On-Line Sensors for Condition Monitoring

61st STLE
Annual Meeting
Condition Monitoring
Technical Session
Calgary, AB
Canada

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Introducing Kittiwake

Kittiwake
Measuring, Monitoring & Managing

Measuring, Monitoring & Managing...

- **Oil Sampling and Field Testing**
- **Water Sampling and Field Testing**
- **Lab and Field Wear Debris Analysis**
- **Online Oil & Wear Debris Analysis**
- **Laboratory Logistics**
- **Research & Development**

Condition Monitoring International

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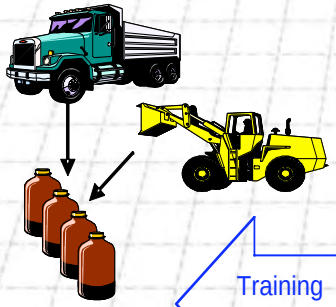
Global Solutions for Condition Monitoring Services and Support

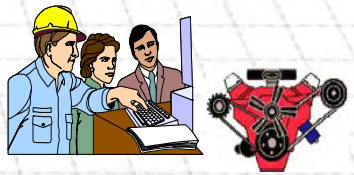
Laboratory
Oil Testing
Instruments



Oil Samples
to Check
Machine
Health

Training
and Education

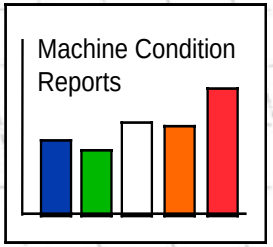
CMI
CONDITION MONITORING
INTERNATIONAL



Diagnoses by ***Prescient***^{sm}

On-board
Oil and Vibration
Machine Monitoring
Sensors

Machine Condition
Reports



Online Oil & Wear Debris Analysis

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- **Online Sensor Technologies - The ultimate in Condition Monitoring**
- **Real Time measurements**
- **In Remote Locations**
- **Multiple outputs for data collection**
- **Online Analysis of:**
  - **Ferrous & Non Ferrous Wear Debris**
  - **Particle Count**
  - **Oil Condition**
  - **Moisture**

What we will be talking about?

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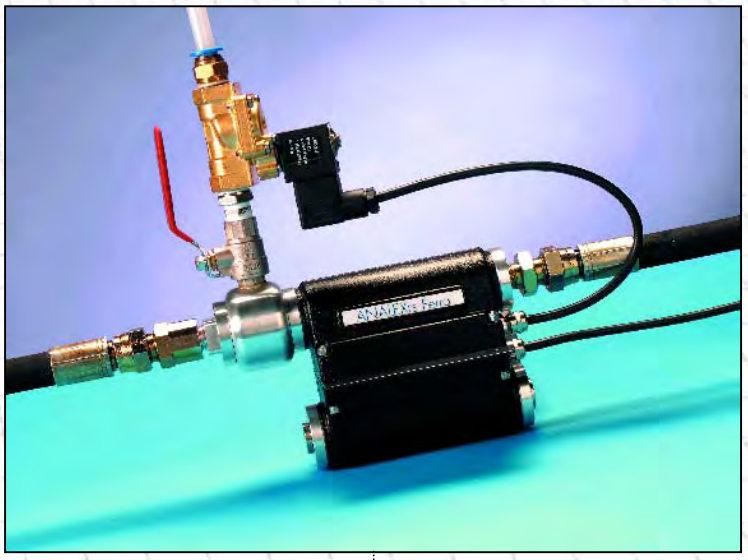
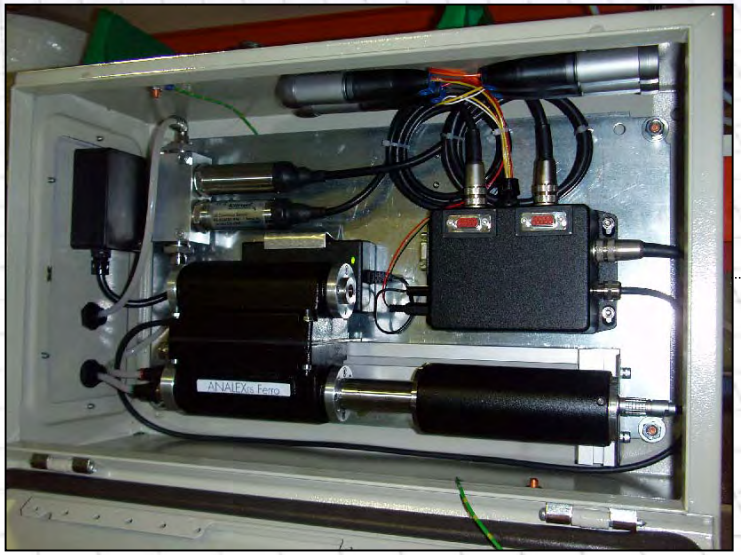
- Range of ANALEXrs wear debris sensors
- Technology behind the sensors
- Sensor development
- Features
- Sensor history
- Real life testing
- Summary and questions

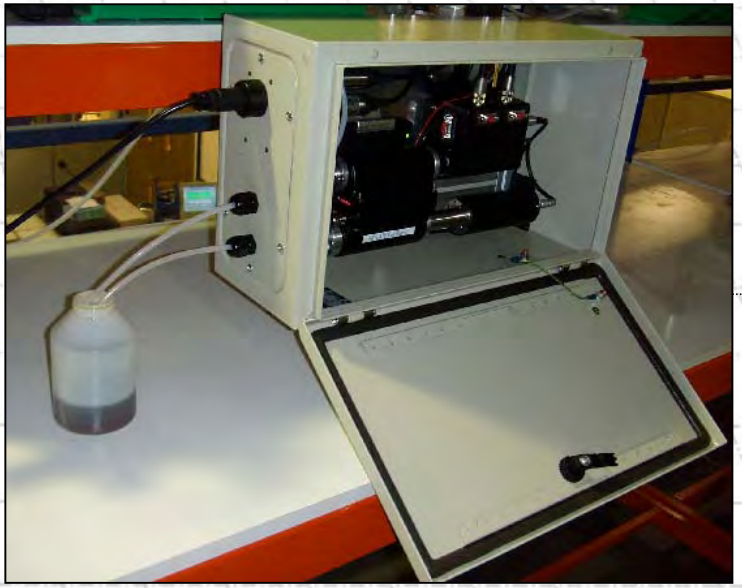


What we will be talking about?

Kittiwake
Measuring, Monitoring & Managing

- Range of ANALEXrs wear debris sensors
- ANALEXrs Oil Condition sensor
- ANALEXrs Moisture sensor
- Technology behind the sensors
- Sensors Development
- Real life testing
- Realising cost benefits from sensor technologies
- Interfacing sensors
- Summary and questions





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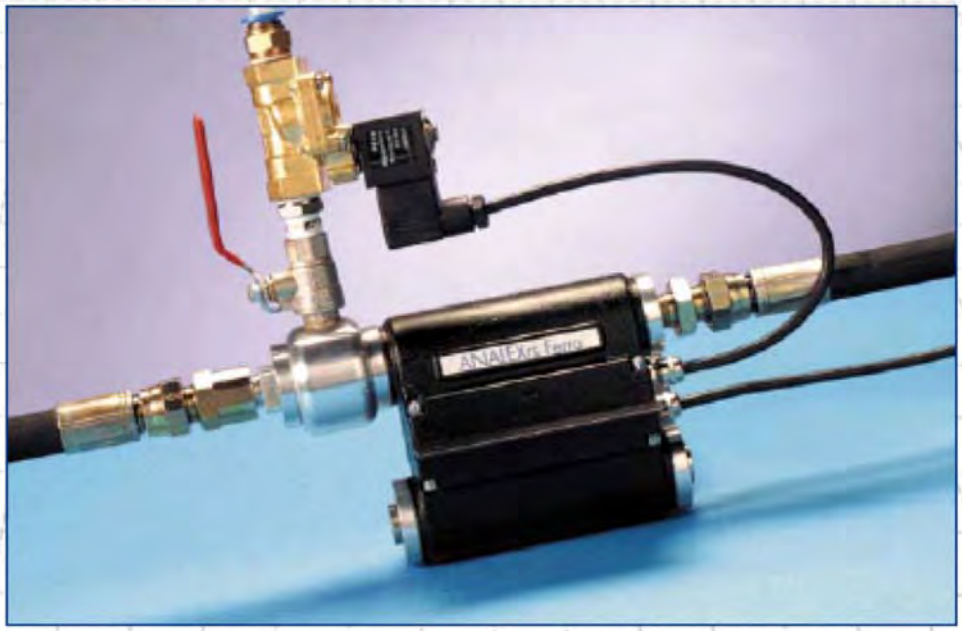
Total Ferrous Debris Sensor



Remote Sensors - the online link between your machines and ultimate reliability

ANALEXrs Wear Debris Sensors

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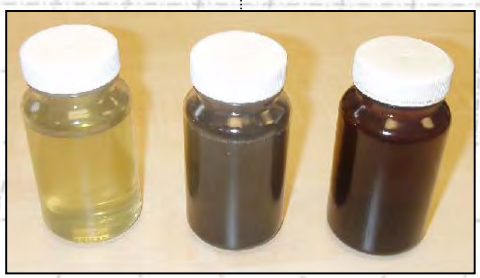
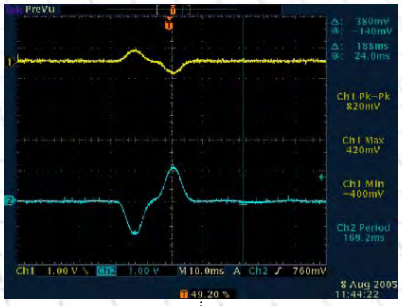


