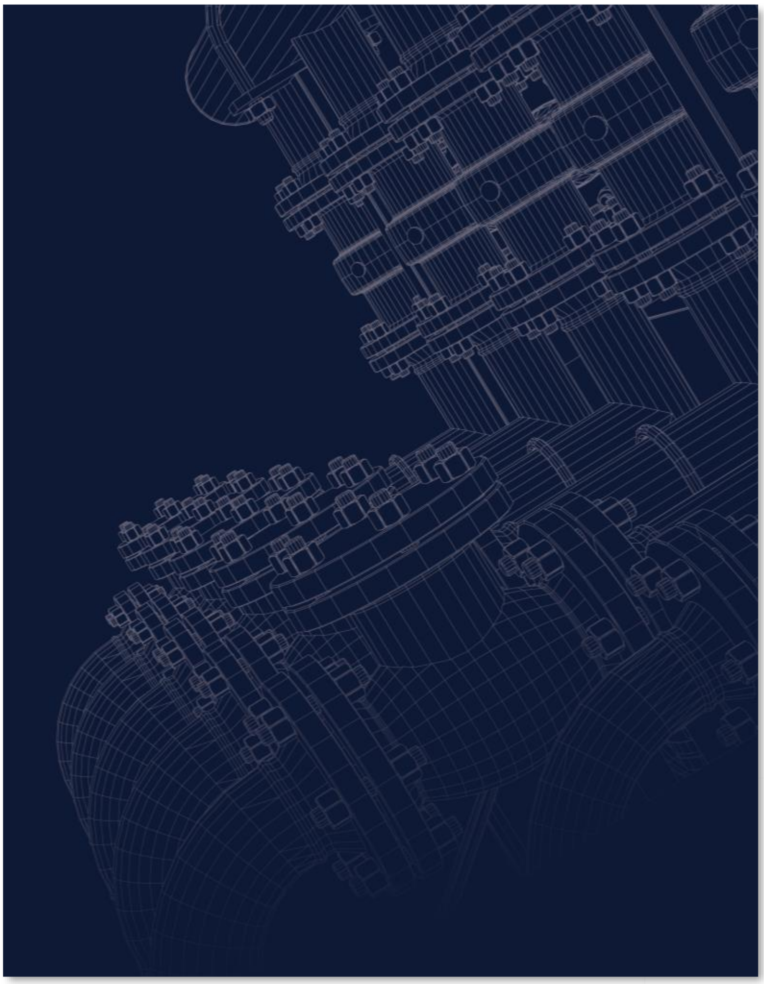

TANDELTA

Oil Condition Monitoring

OIL QUALITY SENSOR & ASSOCIATED ACCESSORIES

USER GUIDE

UG/OQSxG2/23/0025

CONTACT DETAILS

Tan Delta Systems plc
1 Carrera Court
Church Road
Dinnington
Sheffield
UK
S25 2RG

Tel: +44 (0)845 094 8710
support@tandeltasystems.com

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Disclaimer

Read these instructions carefully and look at the equipment to become familiar with the device before trying to install, operate, service, or maintain. Always ensure the correct configuration, installation, and connection of the sensor in accordance with these instructions prior to any use.

The information contained within this manual affects your legal rights, responsibilities, and safety. Failure to read and follow any instructions and warnings contained within this document may result in a serious injury to yourself or others, damage to your Tan Delta Systems product(s), or damage to other objects.

By installing and using your Tan Delta Systems product(s), you are agreeing that you acknowledge and understand this disclaimer and warning.

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AMENDMENT SHEET

Version No.	Amendment	Amended By	Date
2.0	Document re-write	R Vahter	24/10/2022
2.1	Gateway Hub Update	R Vahter	05/12/2022
2.2	Format changes	R Vahter	06/02/2023
2.3	Update to page numbering	R Vahter	10/03/2023
2.4	Update to Display Express	R Vahter	05/06/2023
2.5	General Updates to Display Express & Communications Protocols. Update to Software License.	R Vahter	09/11/2023
2.6	General text updates & update to display express.	R Vahter	01/02/2024
2.7	EX sensor section updates	R Vahter	15/04/2024

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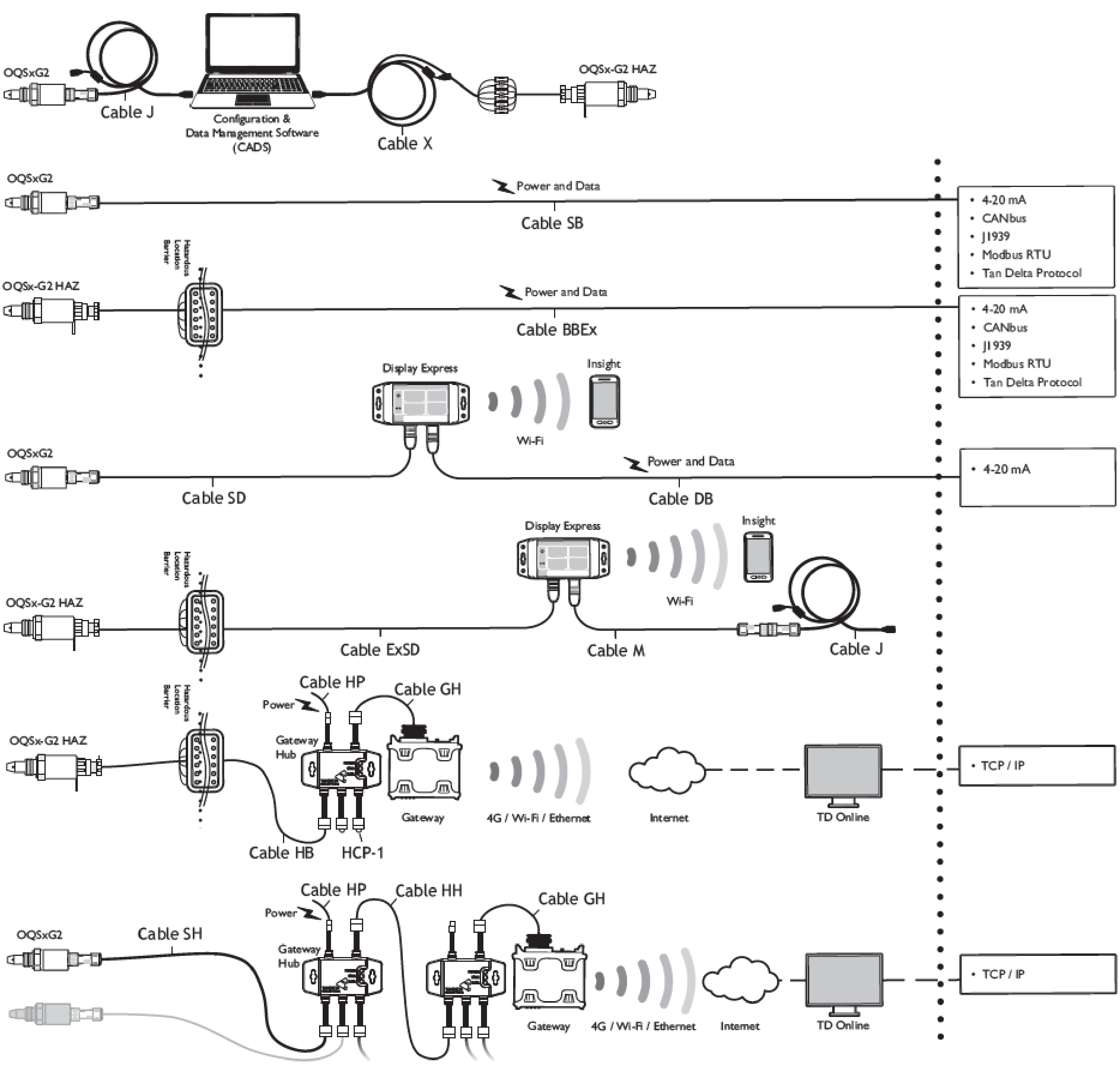
1 Contents

1.1 Figures

2 System Architecture

Tan Delta System Architecture



(Connect multiple Gateway Hubs with a single Gateway)

No of Gateway Hubs	No of Sensors Supported
1	3
2	5
3	7
n	2n + 1

Product Code	New Description	Default Length
Cable J	Configuration Cable	1.9m
Cable X	Ex-Sensor Configuration Cable	1.9m
Cable M	Display to Config Cable	0.3m
Cable HP	Gateway Hub Power Cable	10m
Cable GH	Gateway Hub to Gateway Cable	0.2m
Cable DBXX	Display to Bare Ends Cable	XXm
Cable SDXX	Sensor to Display Cable	XXm
Cable SBXX	Sensor to Bare Ends Cable	XXm
Cable SHXX	Sensor to Gateway Hub Cable	XXm
Cable HHXX	Gateway Hub to Gateway Hub Cable	XXm
Cable HBXX	Gateway Hub to Bare Ends Cable	XXm
Cable ExSDXX	Ex-Sensor to Display Cable	XXm
Cable BBExXX	Bare Ended Ex-Sensor Cable	XXm
HCP-1	Gateway Hub Continuity Plug**	N/A

Key:
XX = Length in metres*

**Standard cable lengths available are 2m, 5m, 10m, 15m, 25m, 50m, 100m. Custom lengths of all cables are available upon request*
***Gateway Hub Continuity Plug must be fitted to unpopulated Sensor Slots*

Figure 1 - System Architecture

3 Accessories

Tan Delta Systems produce and supply a range of accessories and add-ons specifically designed and engineered to work with the Oil Quality Sensor range.

Accessories include the following:

- Oil Condition Display Express
- Oil Condition Telemetry Gateway
- Oil Condition Telemetry Gateway Hub
- Oil Condition Sensor Manifold
- A range of cables and fittings

For details of the full range of available accessories, please contact your distributor.

4 Introduction

The Tan Delta range of Oil Quality Sensors allow real-time reporting of oil quality in virtually any application. The sensor utilises sophisticated electronics to indicate the current condition of oil, relative to an initial profiled condition of new oil.

Based on the sensor output, the oil drain-down intervals may be extended on large industrial equipment where the cost of replacing and monitoring the oil is expensive. The sensor can trigger an investigation into the quality of the oil, preventing the need for expensive routine maintenance.

The Tan Delta Sensors can reduce the overall operating cost of machinery through the removal of routine inspections, waste oil disposal and subsequent renewal.

The Tan Delta range of Oil Quality Sensors are designed to be easy to use in a variety of configurations depending on the monitoring equipment to which you would like to interface. They use a simple connection to connect to a power supply and output the oil condition and temperature on individual 4-20mA current sink outputs. The connection is also provided with additional wires if you would like to use an RS485, CANbus or Modbus interface to connect to an external device or system.

