Extended Gear Life

Through Dedicated Oil Conditioning and Remote Monitoring

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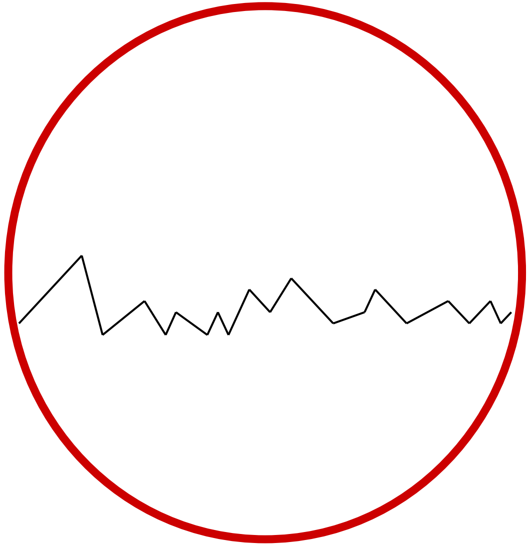
Extended Gear Life
Through Dedicated Oil Conditioning and Remote Monitoring

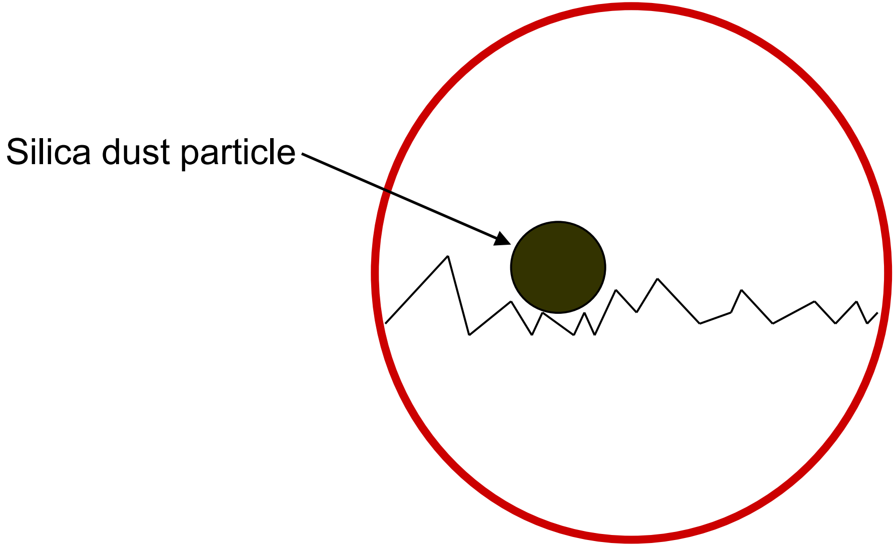
1) **Theory:**
   - Machine components
   - Contaminants
   - Wear
2) **Application:**
   - Machine & Oil Life Extension
   - Kidney-Loop Depth Filtration
3) **Examples**
   - Installations
4) **Remote Monitoring**
5) **Benefits**

