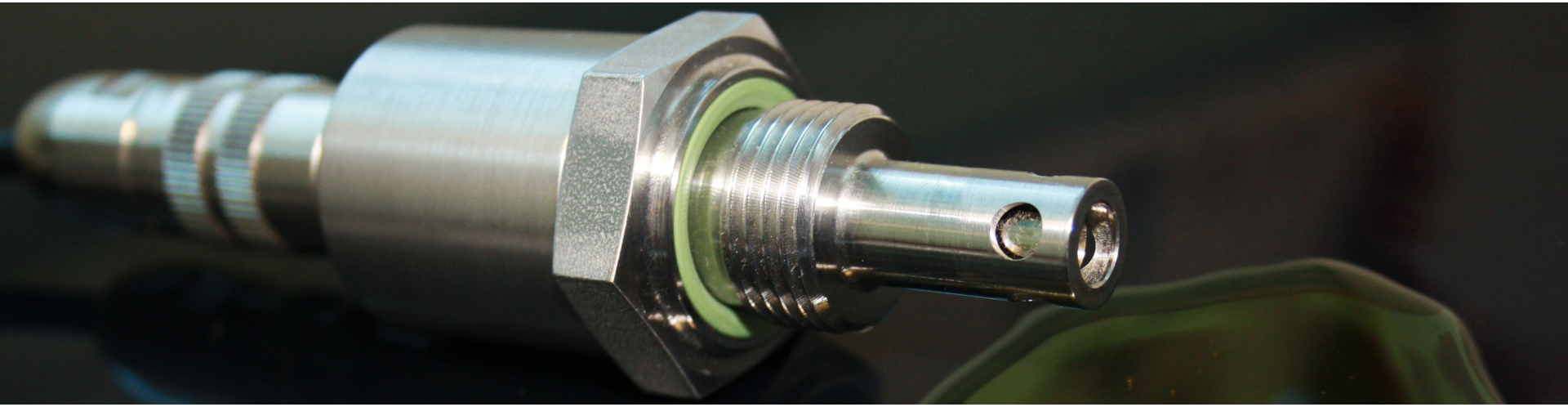
TANDELTA

TAN DELTA SYSTEMS LIMITED

- Sensor Technology & Failure Mode Correlation

OUR MISSION



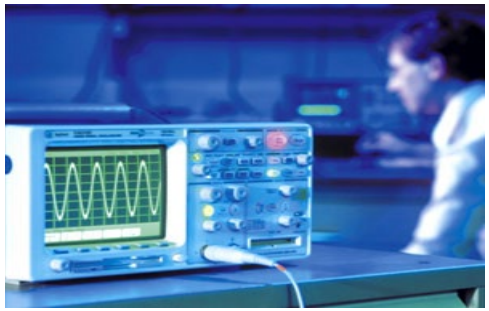
The provision of oil condition monitoring solutions that enable equipment operators to reduce operating costs, minimise break downs, extend equipment life and increase equipment productivity

ABOUT TAN DELTA

- Privately owned company based in the UK
- Experts in oil condition monitoring technology, products and solutions
- Patented core technologies that deliver exceptional performance
- Quality product engineering and manufacturing
- Global network of distributors and industrial and commercial end users
- Products that deliver measurable benefits to equipment operators

CORE CAPABILITIES

EXPERTS IN OIL CONDITION MONITORING



TECHNOLOGY

Tan Delta's in house developed and patented technology delivers superior oil quality monitoring - exceptional sensitivity, accuracy and reliability in any oil type.

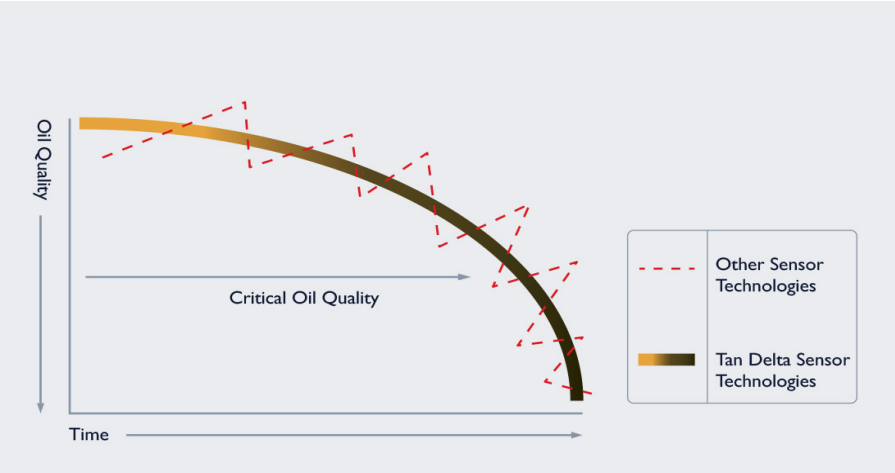
SOLUTIONS

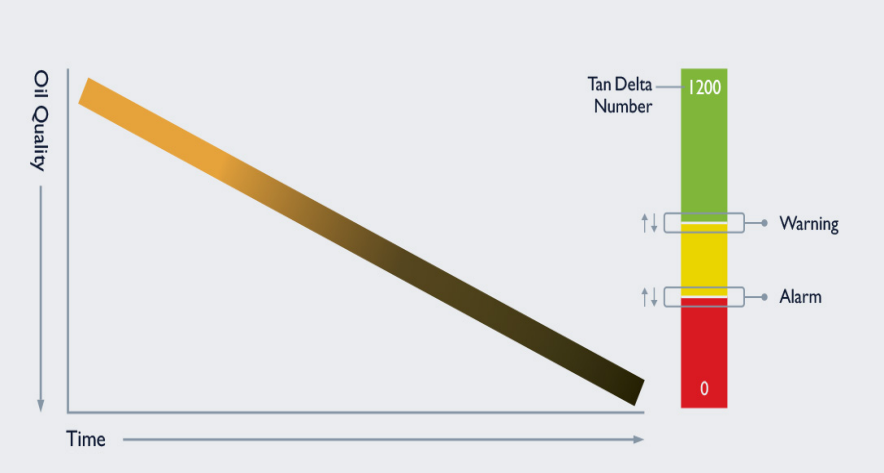
Tan Delta's products are engineered for ease of use, reliability and deployment on any equipment in any commercial or industrial environment. Engines, gear boxes, hydraulics and transformers.

SUPPORT

Tan Delta are experts at working with customers to design, deliver and support, easy to install solutions that deliver significant operating cost reductions and increases in productivity.

TECHNOLOGY





- Tan Delta patented sensor technology delivers exceptional sensitivity to any change in oil condition – all wear and contamination: for example water, acid, soot, carbon etc
- Real time, in line, monitoring second by second of any oil type , in any application, across all temperature and pressure ranges
- Independently certified sensitivity and accuracy
- Precise, reliable data empowers effective no risk maintenance decision making

HOW IT WORKS

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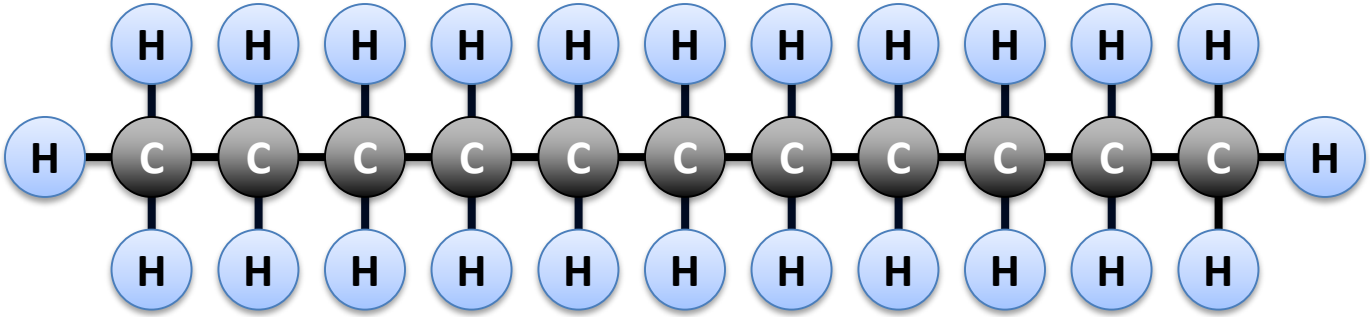
Any industrial oil has



A base oil type

- Mineral
- Semi-Synthetic
- Synthetic

Various additive packages

- Bases
- Extreme Pressure
- Anti Foaming
- Anti Wear
- Anti Corrosion
- Specialised

And a Viscosity

- Low – Hydraulics
- Mid – Industrial
- High – Worm Gears

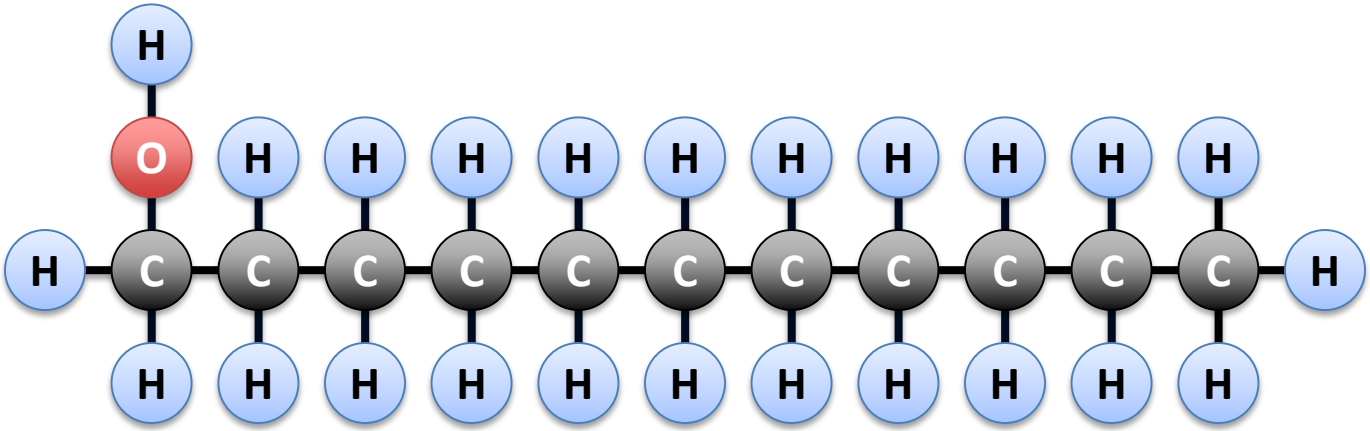
Individual Electro-Chemical Fingerprint

“Therefore every oil has a unique chemical make-up”