4.1 Important Safety Notes

Please pay attention to the following safety notes:

- **Standard Sensor is not IECEx certified.**
- **Never reassemble, repair or tamper with a sensor.**
- **Ensure that the supply voltage is within the specified range.**
- **Ensure the load currents do not exceed the rated value.**
- **Check all the wiring for correct connection before powering the unit.**
- **Ensure the sensor case is earthed.**

5 Measuring Oil Quality

5.1 Introduction

There are a number of ways to describe oil wear and oil condition:

- Tan Delta Number (TDN)
- Loss Factor Percentage

5.2 Tan Delta Number

To make it easier to monitor and trend the overall oil condition, regardless of your current method, we have introduced the "Tan Delta Number" (TDN). The TDN has been designed to be easy to understand, to give a very good level of accuracy and to create a common language for describing overall oil wear and oil condition, which can also be combined with other methods such as ISO cleanliness levels and laboratory test results.

The full scale goes from 1200 to 0, with the value decreasing as oil quality degrades. For most applications, the useable range is from 1050 to 300.

5.3 Oil Degradation

It is important to understand that oil degradation is exponential and your use of Tan Delta products should reflect this. Once the TDN begins to fall at an increasing rate you know the oil is nearing the end of its life and you need to be vigilant. To help with this, our Display Express has Check, Alert, and OLR functions to alert you to any potential issues.

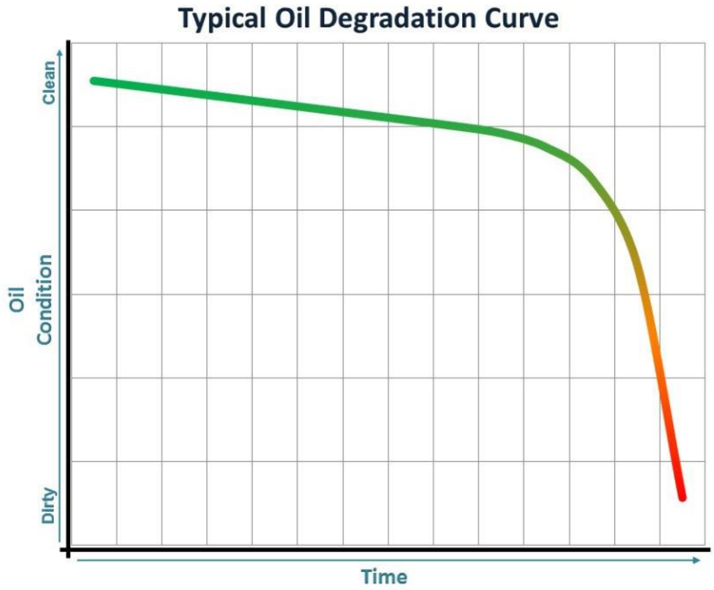


Figure 2 - Typical Oil Degradation Curve

5.4 TDN Value vs Loss Factor Percentage

The underlying value which the sensor is recording for the oil condition is the Loss Factor Percentage which is then converted into a TDN value as shown in **Appendix (Section 14).**

5.5 Traffic Lights

First and foremost, the TDN scale offers a 'traffic light' view of oil quality. There is a Green section, an Amber section and a Red section to illustrate OK, Warning and Alarm conditions respectively. The thresholds for these sections can be user-defined for any application. Factors such as likelihood/nature of contamination, how critical the machinery is and manufacturers' guidelines should all be considered when setting the thresholds. Please contact your distributor or support@tandeltasystems.com for further guidance on setting your warning/alarm levels.

5.6 Numbering/Levels

The TDN scale extends from 1200 down to 0. For most applications, the 'green' section includes all values from 1050 to 420. 'Amber' (warning) will go from 400 to 300: this is the point at which you need to monitor the quality closely and prepare to filter or change the oil. The 'red' (alarm) section applies to values of 300 and below. At this point, the oil needs to be changed as it is no longer providing sufficient lubrication.

5.7 Clean Point (Start Point)

The starting point for a new oil is called the Clean Point. For most oils, this will generally be between 950 and 850 on the TDN scale. The actual value will depend on a number of factors but most importantly how pure the base stock is and what additive packages have been included.

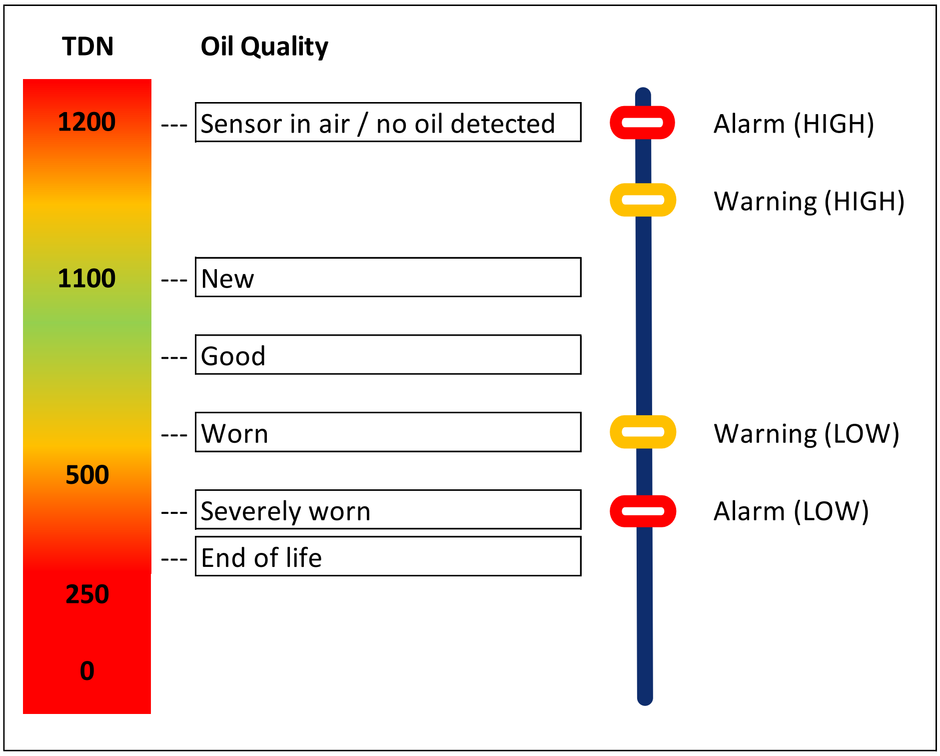


Figure 3- Example of Oil Quality Warnings & Alarms

As the oil begins to deteriorate the value will decrease.

NOTE: TDN does not start at 1000 for a new, clean oil, as some oils can be improved by using sophisticated on-line or off-line filtration. Oil can also improve on the TDN scale, as well as deteriorate.

5.8 Loss Factor

A clean oil has a Loss Factor Percentage of approximately 0% and then as the oil changes and degrades this Loss Factor Percentage increases. For most applications, oil would be considered to be degraded at a Loss Factor Percentage of 25% and at the “end of life” at a Loss Factor Percentage of 30% or above.

TANDELTA

6 OQSxG2 (Standard Sensor)

6.1 Sensor Configuration

Before installation, it is necessary to configure the sensor to your specifications using the Tan Delta Configuration and Data Management Software (CADS). This is a software application, supplied on the USB memory stick, which must be installed on a windows PC or laptop. (Please note the software does not operate on Mac devices or on Chromebook devices.)

6.1.1 Set Up

6.1.1.1 *Install the CADS application onto a PC / Laptop*

To install the software:

- Connect the PC or laptop to the sensor using the configuration cable.
- Connect the memory stick to a USB port on your PC or laptop. Allow the PC/laptop to automatically update drivers, if needed.
- When prompted, select **Open folder** to view files.
- Launch the **setup.exe** file and follow the instructions in the setup wizard.
- When prompted, click on **Install**.
- When installation is complete, CADS is displayed.

It may take up to a minute for the software to identify the OQSxG2.

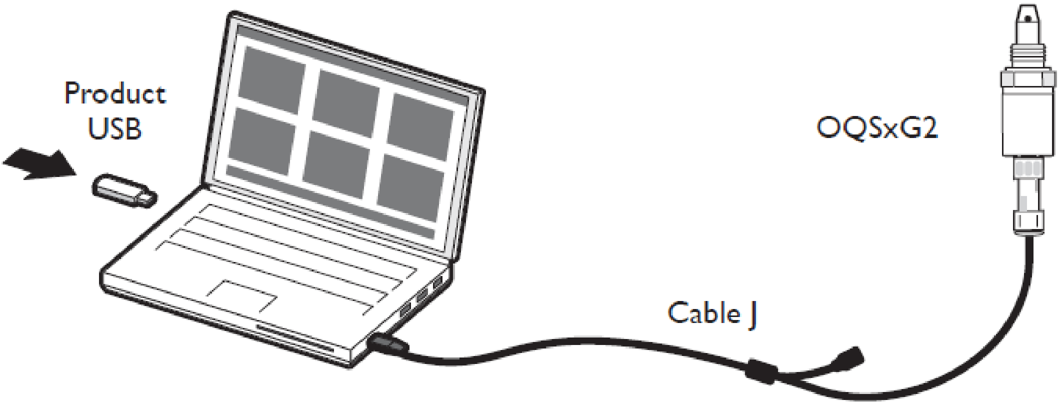


Figure 4 - Setting up a sensor for configuration (Standard sensor shown)

6.1.1.2 *Launch the software*

Launch CADS and wait for the home screen to load.

6.1.1.3 *Connect OQSxG2*

Once the home screen has loaded, select 'Configure Oil Quality Sensor' from the tiles on the home screen. Next connect the OQSxG2 to your computer using the configuration cable (cable J) as shown in **Figure 4.**

NOTE: If sensors are configured to Modbus/CANbus, you must open the software first, and then connect the sensor.

6.1.1.4 *Select sensor*

You will be presented with a list of all connected devices, identified by serial number. Select the required device.

Click the arrow in the top right hand corner to proceed.