Machine Components



Surface asperities under microscope

Machine Components



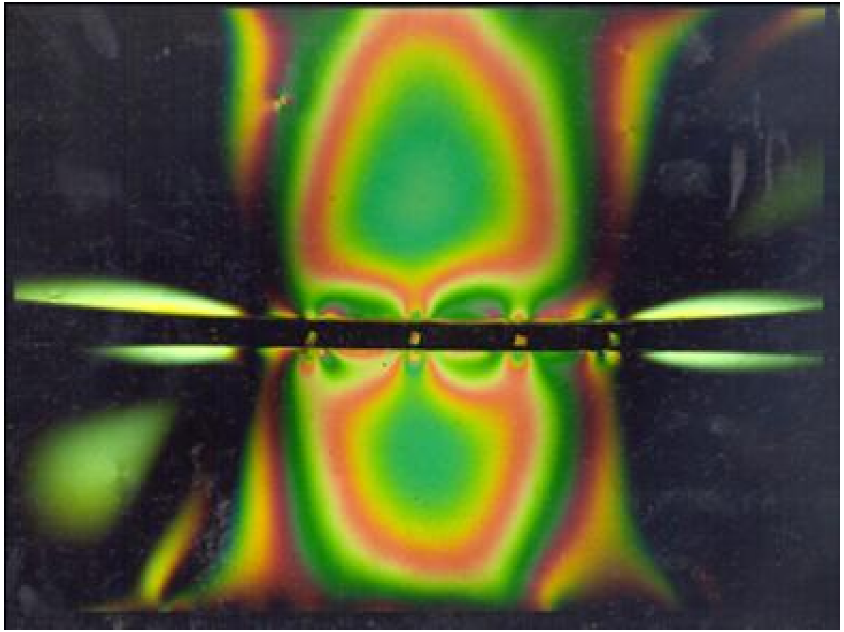
Surface asperities under microscope

Dynamic Oil Film

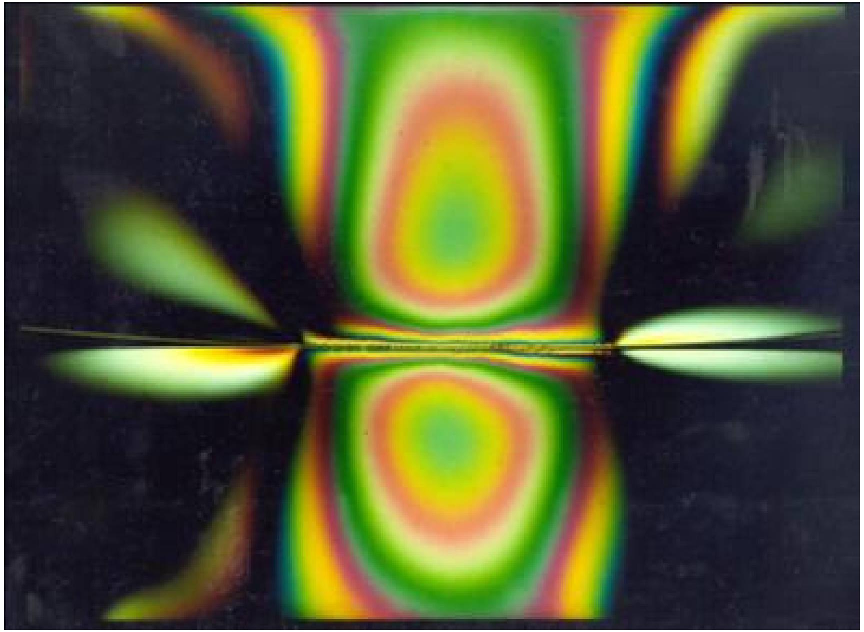
	Oil film thickness:
Rolling element bearings / ball bearings:	0.1 – 3 microns
Journal, slide and sleeve bearings:	0.5 – 100 microns
Engines, ring/cylinder:	0.3 – 7 microns
Gears:	0.1 – 1 micron
Servo and proportional valves:	1 – 3 microns
Gear pumps:	0.5 – 5 microns
Piston pumps:	0.5 – 5 microns
Hydraulic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

