



# Two Keys of Reliability Initiatives – Clean Oil and Oil Condition

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**2009 Wind Turbine Reliability Workshop**



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

“Replacing 40-25 $\mu$ m filters by units rated at 3 $\mu$ m 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.”

**1979**

The Influence of Filtration on Rolling Element Bearing Life

Source:

R. Bhachu, R. Sayles, and P.B. Macpherson



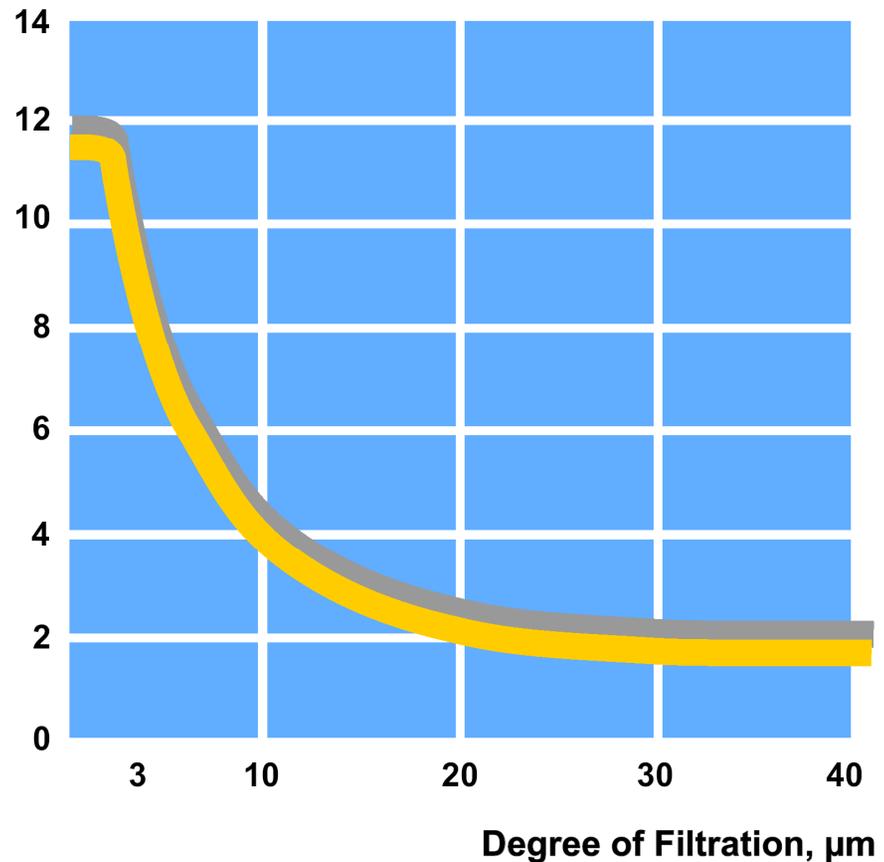
# Macpherson Curve

## DID YOU KNOW...



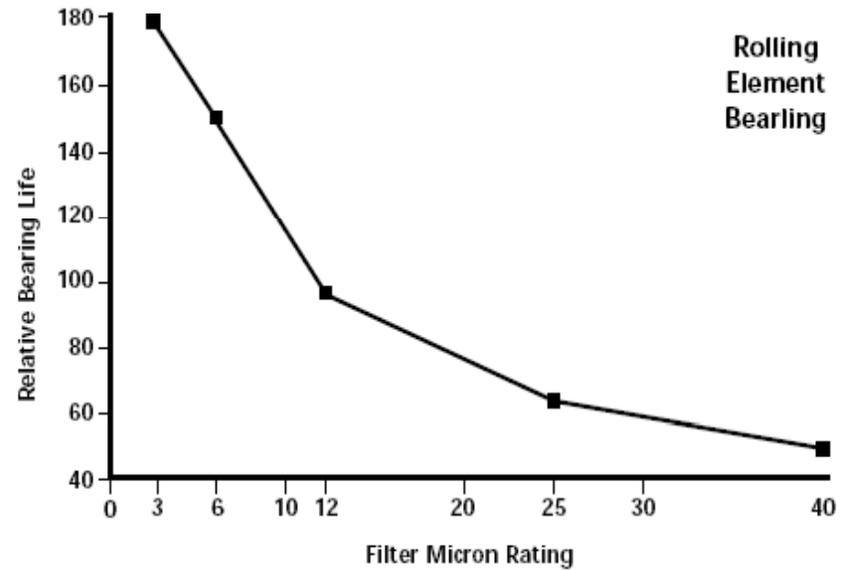
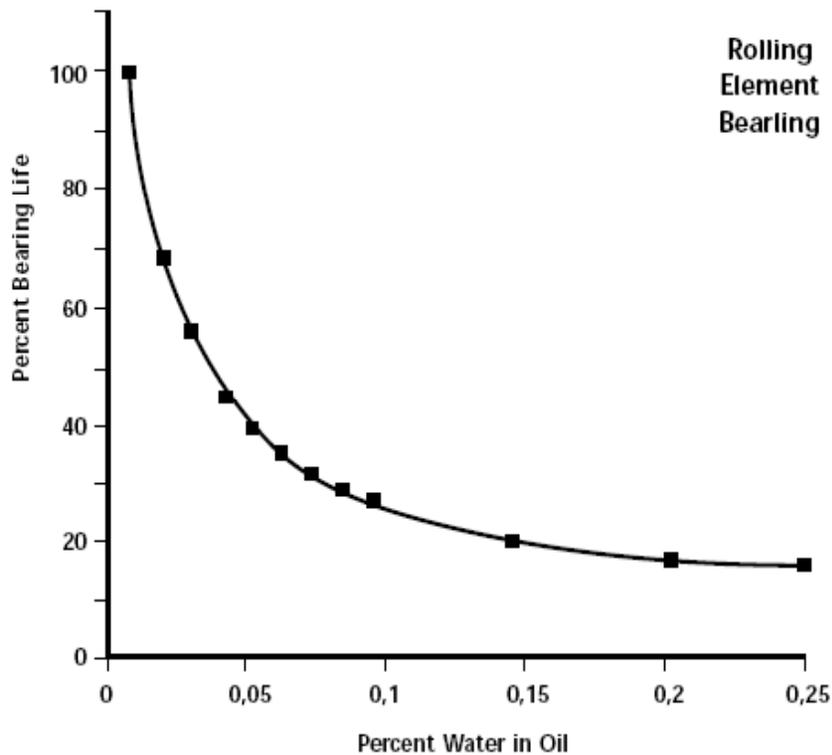
Researchers from London's Imperial College, Sayles and Macpherson, showed gearbox life can be increased up to seven times by changing from a 40 micron filter to a 3 micron filter.

Testing period,  $10^6$  revs





# Contamination Kills Bearings



Source:  
SKF



## ***THE RELIABILITY CHALLENGE***

**QUESTION:** Can a wind turbine gearbox reach it's full reliability potential with a 10 micron filter only?

**What Scientific Research Teaches:** For optimum life and reliability of gears, bearings and lubricants a 3 micron filter must be employed. Furthermore, removing moisture 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 removal capacity.