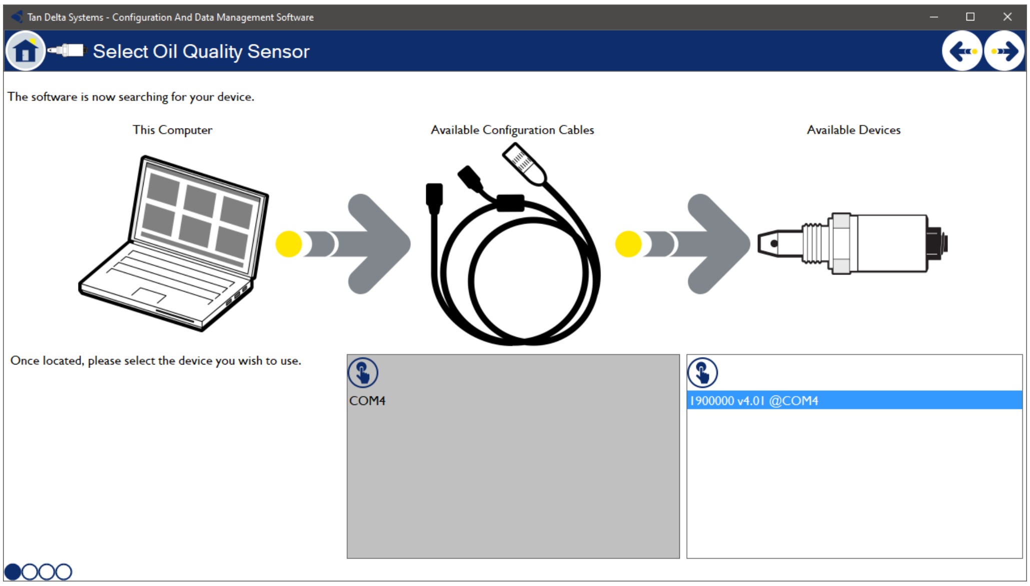


Figure 5 - CADS Search Screen

6.1.1.5 *Communications settings*

This next screen lists the options for the device you wish to connect the sensor to:

- **Oil Quality Display Express** - sets the sensor to use our proprietary RS485 communications protocol.
- **Oil Quality Telemetry Gateway** – This sets the sensor to CANbus for use with our legacy range of gateway devices operating on CANbus. Ensure sensors are uniquely numbered from 1-10. (**NOTE:** The newer versions of the Gateway Device are supplied configured for Modbus and therefore require Custom Communications Settings)
- **Custom Communications Settings** - Allows you to select custom node ID and bit rate for RS485, CANbus, J1939, Modbus.

> - **Note: CANbus Self Starting allows the sensor to power up straight into Operational mode and begin sending Process Data Object (PDO) responses without validation from a CANopen master so the sensor can be used on systems without a full CANopen master.**

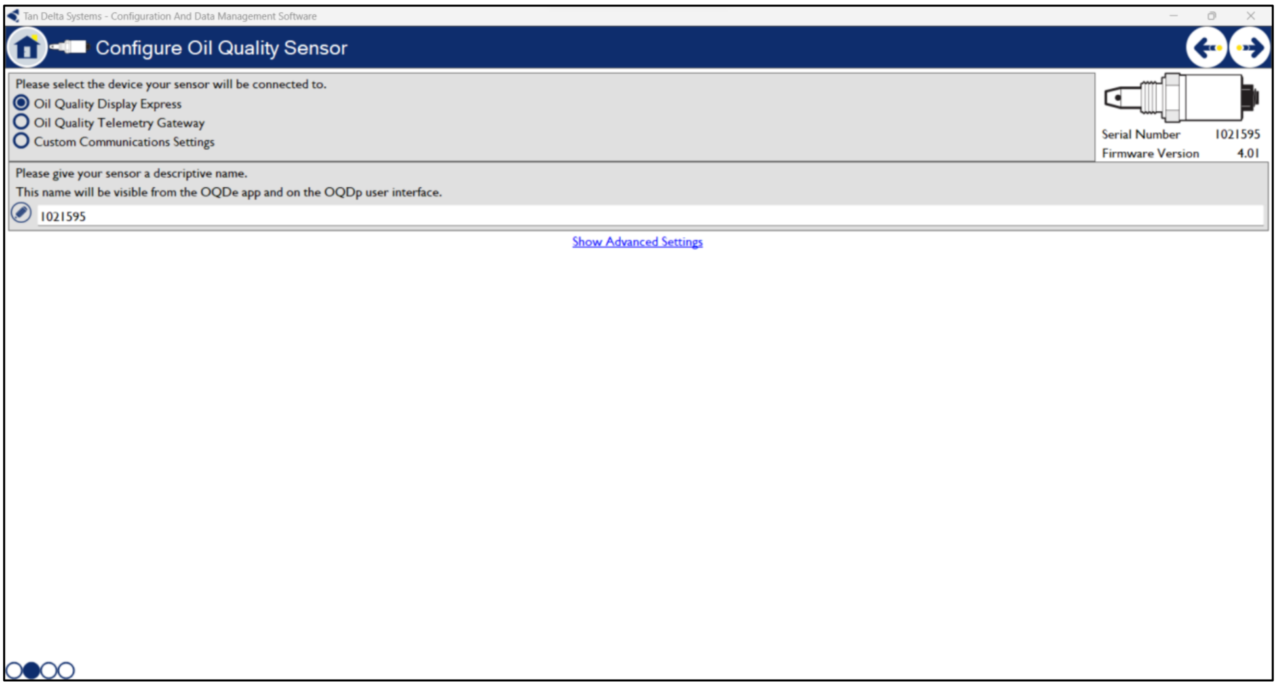


Figure 6 - Communication Options

> **Note: If you are using the sensor with the OQTg, Node ID must be set uniquely to each sensor, numbered 1-16.**

6.1.1.6 *Advanced Settings*

This function uses hysteresis to reduce the noise caused by changes in the oil such as temperature. In order for the algorithms to settle the sensor must go through at least one 'thermal cycle' of the application, this just means running the machine from standby until it reaches its highest normal operating temperature.

We recommend you start with the filter disabled and run the sensor in-situ for a few weeks (definitely over a few thermal cycles of the application). If the data is relatively smooth leave the smoothing disabled, if not, enable the smoothing.

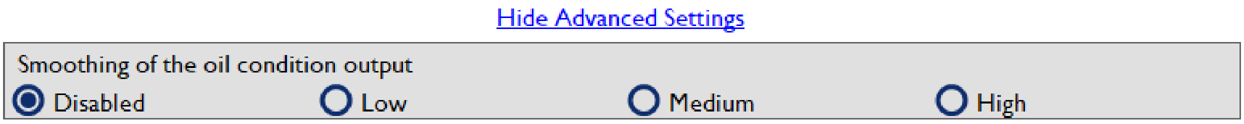


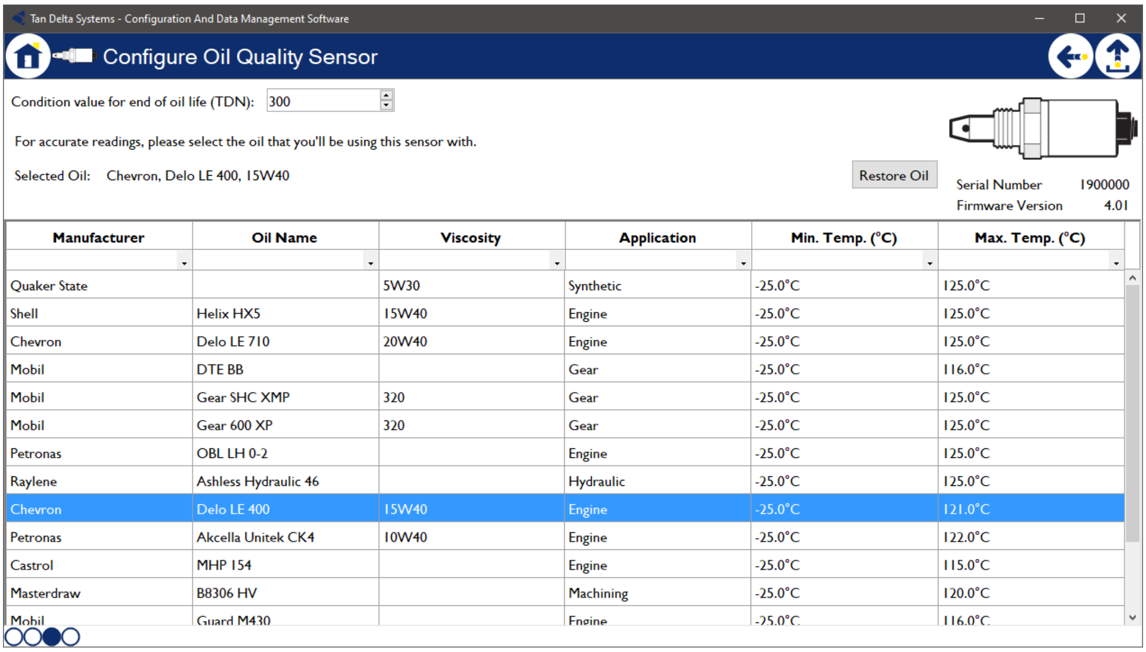
Figure 7 - Advanced Settings

Once your required settings are selected, use the arrow to navigate to the next page.

6.1.1.7 *Oil Configuration*

This page allows you to select any oil from our database. The boxes at the top of each column allow you to either search or filter the database with the drop-down menu or by typing directly into the box.

If the oil you require is not in the database, please contact support@tandeltasystems.com for assistance.



Manufacturer	Oil Name	Viscosity	Application	Min. Temp. (°C)	Max. Temp. (°C)
Quaker State		5W30	Synthetic	-25.0°C	125.0°C
Shell	Helix HX5	15W40	Engine	-25.0°C	125.0°C
Chevron	Delo LE 710	20W40	Engine	-25.0°C	125.0°C
Mobil	DTE BB		Gear	-25.0°C	116.0°C
Mobil	Gear SHC XMP	320	Gear	-25.0°C	125.0°C
Mobil	Gear 600 XP	320	Gear	-25.0°C	125.0°C
Petronas	OBL LH 0-2		Engine	-25.0°C	125.0°C
Raylene	Ashless Hydraulic 46		Hydraulic	-25.0°C	125.0°C
Chevron	Delo LE 400	15W40	Engine	-25.0°C	121.0°C
Petronas	Akcella Unitek CK4	10W40	Engine	-25.0°C	122.0°C
Castrol	MHP 154		Engine	-25.0°C	115.0°C
Masterdraw	B8306 HV		Machining	-25.0°C	120.0°C
Mobil	Guard M430		Engine	-25.0°C	116.0°C

Figure 8 - Oil Selection

6.2 Installation

6.2.1 Precautions

Please read these instructions before installing the oil quality sensor. The sensor has been designed to be robust, however it can be damaged by mistreatment. The following must be noted:

- Install the sensor into the equipment before attempting electrical/wiring connections.
- To avoid thread damage, do not use with taper fittings.
- Tighten with a correctly adjusted size spanner (32mm) and do not over tighten.
- Do not attempt to screw or tighten the sensor using the body. Always use the “Hex” head with the correct size spanner (32mm).
- To prevent vibration having any adverse effects to the cable/sensor connectors, the cable should either be mounted on the same plane at the sensor, or have a loop fitted to absorb vibration, as per diagrams below;