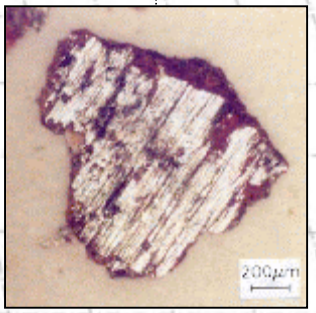
Two base sensors which share similar

- Sensing technologies
- Parts
- Inputs and outputs
- Connection Wiring
- Potential customers

But with different

- Detection methods
- Data output
- Potential applications





ANALEXrs Total Ferrous Debris Sensor

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Philosophy

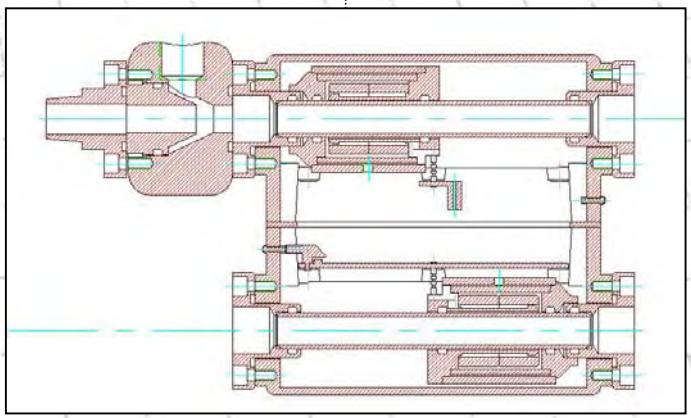
- Measurement of total ferrous debris by Magnetometry reporting output in ppm
- On-line technology
- Automatic operation
- No chemicals

Technology

- Measures >5 micron (unlike ICP)
- No radioactive source (unlike XRF)
- Linear response
- Independent of oil flow speed

Outputs

- CAN interface
- 4-20 mA, RS232, RS485
- Radio link with built-in web server



Base models

- Two base models
- Targeted at steel works, large marine engines, wind turbines, gear boxes

ANALEXrs Total Ferrous Debris Sensor

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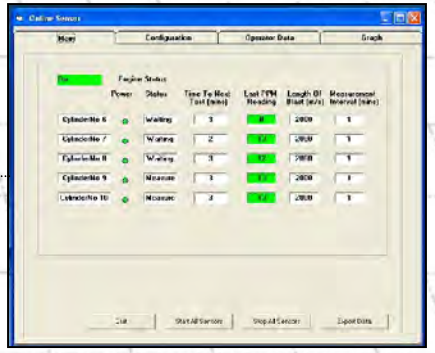
History

- Kittiwake asked by ExxonMobil to produce an on-line iron sensor for trending scrapedown oil.
- Generation 1 designed,made and tested successfully on a land based test engine
- Laboratory tests successfully completed at steel works
- 5 generation 1 sensors fitted to a slow speed marine diesel
- 2 generation 1 units fitted to a nuclear submarine gearbox
- Generation 1 re-designed, improved, and produced to become generation 2
- 5 generation 2 fitted to the same slow speed marine diesel and all 10 sensors connected to a specialist data collection software on a CAN network



ANALEXrs Total Ferrous Debris Sensor

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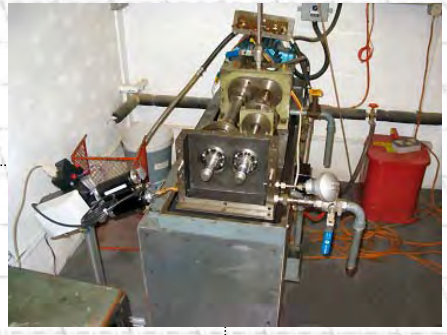
History Continued

- Piston version of sensor designed for installations where an using an air blast to zero is not available or appropriate
- Piston version successfully trailed by QinetiQ (Formally UK Defense, Evaluation and Research Agency). On an industry standard gear failure test rig.

Short term Future / Testing

- Continued support and receive data from the 10 sensors fitted to the slow speed marine diesel trials
- Trial with steel works to continue
- Trial of a piston sensor on a wind turbine gearbox with GE Wind to begin in approximately 1 month
- Sensor to be built into an automated oil sampling test rig to show correlation with the laboratory results



ANALEXrs Total Ferrous Debris Sensor

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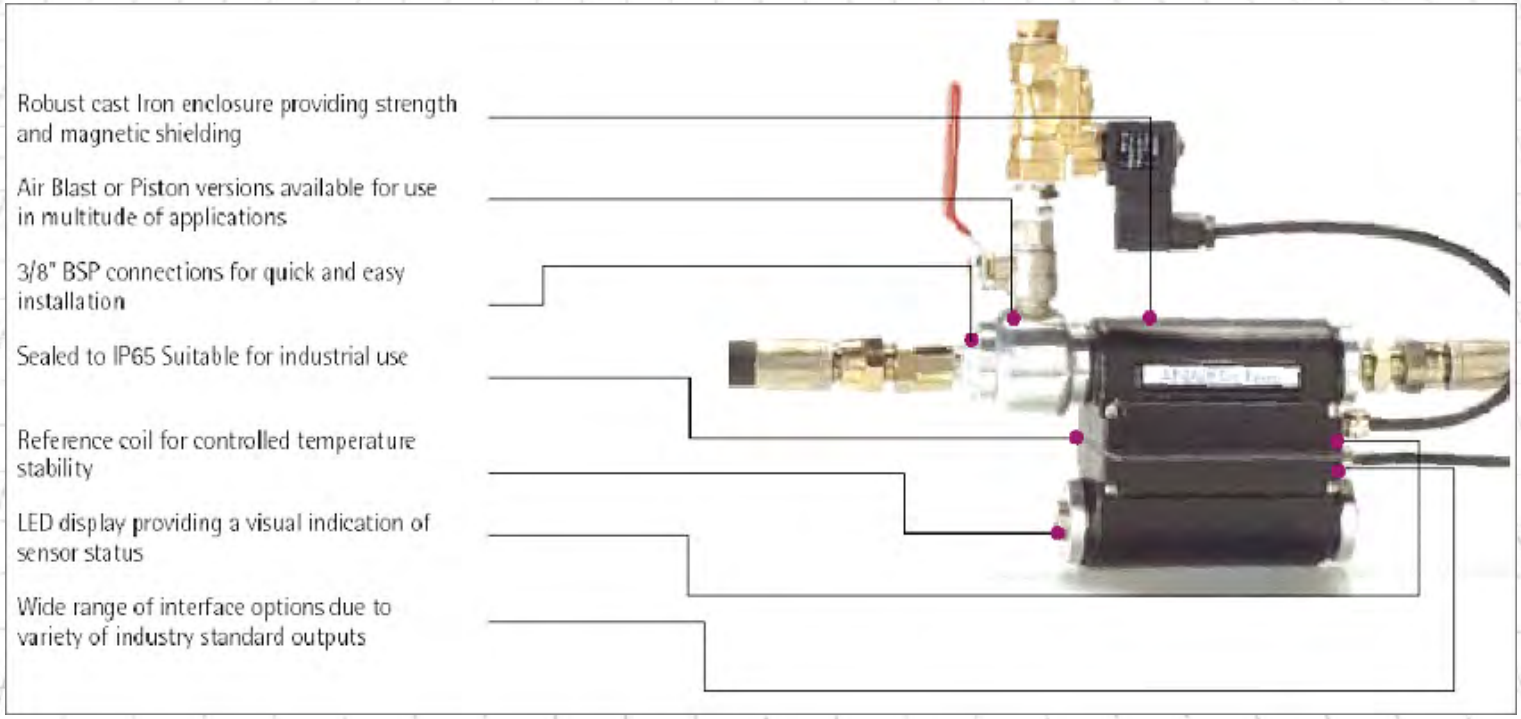
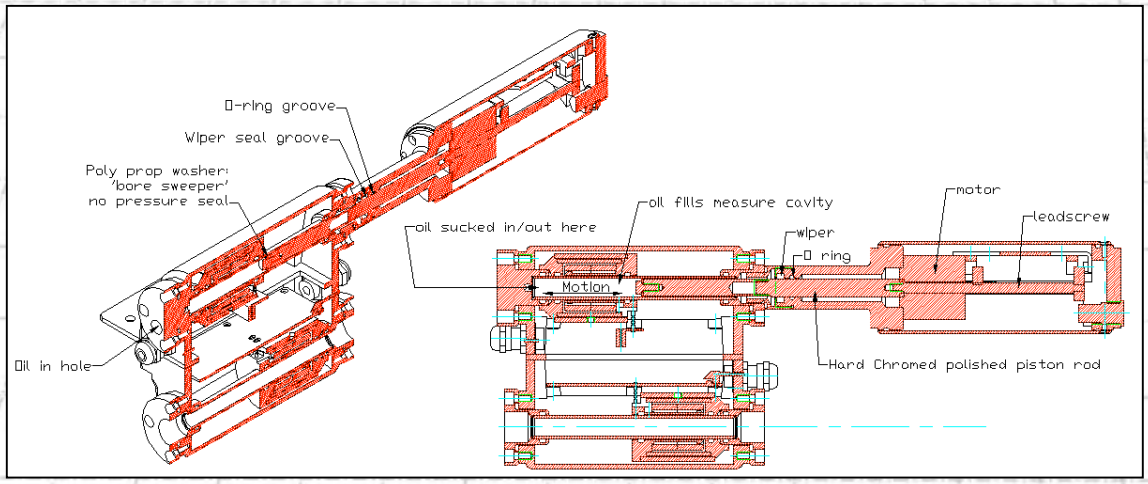
- **Features**