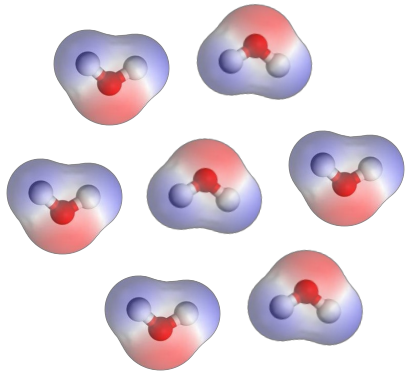
HOW IT WORKS

TANDELTA

As the oil changes due to



"Creating Polar Molecules"



Energy

- Heat
- Pressure
- Motion

Chemical Change

- Impurities
- Water/Coolant
- Wear Particles
- Dust
- Fuel

Chemical Process

- Free Radicals
- Aldehydes
- Ketones
- Hydro-peroxides
- Carboxylic Acid

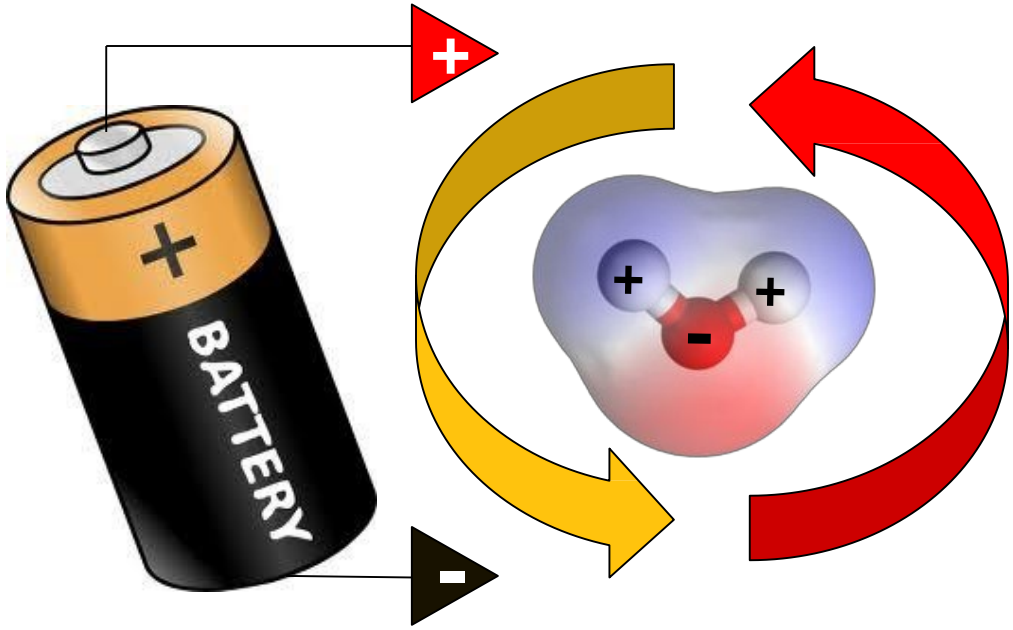
"Effects which permanently change the oils chemistry"

HOW IT WORKS

By simply introducing a very high frequency AC waveform we can then accurately measure the oil's ability to store energy (Capacitance) and the oil's ability to conduct current (Conductance).

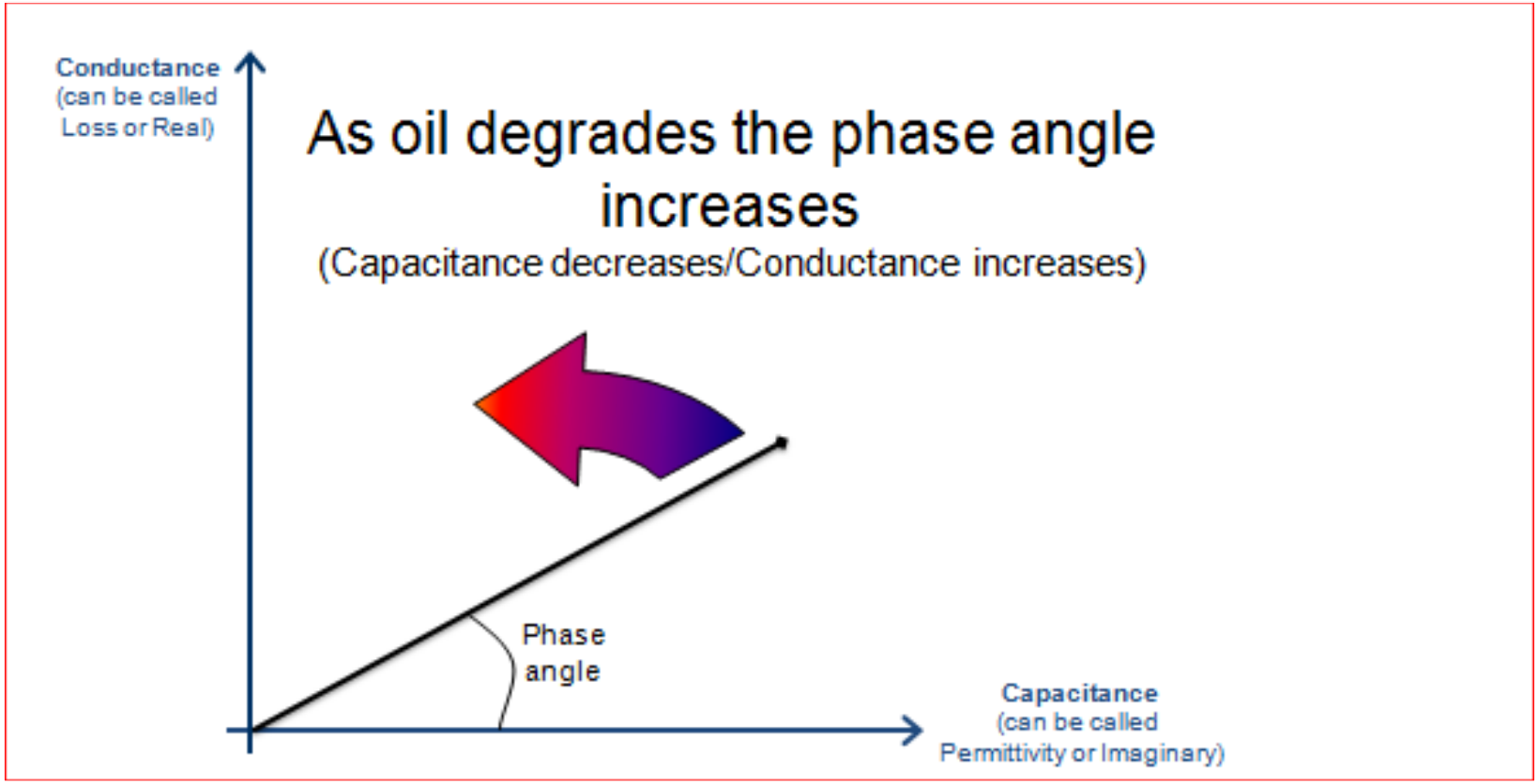
The ratio of these two factors combined (patented method) tells us how much change (and therefore damage) has been done to the oil. This measure is called the "Loss Factor" and is given as a percentage change from a baselined new oil.

Loss factor is a single combined index value taking into account all of the changes in the oil. Tan Delta Number is derived from the loss factor value to give a simple decreasing scale for oil condition.



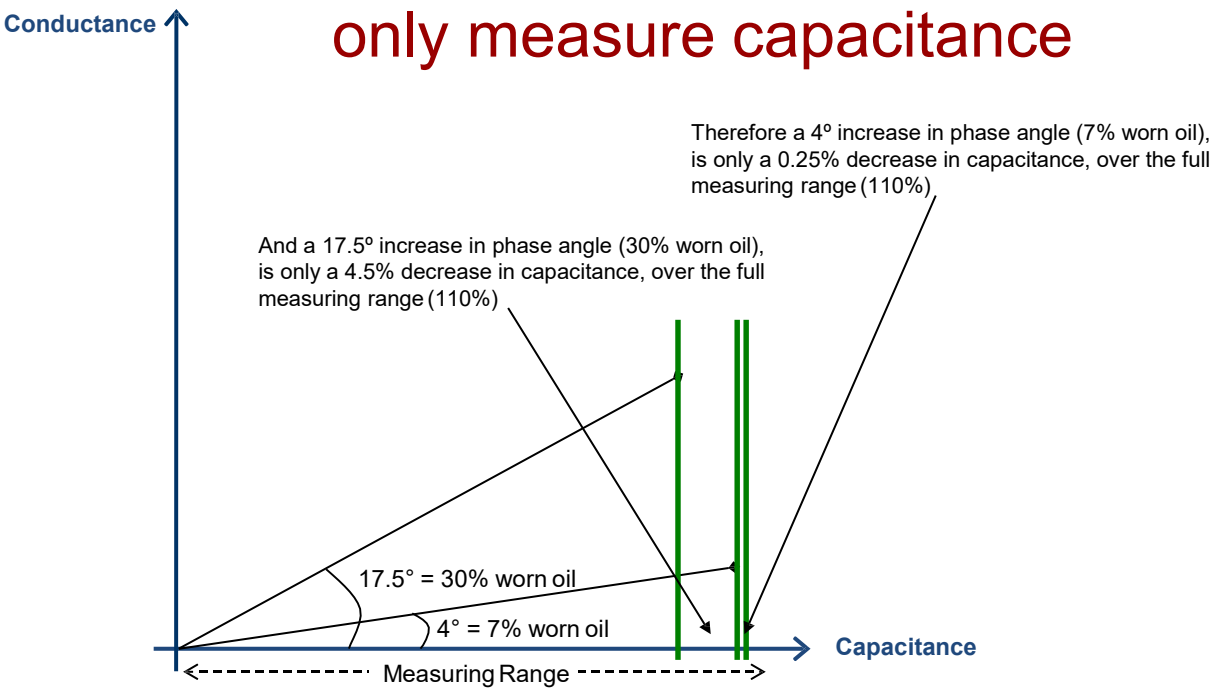
"Energy makes the polar molecules move or bend"