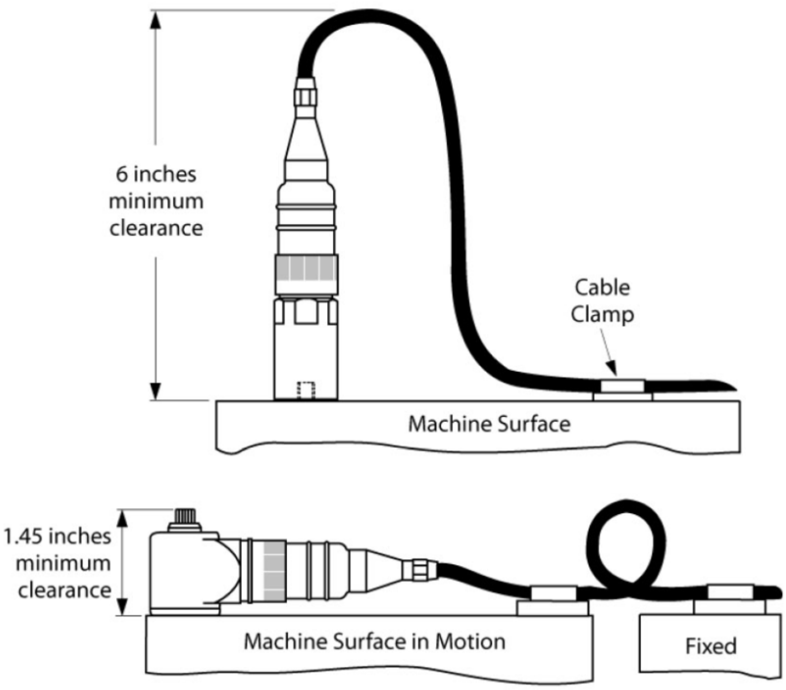


Figure 9 - Cable Fitting

- Do not twist the cable relative to the sensor head.
- Keep away from sharp edges which may cut into the cable.
- Do not bend the cable excessively, minimum bend radius = 50mm (2 inches).
- Where possible, keep the cable away from sources of heat, (such as an engine block), and electrical interfaces.
- Oil pressure should not exceed 70 bar.

6.2.2 Choosing the Sensor Mounting Location

The performance of the sensor will be enhanced through careful consideration of the mounting location. The following guidelines should be followed, See Figure 10:

- Sensor should be in a horizontal position.
- The sensor should not be mounted in the bottom of a sump since the sensor head may become restricted preventing correct operation.
- Dynamic oil flow is necessary; do not mount in places where the oil is likely to stagnate or be static, since the oil in the sensor needs to be representative of the whole system.
- When the oil quality sensor is mounted in a pipeline, please ensure that the sensor will not restrict flow.
- When mounting the oil quality sensor in a lubrication system, for maximum performance, please ensure the sensor is located prior to the oil filters, oil coolers etc. to ensure oil is representative of the whole system.

6.2.3 Fitting Method

- The standard thread is ½ inch BSPP/NPT requiring an 32mm spanner for installation.
- Decide on an appropriate location for sensor head installation.
- Drain the lubricant sufficiently to allow the sensor to be fitted.
- Install the sensor head into the selected location/position, torque to 20Nm being careful not to over tighten.
- Route the cable, fixing (cable ties) at appropriate intervals.
- Avoid sharp edges and hot surfaces.
- Connect the sensor to the chosen interface.

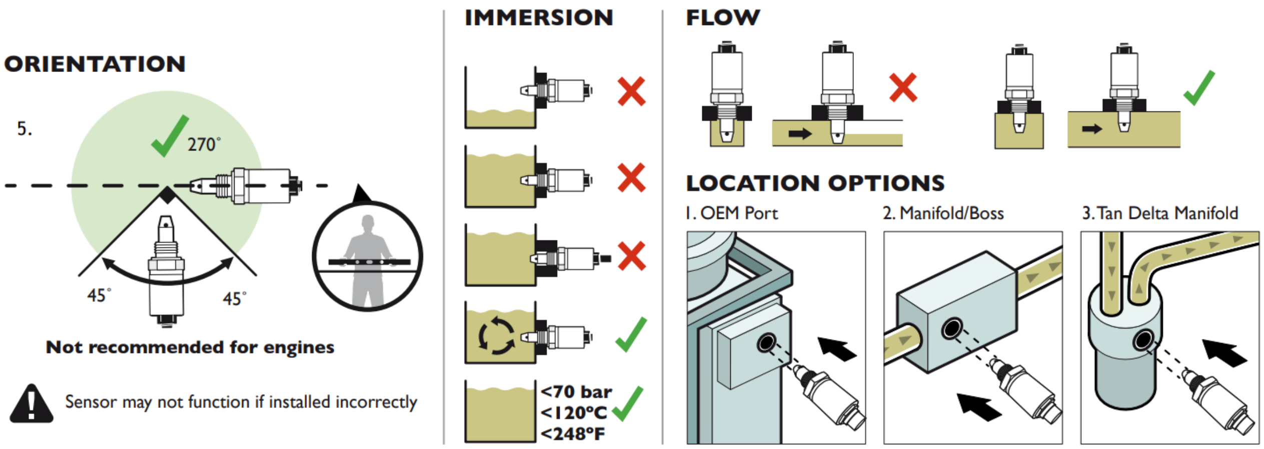


Figure 10 - Installing the Sensor

6.2.4 Electrical Connection

6.2.4.1 *Power Supply*

Connect a suitable power supply (9-30Vdc, at least 100mA) to pins 1&5.

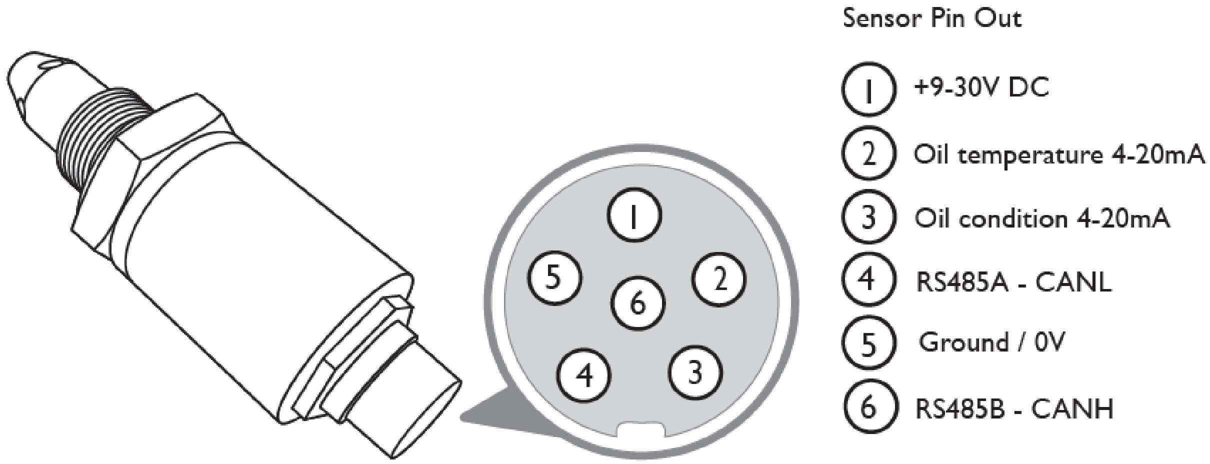


Figure 11 - Pin Outs for Power Supply & Data Output

6.2.4.2 *Connecting to a Tan Delta OQDe*

Connect the OQSxG2 to the left-hand connector. We recommend using a Tan Delta OQSxG2 to OQDe cable (Cable SD – various lengths available). Align and slot in the 6-pin connector and then tighten the connector screw-cap. Please refer to the OQDe section of the manual for further information about OQDe setup and configuration.

6.2.4.3 *Data output*

You can use the output from Pins 5&6 to provide analog indication of the oil temperature and condition on other, third party, data acquisition and control systems.

6.2.4.4 *Using the Oil Condition analog output*

Oil condition is output on Pin 3 and is linearly scaled from 4mA to 20mA. This can easily be converted to the TDN or Loss Factor scale using the table at the Appendix (Section 14). A clean oil should provide an output of about 8mA. For some common applications we recommend the warning/alarm settings in the table below. Any value below 4mA indicates a fault.

	Engine (e.g. Diesel)	Gas Engine	Hydraulic	Compressor	Transmission
High Alarm	5.6mA (1140 TDN)	5.6mA (1140 TDN)	6.4mA (1060 TDN)	6.7mA (1050 TDN)	6mA (1100 TDN)
High Warning	6.4mA (1060 TDN)	6.4mA (1060 TDN)	7mA (1000 TDN)	7mA (1000 TDN)	7mA (1000 TDN)
Condition OK					
Low Warning	13mA (400 TDN)	9.4mA (760 TDN)	9.4mA (760 TDN)	10.5mA (650 TDN)	10mA (700 TDN)
Low Alarm	14mA (300 TDN)	10.4mA (660 TDN)	10.4mA (660 TDN)	11mA (600 TDN)	12mA (500 TDN)

Figure 12 - Generic Warnings / Alarms (Inc 4-20mA)

6.2.4.5 *Using the Oil Temperature analog output*

The analog output on pin 2 provides a linearly scaled measure of Oil Temperature in °C between -30°C (4mA) and +130°C (20mA) – see Appendix (Section 14).

6.3 Cleaning & Maintenance

Please follow this procedure to clean the sensor:

- Clean any excess oil from the end of the sensor with absorbent paper
- Remove the remaining oil by spraying Loctite 7063 cleaner (other low residue cleaners may also be suitable, please refer to your distributor for more information):
    - Into each of the four holes at the end of the sensor.
    - Into the end of the sensor.
    - All over the outside of the tip.
- Remove any excess cleaner, ideally with an airline or with a quick shake of the sensor.
- Blow-dry the end of the sensor using a hot-air gun set to a low temperature (60 to 80°C) for one minute to ensure no solvent or moisture remains. Alternatively leave sensor to air dry for 5 minutes.

NOTE: The sensor does not require cleaning once it has been installed unless the application is particularly high in particulate contamination.