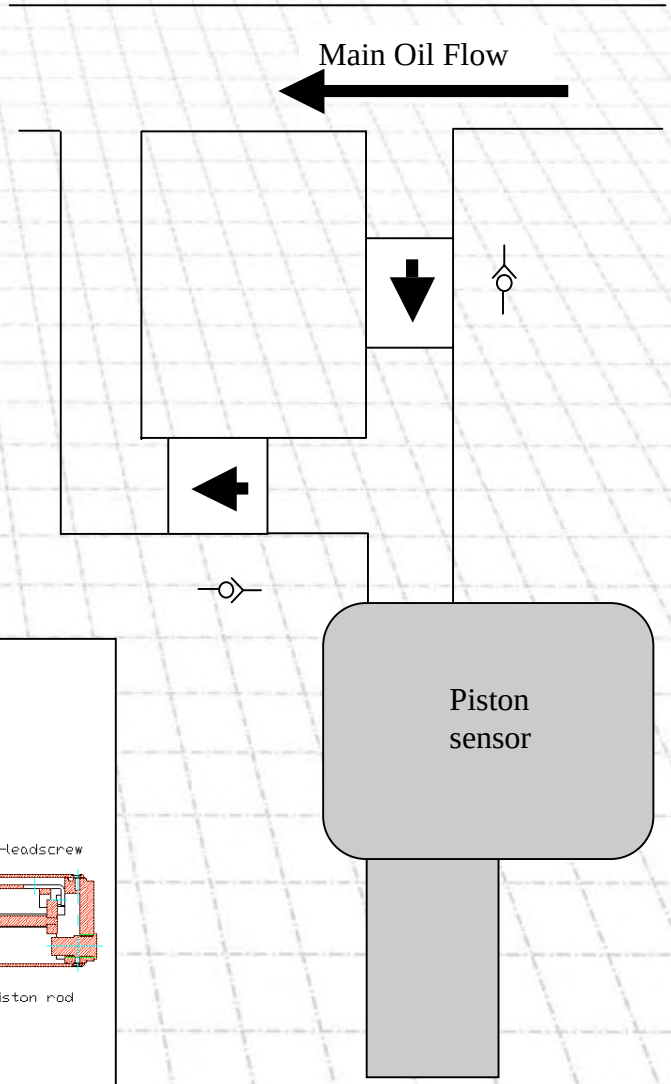


- **Applications**
  - Marine & Industrial Engines
  - Gearboxes and Bearings
  - Steel Production
  - Power generation

Total Ferrous Piston Set-up

- **Potential fitting arrangement**
  - Piston sensor is suitable for almost all applications where customers already use PQ instruments
  - Suitable for systems where no air is available or an air blast is inappropriate
    - Trains
    - Wind turbines (on and offshore)
    - Construction vehicles
    - Mining





Total Ferrous Piston Test set-up

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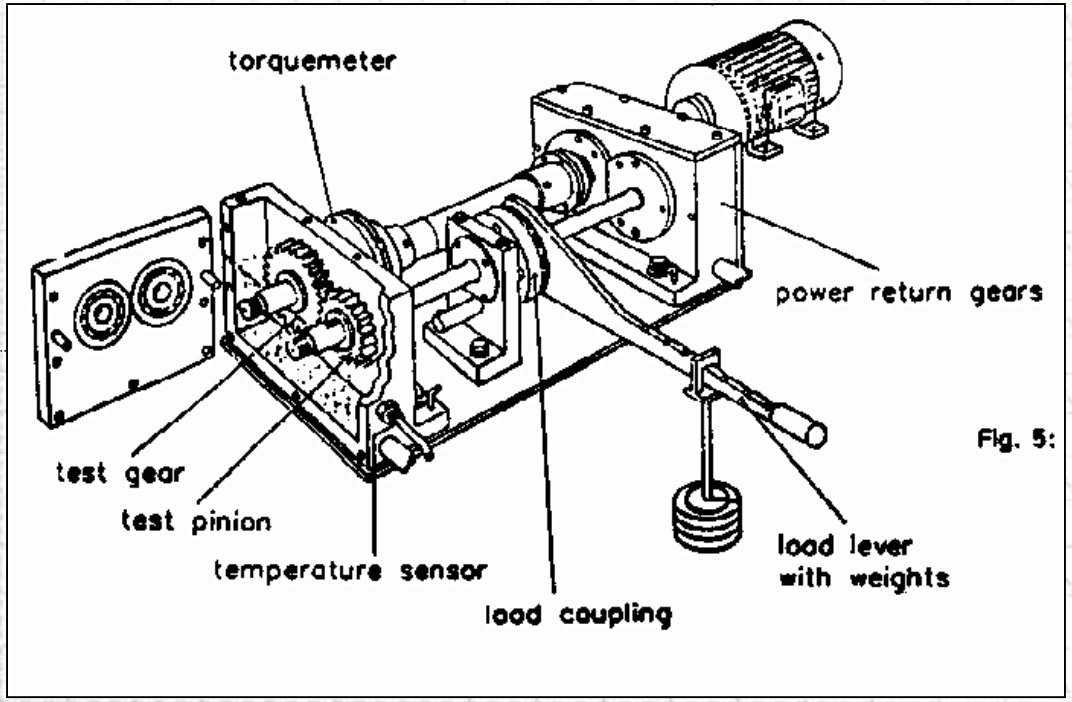
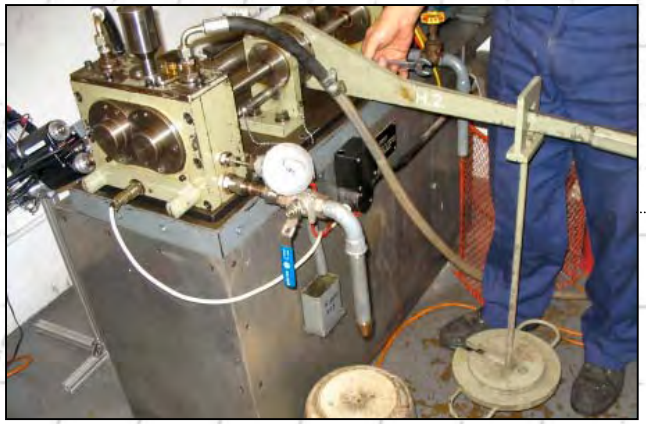
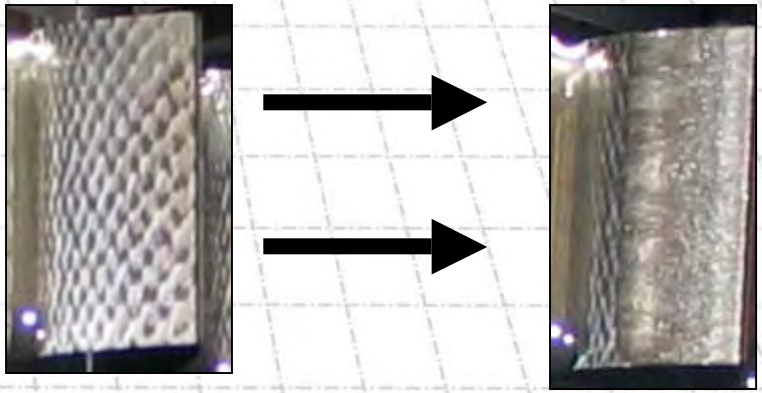
- **Installation on FZG gear test Rig**
  - FZG = Forschungsstelle für Zahnräder und Getriebebau - Technical Institute for the study of Gears and Drive Mechanisms).
  - Industry standard gear testing rig
  - 12 load stages
  - 15 minutes a stage
  - Inspection at each stage to check on tooth wear