PATENTED METHOD



PATENTED METHOD

Traditional dielectric sensors only measure capacitance



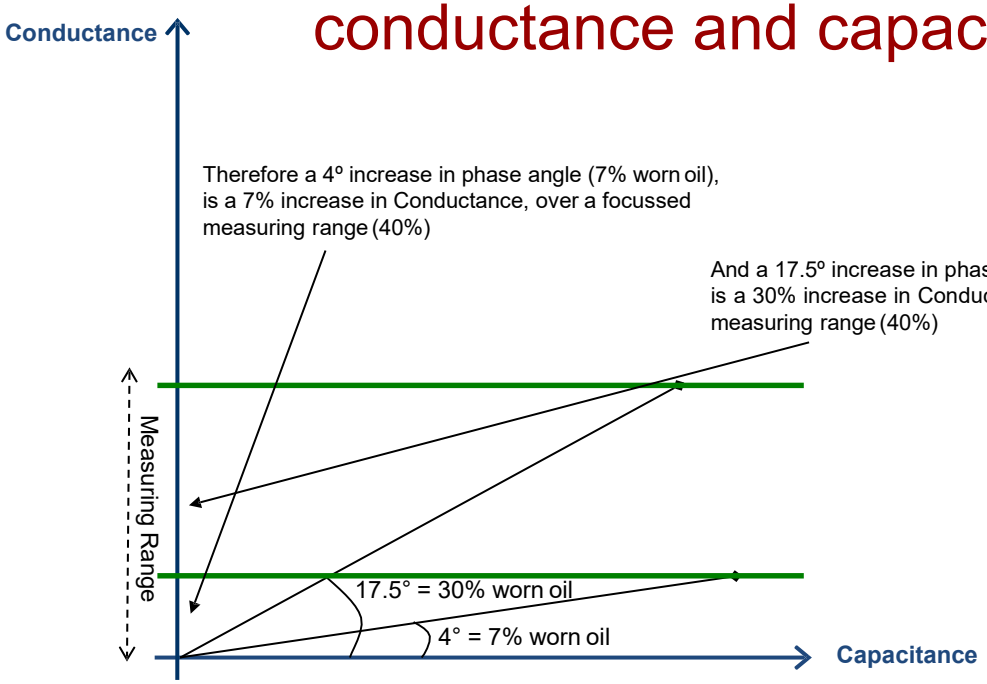
No sensitivity to changes in oil condition

Temperature instability

Very limited configuration options

PATENTED METHOD

Patented method uses ratio between conductance and capacitance



High sensitivity to changes in oil condition (on average 62 times more sensitive)

Temperature stable

Configurable warning and alarm levels

FAILURE MODES

TANDELTA

The sensor will detect the following failure modes:-

- Oxidation
- TAN changes
- TBN changes
- Additive depletion
- Particulate contamination
  - Wear debris
  - Process related (product)
  - Environment related (dust, sand)
  - Partially burnt fuel
  - Soot
- Fluid contamination
  - Water/Coolant ingress
  - Process related (product)
  - Fuel dilution
- Major viscosity changes
- Poor oil changes
- Incorrect oil type

LAB ANALYSIS CORRELATION

Gas Reclamation Engine – 3 x circa 850 hour cycles

LAB ANALYSIS CORRELATION

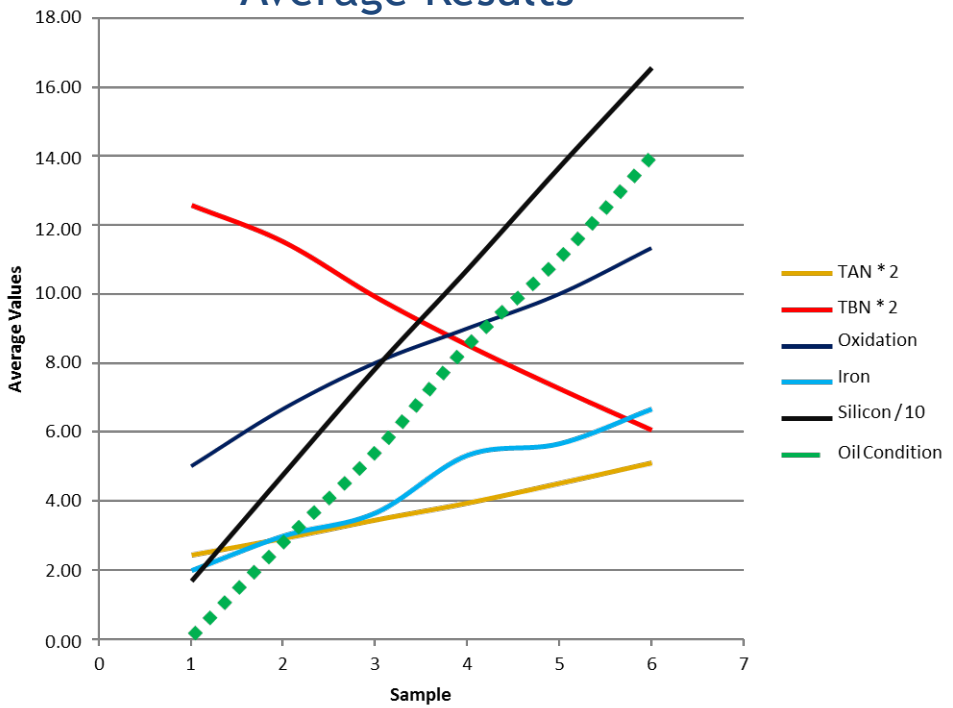
Lab Analysis

Sample	TAN	TBN	Oxidation	Iron	Silicon	~Hours Run	Oil Condition
A	1.12	6.2	5	2	16	0	0.0
B	1.32	5.6	6	2	46	168	3.5
C	1.55	4.7	8	2	77	336	6.4
D	1.84	3.9	9	3	106	504	8.4
E	2.06	3.2	10	3	138	672	10.3
F	2.37	2.3	12	4	167	840	13.5

Sample	TAN	TBN	Oxidation	Iron	Silicon	~Hours Run	Oil Condition
G	1.29	6.2	5	2	17	0	0.1
H	1.57	5.7	7	4	48	168	2.8
I	1.83	4.9	8	4	77	336	5.8
J	2.02	4.5	9	6	106	504	9.0
K	2.33	4.1	10	7	135	672	12.0
L	2.54	3.6	11	7	163	840	14.3

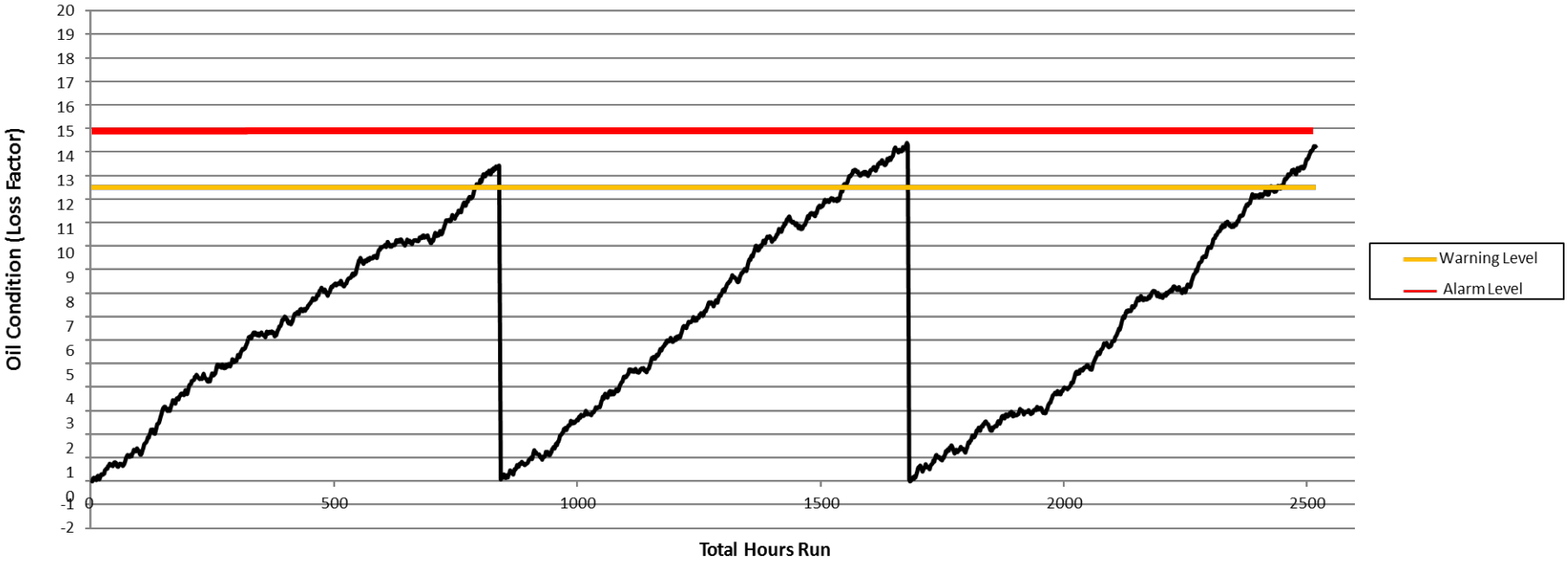
Sample	TAN	TBN	Oxidation	Iron	Silicon	~Hours Run	Oil Condition
M	1.27	6.5	5	2	18	0	0.1
N	1.52	6.0	7	3	50	168	2.2
O	1.83	5.3	8	5	82	336	4.2
P	2.09	4.4	9	7	110	504	8.1
Q	2.42	3.6	10	7	138	672	10.9
R	2.79	3.2	11	9	167	840	14.2