6.4 Physical Dimensions

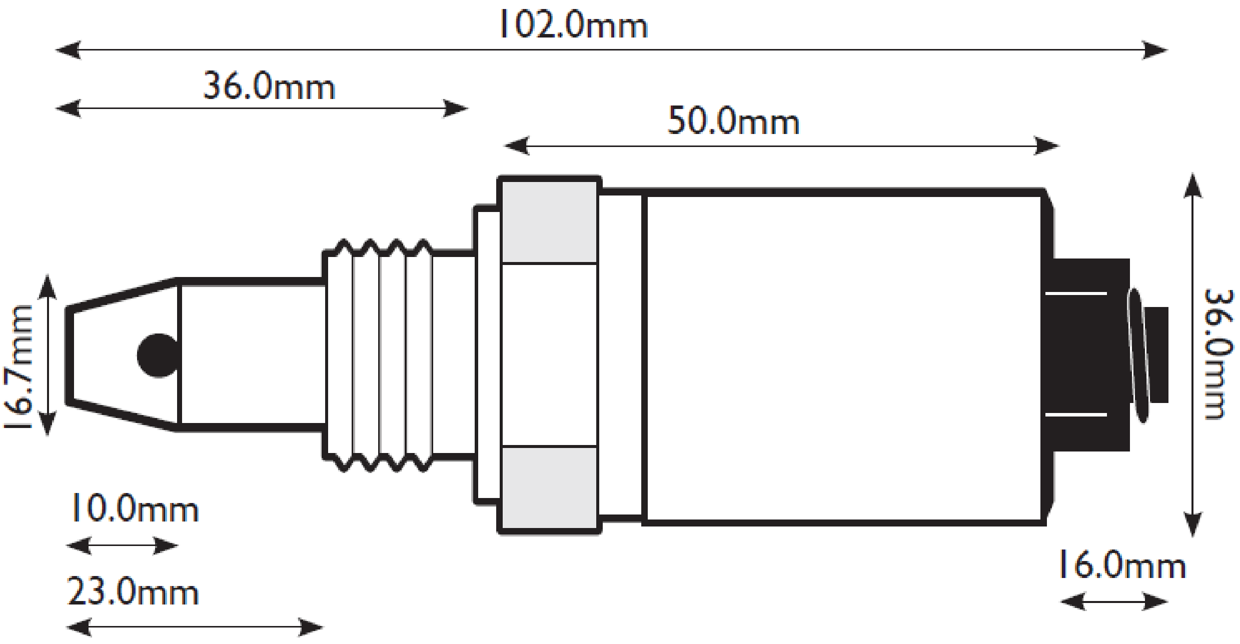


Figure 13 - Physical Dimensions

6.5 Product Specification

6.5.1 Environmental Specifications

Operating Temperature	-40ºC (-40ºF) to +120ºC (+248ºF)
Calibrated Temperature	-20ºC (-4ºF) to +120ºC (+248ºF)
Fluid Temperature	-40ºC (-40ºF) to +120ºC (+248ºF)
Fluid Pressure	up to 70 bar (1015 psi)
Storage Temperature	-55ºC (-67ºF) to +150ºC (+302ºF)

6.5.2 Physical Characteristics

Material	Stainless Steel AISI304
Dimensions	102mm x 36mm (L x W)
Weight	180g
Connection	32mm AF Hex Collar
Torque	25Nm

6.5.3 Available Threads

Thread	***Seal***
1/2" BSPP	Dowty Type
1/2" NPT	n/a
7/8" UNF	'O' Ring
M18	Dowty Type

6.5.4 Connections

Connector	6 pin Bulgin 4000 series

6.5.5 Electrical

Supply	+9-30 V DC
Consumption	0.4w Average

6.5.6 Data Output/Input

Digital Output	RS485, CANbus
Protocols Supported	Modbus, CANopen and J1939
Analog Output	4-20mA

6.5.7 Oil Quality Detection Parameters

Frequency	Every 2 seconds
Output	Tan Delta Number (TDN), Oil Temperature (C or F)
Elements	All wear and contamination
Accuracy	+/- 0.5%

6.5.8 Range and Accuracy

Sensor oil quality normal operating range	-10% to +30% loss factor
Sensor oil quality accuracy/repeatability	+/- 3% loss factor
Sensor temperature normalisation accuracy	Pre V2.4 +/- 3% loss factor Post V2.4 +/- 1.5% loss factor
Sensor oil temperature normal operating range	-20C to +120C
Sensor oil temperature accuracy	+/-3% of full range (+/-4.2°C)
Sensor internal temperature operating range	-20C to +120°C
Sensor internal temperature accuracy	+/-3% of full range (+/-4.2°C)
Sensor 4-20mA accuracy	+/- 1% of full range (+/- 0.2mA)*

6.5.9 Standards and Certification

Water & Dust	IP68 when connected
Shock & Vibration	BS EN 60068-2-30 (Test Db - Cyc. Hum.) BS EN 60068-2-6 (Test Fc - Sine Vib.) BS EN 60068-2-27 (Test Ea -Mech. Shock)
EMC	EN 61000-6-4:2007 (Generic Emissions Standard for Industrial Environments) EN 61000-6-2:2005 (Generic Immunity Standard for Industrial Environments)
Conformity	CE Marked RoHS Compliant

7 EX GEN II ATEX, IECEX, US/C, UKEX Oil Quality Sensor

7.1 Important Safety Notes

Please pay attention to following safety notes:

- **Never reassemble, repair or tamper with the sensor.**
- **Ensure that the supply voltage is within the specified range.**
- **Ensure the load currents do not exceed the rated value.**
- **Ensure explosive atmosphere is not present when connecting/disconnecting the Sensor.**
- **Check all the wiring for correct connection before powering the unit.**
- **Ensure the sensor case is earthed and power connected as detailed below in 1.1.1 Additional Ex notes.**
- **The unterminated end of the integral cable must be terminated in a receptacle meeting an ingress protection rating of IP20.**
- **The equipment must be installed in a manner that any heating from the process connection does not exceed the ambient temperature assigned to the equipment.**

7.2 Additional EX notes:

1) Working Voltage (peak value) must be less than 28.8V d.c., or 24V d.c. + 20%.
2) Sensor must be powered using an IEC / EN 60950-1 compliant power supply, or through a suitable EX barrier (e.g. MTL5522) which is earthed to the Equipotential Bonding System and from a power supply with negligible output series inductance.
3) Any additional interface circuits monitoring the serial outputs or the 4-20mA analogue outputs must be similarly IEC / EN 60950-1 compliant or through a similar EX barrier.
4) The sensor body must be directly screwed into the earthed body of the machine on which it is used, or earthed pipework and fittings in the lubrication system for such machine. Insulating bushes or adaptors must not be used. Ensure the sensor case is earthed using the earthing lug on the sensor connected directly and at a single point to the Equipotential Bonding System.
5) The manufacturer confirms that the verifications necessary to ensure that the electrical equipment complies with the documentation will be carried out. All manufacture is to be carried out using a fully ISO 9001 compliant sub-contractor and full documentation retained for both the manufacture and testing process. Compliance is guaranteed by design for all electronic and mechanical components and by process for the overall manufacture.
6) The equipment is prefabricated with an unterminated integral cable i.e. flying leads which can be provided up to a maximum length of 350m.

7) The equipment should be supplied by an intrinsically safe Power Source for Zone applications, via a 6-core cable carrying a ground connection/conductor, a supply conductor/connection, two (2) 4 - 20mA loop output conductors/connections and two (2) RS485/CAN output conductors/connections. The following tables detail the maximum Terminal Parameters for each cable length option.

Parameter Table 1 (10 m Integral Cable)

V+	4-20mA	RS485/CAN
Ui = 28.8 V	Uo = 28.8 V	Uo = 5.0 V
Ii = 400 mA	Io = 25.40 mA	Io = 120 mA
Pi = 2.20 W	Po = 731.52 mW	Po = 600 mW
Ci = 1.32 nF		
Li = 11.49 µH		

Parameter Table 2 (150 m Integral Cable)

V+	4-20mA	RS485/CAN
Ui = 28.8 V	Uo = 28.8 V	Uo = 5.0 V
Ii = 400 mA	Io = 25.40 mA	Io = 120 mA
Pi = 2.20 W	Po = 731.52 mW	Po = 600 mW
Ci = 19.69 nF		
Li = 172.25 µH		

Parameter Table 3 (350 m Integral Cable)

V+	4-20mA	RS485/CAN
Ui = 28.8 V	Uo = 28.8 V	Uo = 5.0 V
Ii = 400 mA	Io = 25.40 mA	Io = 120 mA
Pi = 2.20 W	Po = 731.52 mW	Po = 600 mW
Ci = 45.94 nF		
Li = 401.91 µH		

Note: All voltages are with respect to Ground.

Where:

- Ui ≥ Uob.
- Ii ≥ Ioc.
- Pi ≥ Pod.
- Ci ≤ Co + Ccable
- Li ≤ Lo + Lcablef.
- Ci and Li on the terminal parameters include capacitance and inductance of integral cable up to a maximum length of 350m.

8) For Class 1, Division 2 applications the equipment should be supplied by a suitably certified Power Source and the non-incendive output parameters do not apply.

The equipment is also intended for use in process temperatures no greater than the stated ambient temperature range of the product.

Any deviation from the above parameters requires input from Tan Delta Systems PLC.

7.3 External Marking on product or in accompanying documentation.

In accompanying documentation:-

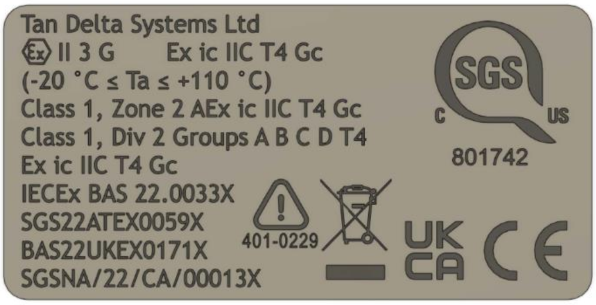
a. Name and address of manufacturer.
   Tan Delta Systems PLC.
   1 Carrera Court,
   Church Lane,
   Dinnington,
   South Yorks.
   S25 2RG
b. Manufacturer's type identification.
c. **OQSx-G2 HAZ Sensor**
d. Serial Number
   nnnnnnn (e.g. 1234567)
e. Certificate Numbers
   SGS22ATEX0059X
   IECEx BAS 22.0033X
   SGSNA/22/CA/00013X
   BAS22UKEX0171X
f. Specific Ex marking
   See Certification Marking Options below:

On Product:-

Certification Markings:

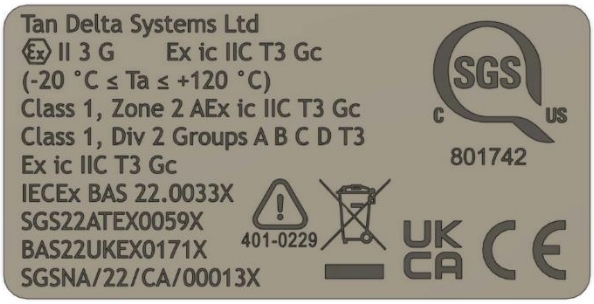
There are 4 options for Certification Markings of this product. These are displayed below. Unless requested otherwise by the customer the default Certification Label will be applied to the product. **<u>It is critical the customer checks which marking refers to their application.</u>**

1.
(DEFAULT)



4.