Source: Noria Corporation

Abrasive Wear on Bearings and Gears



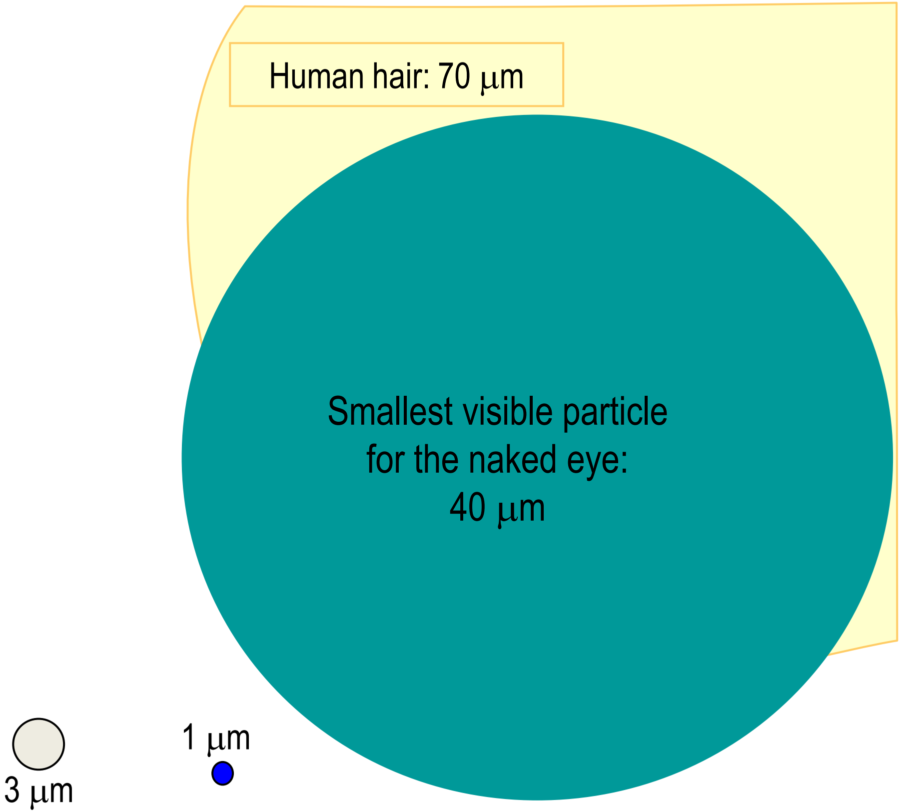
Oil film with particles



Smooth and even oil film

1. Theory

Particle visibility



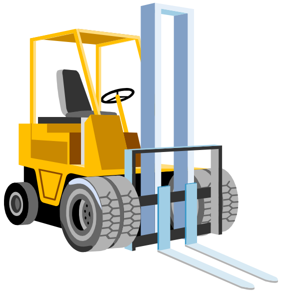
Particles and Water in Oil

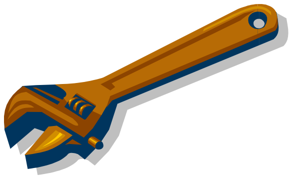
Where do the particles in the oil come from?

- Built-in: assembly or transport
- Delivered in new oil and fuel
- Generated – from wear and oxidation
- Ingress – from the environment

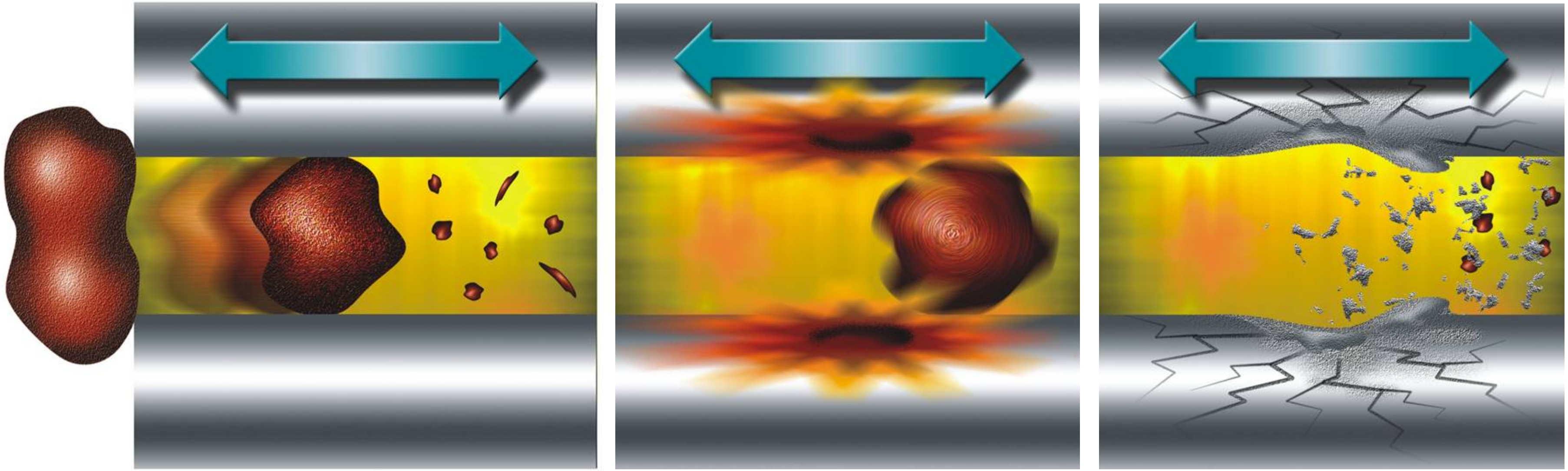
Where does the water in the oil come from?