Average Results



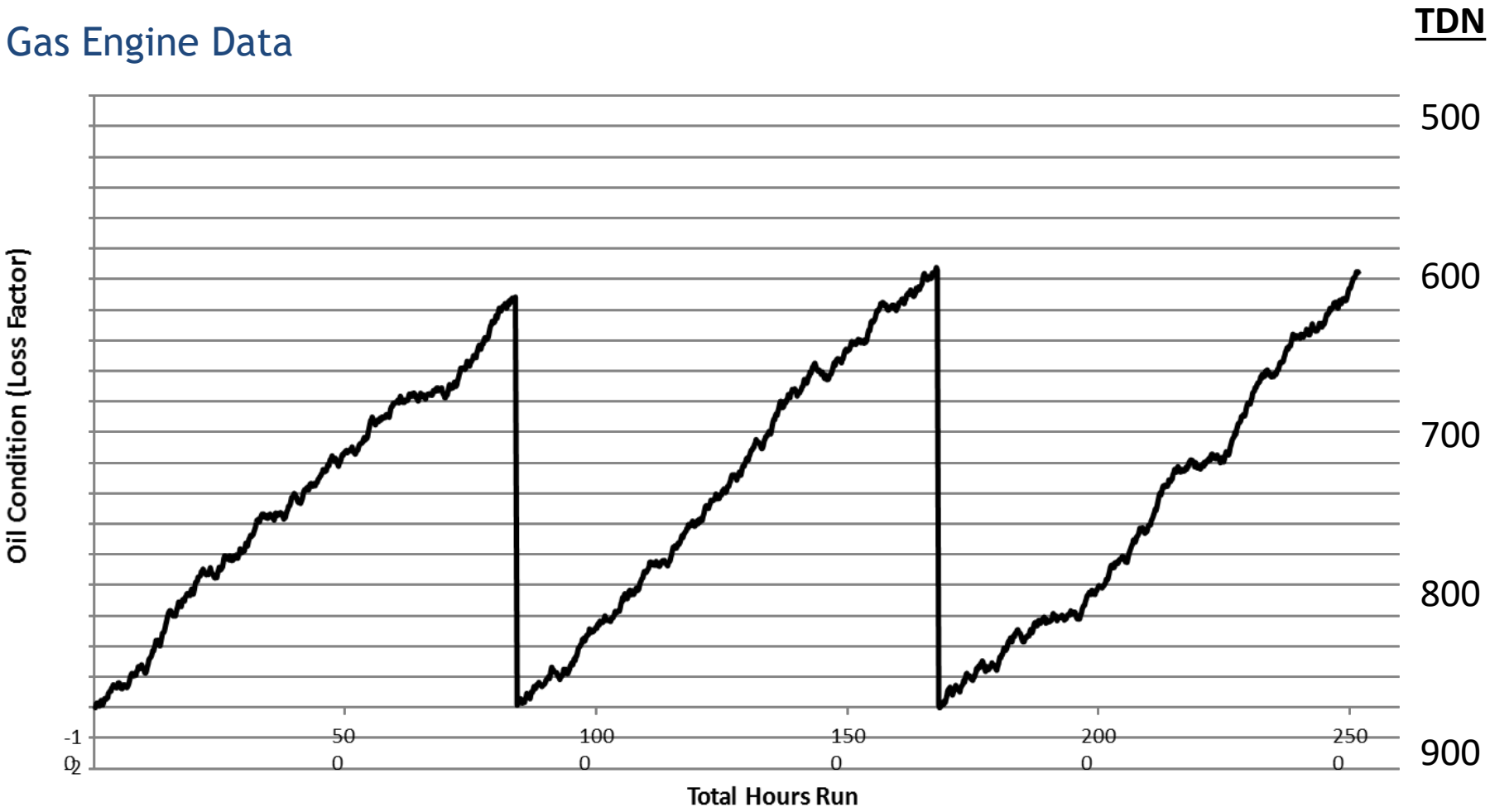
LAB ANALYSIS CORRELATION

Lab Analysis vs Sensor Output

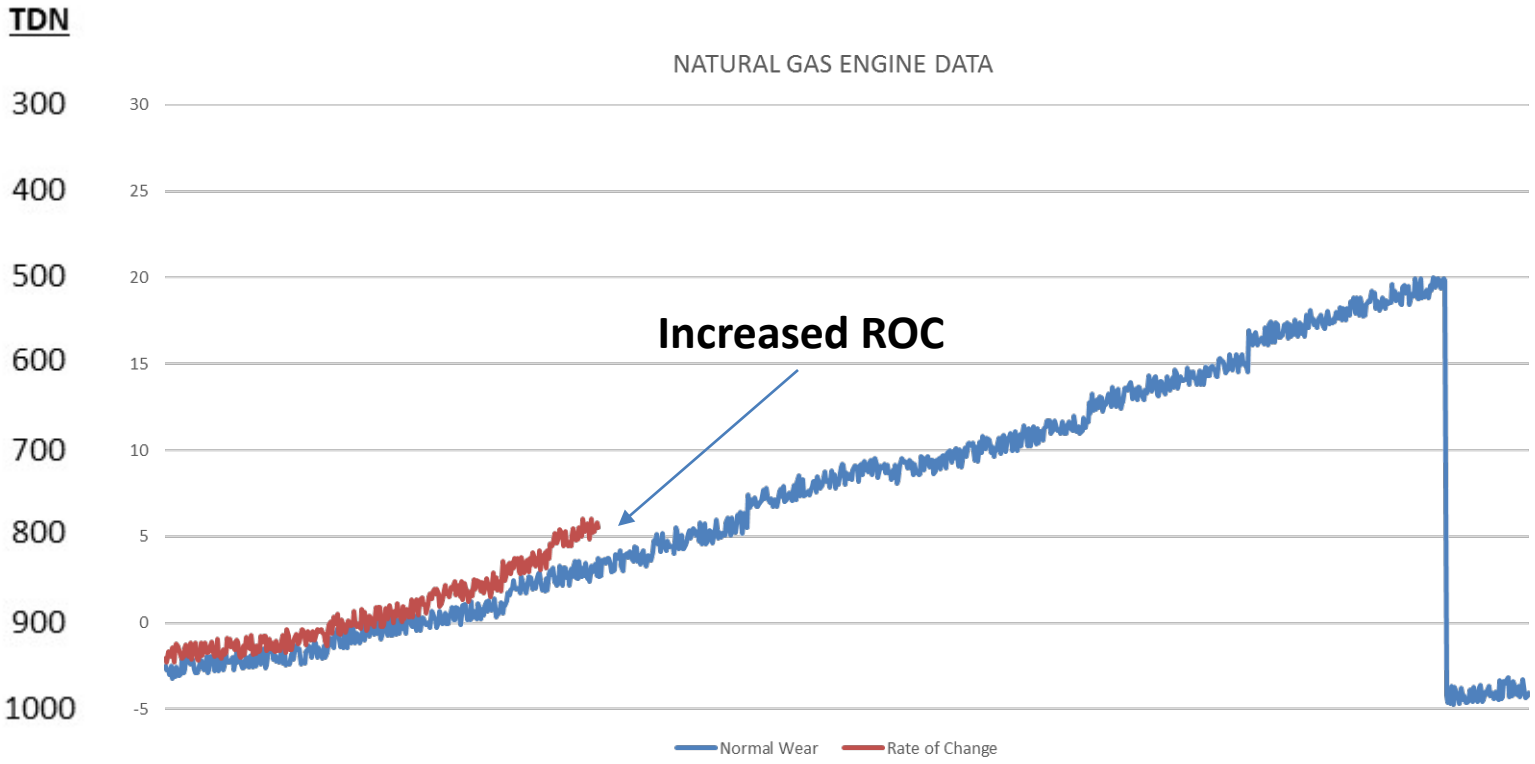


FAILURE MODE – OIL CHANGE

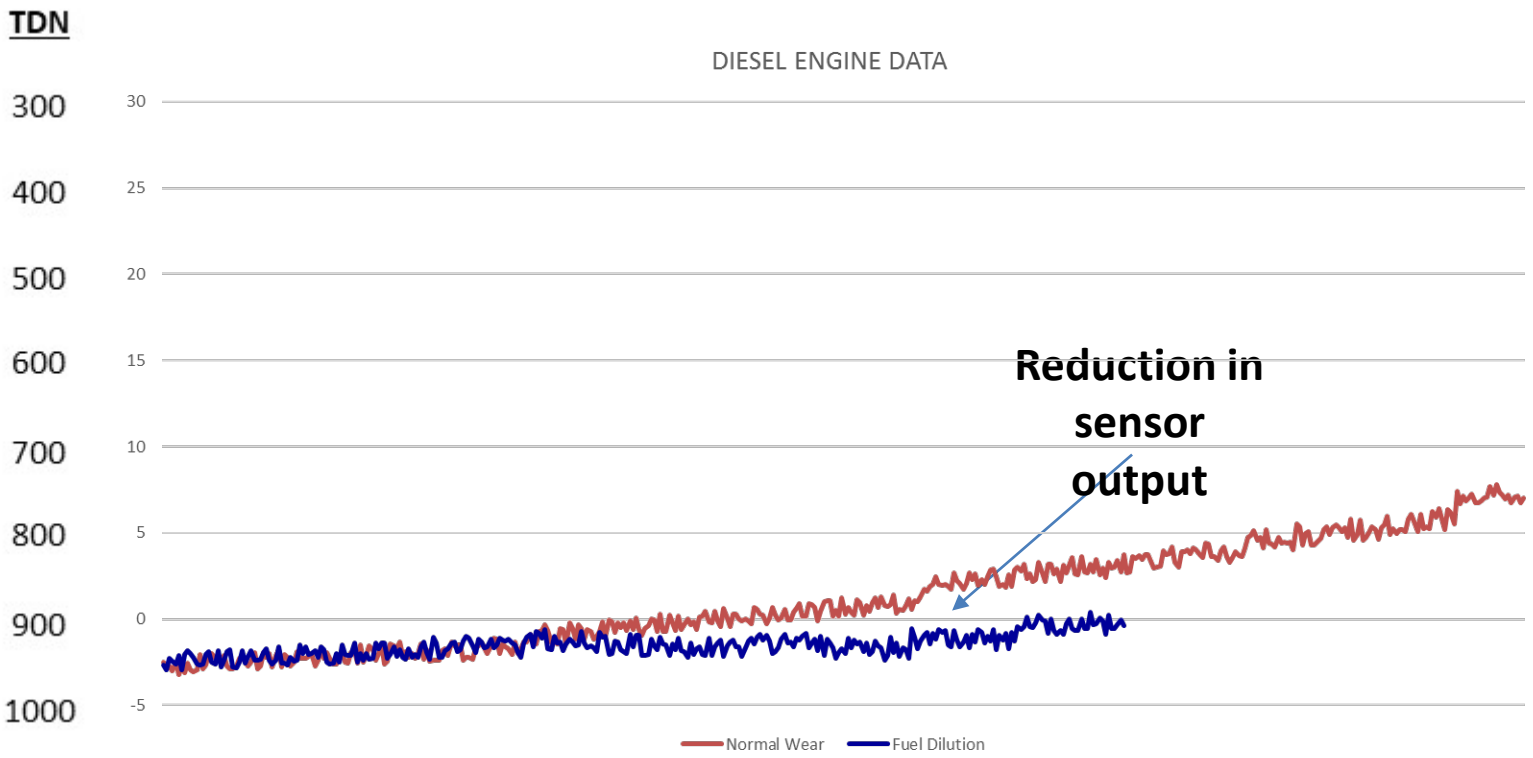
Gas Engine Data