# How “Clean” Is Clean Oil?

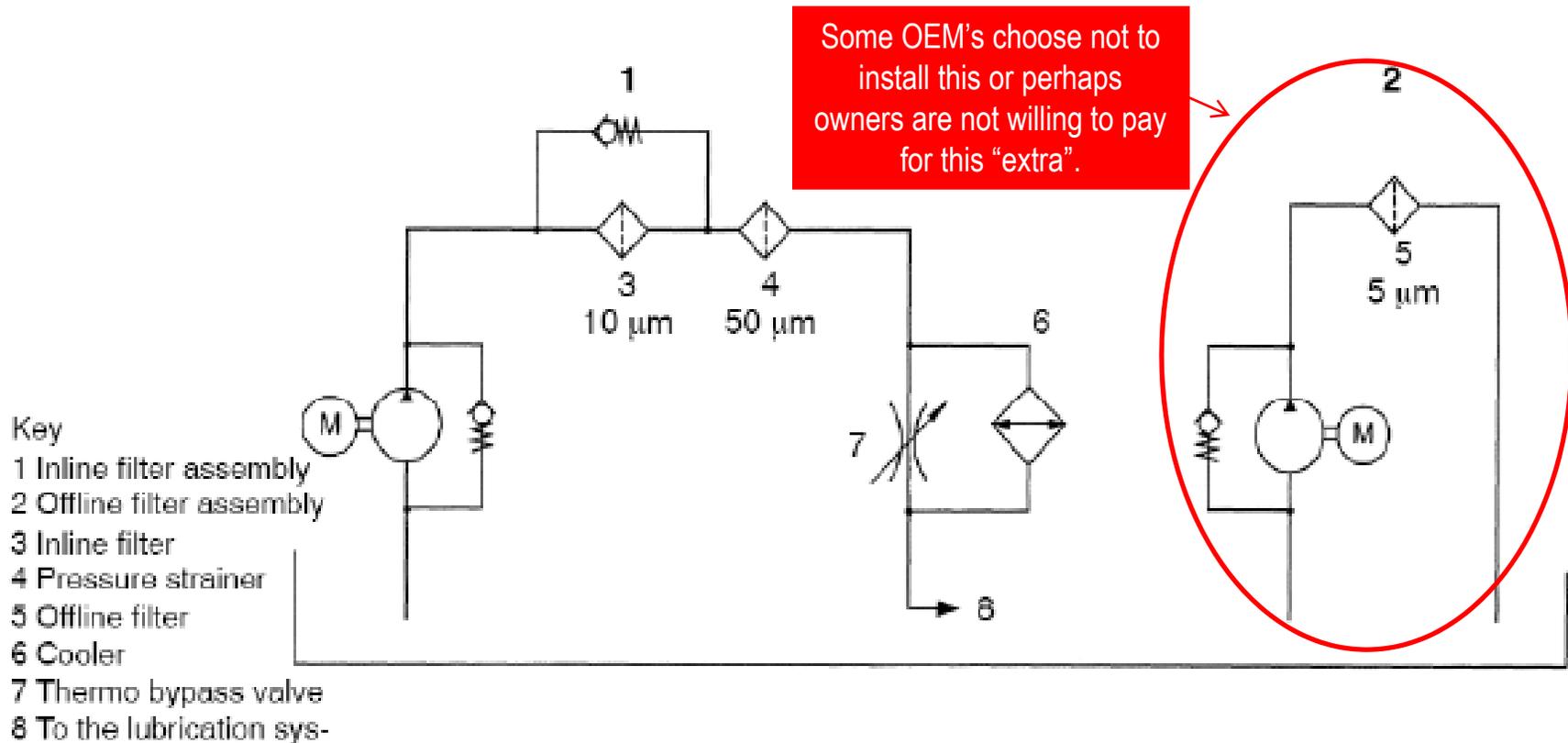
ISO 81400-4 Wind Turbines Part 4: Design and Specification of Gearboxes

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



# Configuration of Filtration System

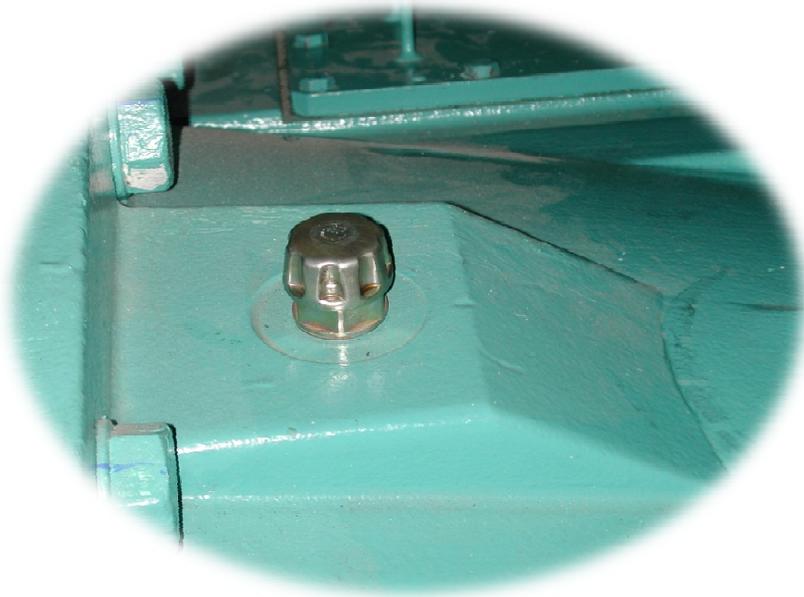


Ref:

ISO 81400-4 Wind Turbines Part 4: Design and Specification of Gearboxes



# Breathers



Old School



High Quality  
Desiccant Type



## Inline Filters



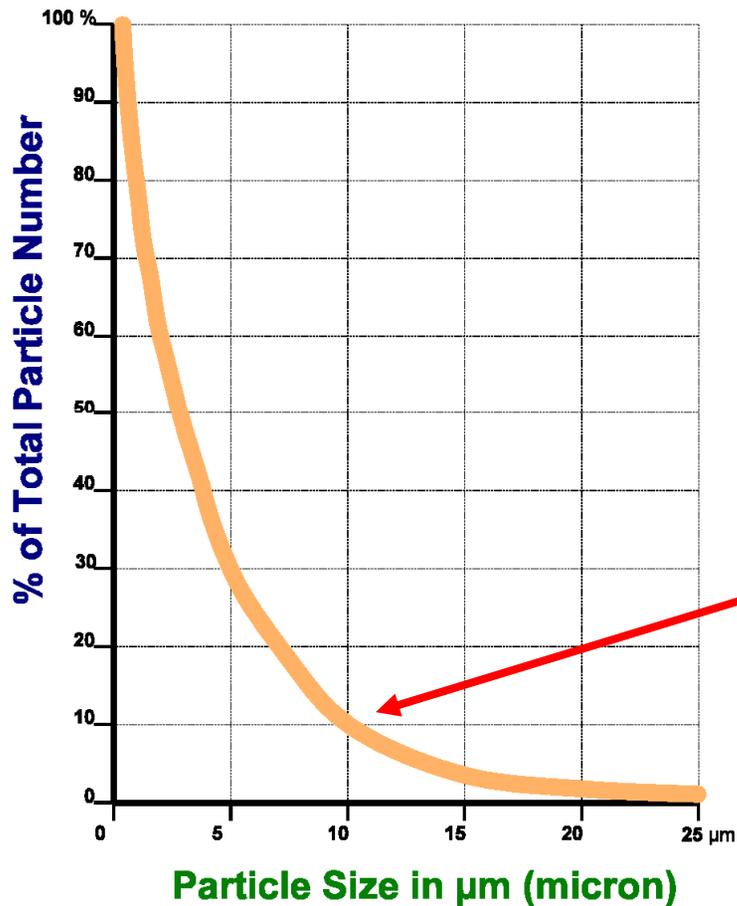
Typically Installed in Cooling Circuit  
High Flow – Low Surface Area



