleanliness according to ISO 4406
- See the gearbox aging process and meantime to failure
- See if wear is accelerating
- See under what condition and turbine operation modes abnormal wear is happening
- Predict imminent gearbox failure
- Contributes to improved gearbox and turbine design

Clean Oil – Step 5: *Condition Monitoring*



Offline Filter fitted with Particle Counter

2 MW Turbine

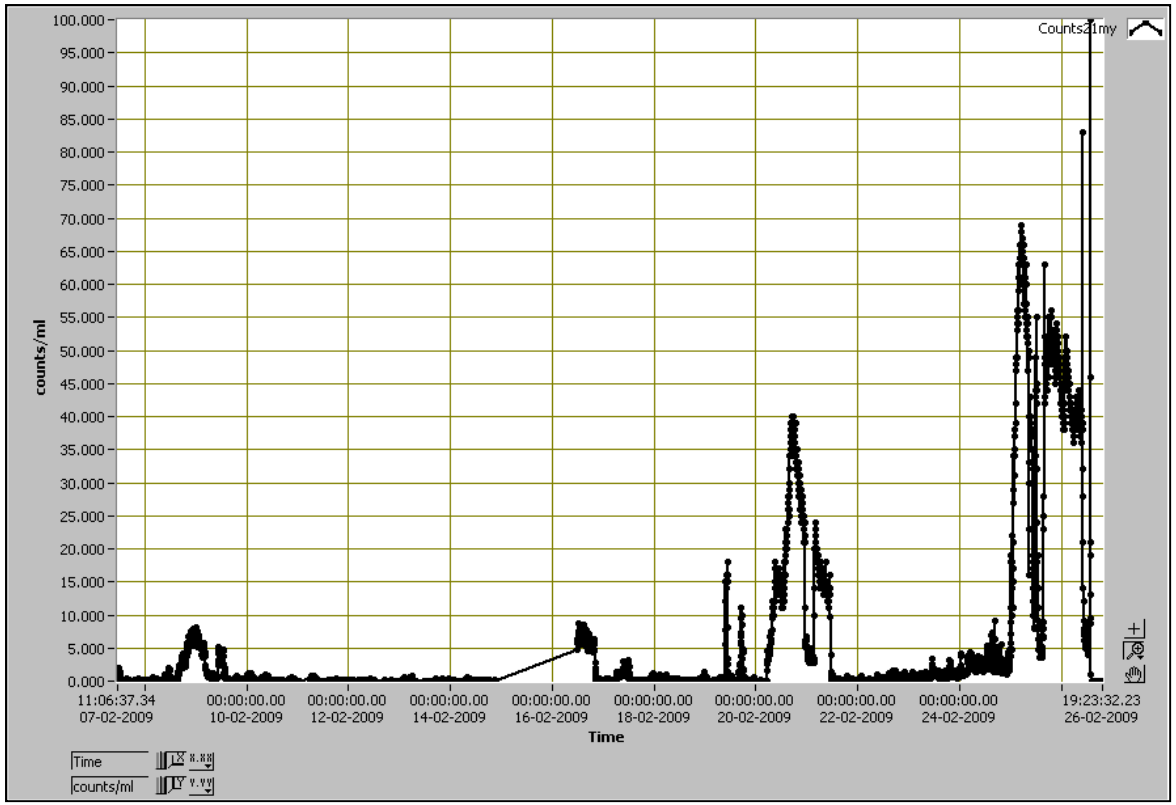
This chart shows counts at 4 and 21 micron

Clean Oil – Step 5: *Condition Monitoring*

Gearbox failure and imminent breakdown

Feb 9th – 27th , 2009

3 peaks in a row 9th, 20th, 25th and every time the particles increase. The particle level increases exponentially as wear and particle generation accelerate. Inline and offline filters cannot eliminate the particles at the same speed they are generated due to wear. This chart shows the particle count at 21 micron.



The owner was informed and advised 6 days before the turbine was stopped for preventive condition based maintenance during which the gearbox damage was confirmed after a visual inspection. At the time when the particle counter indicated the failing gearbox and imminent breakdown, there was no other SCADA warning. The gearbox was replaced and repaired within a planned turbine stop. The owner calculated a savings of approximately $80,000.

The Roadmap Summary…

Filter "New" Oil

Filter carts or pre-filters

Minimize Ingression

Desiccant breathers

Quality seals

Filter carts to add oil

Careful Maintenance

Inline Filters

System protection

Offline Filters

3 micron fine filtration

Water removal

Varnish adsorption

Condition Monitoring

Combine with inline or offline filters

References

1. R. Bhachu, R. Sayles, and P.B. Macpherson (1979). “The Influence of Filtration on Rolling Element Bearing Life”
2. E. Ioannides, E. Beghini, G. Bergling, J. Goodall Wuttkowski and B. Jacobson (1993). "Cleanliness and its Importance to Bearing Performance“. SKF Ball Bearing Journal, No. 242, 1993, pp. 8-15.
3. M. Williamson (2006). “Best Practices of Reliability Driven Lubrication for Wind Turbines”
4. “ISO 81400-4 Wind Turbines Part 4: Design and Specification of Gearboxes”
5. R. Errichello and J. Muller (2002). "Oil Cleanliness in Wind Turbine Gearboxes". Machinery Lubrication Magazine.
6. S. Skriver (2000). “Large Turbines Need Offline Filters”. WindStats Newsletter, Vol. 13, No. 3, pp 6-7.
7. S. Raadnui . “Magnetic Chip Detector Wear Particle Analysis”