2.



5.

And elsewhere on Product:-

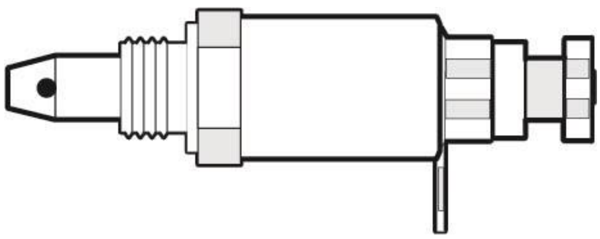
The serial number is applied to the hex of the main sensor body along with a data matrix code which displays the serial number and thread type if scanned.

E.g. S/N 1234567 ½” BSPP

7.4 What's in the box?

When unpacking your OQSExISG2 unit, please ensure that all the following items are present. If any of the items are missing, please contact your dealer or support@tandeltasystems.com.

- OQSExISG2 Oil Quality Sensor
- Configuration cable
- Product USB memory stick
- Quick start guide
- Warranty



OQSExISG2 Oil Quality Sensor

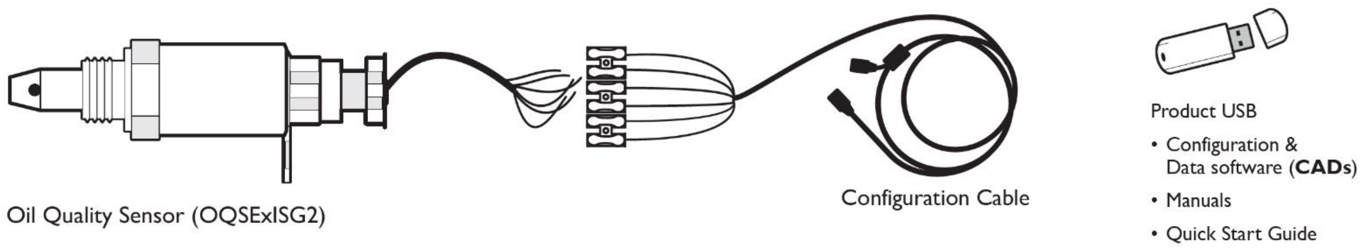


Figure 14 - OQSExISG2 Contents

7.5 Configuration

Before installation, configure the OQSExISG2 to your specifications using the Tan Delta Configuration and Data Management Software (CADS). This is a software application, supplied on the USB memory stick, which must be installed on a PC or laptop. Note that this must be done in the Safe Area, not the Hazardous Area as the Configuration Cable is not EX certified.

7.5.1 Set Up

To connect the OQSExISG2 to the configuration cable, connect the wires as shown in the illustration below:

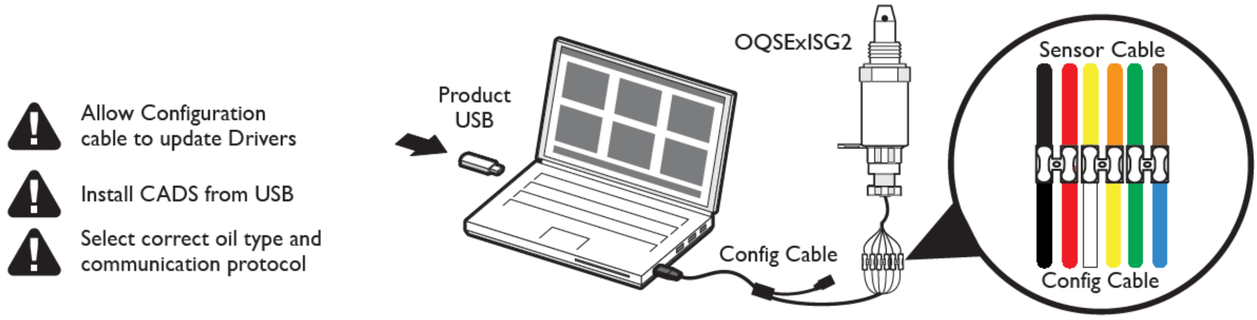


Figure 15 - Setting Up the OQSExISG2 for Configuration

The sensor should be set up using CADS in the same manner as outlined in section 6.1.1.2 of this manual.

7.6 Installation

7.6.1 Precautions

Please read these instructions before installing the oil quality sensor. The sensor has been designed to be robust, however it is liable to be damaged by mistreatment. The following must be noted:

- The sensor must be powered using an EN6950 compliant power supply, or through a suitable EX barrier (e.g. GEORGIN BXNE41200E) which is earthed to the Equipotential Bonding System and from a power supply with negligible output series inductance.
- Any additional interface circuits monitoring the serial outputs or the 4-20mA analogue outputs must be similarly EN6950 compliant or through a similar EX barrier.
- The sensor body must be directly screwed into the earthed body of the machine on which it is used, or earthed pipework and fittings in the lubrication system for such machine. Insulating bushes or adaptors must not be used. Ensure the sensor case is earthed using the earthing lug on the sensor connected directly and at a single point to the Equipotential Bonding System.
- Working Voltage (peak value) must not exceed 28.8V d.c., or 24V d.c. + 20%.
- Install the sensor into the equipment before attempting electrical/wiring connections.
- Tighten with a correctly adjusted size spanner (32mm) and do not over tighten.
- Do not attempt to screw or tighten the sensor using the body. Always use the “Hex” head with the correct size spanner (32mm).
- Do not twist the cable relative to the sensor head.
- Keep away from sharp edges which may cut into the cable.

- Do not bend the cable, minimum bend radius = 66.3mm.
- Where possible, keep the cable away from sources of heat, (such as an engine block), and electrical interfaces.

7.6.2 Choosing the Sensor Mounting Location

The performance of the sensor will be enhanced through careful consideration of the mounting location. The following guidelines should be followed:

- The sensor should not be mounted in the bottom of a sump since the sensor head may become restricted preventing correct operation.
- Dynamic oil flow is necessary; do not mount in places where the oil is likely to stagnate or be static, since the oil in the sensor needs to be representative of the whole system.
- When the oil quality sensor is mounted in a pipeline, please ensure that the sensor will not restrict flow.
- When mounting the oil quality sensor in a lubrication system, for maximum performance, please ensure the sensor is located prior to the oil filters, oil coolers etc. to ensure oil is representative of the whole system.

7.6.3 Fitting Method

- The standard thread is ½ inch BSPP/NPT requiring an 32mm spanner for installation.
- Decide on an appropriate location for sensor head installation.
- Drain the lubricant sufficiently to allow the sensor to be fitted.
- Install the sensor head into the selected location/position, torque to 5Nm being careful not to over tighten. Ensure the integral cable is not twisted excessively during this process.
- Route the cable, fixing (cable ties) at appropriate intervals.
- Avoid sharp edges and hot surfaces.
- Connect the sensor to the chosen interface.

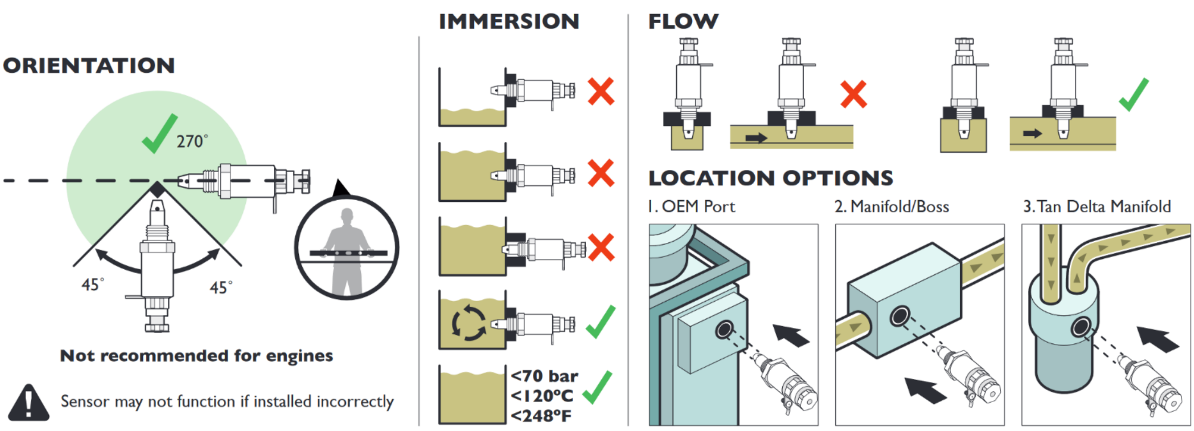


Figure 16 - Installing the Sensor

7.6.4 Electrical Connection

7.6.4.1 *Power Supply*

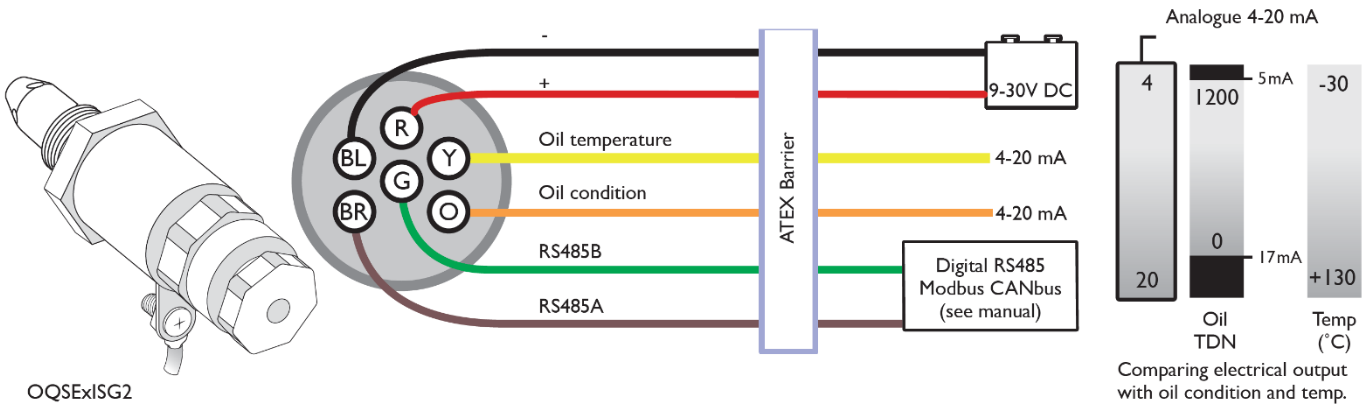


Figure 17 - Wiring Diagram for Power Supply & Data Output (Inc 4-20mA)

7.6.4.2 *Connecting to a Tan Delta OQDe*

NOTE: The OQDe is not EX certified so must be mounted outside the Hazardous Area.