Typically 10µm



# Is a 10 $\mu$ m Filter Good Enough for Reliability?



## Particle Size Distribution

On average, 10 $\mu$ m particles only comprise 10% of the total particle population

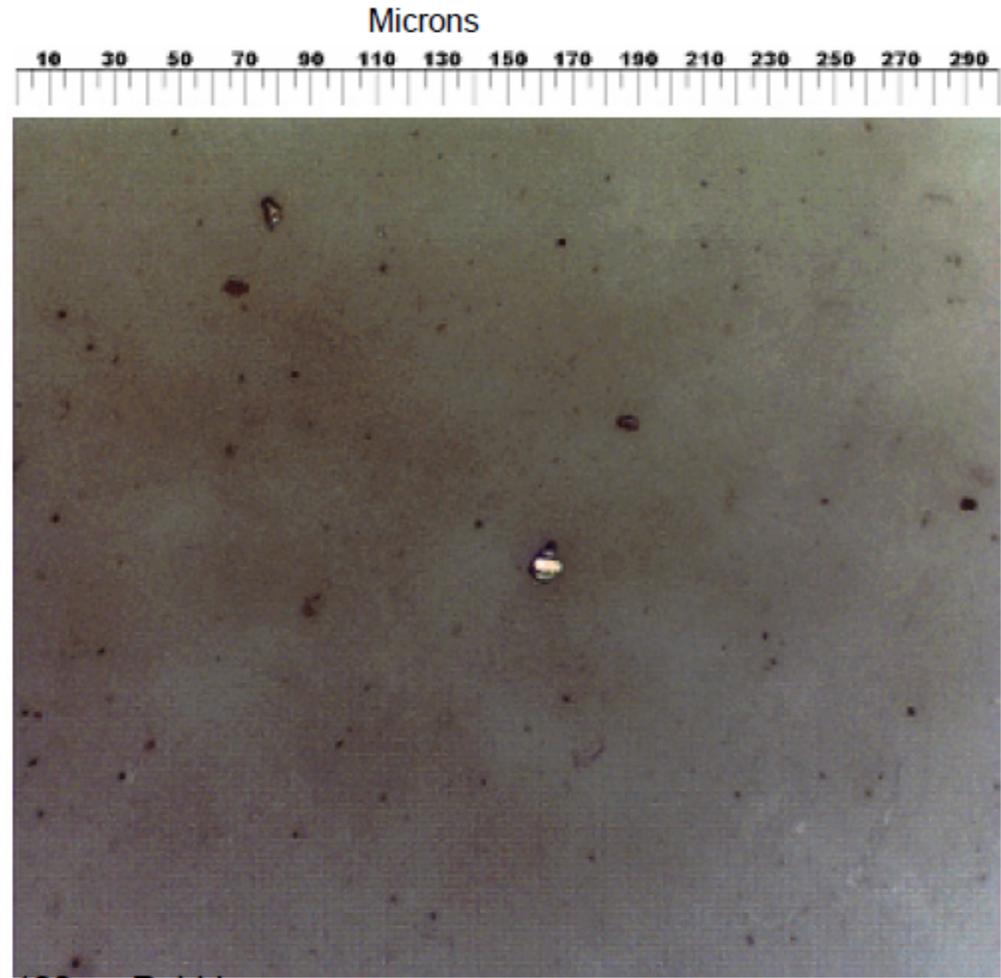


# Inline Filter Performance

**Turbine:**  
**>1 MW**

**Year Online:**  
**2009**

**ISO Code:**  
**20/18/15**

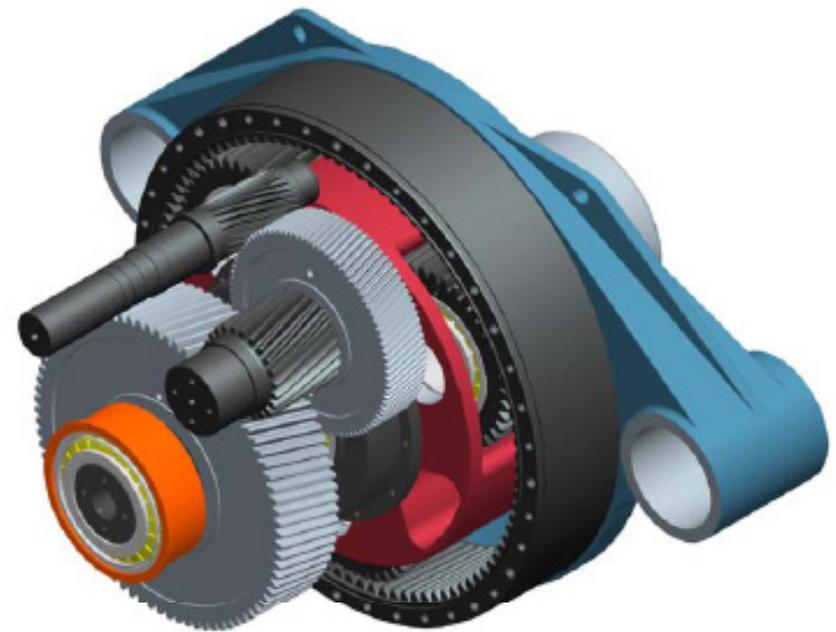


100x Rubbing wear.