ANALEXrs Total Ferrous Test Results

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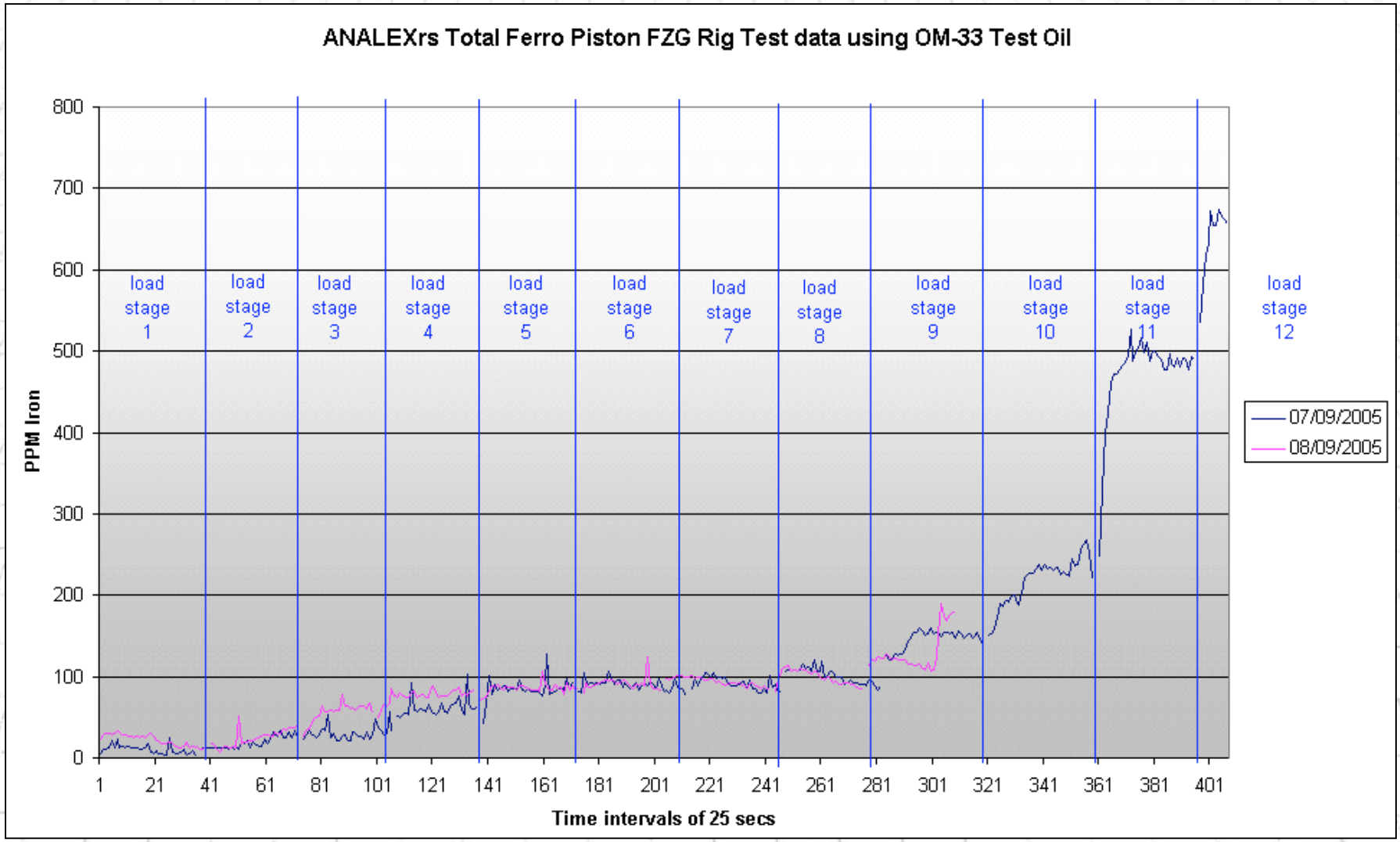

ANALEXrs Particle Content Sensor

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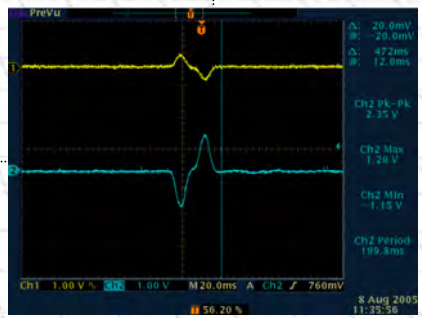
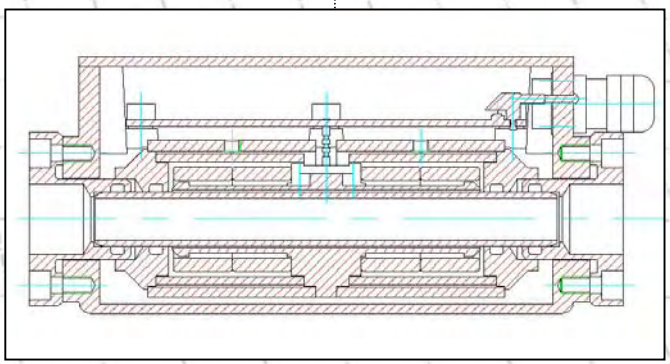
- **Philosophy**
  - Measurement of individual wear debris particles to indicate the onset of machinery damage
- **Technology**
  - As particles enter a highly sensitive magnetic field they are detected due to their magnetic and conductive properties
  - The magnitude and direction of spikes in magnetic flux indicate partial size and type
  - Ferrous and non-ferrous wear particles counted separately and sized Individually
  - Non optical – Unaffected by Oil, Contaminant Type or Flow rate
    - Detects: >60µm (Fe) and >100µm (Non-Fe)
    - Temperature stable operation
    - Future possibilities to classify the material of the particle
- **Outputs**
  - CAN interface
  - 4-20 mA, RS232, RS485
  - Radio link with built-in web server





ANALEXrs Particle Content Sensor

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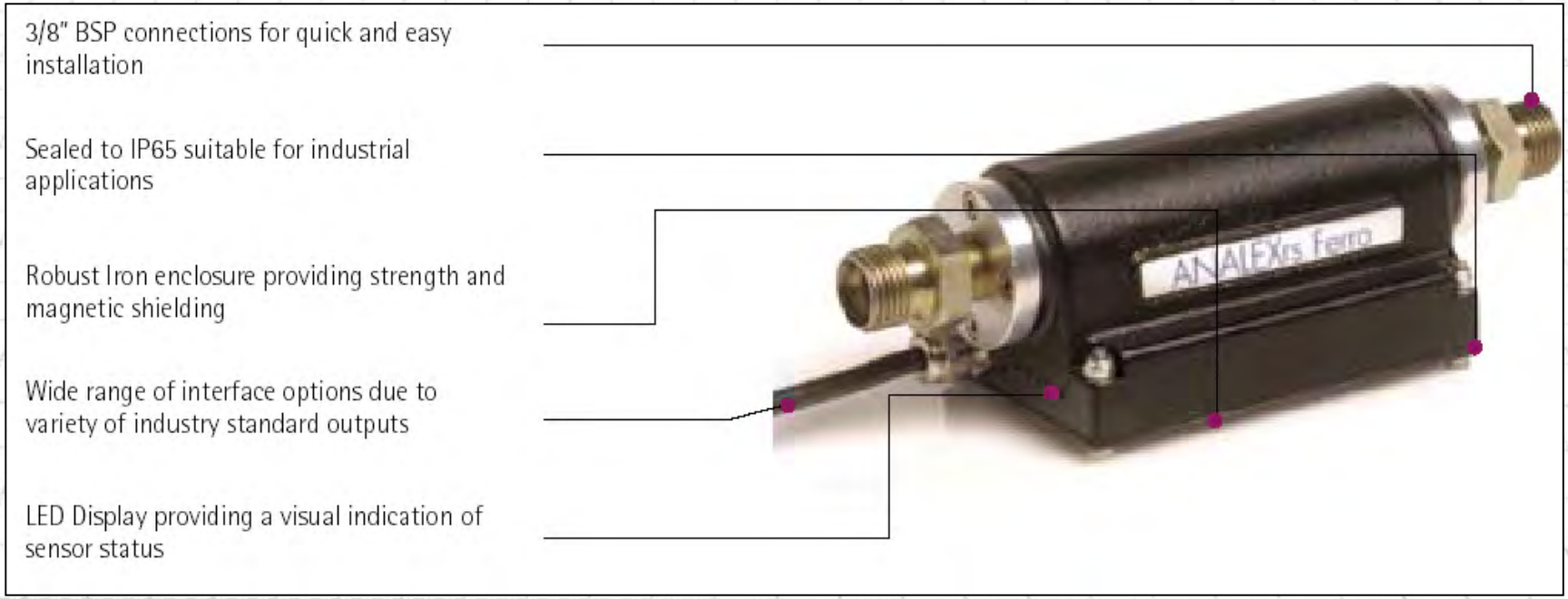
Measuring, Monitoring & Managing

- **Features**



- **Applications**
  - Gearboxes and Bearings
  - Turbines
  - Steel Production
  - Power generation

ANALEXrs Particle Content Sensor

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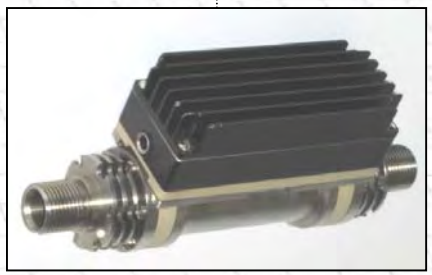
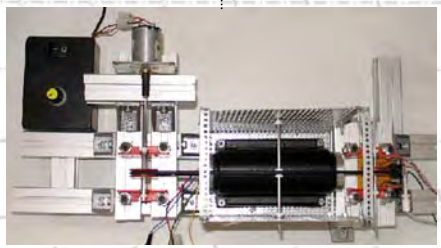
Measuring, Monitoring & Managing

History

- First prototype designed and successfully trailed at QinetiQ (Formally UK Defense, Evaluation and Research Agency).
- Tests carried out on the gearbox of the EuroFighter (Typhoon).
- Particles detected down to 60 micron (ferrous)
- Kittiwake acquires licence for the patented technology
- Kittiwake mechanically redesigns the sensor to have commonality of parts with the total ferrous sensor.
- Digital side of the PCB designed to include high speed data processing capabilities
- Particle detection software currently in progress