- Condensation – temperature changes and humidity
- Ingress – leakage from seals / cooler or accidents
- Delivered in new oil
- Faults in oil handling

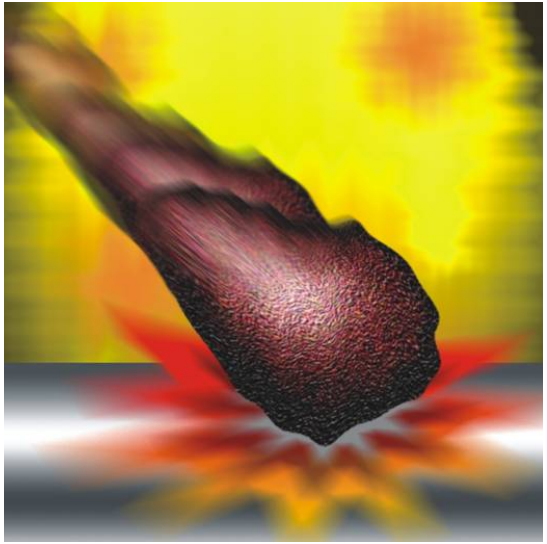


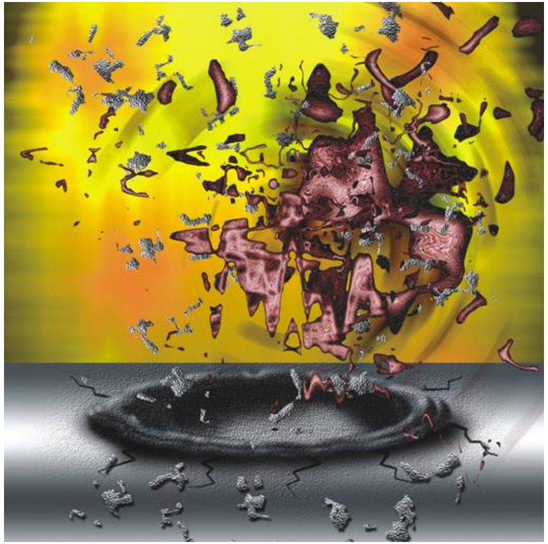


Abrasion - seizing

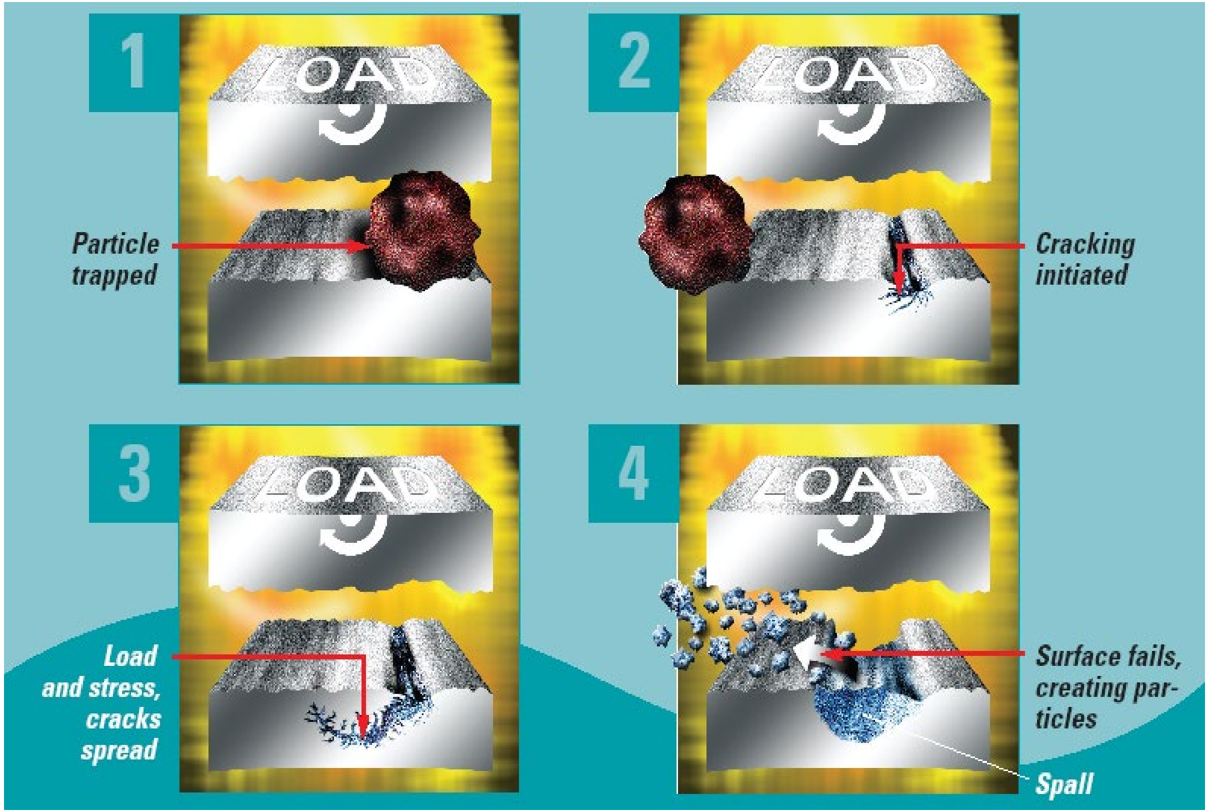


Erosion – sand paper effect

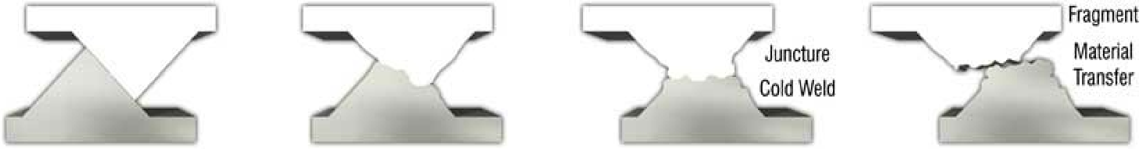




Fatigue Wear



Adhesive Wear



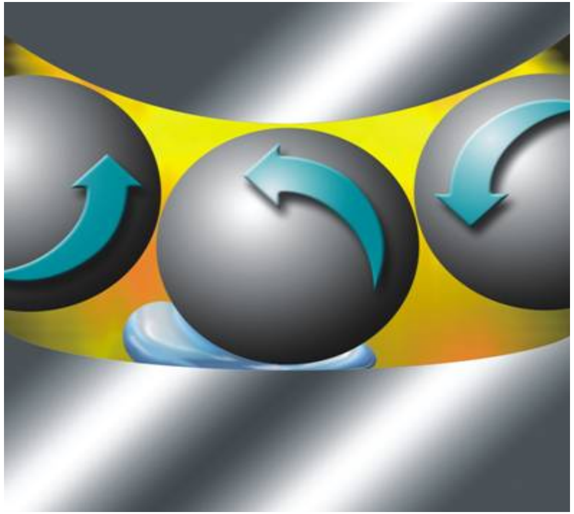
Also called scuffing or galling

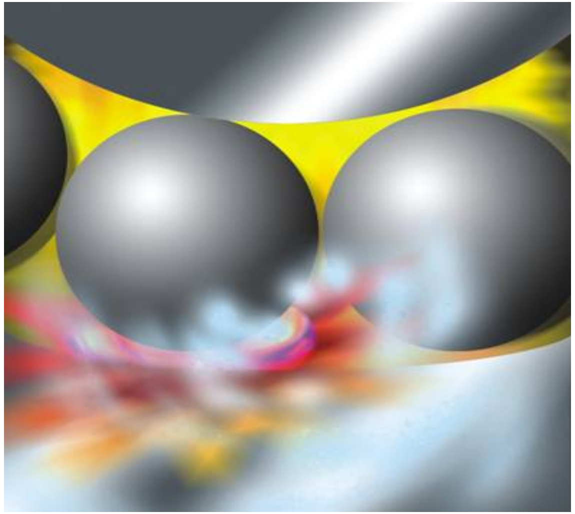
Metal-to-metal contact creates ”spot welding”

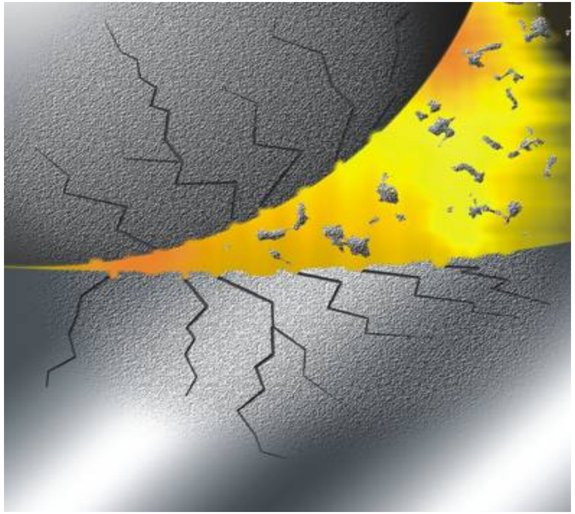
Influencing factors:

- Oil film thickness (depending on oil viscosity, load, temperature)
- High loads, slow speed and large gear teeth
- Surface hardness and alignment of components
- Improper use of anti-scuff/AW/EP additives
- Water or fuel in the lubrication oil
- Particle contamination is normally <u>not</u> a triggering factor