# Is it a Gearbox or Dirtbox?

Filter Rating	ISO Code	Dirt (lbs)	50 lb Bags
10 $\mu\text{m}$	20/18/15	1,065	21.3
3 $\mu\text{m}$	14/12/9	14	0.28



Oil Cooler Circuit  
32 gpm flow rate  
1 Year of Operation

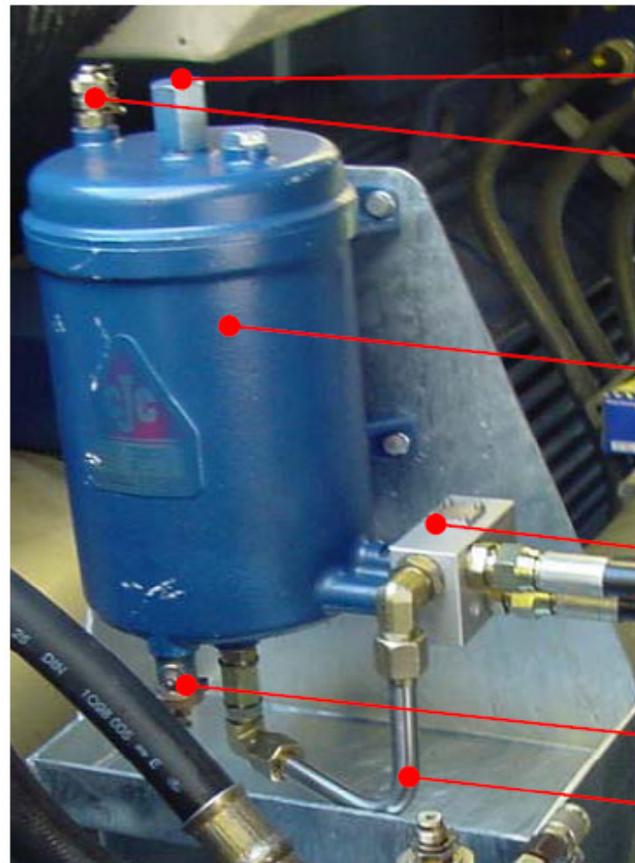


# Bypass Filters

Typically 3-10 $\mu$ m

Only functions when  
the oil cooler circuit is  
operating

Consumes energy



Acorn nut, HDU 15/25

Meter connection

CCJ by-pass filter housing

Valve block

Drain cock

16mm pipe



## Offline Filters



Low Flow – High Surface Area

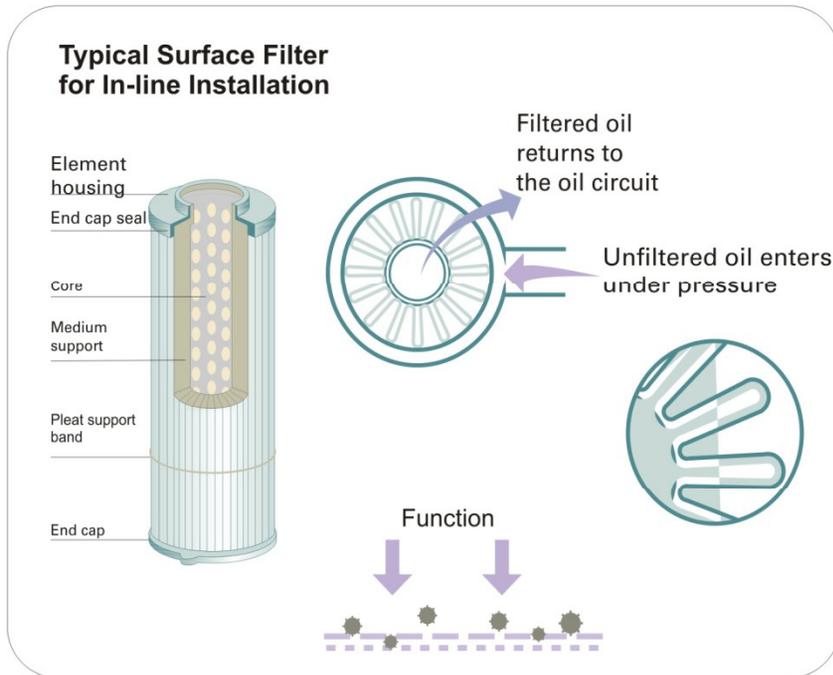


Typically 3 $\mu$ m  
Removes Particles, Water,  
and Varnish

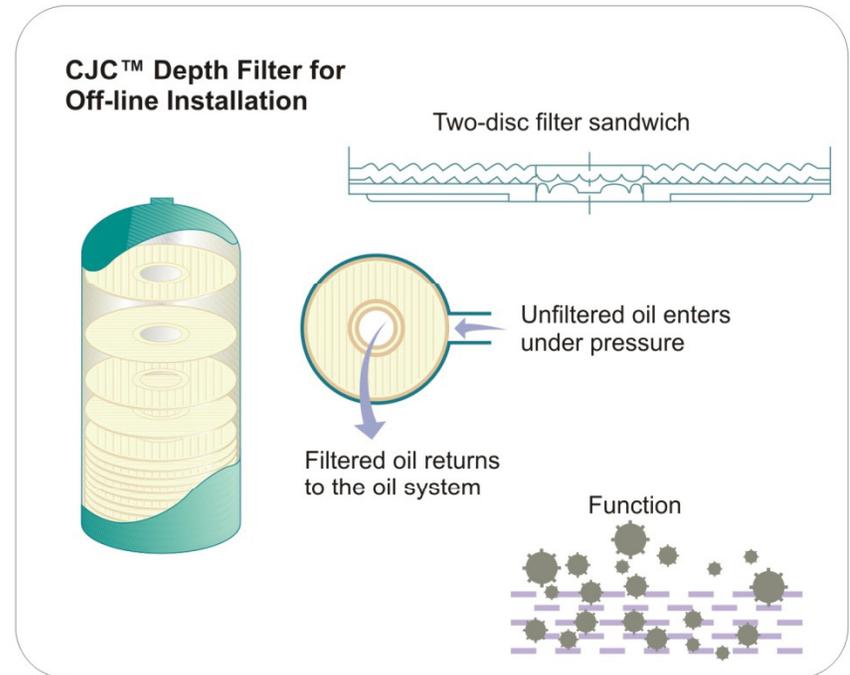


## Filtration Comparison, Surface vs. Depth

### Surface Filter



### Depth Filter

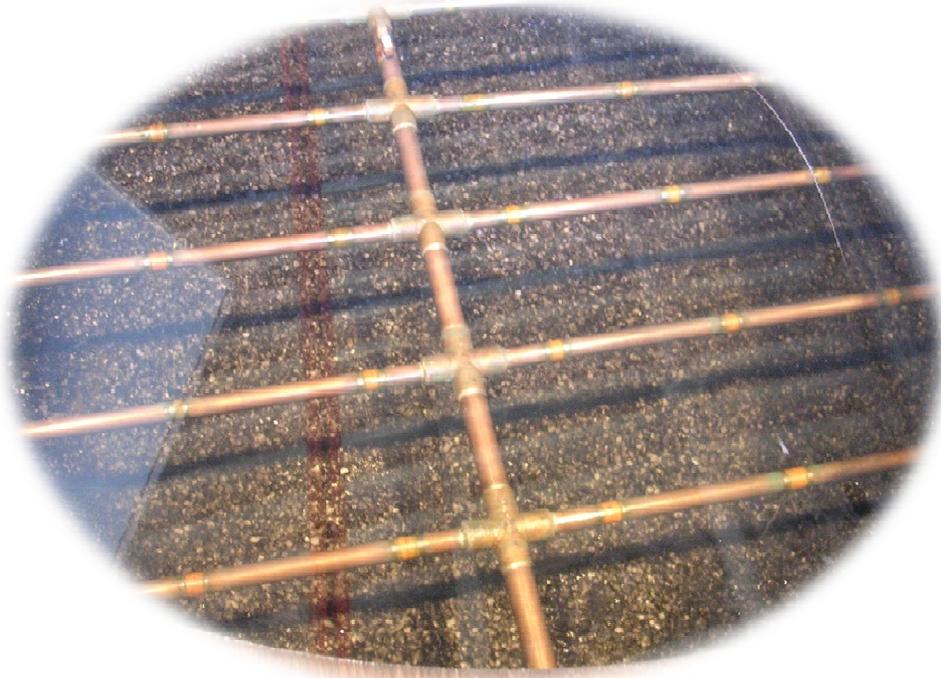




### ILLUSTRATION

#### Jack Daniels Distillery – Lynchburg, TN

At Jack Daniels they employ a depth filtration process called “Charcoal Mellowing”. This purifies the product and improves it’s characteristics.