Connect the OQSExISG2 to the left-hand connector of the OQDe. This will require a Tan Delta OQDe Cable ExSD (various length versions available) and suitable EX Zener barrier, which must be earthed to the Equipotential bonding system. Connect the Sensor cable RS485 wires (green, brown and black) via an EX certified Junction Box to a suitable EX isolating or Zener barrier. Connect the safe-area Zener barrier pins to the OQDe Cable ExSD (see OQDe section of this manual for wiring colours). Align and slot in the 6-pin connector to the OQDe and then tighten the connector screw-cap. Please refer to the OQDe section of this manual for further information about OQDe setup and configuration.

7.6.4.3 *Data output*

You can use the output from yellow and orange wires to provide analog indication of the oil temperature and condition on other, third party, data acquisition and control systems.

7.6.4.4 *Using the Oil Condition analog output*

Oil condition is output on the orange wire as a Loss Factor Percentage and is linearly scaled from -20% (4mA) to 60% (20mA). Loss Factor Percentage can easily be converted to the TDN scale using the table in the appendix - section 14. A clean oil should provide an output of about 8mA. For most applications, we recommend setting a warning alert for a value of 13mA and an alarm notification for values over 14mA. Any value below 4mA indicates a fault. This output must be connected via a suitable isolating or Zener barrier if the monitoring equipment is mounted in the safe area.

7.6.4.5 *Using the Oil Temperature analog output*

The analog output on the yellow wire provides a linearly scaled measure of Oil Temperature in °C between -30°C (4mA) and +130°C (20mA) – (See Appendix – Section 14). This output must be connected via a suitable isolating or Zener barrier if the monitoring equipment is mounted in the safe area.

For both analog outputs, in order to avoid excessive power dissipation inside the sensor, ensure that the 4-20mA current sense resistances fitted to the third party monitoring equipment/Zener barrier are greater than the values in the graph as shown below.

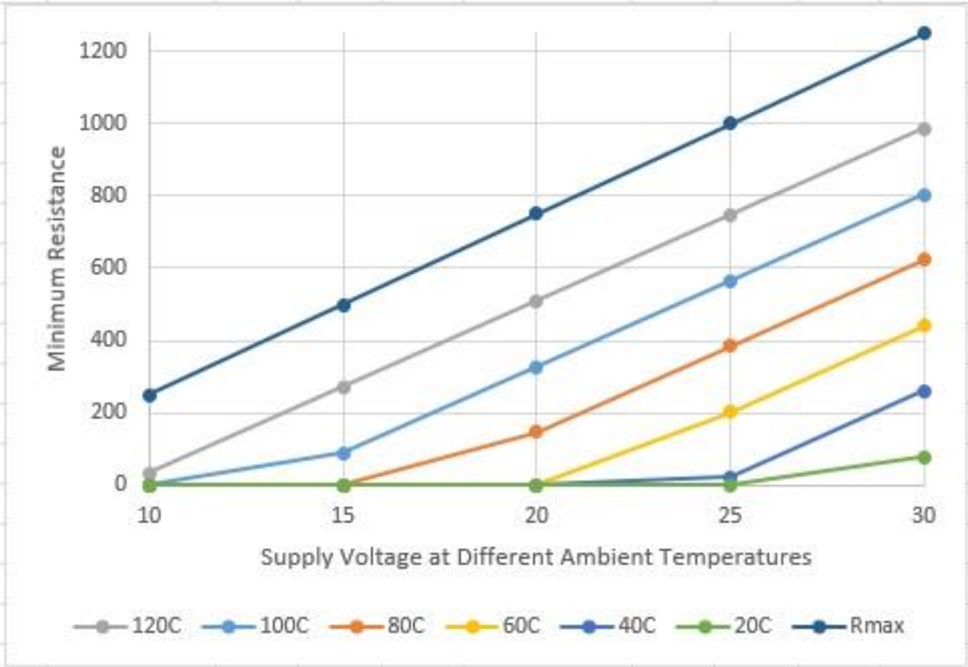
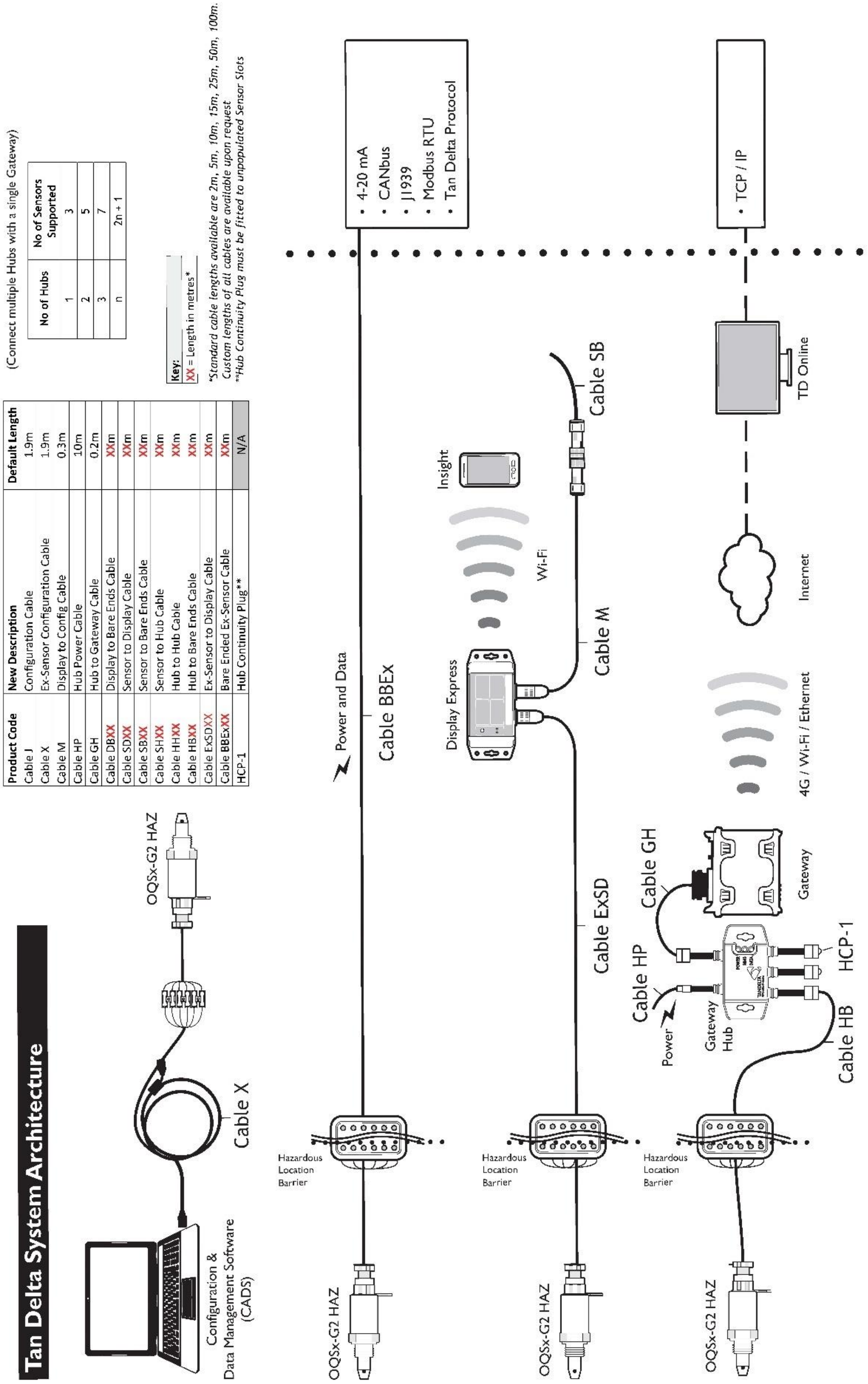


Figure 18 - Current Loop Output Resistance Limitations Graph



Product Code	New Description	Default Length
Cable J	Configuration Cable	1.9m
Cable X	Ex-Sensor Configuration Cable	1.9m
Cable M	Display to Config Cable	0.3m
Cable HP	Hub Power Cable	10m
Cable GH	Hub to Gateway Cable	0.2m
Cable DBXX	Display to Bare Ends Cable	XXm
Cable SDXX	Sensor to Display Cable	XXm
Cable SBXX	Sensor to Bare Ends Cable	XXm
Cable SHXX	Sensor to Hub Cable	XXm
Cable HHXX	Hub to Hub Cable	XXm
Cable HBXX	Hub to Bare Ends Cable	XXm
Cable ExSDXX	Ex-Sensor to Display Cable	XXm
Cable BBExXX	Bare Ended Ex-Sensor Cable	XXm
HCP-1	Hub Continuity Plug**	N/A

(Connect multiple Hubs with a single Gateway)

No of Hubs	No of Sensors Supported
1	3
2	5
3	7
n	2n + 1

Key:
XX = Length in metres*

**Standard cable lengths available are 2m, 5m, 10m, 15m, 25m, 50m, 100m.*
Custom lengths of all cables are available upon request
***Hub Continuity Plug must be fitted to unpopulated Sensor Slots*