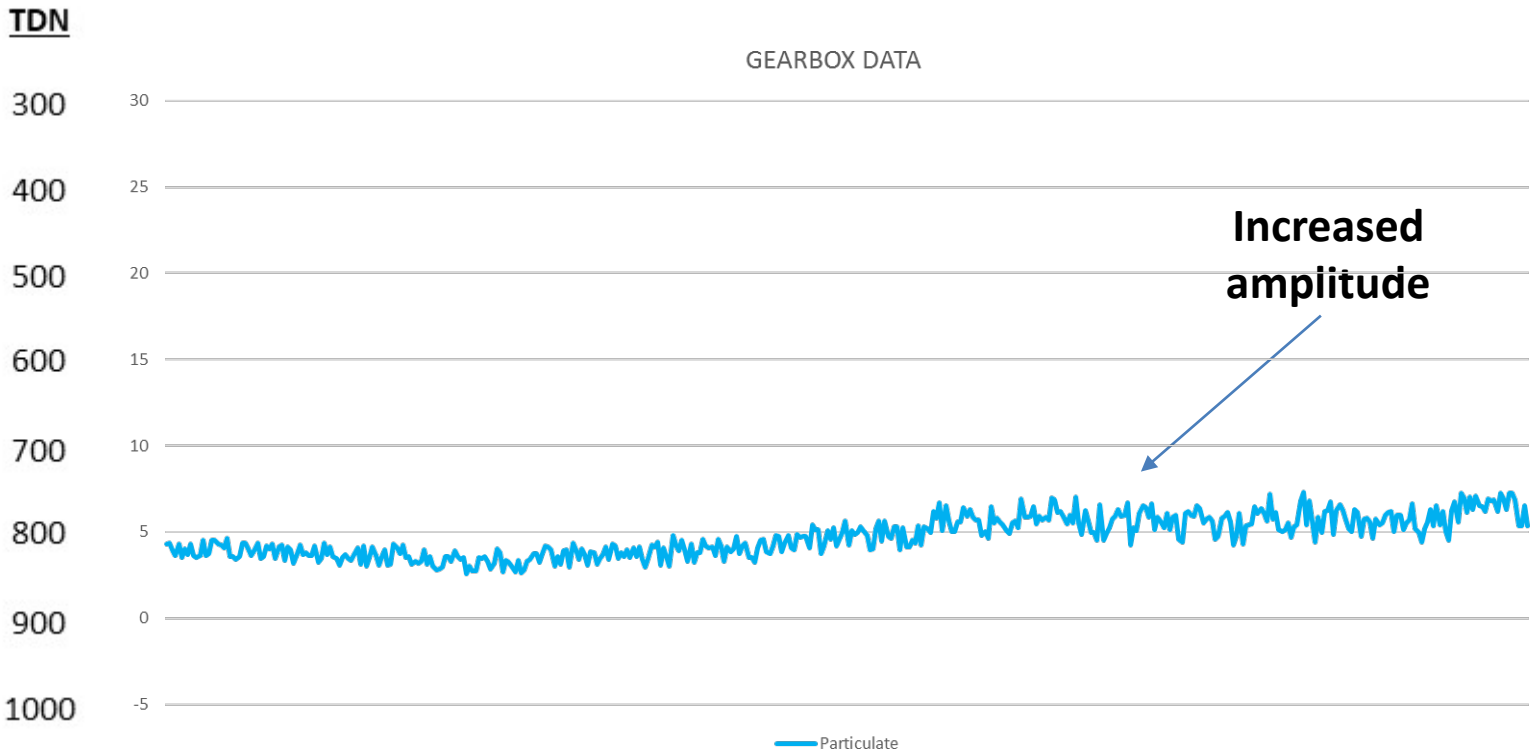
FAILURE MODE – INCREASED RATE OF CHANGE



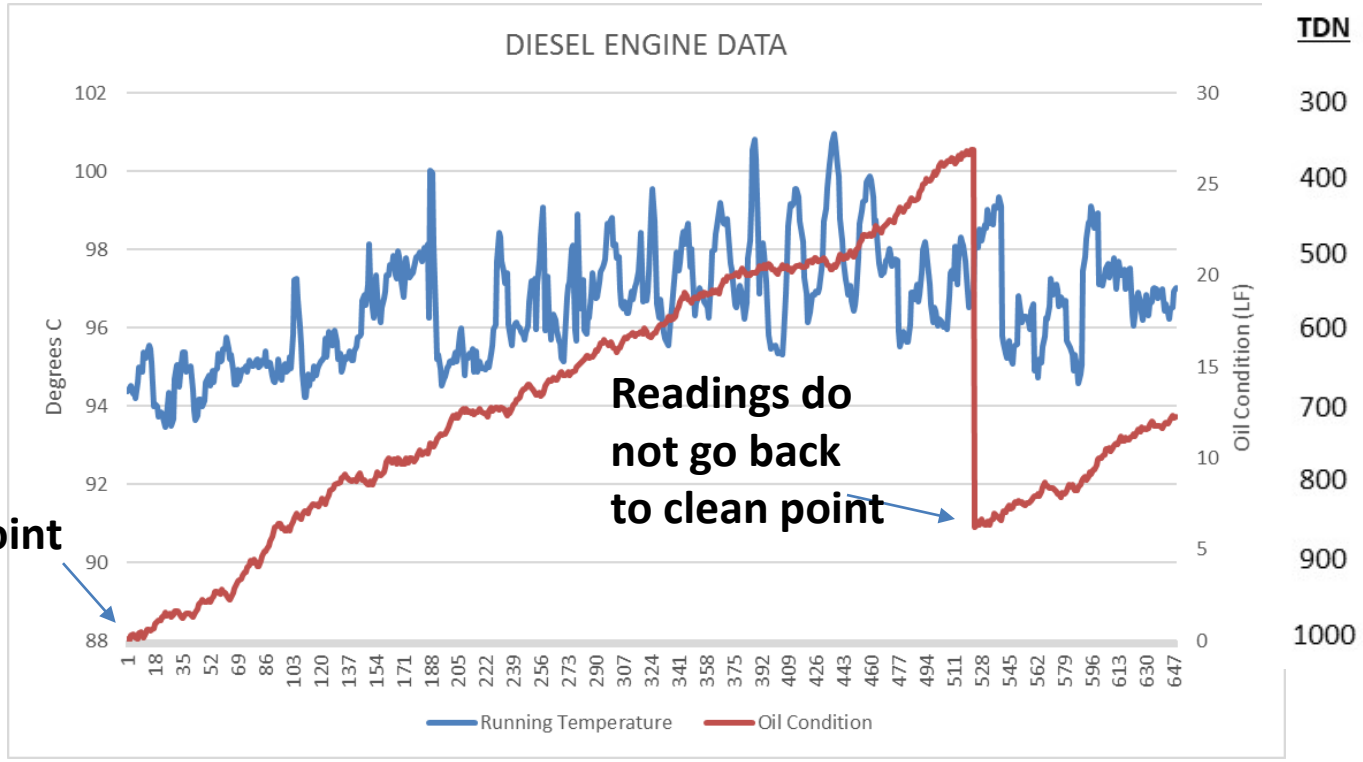
FAILURE MODE – FUEL DILUTION



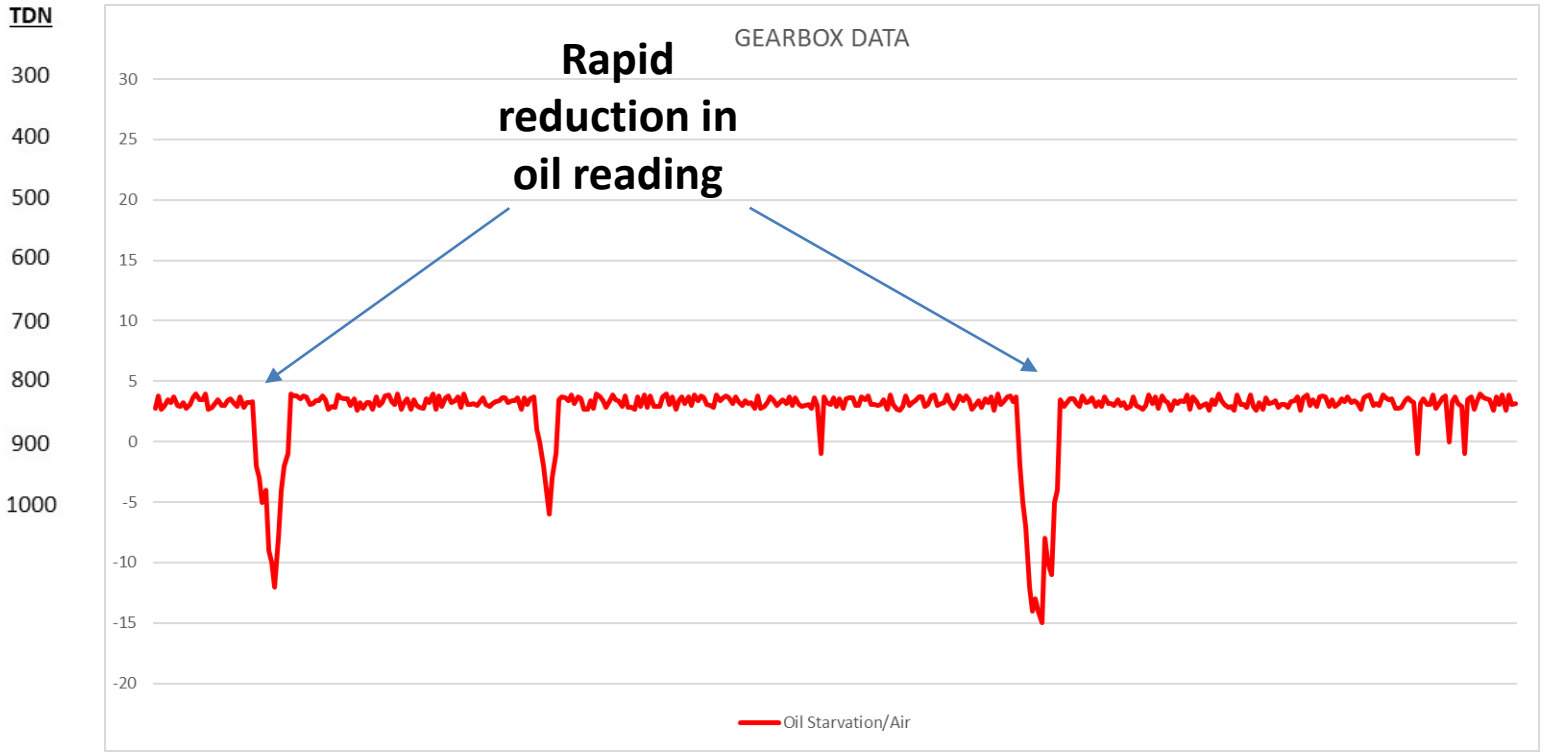
FAILURE MODE – PARTICULATE CONTAMINATION