ANALEXrs Particle Counter Test Results

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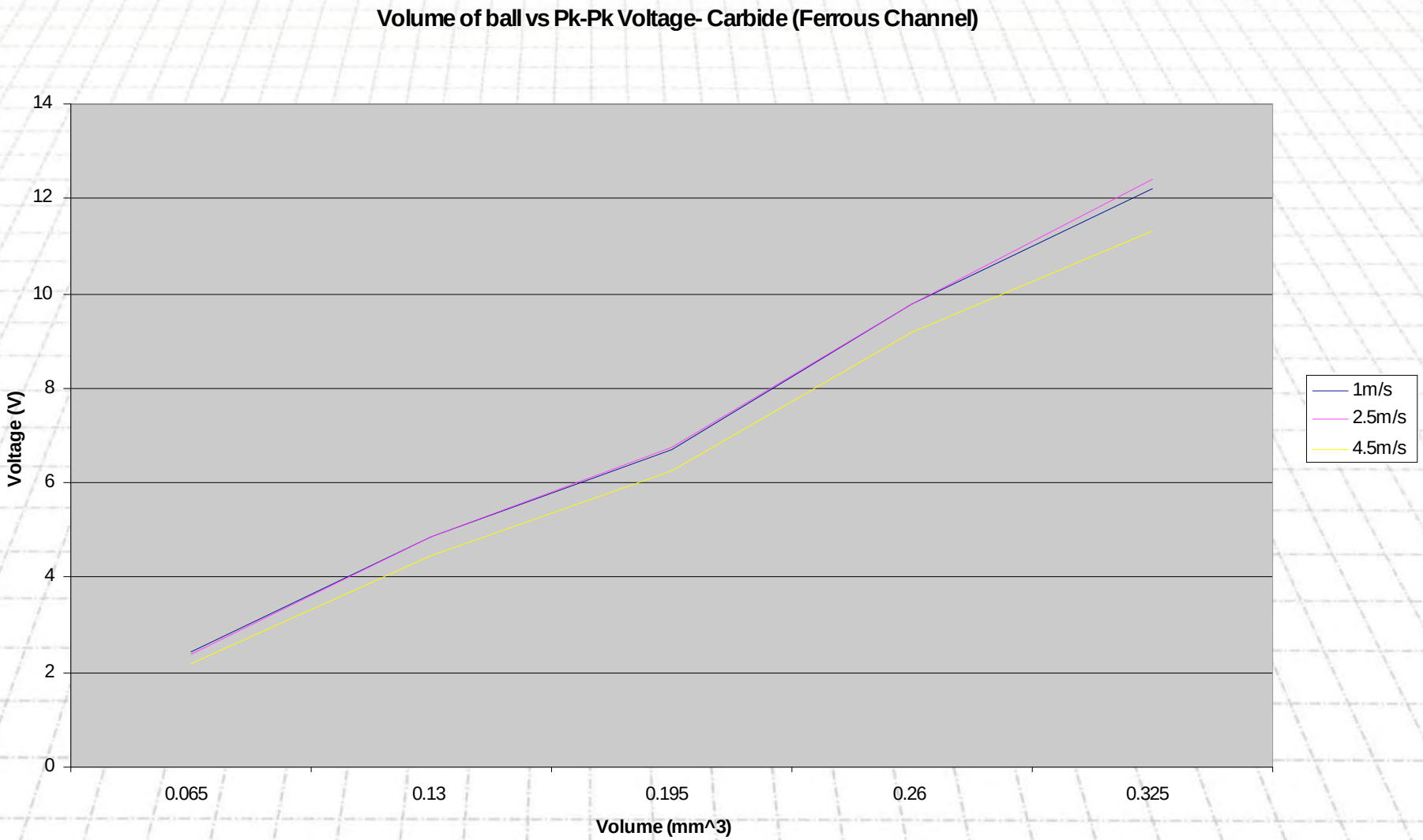

ANALEXrs Particle Counter Test Results

Kittiwake
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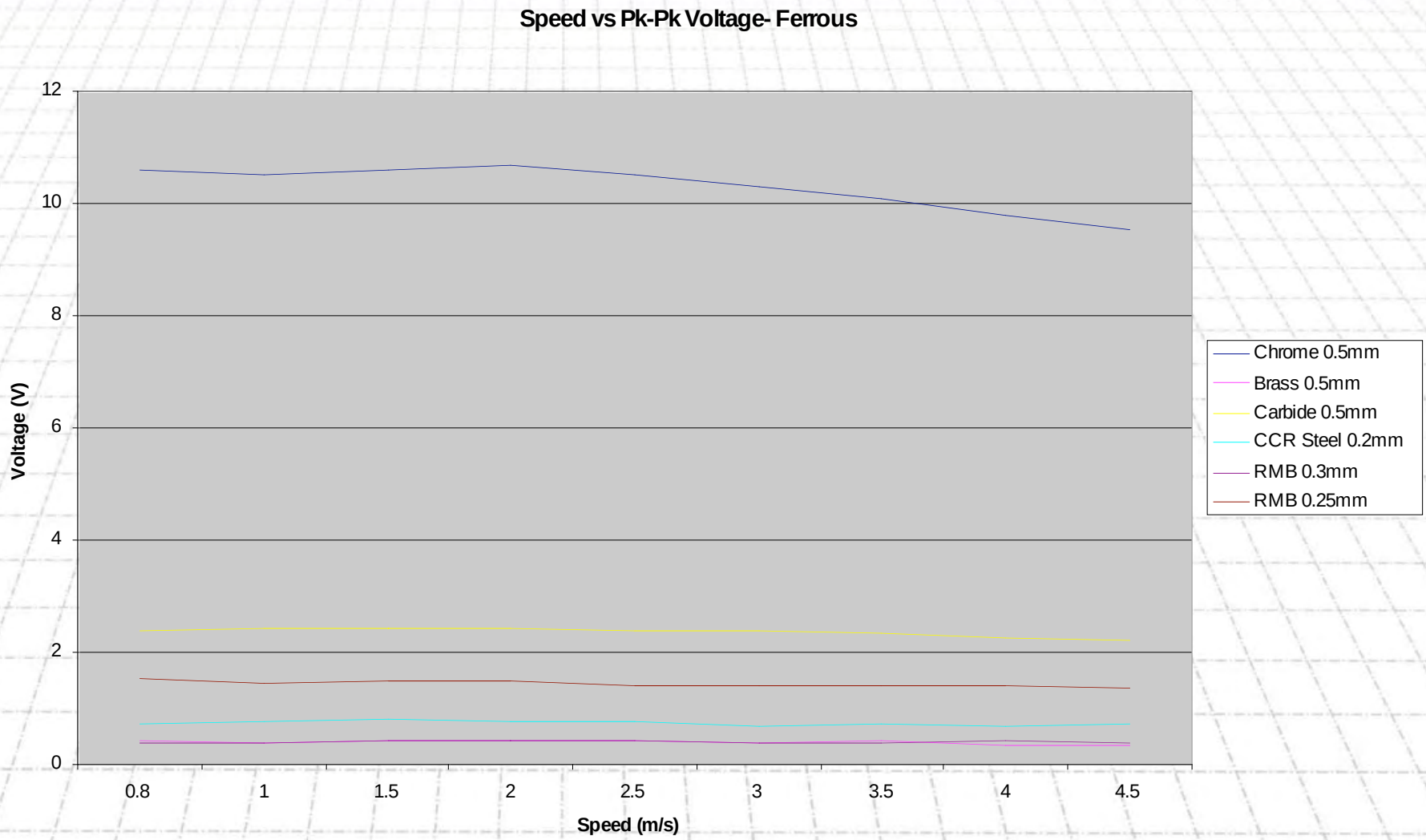

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Oil Condition Sensor

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Oil Condition

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- **Tan Delta [30-200mhz]**
  - Measures dielectric properties of oil at a fixed frequency
  - Dielectric constant
    - 'Real' [Energy storage]
    - 'Imaginary' [Energy loss]
  - Advantages
    - Ease of construction, robust and small
    - Insensitive to contamination: large measurement path
    - Contaminants have similar scale effects
  - Disadvantages
    - Individual contaminants cannot be identified discretely
  - Sensor technology protected under US Patent 6,459,995 B1 [1st October 1992] and UK Patent 2,306,660 A [7th May 1997]