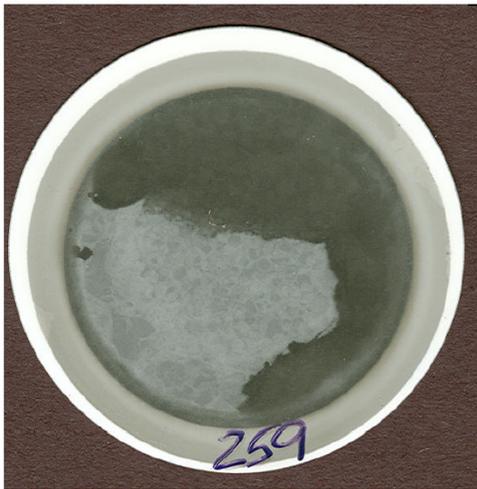


**Lesson:** Depth filtration will provide higher quality oil while improving performance. Modern wind turbine gearboxes will benefit from a similar “old-fashioned” approach to purification.

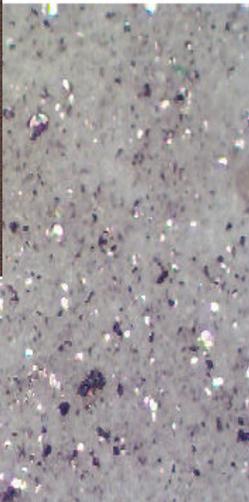


# Offline (Depth) Filter Performance

<1 MW Wind Turbine  
24 Hours



259



x100 Contami

**Before Retrofit:**  
ISO 25/24/19



262



**After Retrofit:**  
ISO 18/16/13



# A Danish Perspective...

## Danish Wind Turbine Owners' Association



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!”**

Ref: Skriver, S., Large Wind Turbines Should Have Offline Oil Filters



# Condition Monitoring - Particle Counters

## Three Commercially Available Sensors



**Method**  
Eddy Current

**Detection**  
≥50 µm

**Communication**  
RS232



**Method**  
Eddy Current

**Detection**  
≥100 µm