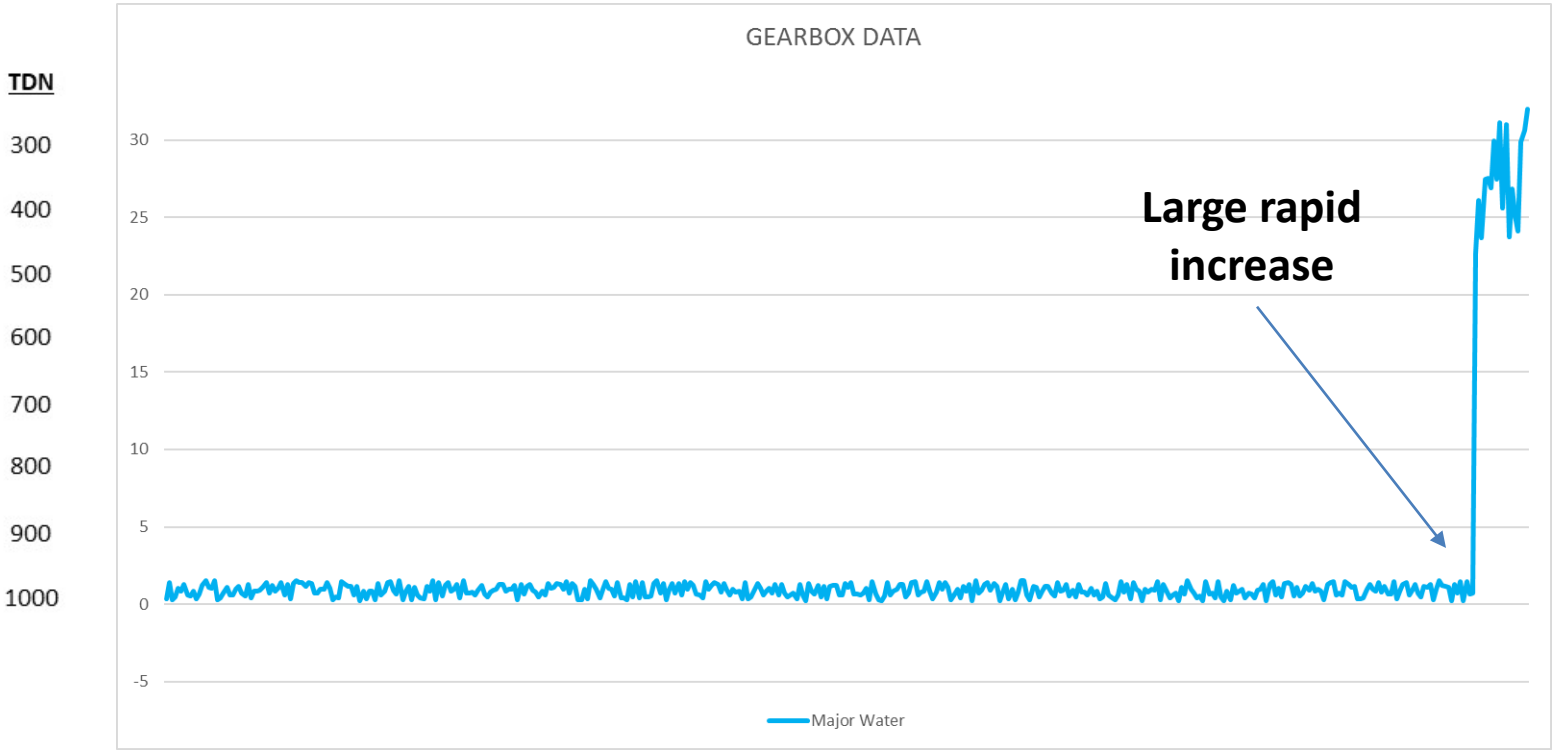
FAILURE MODE – POOR OIL CHANGE



FAILURE MODE – OIL STARVATION/AIR/CAVITATION

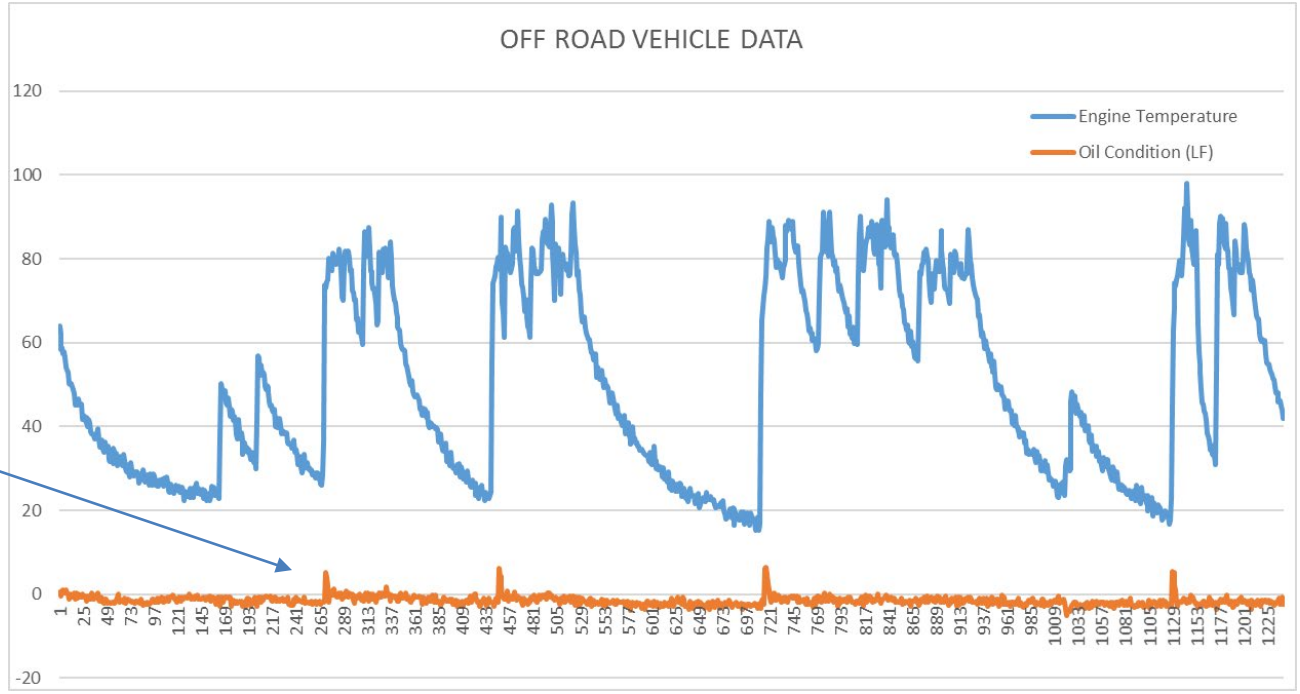


FAILURE MODE – MAJOR WATER INGRESS

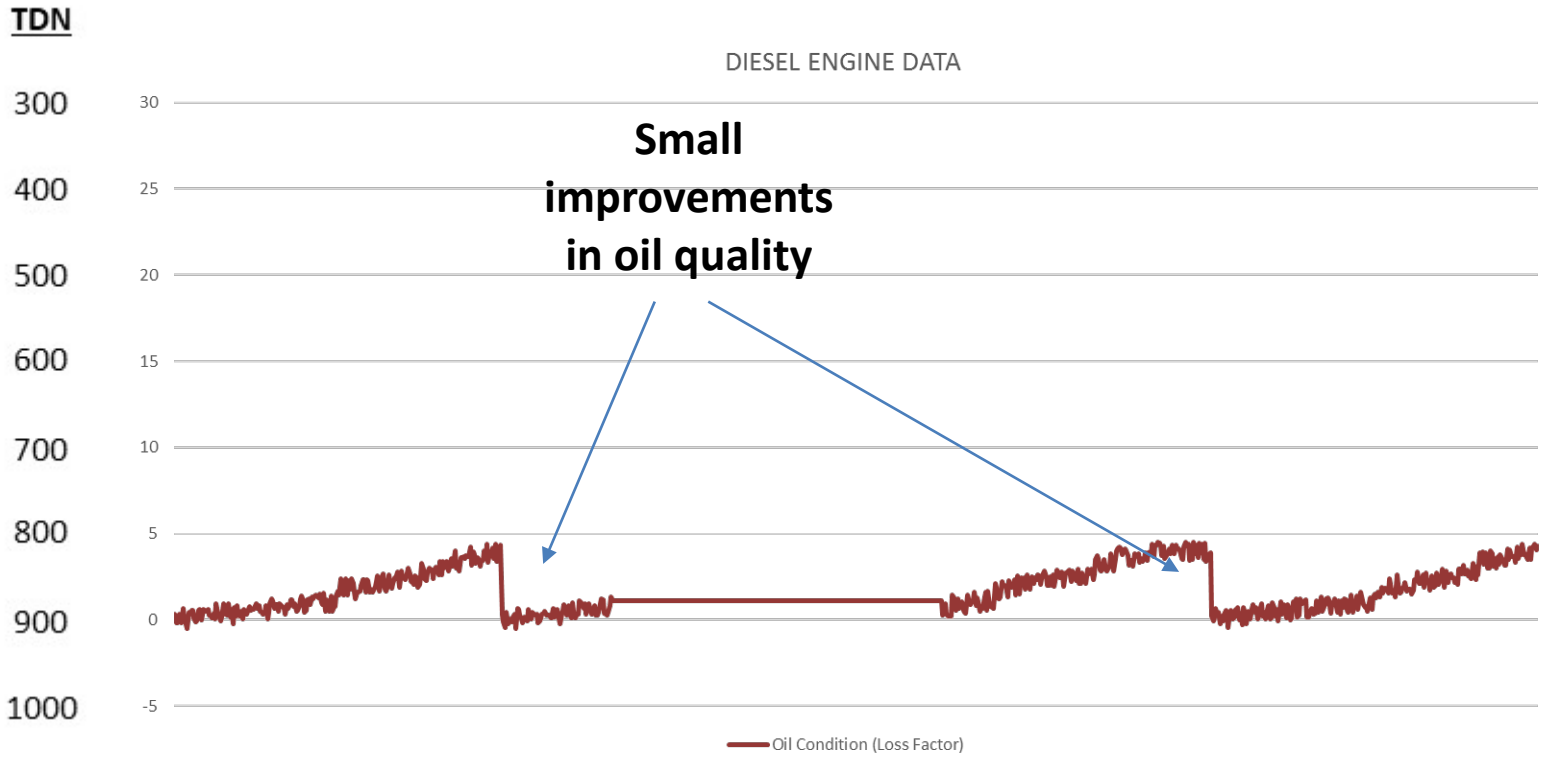


FAILURE MODE – GRADUAL WATER INGRESS

Small spikes at start up then boiled off



FAILURE MODE – TOP UP/FRESHENING

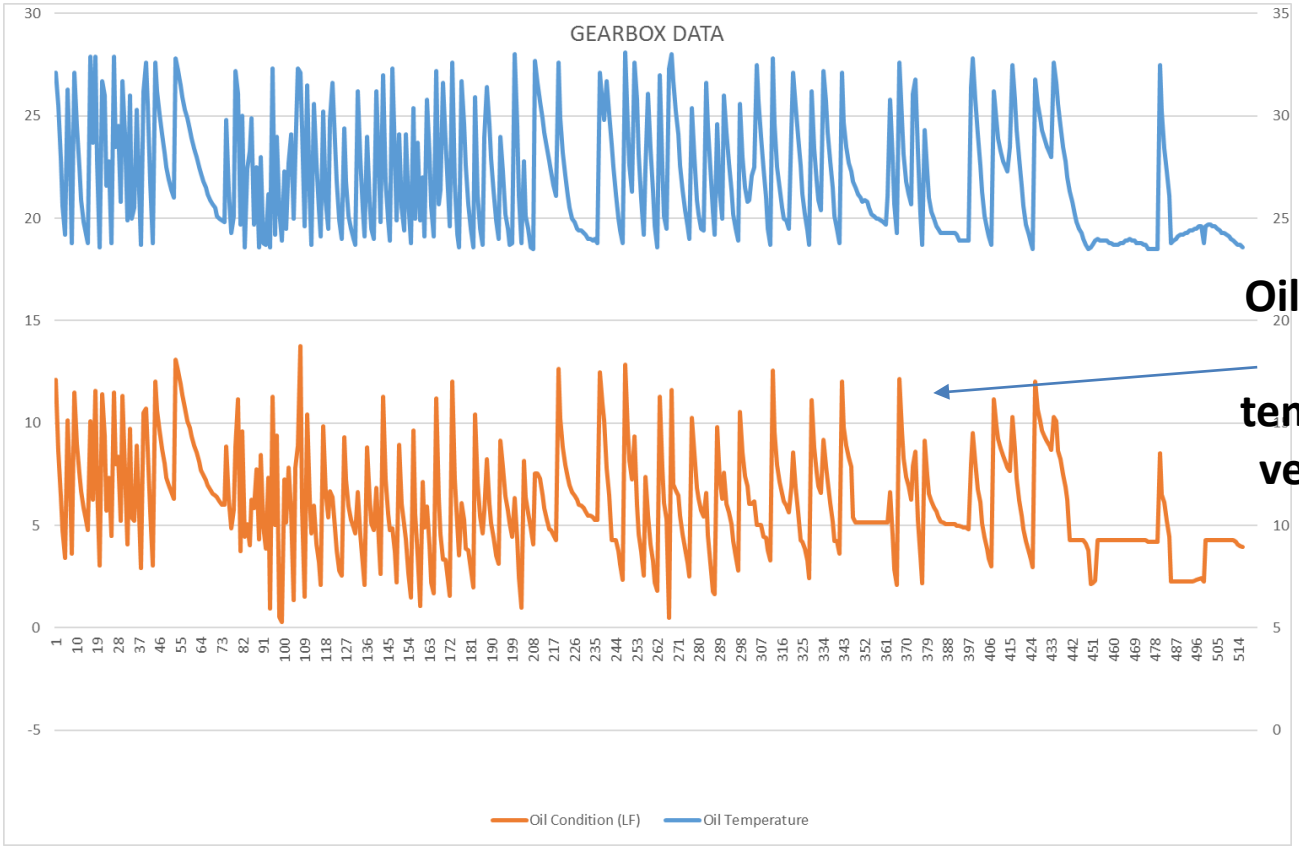


FAILURE MODE – WRONG OIL TYPE

TANDELTA

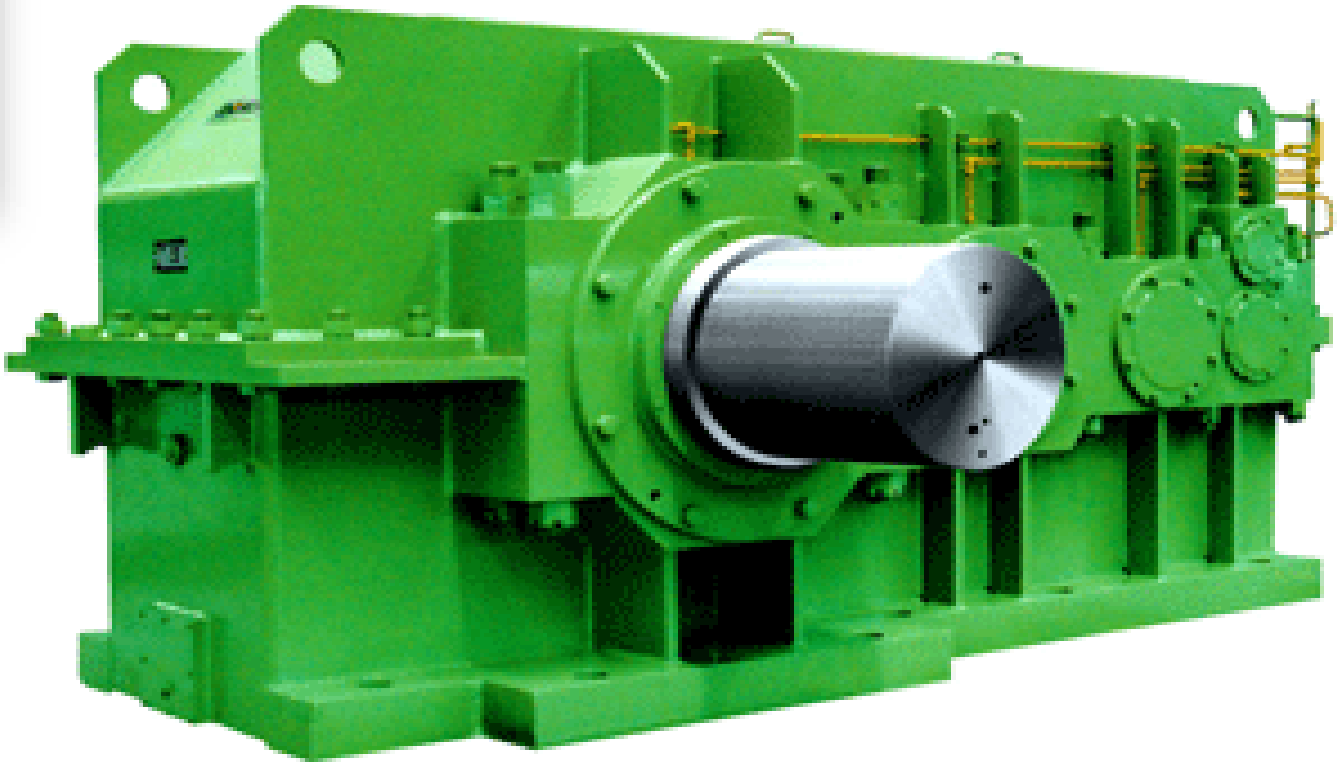
TDN

300
400
500
600
700
800
900
1000

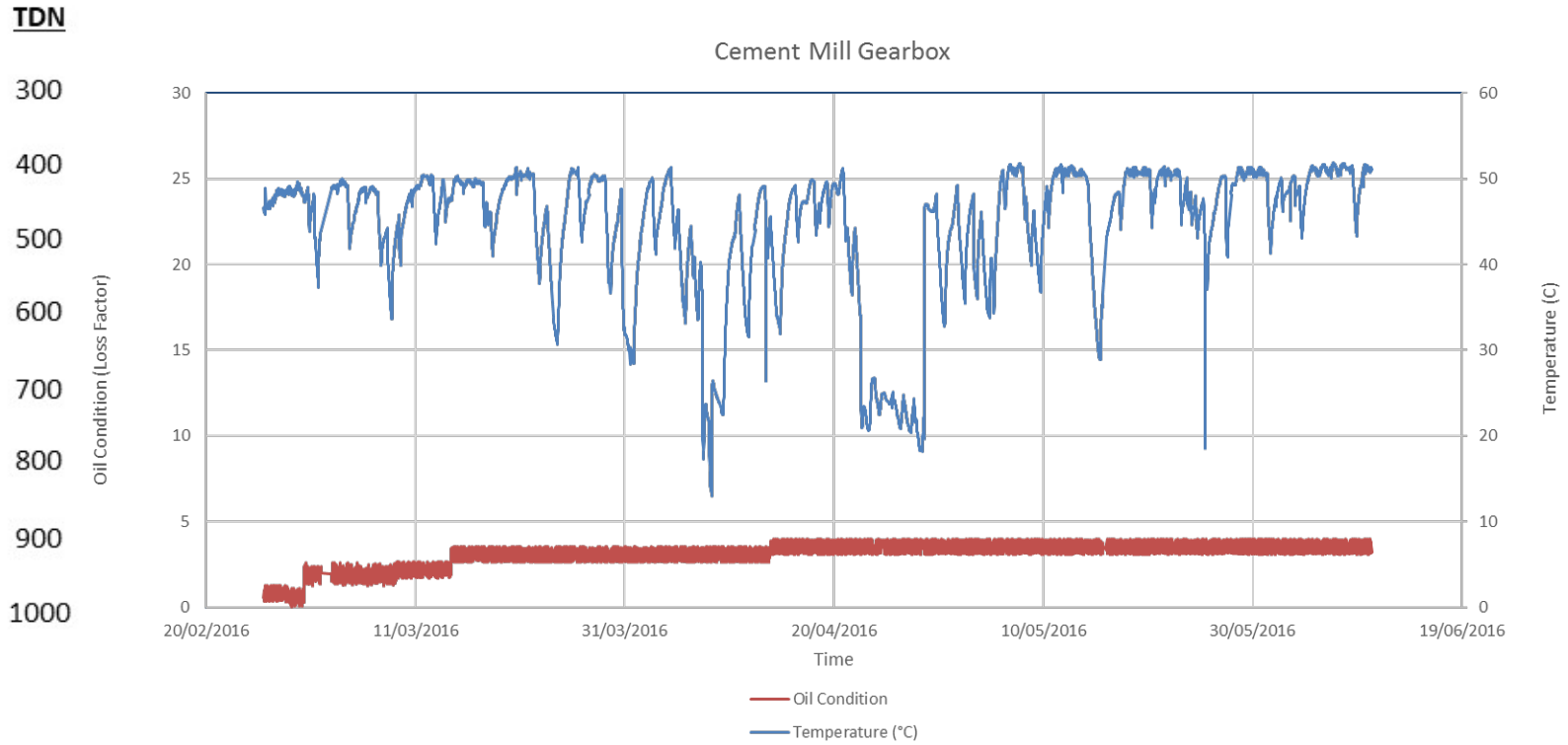


Oil condition follows temperature, very erratic

LIVE EXAMPLES – CEMENT MILL GEARBOX

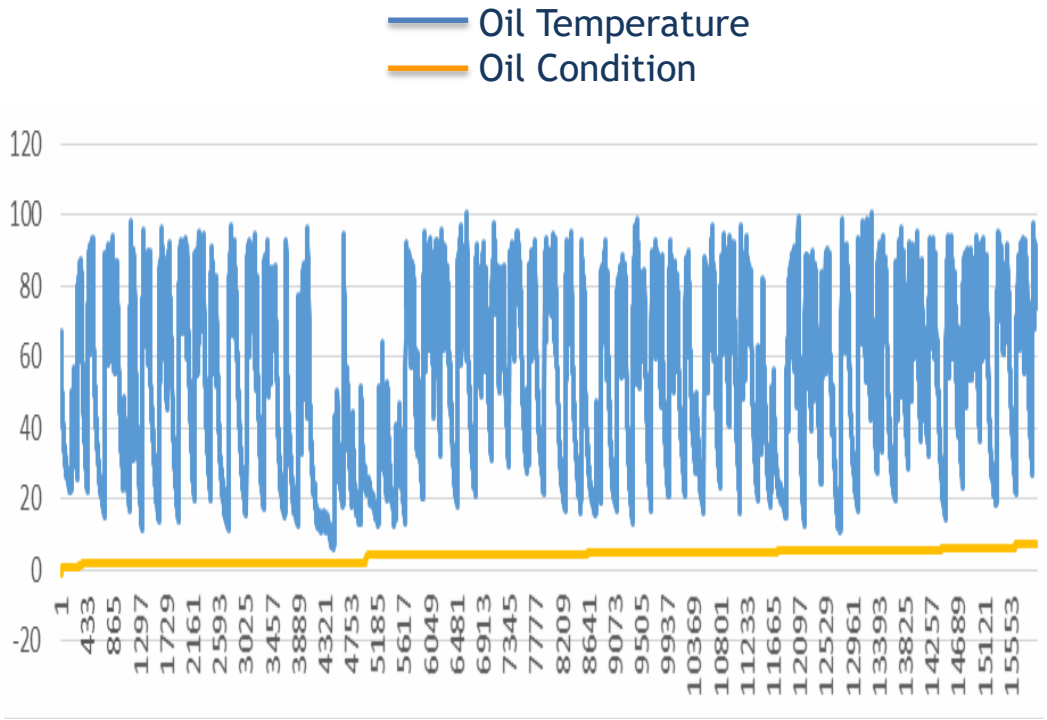


LIVE EXAMPLES – CEMENT MILL GEARBOX



LIVE EXAMPLES – LARGE DUMP TRUCK

LIVE EXAMPLES – LARGE DUMP TRUCK

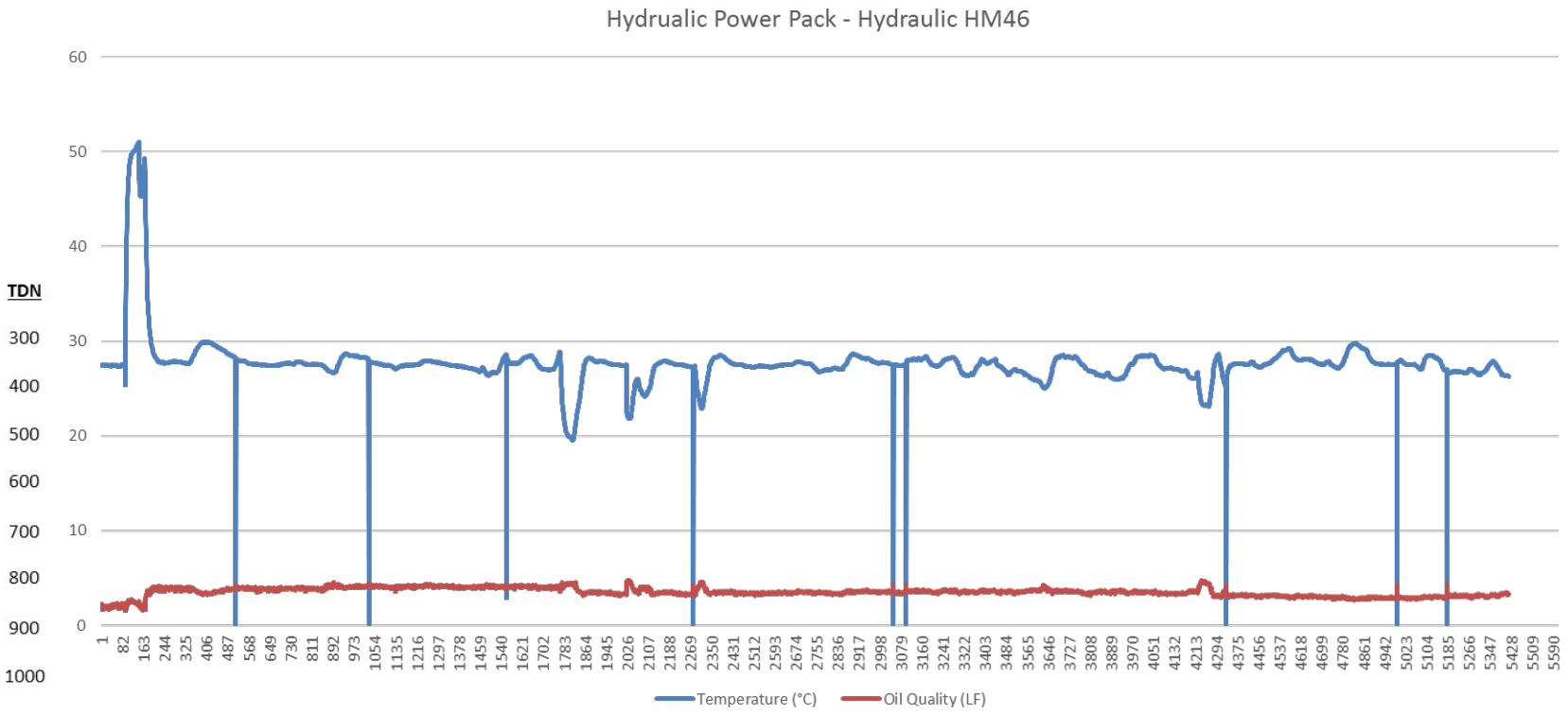


Lab Analysis

Ref Oil	Mobil - Delvac (TAN Delta) - XHP 10W40			
Sample Date	01/05/2014	25/04/2014	10/04/2014	01/04/2014
Sample #	2412106	2410903	2412103	2394003
Lab #	2412106	2410903	2412103	2394003
Analyst	Chris	Chris	Chris	Andrew
Unit Usage - hrs				
Oil Usage - hrs				
Oil Added - gus				
Wear	0	0	0	0
Copper - ppm	0	0	1	6
Iron - ppm	6	5	5	20
Lead - ppm	0	0	0	7
Chromium - ppm	1	1	1	1
Nickel - ppm	0	0	0	0
Aluminum - ppm	2	1	2	10
Tin - ppm	0	1	1	4
FW Idx - Idx	5	4	4	5
Titanium - ppm	0	0	0	0
Contamination	0	0	0	29
Boron - ppm	29	29	31	2
Silicon - ppm	6	7	7	31