Tan Delta

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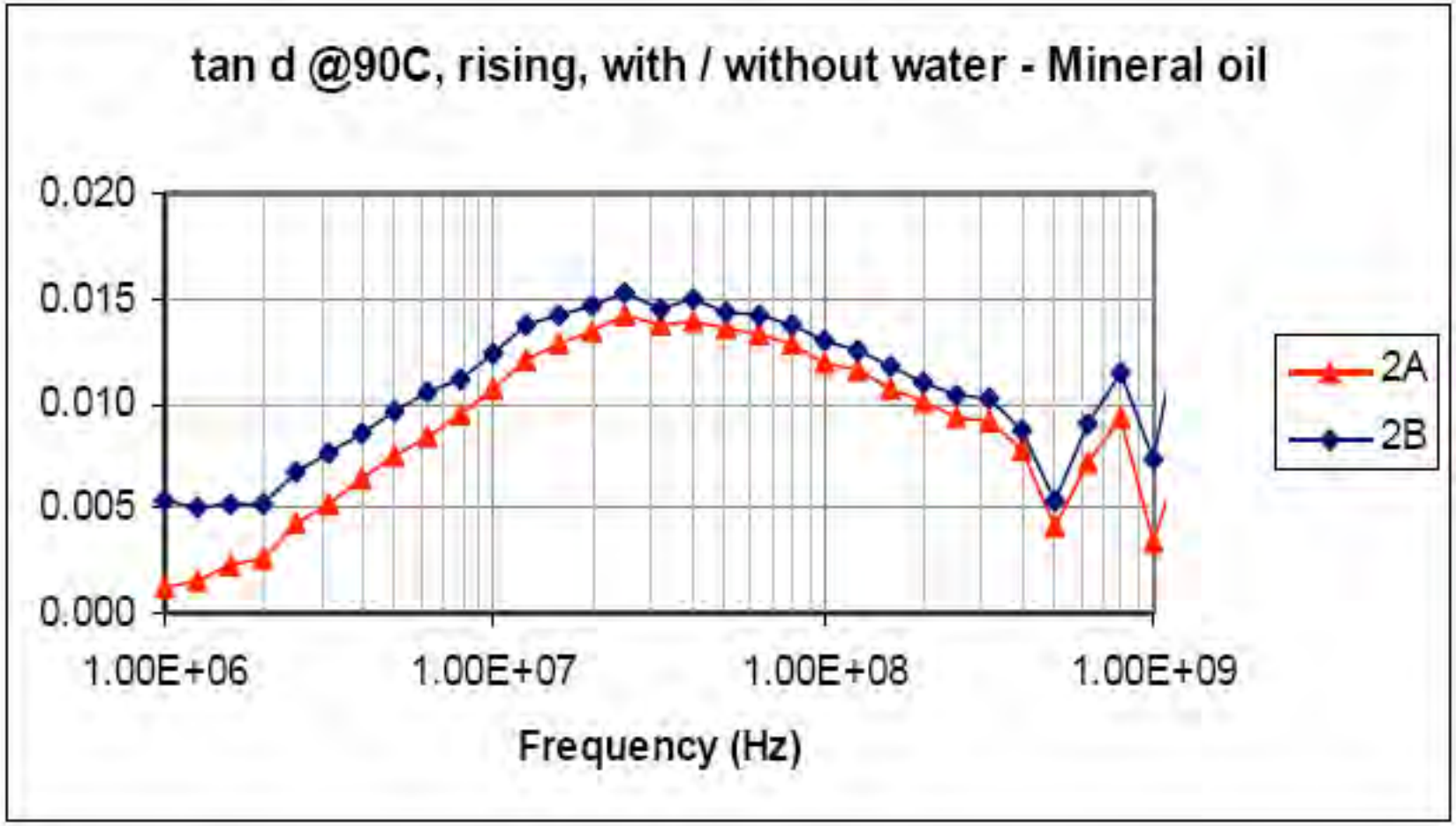

Oil condition monitoring

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- **Your needs…**
  - Reduce operating costs
  - Reduce failure nightmare
  - Measure, Monitor & Manage critical systems
- **Critical performance parameters**
  - Measurable
  - Consistent
  - Repeatable
- **On-line technologies**
  - Key indicators – trending
  - Real time
  - Work where man cannot

Oil Condition	
Parameter	**Quantified as:**
Base Number (BN)	50% Depletion
Acid Number (AN)	50% Increase
Insolubles (Soot)	0% - 2%
Glycol	0.05% - 0.5%
Water	0.05% - 1%

Integrated industrial solution

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Stainless steel housing – Rugged and long life performance

Internal processing power - offers wide interface options

High integrity sealing – using standard automotive techniques

Widely used ½" BSP thread – Quick and easy installation to a wide range of machinery

Gold oil sensing contact – long life and sensitivity

Wind turbine gear oil tests

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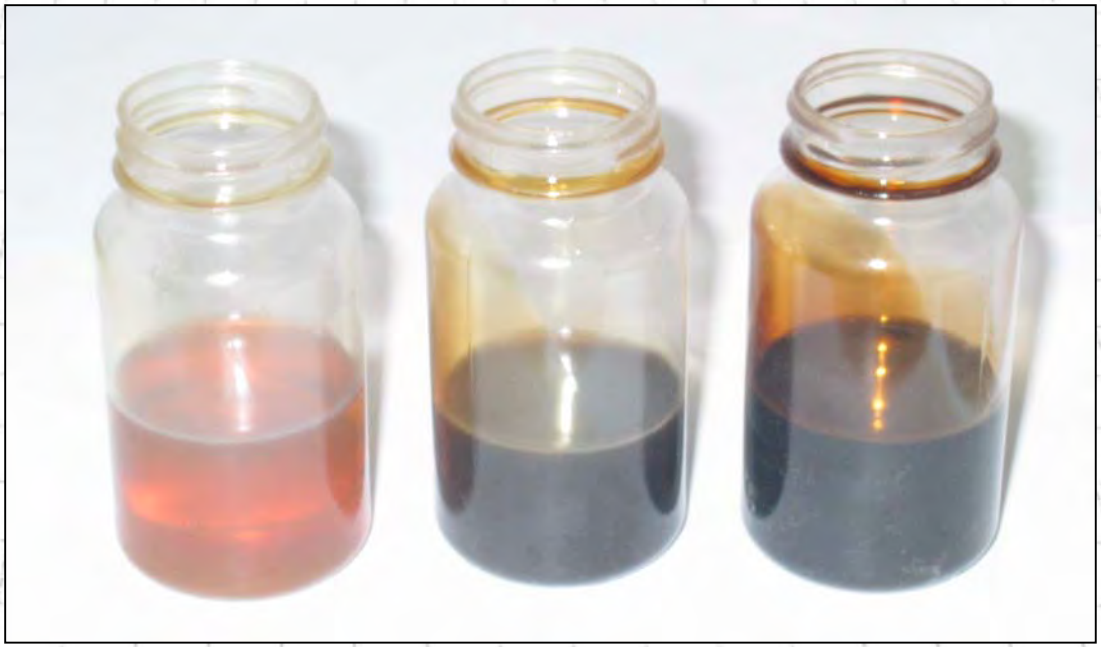
- **Oxidised samples tested**
- **Water contaminated samples tested 0.5% conc.**



1	2	3
TAN mg KOH 0.28	TAN mg KOH 0.39	TAN mg KOH 1.44

Wind turbine gearbox: oxidised oil

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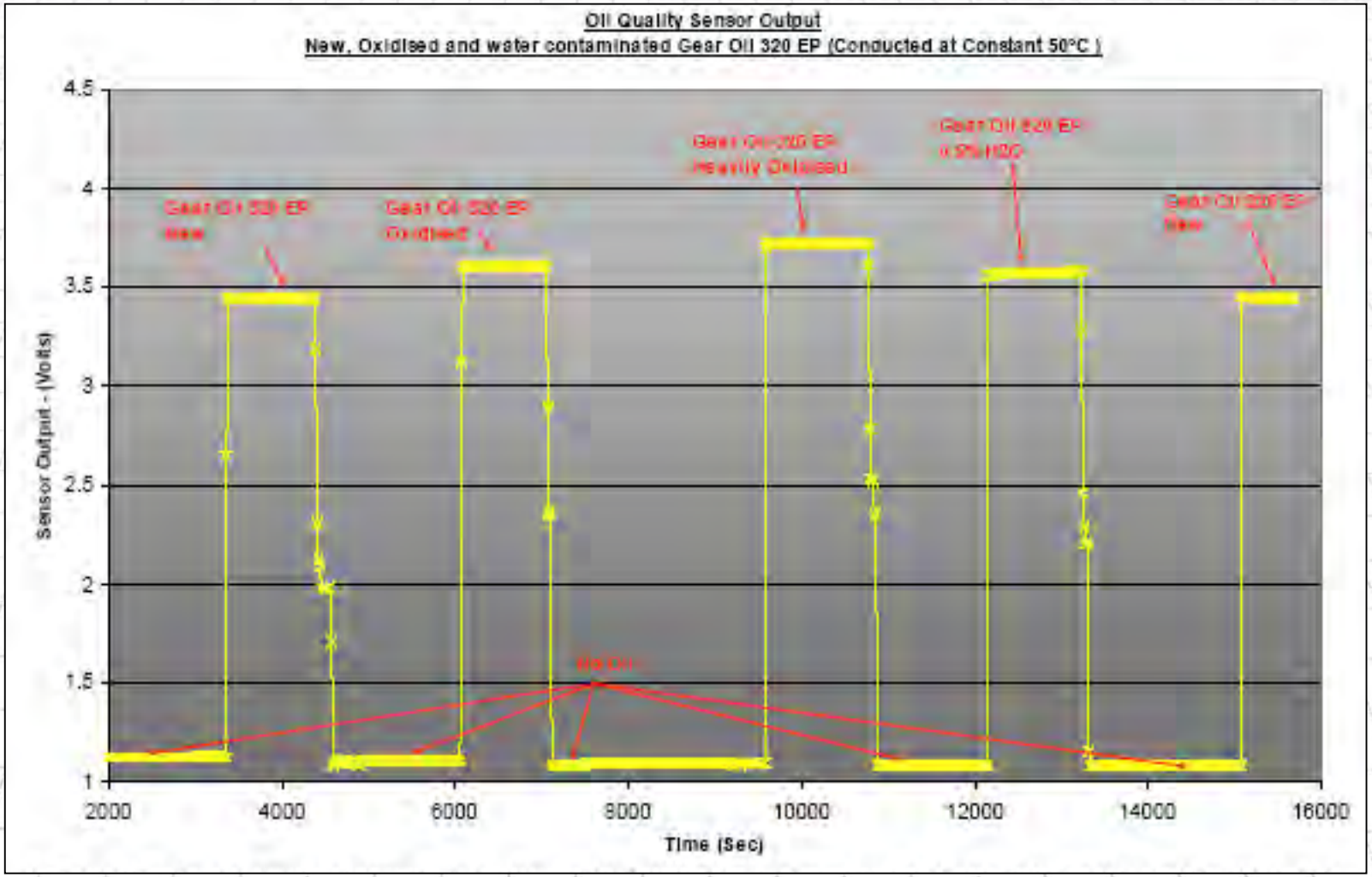