**Communication**  
Digital Output



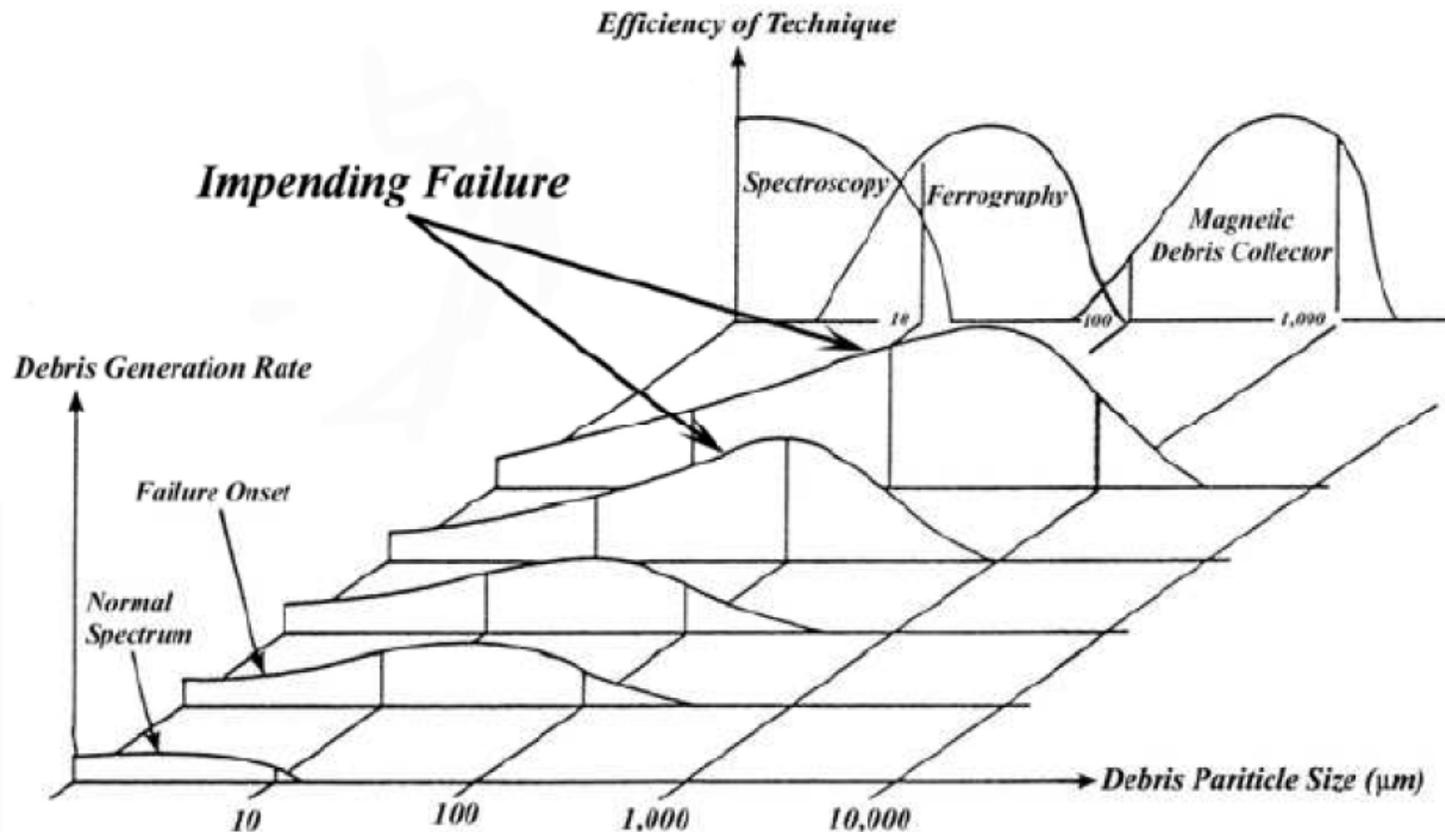
**Method**  
Laser

**Detection**  
≥ 4 µm

**Communication**  
GPRS Modem,  
RS485 Network,  
PLC, RS232



# Small Particles Show Up First



Ref: Raadnui, S., Magnetic Chip Detector Wear Particle Analysis



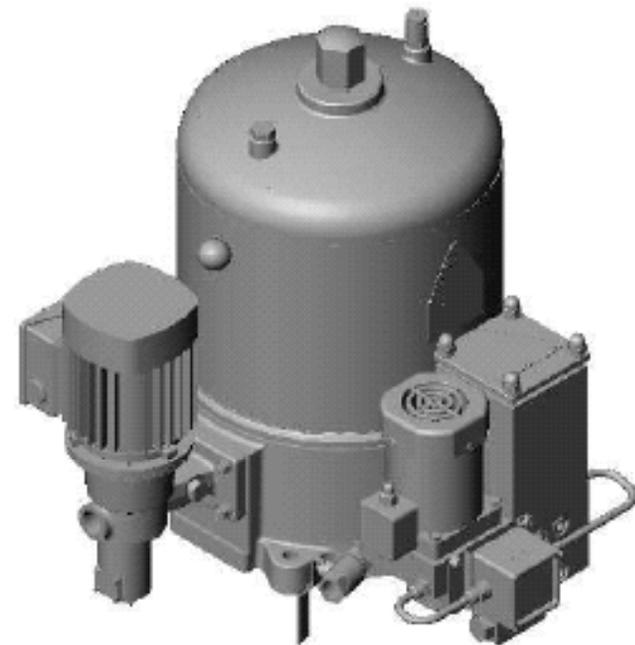
# Case Study – Laser Particle Counter

Measures oil cleanliness according to ISO 4406;  
4,6, 14  $\mu\text{m}$  and 21  $\mu\text{m}$

Installed with Offline Filter System  
(connected to measure before off-line filter from  
most dirty point in gearbox)

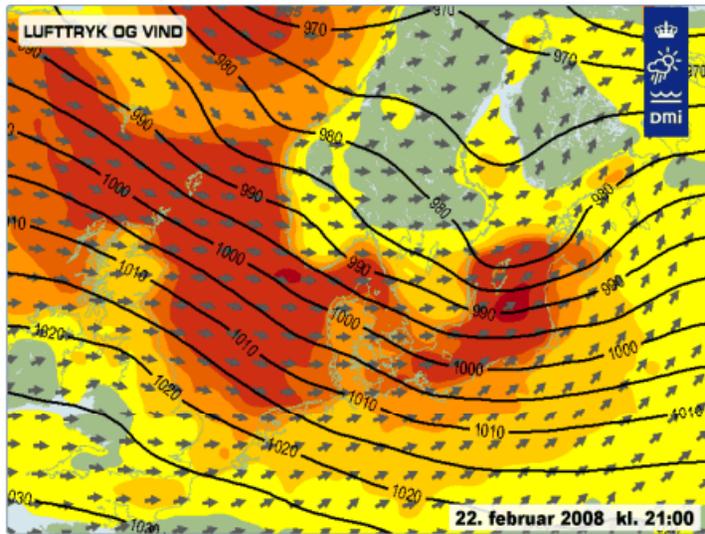
Not sensitive to air

Easy to use interface at [www.cjconline.dk](http://www.cjconline.dk)

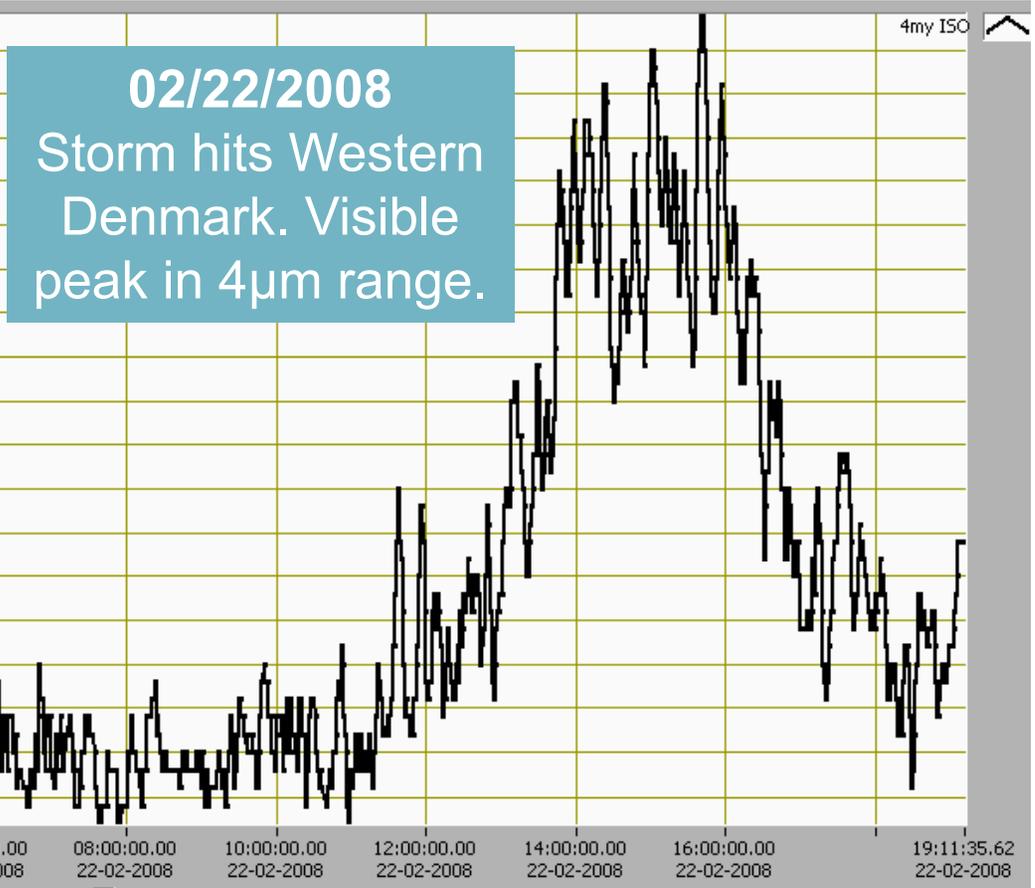




# Case Study – Laser Particle Counter



Vindstyrke og vindretning omkring Danmark klokken 21:00 den 22. februar 2008.