Corrosive Wear

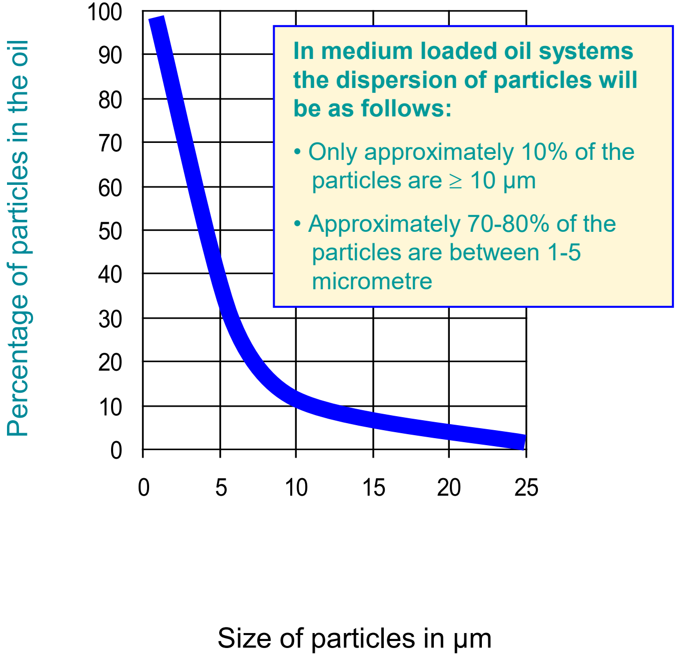






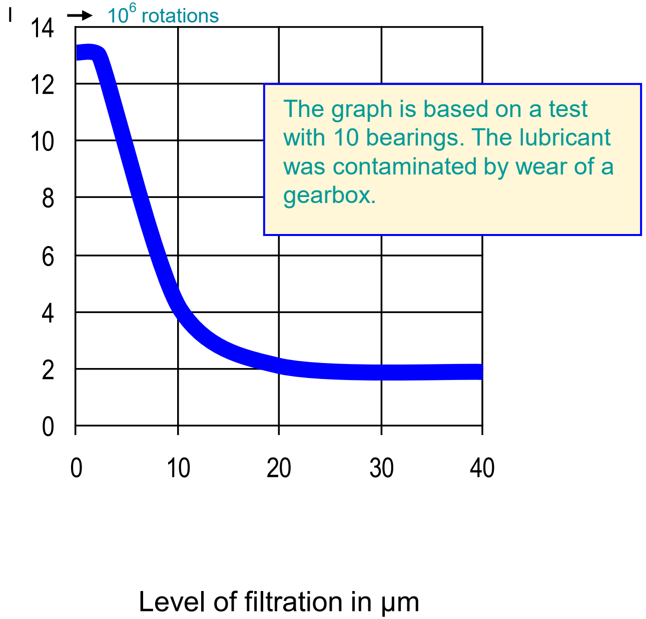
Particles in Oil

Dispersion of particles by size



The importance of particles

MacPherson graphic



ISO particle cleanliness

The ISO 4406/1999 classification of particle contents was introduced to facilitate comparions in particle counting, using automatic particle counters.

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

Sudden break-down in an oil system is often caused by large particles (> 14 µm) in the oil while slower, progressive faults, e.g. wear and tear, are caused by the smaller particles (4-6 µm).

This is one of the explanations why the particle reference sizes were set to 4 µm, 6 µm and 14 µm in ISO 4406/1999. A typical sample from a wind turbine gearbox, for example, contains in every 100 mL of oil:

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

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

Contamination classes according to the new ISO 4406/1999 standard

More than	Till	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

Max. number of particles per 100 ml fluid after their size ranges

	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					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							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

Hydraulics and Diesel Engines	Rolling Element Bearings
Journal Bearings and Turbo Machinery	Gear Boxes and others

Moisture Life Extension Method*

M-LEM

Life Extension Factor (LEF)

Current Moisture Level

PPM\	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

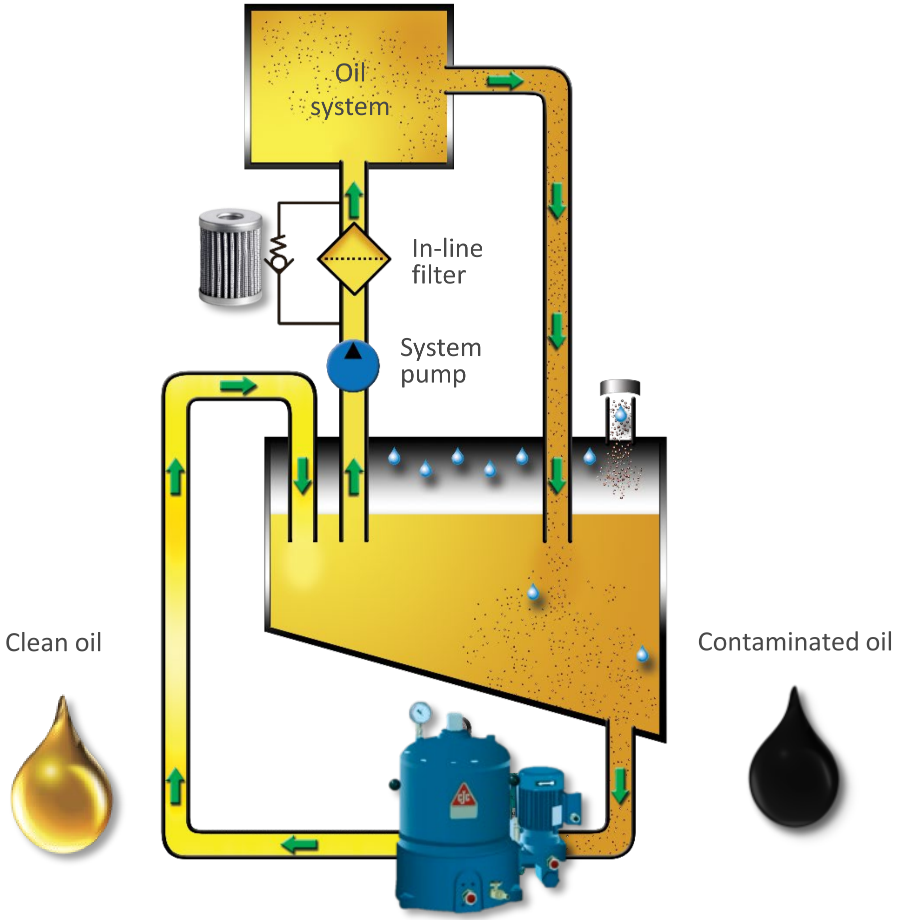
1% water = 10,000 ppm

*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.

Source: Noria

2. Application



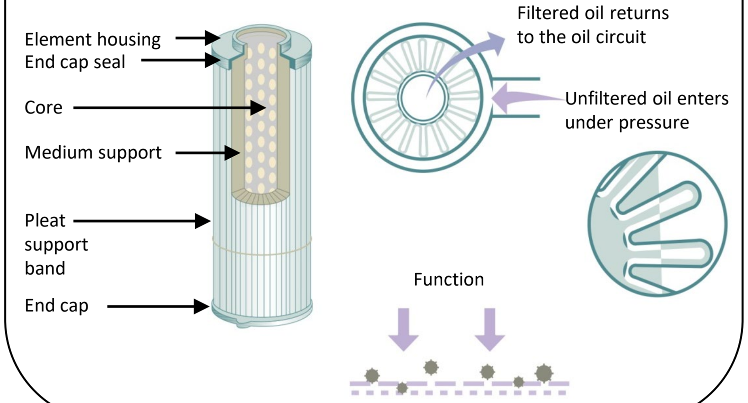
Why "kidney-loop", or "offline" filter?