0.5% Water sample was lab simulated - turbomixed (high shear mixing) for 15 seconds shortly before measurement. Gear oil tested is a polyalphaolefin (PAO) synthetic. Measurements taken successively without turning sensor off – sensor head purged of previous test sample with dried and filtered (0.2µm) compressed air.

Automotive: Coolant and new oil

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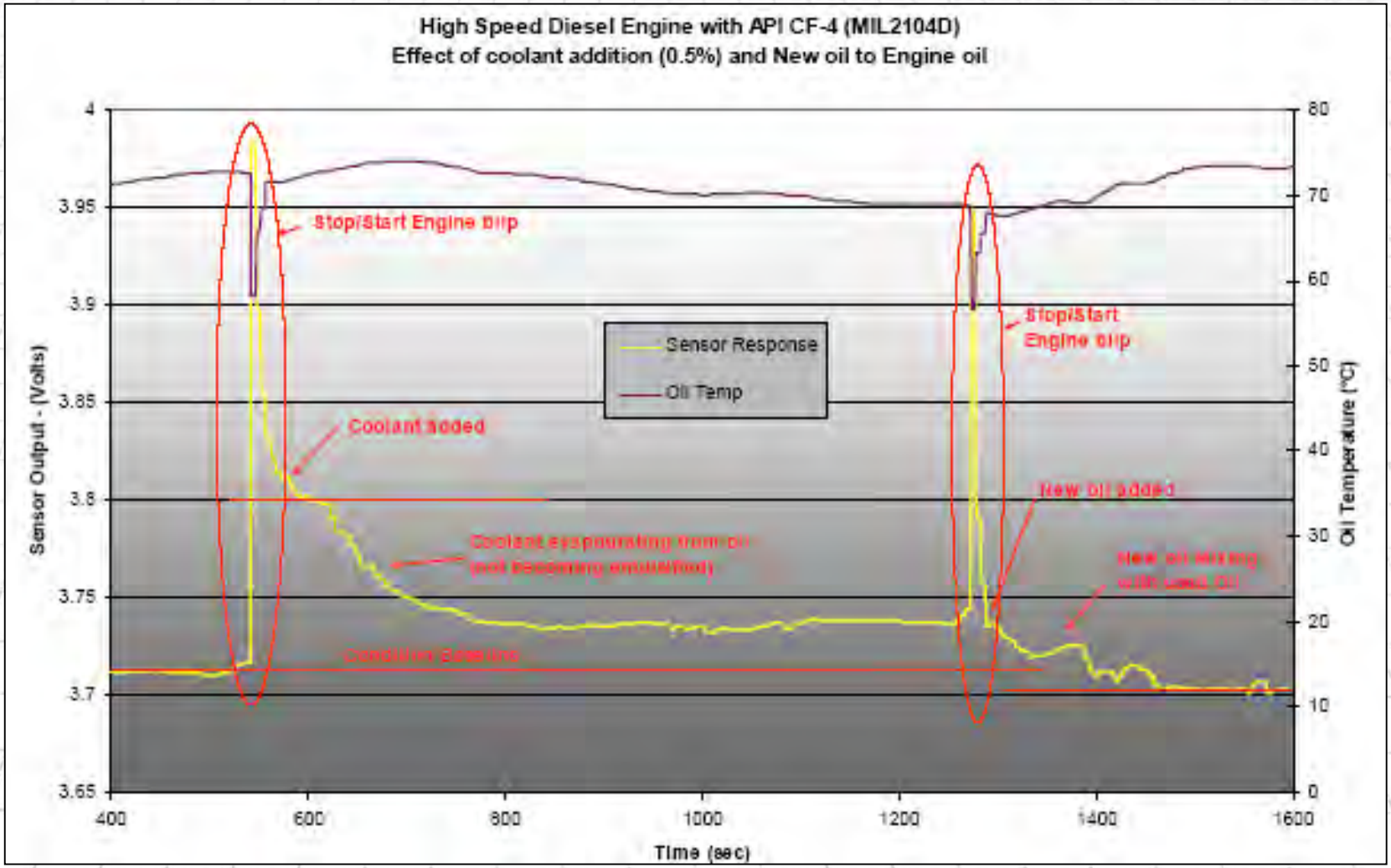

Gearbox: water in Oil

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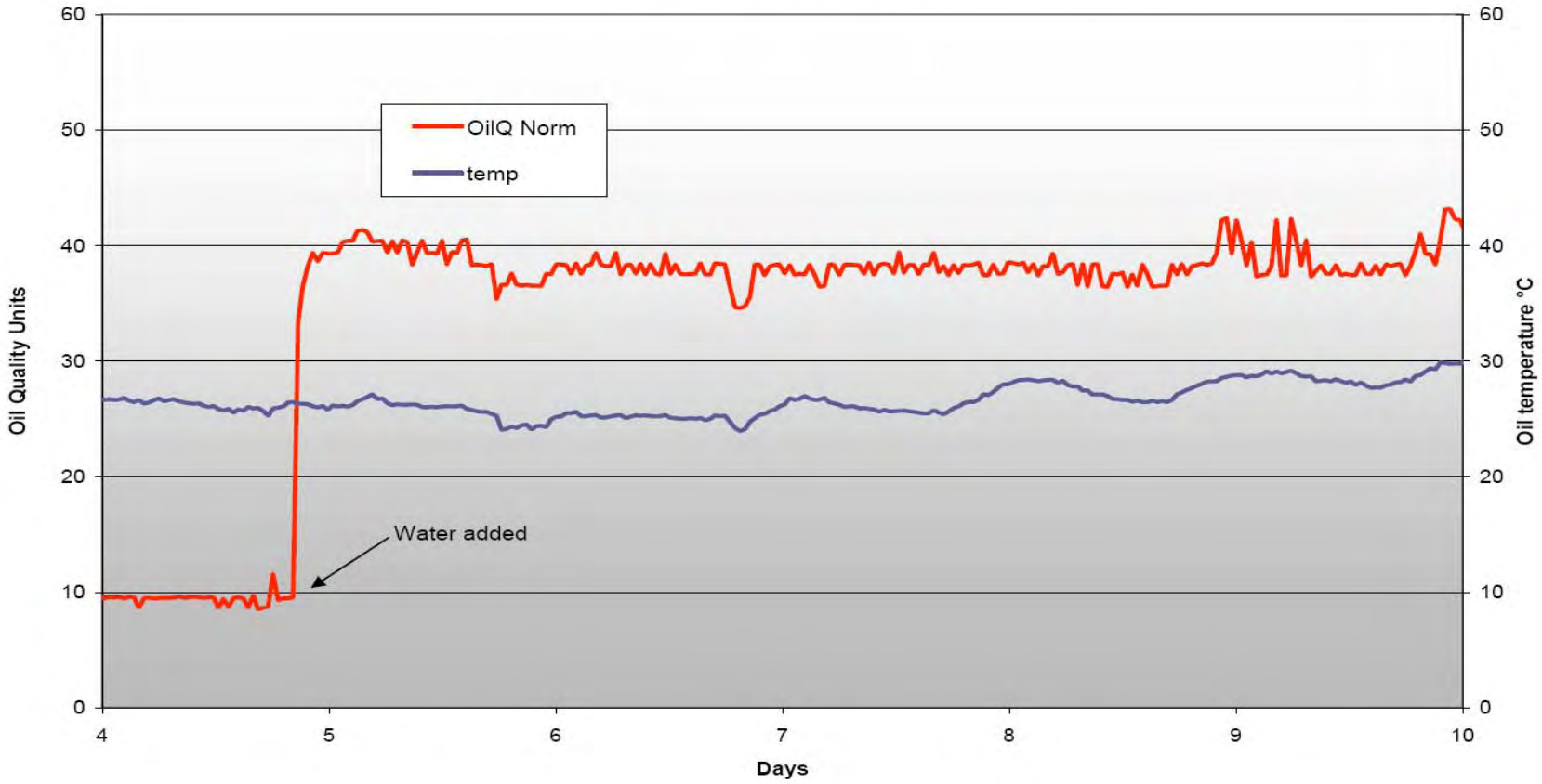
Sensor output vs time
11kW motor into gearbox at 288rpm, 2 litres oil capacity
1% water addition.