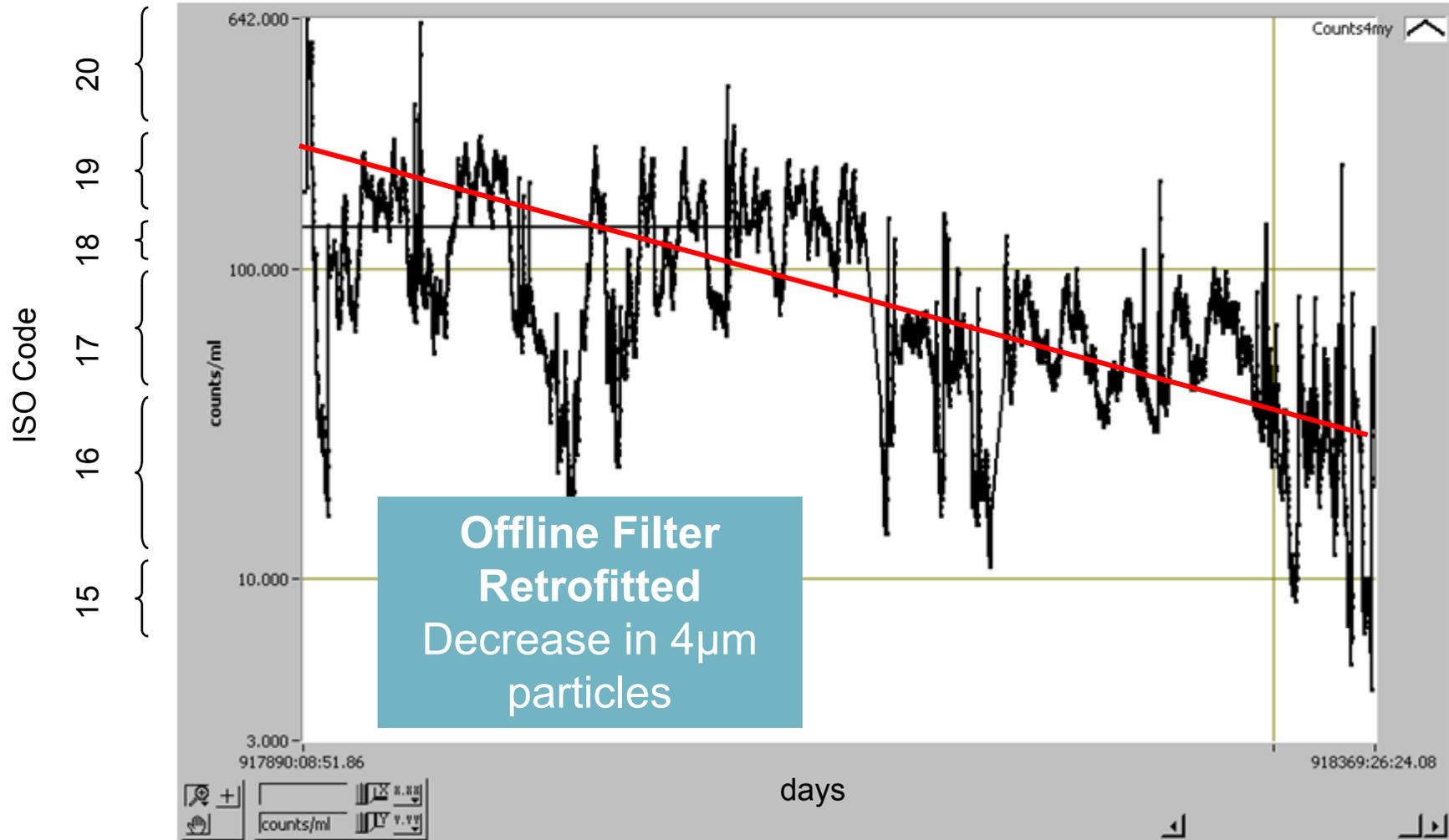


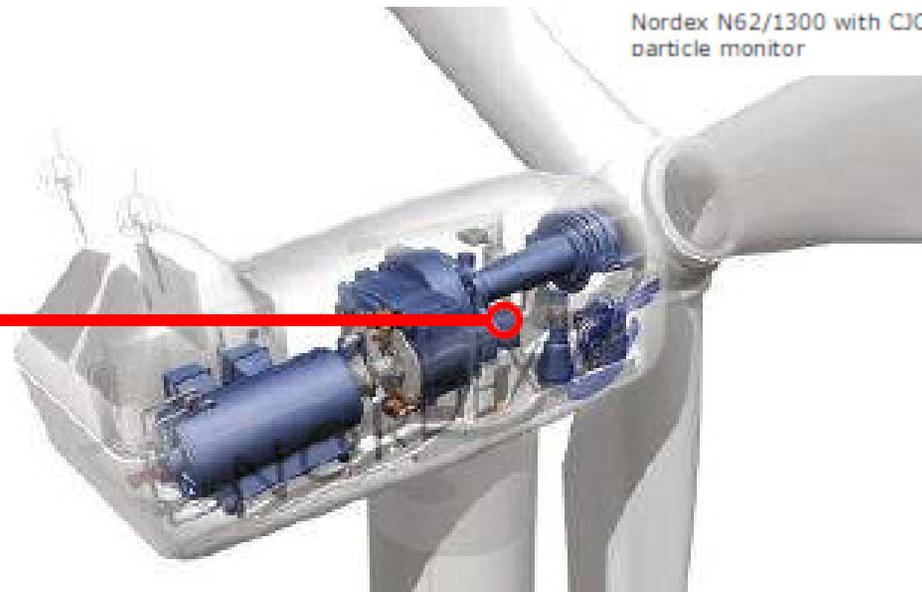
Figure 10 Slow decrease of 4 micron particles after CJC offline filter has been retrofitted. The scale is logarithmic. The abscissa is in days.