Sodium - ppm	5	6	5	4
Water K.Fish - %v	0.000	0.000	0.000	0.000
IR Soot - au	11	11	6	3
Chemistry	0	0	0	0
Molybdenum - ppm	12	13	13	1
Visc 40C - cSt	93.9	95.7	93.8	100.6
Phosphorus - ppm	1,212	1,224	1,213	1,480
Calcium - ppm	2,287	2,348	2,257	2,565
Magnesium - ppm	385	386	384	317
Zinc - ppm	1,311	1,351	1,293	1,558
Barium - ppm	0	0	0	0
Total Acid - koh	2.79	2.78	2.88	
Total Base - koh	9.22	9.23	8.97	9.44
IR Oxidation - n/a	1	3	0	1
IR Sulfation - au	0	1	0	0
IR Nitration - n/a	0	0	0	0

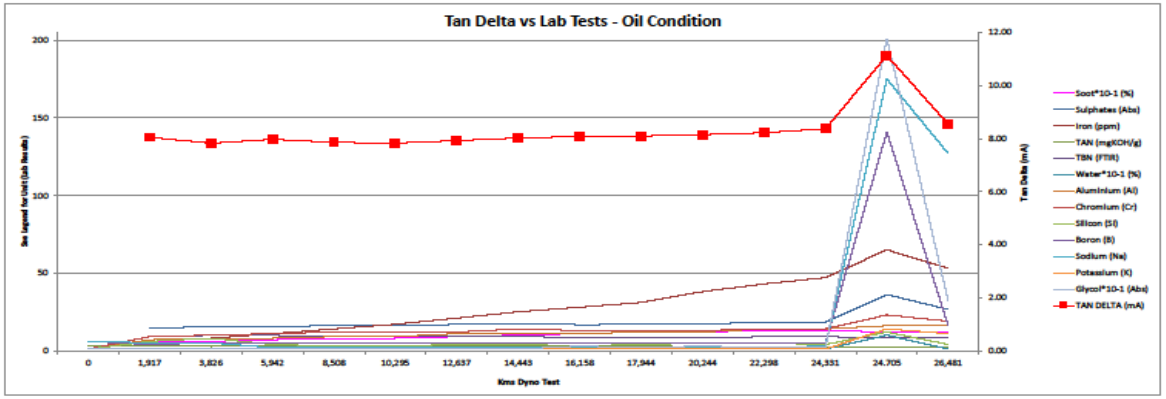
LIVE EXAMPLES – HYDRAULIC POWER PACK

LIVE EXAMPLES – HYDRAULIC POWER PACK



LIVE EXAMPLES – DIESEL GENERATOR SET

LIVE EXAMPLES – DIESEL GENERATOR SET



Lab. Test Result	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12	Sample 13	Sample 14	Sample 15
Soot*10^{-1} (%)		6	6	7	8	8	9	10	11	12	12	13	13	12	12
Sulphates (Abs)		14.2	15.7	15.6	16.1	16.3	16.9	17.2	16.8	16.9	17.3	18.1	18.5	36.1	26.6
Iron (ppm)	1	6	8	11	14	17	21	25	28	31	38	43	47	65	53
TAN (mgKOH/g)	3	3.1	2.7	3	3	3.4	3	3.4	2.8	2.8	2.6	2.4	2.5	2.5	2.7
TBN (FTIR)		8.9	9.9	9.8	9.5	9.6	9.5	9.4	8.2	8.2	8.1	9.1	9	8.2	8.3
Water*10^{-1} (%)	1	1	1	1	1	1	1	1	1	1	1	1	1	10	1
Aluminium (Al)	1	7	8	8	9	9	11	11	11	12	12	14	14	16	16
Chromium (Cr)	1	9	10	11	12	12	12	14	13	13	13	14	14	23	19
Silicon (Si)	1	6	8	4	3	3	4	4	5	4	5	5	4	12	4
Boron (B)	6	4	5	5	5	5	5	5	5	5	5	5	5	141	16
Sodium (Na)	6	5	5	2	2	2	2	2	2	2	2	2	3	175	127