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Moisture Sensor

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Moisture sensor

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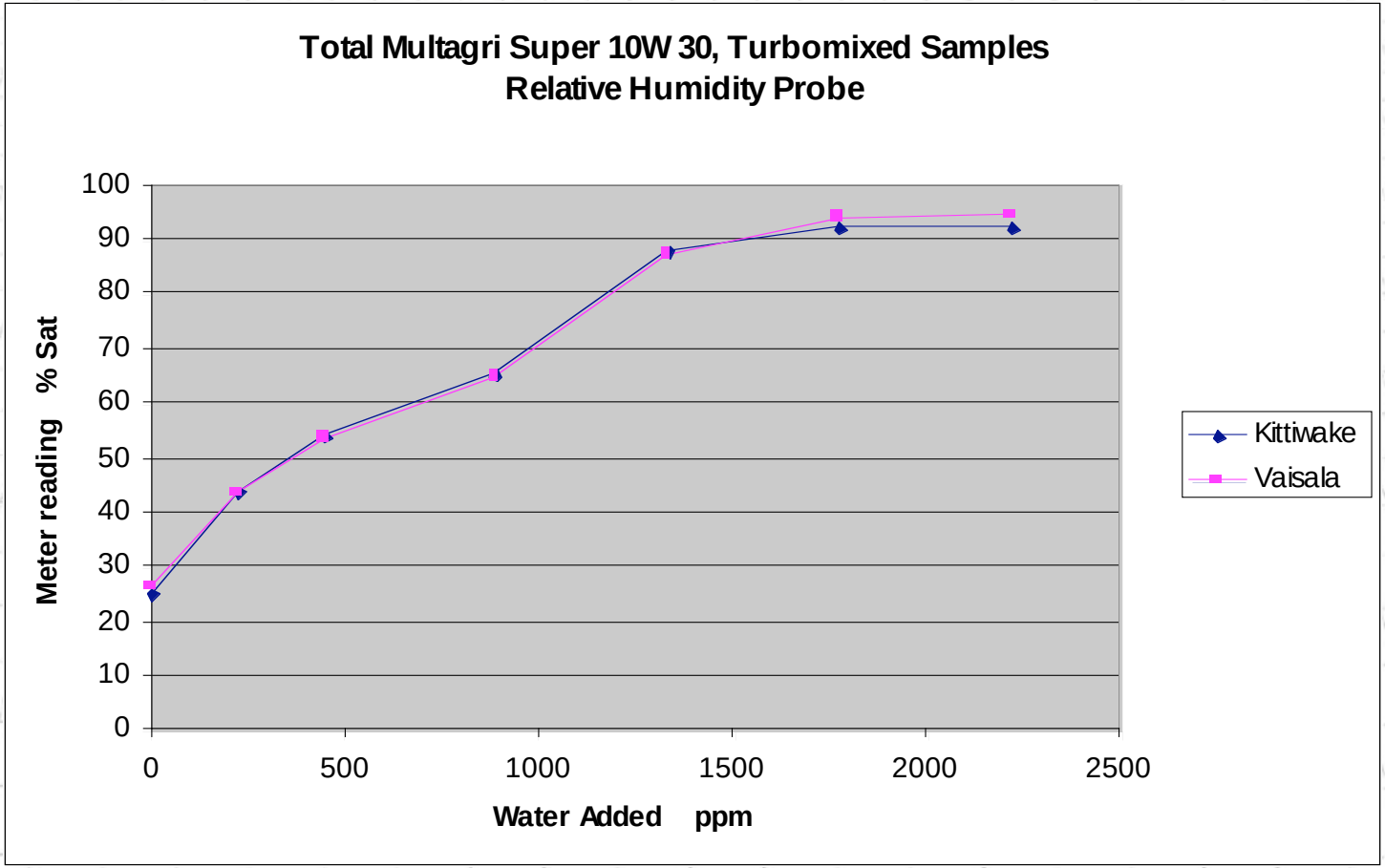
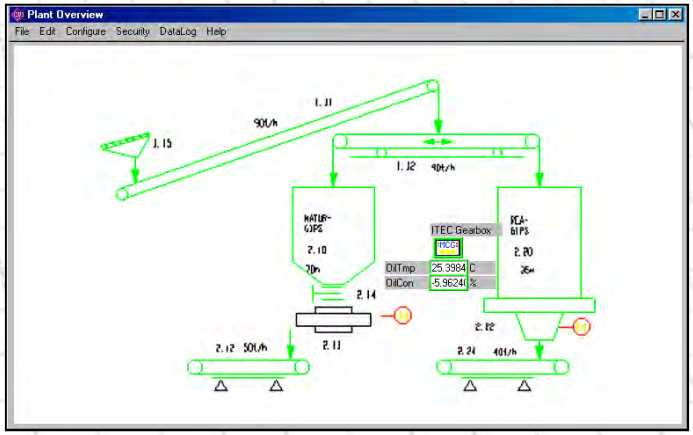
- **Relative humidity means before saturation**
  - Dissolved water: some only detect free and emulsified water
  - No reagents
- **Internal processing power – interface options**
- **Glass to metal hermetic seal**
  - IP68
  - High pressure rating
- **Performance**
  - -40°C to 100°C
  - Temp sensing +/-1%
  - Saturation +/-2%

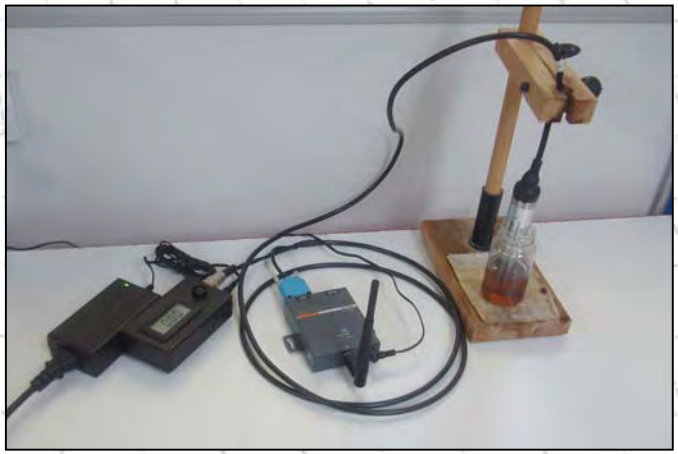
Sensor performance



Interfacing sensors

- **Universal standard Analogue 4-20mA**
- **Digital CAN and RS232**
- **Wireless Communications**
- **Remote Sensing**
- **Link the sensors into control systems**
  - Third Party software
  - Machine control systems
  - OEM’s
  - Data loggers





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Technical Specifications and Applications

Typical applications:

The sensor will prove most valuable when used with machines that are either:

- A high capital cost
- Production critical
- Safety critical
- Costly to repair
- Have long lead times on spares.
- Remote locations

ANALEXrs equipment can be fitted on any machine with a circulating lubrication system, and where either ferrous or non-ferrous wear debris is a predominant measure of the wear rate. Alternatively, use the ANALEXrs range on a filter cartridge to assess condition of splash lubricated machines.

Examples include equipment such as:

- Engines
- Gearboxes & Transmissions
- Bearings
- Pumps
- Compressors
- Turbines

Industries such as:

- Power Generation (Steam, Nuclear, Wind turbine)
- Steel
- Pulp & Paper
- Petro-chemical/refineries
- Transportation
- Military

ANALEXrs

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Specifications	Total Ferrous Debris Sensor	Oil Condition Sensor	Particle Content Sensor	Moisture Sensor
Product Code	FG-K16120-KW	FG-K14492-KW/FG-K16203-KW	FG-K16121-KW	FG-K16291-KW
Detection	Total Ferrous Wear Debris 0 - 2000ppm	Oil Condition 0-100 Oil Quality Units	Ferrous Particles > 60µm and Metallic Non-Ferrous Debris Particles > 100µm	0-100% Saturation
Analogue Output	4-20mA	4-20mA	4-20mA	4-20ma % saturation & Temp of Oil
Digital Output	CAN, RS232, RS485, radio link	RS232, CAN	CAN, RS232, RS485, radio link	RS232, CAN
Power	18-36 VDC	15-30 VDC, 1 watt max	18-36 VDC	12-24Vdc at 25ms
Maximum Oil Pressure	10 bar (145psi)	10 bar (145psi)	10bar (145psi)	10bar (145psi)
Operating Temperature	-25 to 85°C (-13 to 185°F)**	30 to 130°C (86 – 266°F)	-25 to 85°C (-13 to 185°F)**	-40 to 100 DegC
Protection	IP65	IP67	IP65	IP67
Sensor Weight	2.2kg (4.85lb)	250g (9oz)	1.4 kg (3.1lb)	250g (9oz)

**Kittiwake operates a continuous development program and thus certain specifications may be subject to change.

Summary

Kittiwake
Measuring, Monitoring & Managing

- Sensors can be used to predict failure, reducing unexpected equipment down time and labour costs
- Robust solutions for monitoring oil condition and moisture content
- Provide real time indicators of oil condition
- Robust solutions for monitoring debris in a myriad of applications
- Provide real time indicators of machinery condition
- Advanced connectivity to other sensors in the ANALEXrs Range
- These sensors <u>are</u> the solution to many current problems, and hopefully the solution for some new ones