# Case Study – Laser Particle Counter 1.3 MW Wind Turbine



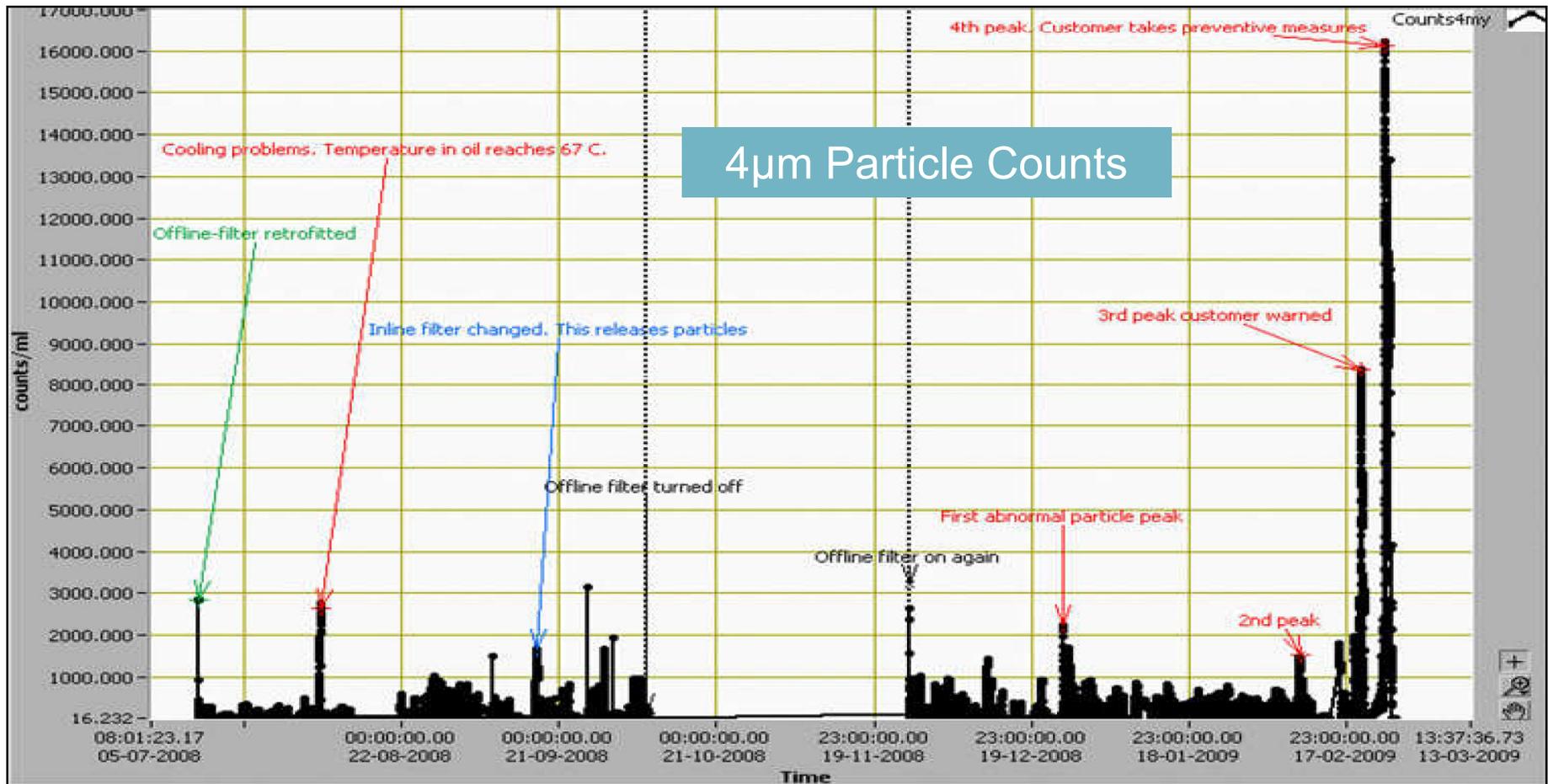
Nordex N62/1300 with CJC On-line particle monitor





# Case Study – Laser Particle Counter

## 1.3 MW Wind Turbine





### RESULTS

The customer was informed and warned 6 days before the turbine was stopped for preventive maintenance during which time the gearbox damage was confirmed after a visual inspection.

At the time when CJC 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.

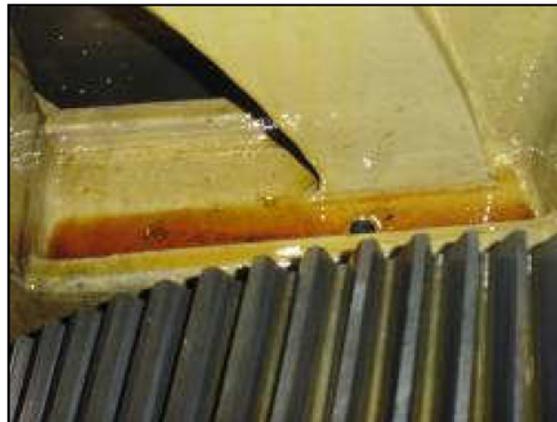


**Picture 1**

Wear particles found during Service stop and visual Gearbox inspection. The customer reconfirmed Gearbox damage after inspection and finding a lot of particles in the Gearbox.



**Picture 2**



**Picture 4**

Micro and macro pitting on planetary gears found during Service stop. Customer reconfirmed Gearbox failure and damage.



**Picture 5**



## Case Study – Laser Particle Counter 1.3 MW Wind Turbine

**A Picture is Worth a  
Thousand Words!**



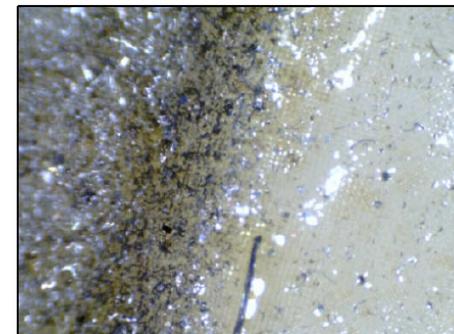
**Picture 6**

Finding of wear particles on the surface of the off-line filter insert that was removed after the gearbox damage was confirmed, confirm that the Off-line filter worked perfectly filtering out a hugh amount of wear particles.



**Picture 7**

The foto of the zoomed in off-line filter surface shows metal wear particles of different sizes and forms. It can be easily seen that more than 70% of the surface it covered with wear particles.

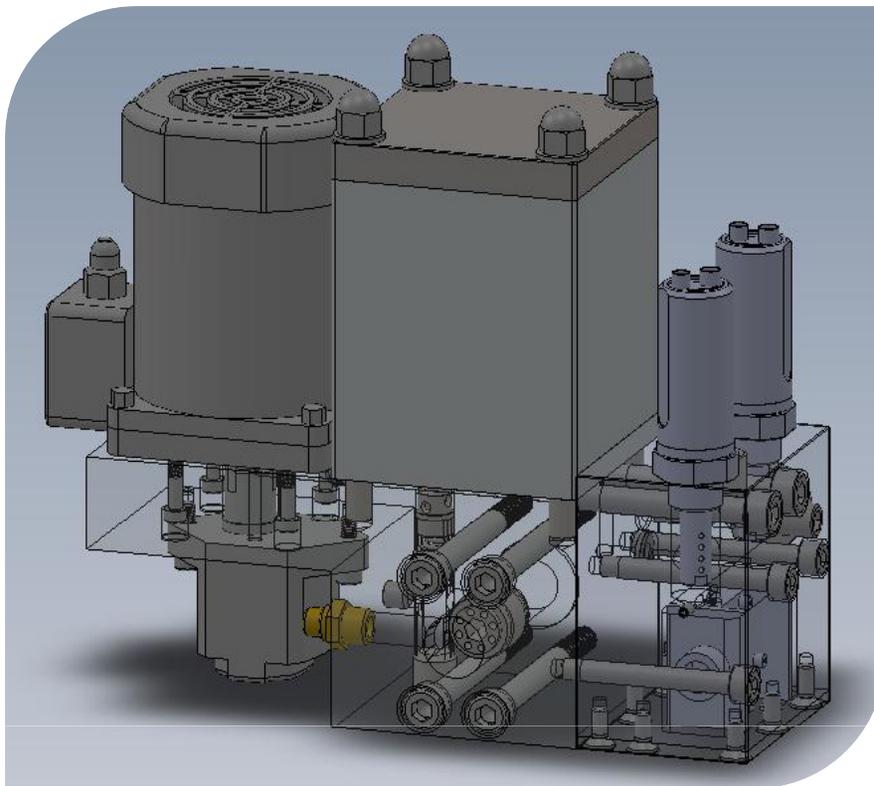


**Picture 8**



## Future Work...

### A Holistic Approach to Oil Condition Monitoring



- ✓ Particle Counter
- ✓ Water Sensor
- ✓ Viscosity Sensor
- ✓ Oxidation Sensor

Compact Design

Integrated with Offline Filter System (“Smart Filter”)