- Independent: can always run
- No disturbance to the system
- Ideal flow rate
- No pressure fluctuation
- Draws from lowest point
- Removes sediment
- Ideal oil sample port:
  - Worst case oil quality
  - Sampled on an ideal circulating point

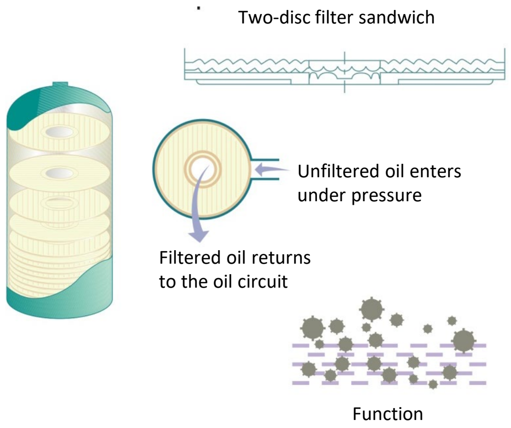
Surface Filtration

Depth Filtration

Typical Surface Filter for Inline Filters



Typical Depth Filter for Offline Filters



Filters particles

Adsorbs Varnish/resins (oxidation)

Absorbs water

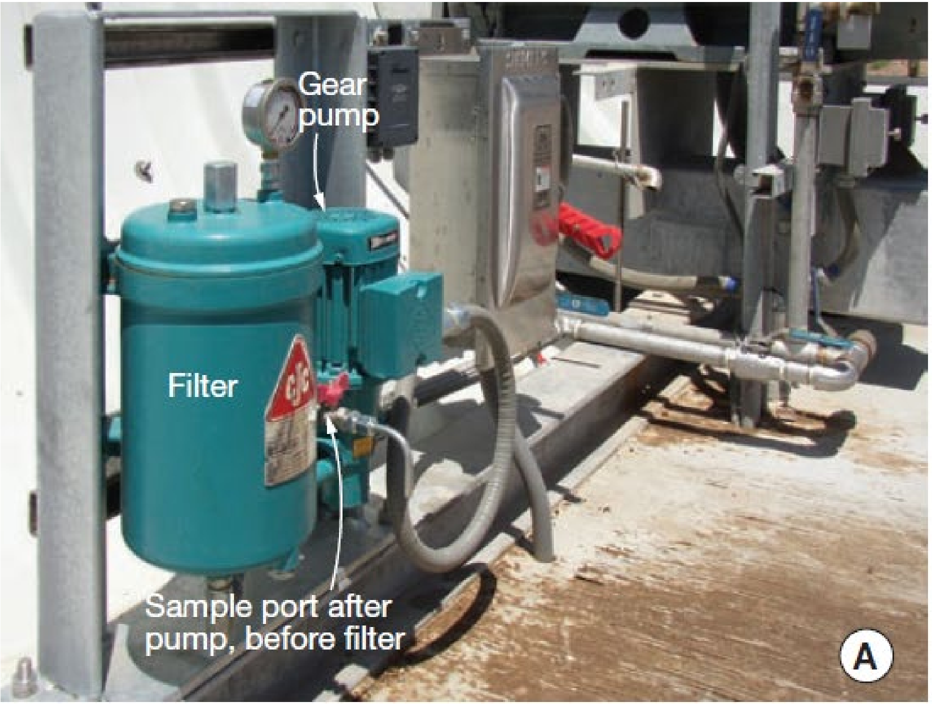
CJC Filter Inserts

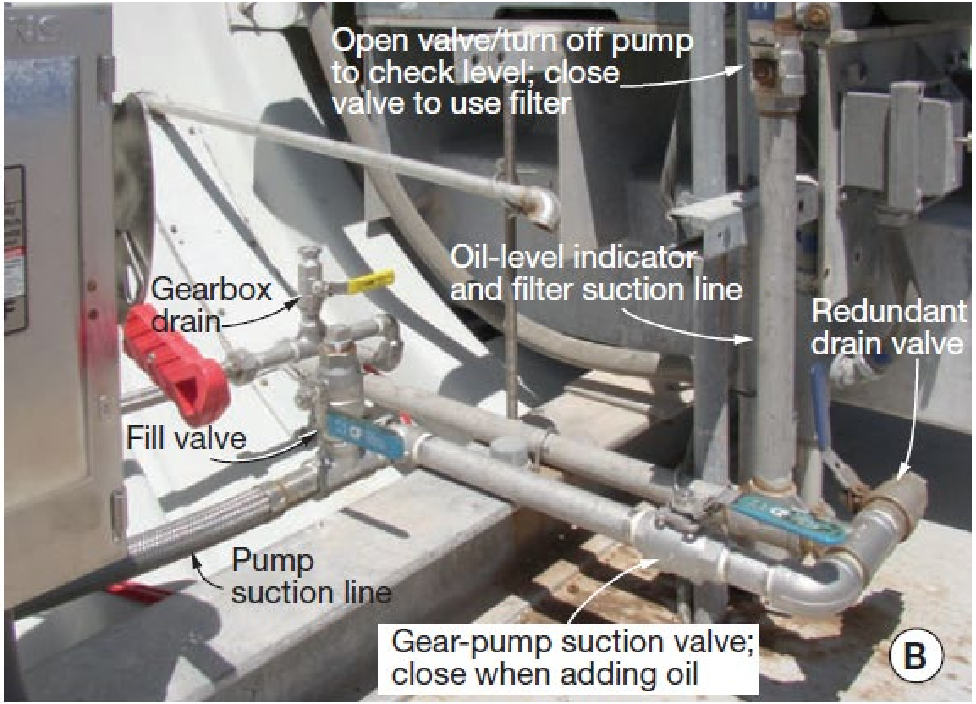
THE RESULT

	General Average Oil Sample Examples **WITHOUT** CJC™ Filtration	AVERAGE Oil Sample AFTER 12 Months **WITH** CJC™ Filtration
Particles > 4 μm	458,400	52,000
Particles > 6 μm	223,290	20,200
Particles > 14 μm	17,420	1,500
ISO Code 4406:99	23/22/19	16/15/11