Potassium (K)	1	1	1	1	1	1	1	1	1	1	1	1	1	14	11
Glycol*10^{-1} (Abs)	1	1	1	1	1	1	1	1	3	2	3	2	2	201	32
Condition															

Lab Oil Condition Chart
Abnormal
Severe
Caution
Normal

TAN DELTA (mA)		8.05	7.82	7.97	7.85	7.83	7.92	8.02	8.08	8.10	8.15	8.22	8.37	11.13	8.54
Condition		Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Moderate	Good
KM's Travelled	0	1,917	3,826	5,942	8,508	10,295	12,637	14,443	16,158	17,944	20,244	22,298	24,331	24.705	26,481

Sample 14: Start of second test after a month of engine sitting, water/coolant present in oil
Sample 15: Water evaporated from oil, filter blocked from filtering metals/chemicals from coolant leak

L:\Engineering\2. Product Development\SMART FILTER\Oil Filter\Kangen\Summary - M.R\Oil Lab Test vs Tan Delta Sensor.xlsx

Tan Delta Oil Condition Chart	
Condition	mA value
Maximum	14.75 - 20.00
Severe	14.00 - 14.74
Significant	13.00 - 13.99
Moderate	11.00 - 12.99
Mild	9.00 - 10.99
Good	6.50 - 8.99
Low	6.00 - 6.49
Error/In Air	4.00 - 5.99
Fault	< 4.00

Gradual oil degradation followed by a sudden water ingress of ~1% over a very short period

SUMMARY

- The world's most advanced oil condition monitoring technology
- Exceptional sensitivity and accuracy to any change in oil quality
- Certified and proven worldwide
- Easy to install and use on any oil type and equipment
- Significant measureable financial and operational benefits
- Average investment payback of under 6 months