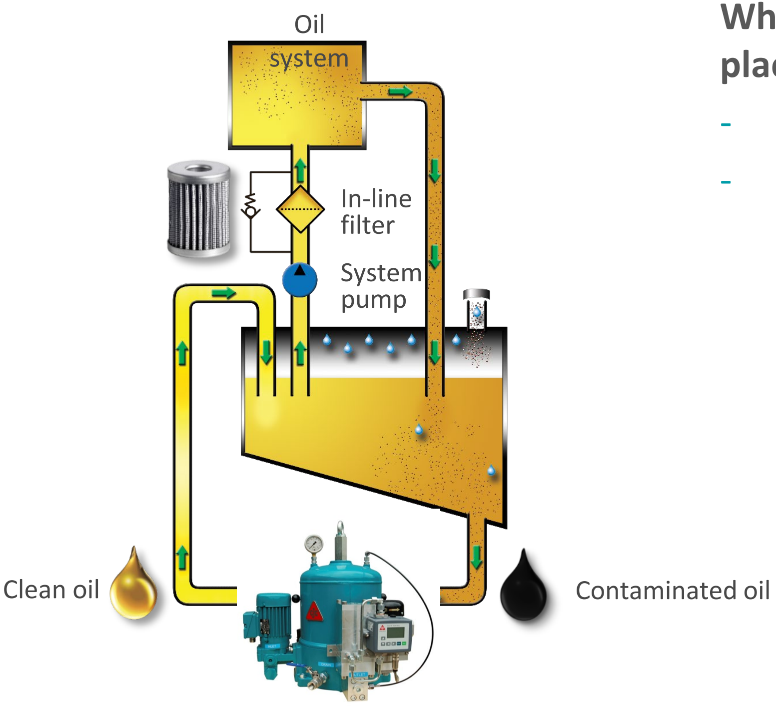

Annual Filter Insert Change

3. Examples


Gear pump
Filter
Sample port after pump, before filter
A


Open valve/turn off pump to check level; close valve to use filter
Gearbox drain
Oil-level indicator and filter suction line
Redundant drain valve
Fill valve
Pump suction line
Gear-pump suction valve; close when adding oil
B

4. Remote Monitoring



Why is the kidney-loop the ideal place for the monitor?

- **Independent: can always run**
- **Ideal oil sample port:**
  - **- Worst case oil quality**
  - **- Sampled on an ideal circulating point**

Two options:

Recommended for smaller equipment, like ACC fan gear:

Connect 2 signals to the control room:
- filter pump On / Off
- high pressure alarm

Pretty safe conclusion:
a) Filter is on?
b) Not high pressure?
c) = Your oil is clean !

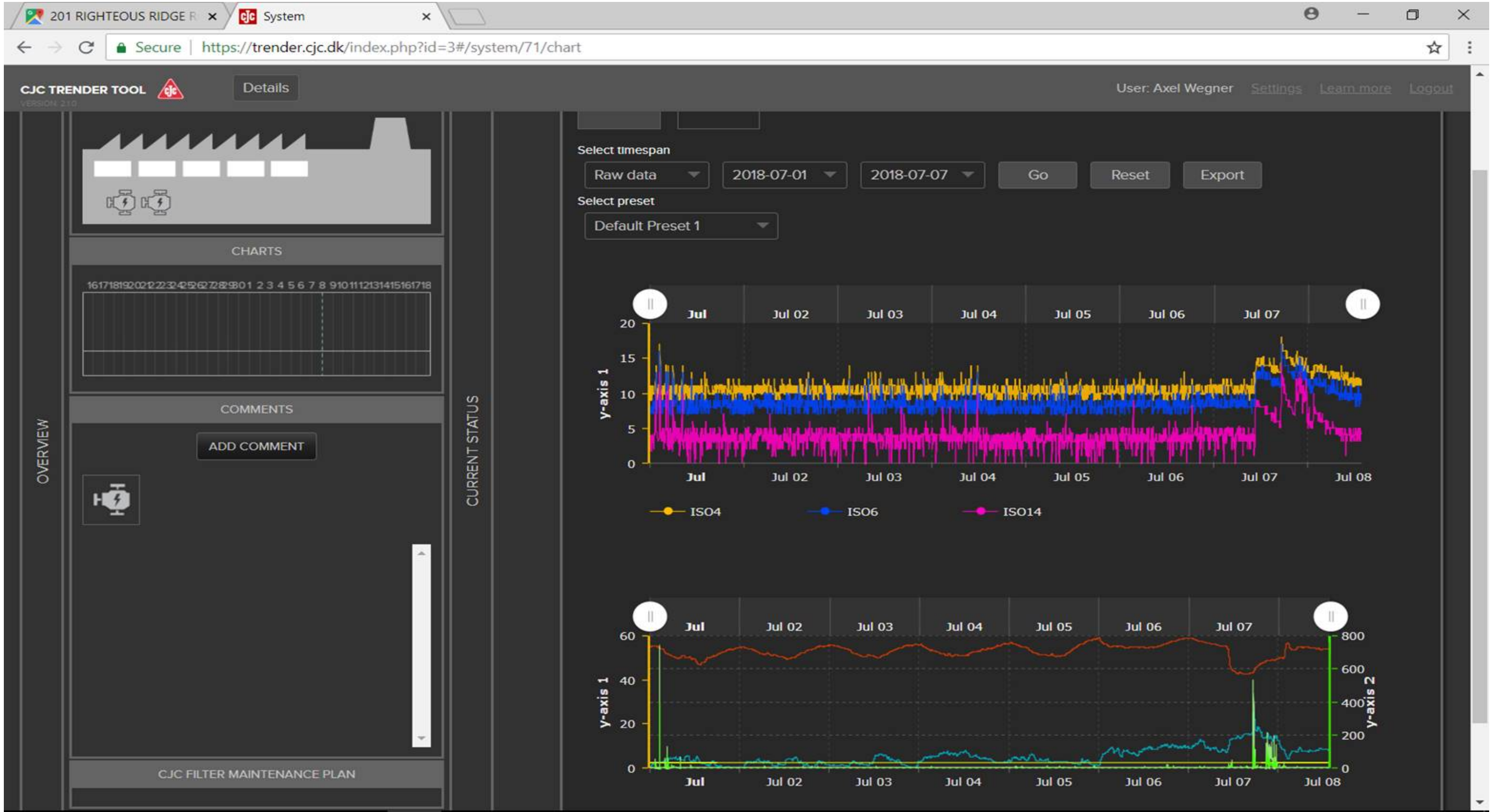
Two options:

Recommended for critical equipment,
like Turbines:

B) Continuous monitoring of Oil Quality:

- ISO particle count
- Water content
- Oxidation
- Resistivity

B) Continuous monitoring of Oil Quality:



Summary of Benefits with dedicated gearbox kidney-loop filter

- Always clean oil ISO 16/14/11 or better
- Always dry oil, < 100ppm
- Typically, no o oil changes necessary
- Use filter pump to add fresh oil to the gear box while it is running
- Take repeatable oil samples while gear is running
- Cooler gear oil by 10-15F
- Add lubrication to upper gear bearing
- Get immediate alerts for water ingress if gear seal breaks
- Easy to connect remote monitoring

5. Benefits

Case Studies & Articles on ccjensen.com

CLEAN OIL
BRIGHT IDEAS

Gear Oil
Cooling Tower Fan Gears - Combined Cycle Power Plant

CJC™ Application Study

Application Study written by:

Axel Wegner
C.C.JENSEN INC
USA

2010

CUSTOMER
NAES (North American Energy Services)
Operated power plant: New Harquahala, Tonopah, AZ

THE SYSTEM
System: Cooling Tower Fan Gear: Amarillo
Oil Type: CONOCO Multipurpose R&O 220
Oil Volume: 83 L/22 gal

THE PROBLEM
One out of 18 cooling towers fan gears needed to be replaced per year due to premature failure caused by contaminated oil (water and particles).

THE SOLUTION
A **CJC™ Fine Filter HDU 15/25 PV** with a flow rate of 55 L/h was installed, using **CJC™ Filter Insert BG 15/25** (3 micron) with a dirt holding capacity of 1.5 L.
Pump type PV2-7-4 and 0.25 gpm.

FINANCIAL BENEFITS
The installation has paid for itself after one year with no oil changes and no faulty gear boxes.

THE TEST
The installation of the CJC™ Fine Filters was completed in August 2009 and the filters have been running continuously since then.

THE RESULT
After 12 months of continuous operation oil samples were taken with excellent results.
In average an ISO code of 16/15/11 is being maintained with not detectable water contents.

One year after installation not one gear box had to be changed and the filters are still running on their first insert, maintaining a better than new oil condition for particles and water with the first set of inserts.

THE RESULT

	General Average Oil Sample Examples WITHOUT CJC™ Filtration	AVERAGE Oil Sample AFTER 12 Months WITH CJC™ Filtration
Particles > 4 µm	458,400	52,000
Particles > 6 µm	223,290	20,200
Particles > 14 µm	17,420	1,500
ISO Code 4406:99	23/22/19	16/15/11

Insight Service, Cleveland, Particle Count pr. 100 ml

CUSTOMER COMMENTS
Mr. Joe Hill, NAES (North American Energy Services)
"Before the installation of the CJC™ Filters it was hard to add oil to the gears and to monitor it's condition. With the CJC™ Filters now installed we can take oil samples and a pressure reading of the filter as indicator of the gear's condition. The oil stays in a better than new condition and we can now even add fresh oil to the gear box with the cooling tower in operation."

ASIN5123-UK
Power Plants
Cooling Tower Gearboxes
24.11.2010

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COMBINED CYCLE Journal

User group gets an assist on fan gearbox lube-oil solution

Attendance by owner/operators at user-group meetings typically was down about 10% in 2009 compared to 2008. The reason generally given was "budget cuts," which seemed short-sighted. People in authority who think they are positively impacting the plant budget with a $1500 cut (about what it costs to send someone to a meeting sponsored by an independent user group) might reconsider their position.

These conferences are not boondoggles; they are working meetings where attendees learn continuously—even during social events, which are paid for by sponsors, not the power producer. It's the rare participant who doesn't bring back ideas that when implemented at the deckplates level fail to pay at least a ten-fold return on the company's investment.

This edition has two outstanding examples of how user groups facilitated solutions that resulted in very significant returns for plant owners. Read "In the boiler business, this is front-page news" to learn how a discussion between a user, frustrated by tube leaks, and an engineering firm at a Western Turbine Users meeting lead to the first application of a new economizer design that has eliminated monthly tube repairs and associated outage time. These "big-ticket" items were costing the plant tens of thousands of dollars annually—and had been for years, with no end in sight.


Motl

The second article is this one on the 1100-MW New Harquahala Generating Co in Tonopah, Ariz, about 60 miles west of Phoenix. It is equipped with three natural-gas-fired 1 × 1 combined cycles powered by Siemens Energy SGT6-6000G (W501G) engines. The plant is operated by NAES Corp, Issaquah, Wash.

Dean Motl was challenged by lube-oil purifier/vacuum dehydrator issues with the plant's steam turbines (STs) back in 2008 when he met Axel Wegner, C C Jensen Inc, Atlanta, at the 501F/G vendor fair. Motl was O&M manager then, plant manager today. He described the

1. New Harquahala Generating Co is an 1100-MW plant with three 1 × 1 combined cycles powered by Siemens Energy SGT6-6000G (W501G) engines

1

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