Figure 19 - Connection to other Tan Delta and 3rd Party Products / Interfaces

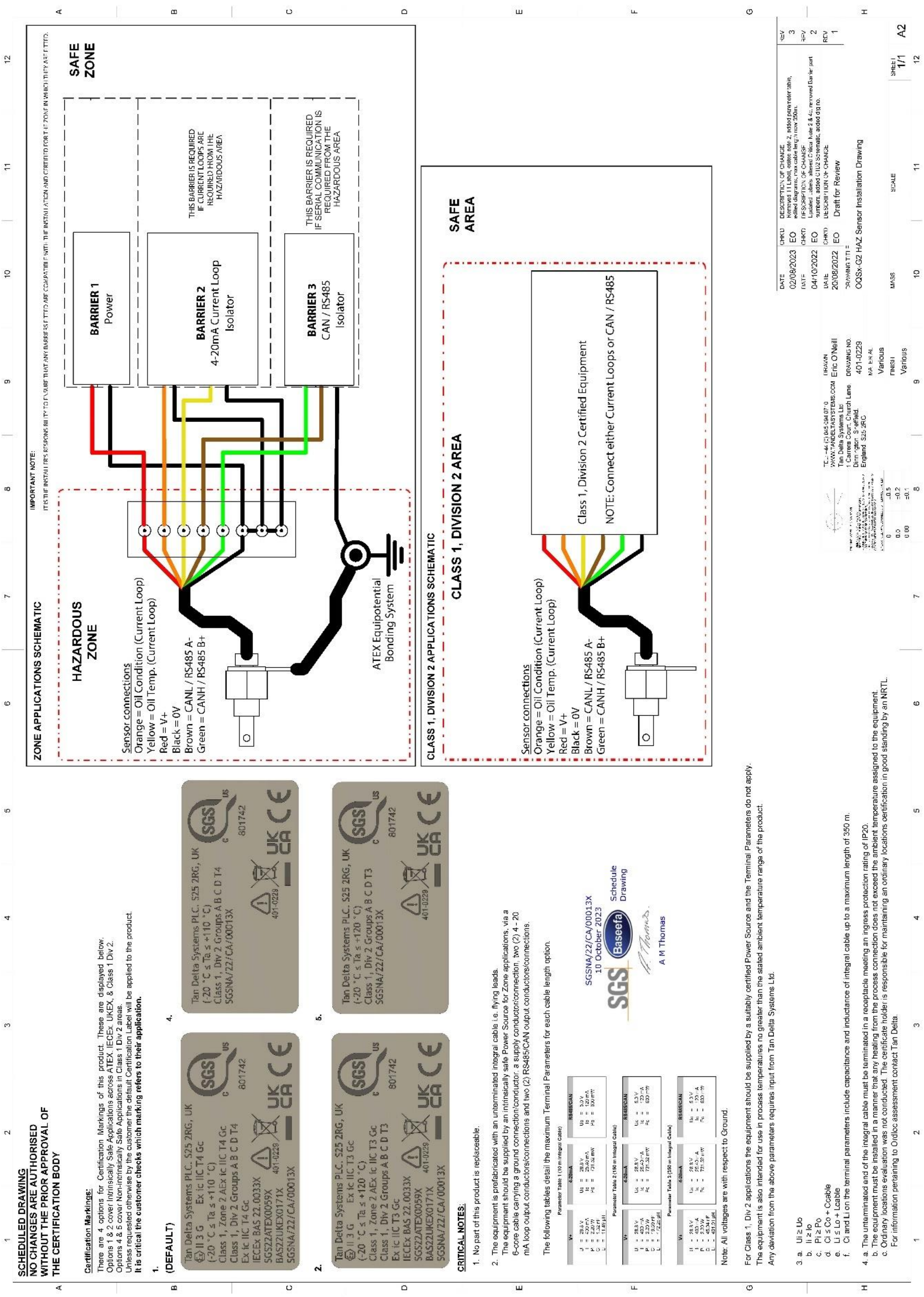


Figure 20 - ExOQSxG2 Ex-Sensor Installation Drawing (Rev 3) STAMPED

7.7 Cleaning & Maintenance

Please follow this procedure to clean the sensor:

- Clean any excess oil from the end of the sensor with absorbent paper
- Remove the remaining oil by spraying Loctite 7063 cleaner (other low residue cleaners may also be suitable, please refer to your dealer for more information):
    - Into each of the four holes at the end of the sensor.
    - Into the end of the sensor.
    - All over the outside of the tip.
- Remove any excess cleaner, ideally with an airline or with a quick shake of the sensor.
- Blow-dry the end of the sensor using a hot-air gun (set to a low temperature (60 to 80°C) for one minute to ensure no solvent or moisture remains. Alternatively leave sensor to air dry for 5 minutes.

NOTE: The sensor does not require cleaning once it has been installed unless the application is particularly high in particulate contamination.

7.8 Physical Dimensions

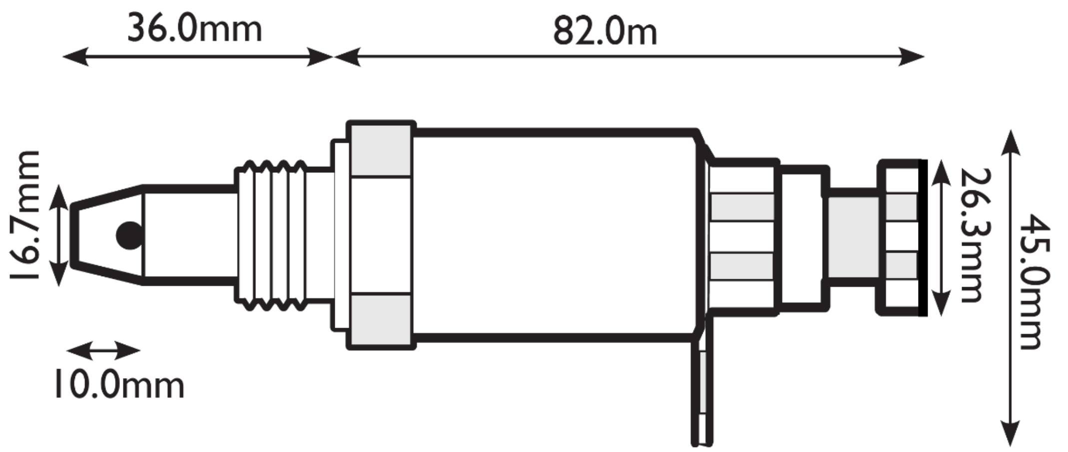


Figure 21 - EX Sensor Physical Dimensions

Notes:

- Overall cable length: 10m (nominal), 350m (Max)
- Strip & tin:5mm
- Strip back sheath: 50mm
- The M6 lug must be connected by 4sq.mm minimum earth cable to the equipotential bonding system

7.9 Product Specification

7.9.1 Environmental Specifications

Protection Rating	IP68
Operating Temperature	-20C to +120C
Fluid Temperature	-20C to +120C
External Pressure	0 bar to 20 bar
Fluid Pressure	Up to 70 bar

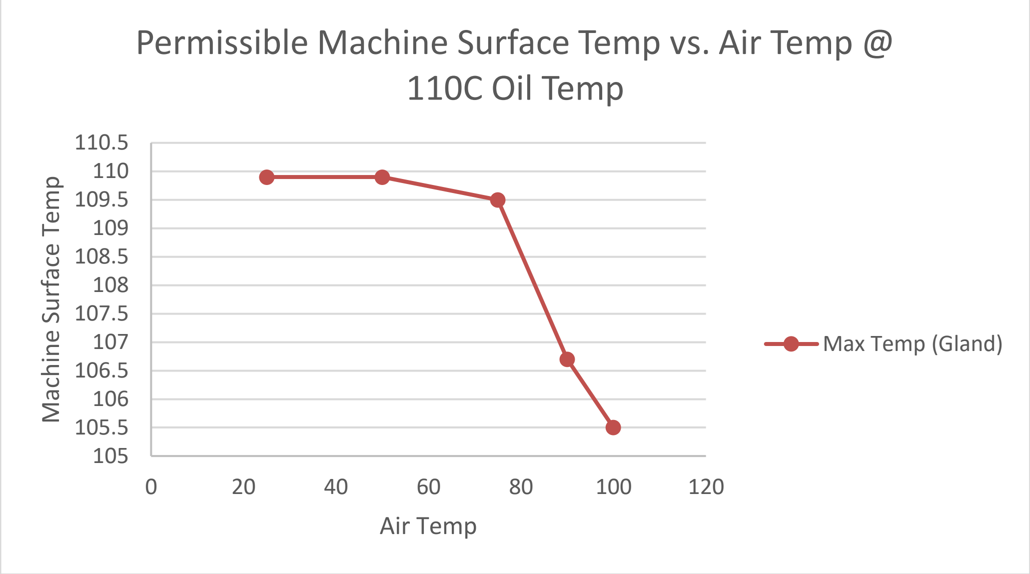


Figure 22 - Temperature Graph

7.9.2 Physical Characteristics

Material	Stainless Steel AISI304
Dimensions	118mm x 45mm
Weight	160g
Thread	½" BSPP/½" NPT/$^{7}/_{8}$" UNF, M18 all use Spanner size 32mm Hex
Seal	DOWTY Seal for BSPP & M18, no seal for NPT, O-ring for UNF

7.9.3 Connectivity

General	Glanded cable entry to integral cable for termination inside EX junction box

7.9.4 Electrical

Power Supply	10-28.8V DC
Power Consumption	Average 0.4w continuous 30mA

7.9.5 Data Output/Input

Analogue Output	2 x 4-20mA (current sourcing, active output)
Digital Output	1 x RS485:9600 baud half duplex Modbus RTU protocol supported on RS485 CANopen protocol supported on CANbus J1939 protocol supported on CANbus

7.9.6 Range and Accuracy

Sensor oil quality normal operating range	-10% to +30% loss factor
Sensor oil quality accuracy/repeatability	+/- 3% loss factor
Sensor temperature normalisation accuracy	Pre V2.4 +/- 3% loss factor Post V2.4 +/- 1.5% loss factor
Sensor oil temperature normal operating range	-20C to +120C
Sensor oil temperature accuracy	+/-3% of full range (+/-4.2°C)
Sensor internal temperature operating range	-20C to +120°C
Sensor internal temperature accuracy	+/-3% of full range (+/-4.2°C)
Sensor 4-20mA accuracy	+/- 1% of full range (+/- 0.2mA)*

7.9.7 Standards and Approvals

CE marked:

- BS EN 60529:1992+A2:2013 IP68 Dust and Water Ingress.
- BS EN 60068-2-30:2005 Cyclic Humidity.
- BS EN 60068-2-6:2008 Sine Vibration.
- BS EN 60068-2-27:2009 Mechanical Shock.
- EN 61000-6-4:2007 Generic Emissions Standard for Industrial Environments.
- EN 61000-6-2:2005 Generic Immunity Standard for Industrial Environments.
- EX approval to BS EN 60079-0: 2018 and BS EN 60079-11:2012

8 Display Express

8.1 Introduction

The Tan Delta Oil Quality Display Express (OQDe) is a display unit for use with a Tan Delta Oil Quality Sensor (OQSxG2).

Figure 23 - OQDe Top View

The OQDe displays, in real-time:

- **Condition**
  Translating the OQSxG2 output into a Tan Delta Number (TDN), or Loss Factor (%). In addition to this, a red/flashing red/green LED system.
  Oil Status LED shows the oil condition. The LED color changes based on default values provided by Tan Delta, or your own custom threshold values: a green color indicates oil quality is OK, red indicates a Check condition and flashing red shows an Alert condition.
- **Temperature**
  Configurable to °C or F.
- **Oil Life Remaining (Days)**
  Shows the calculated number of days oil life remaining based on current oil condition.
- **Event Code**
  An Event Code is displayed to allow you to identify events or issues affecting the oil condition or the equipment. Most Event Codes coincide with either a Check or Alert LED.

NOTE - The Oil Status LED shows the 'worst' state of all read-outs. For example, if oil temperature has hit a Warning/Check level and oil condition is at an Alert threshold, the Oil Status LED will be flashing red to show that an Alert condition has been reached.

8.1.1 Interfaces

The OQDe has two data interfaces:

- RS485 (proprietary protocol) - Connects the OQDe to an OQSxG2 sensor and a PC.
- Wi-Fi - Connects the OQDe to any Wi-Fi enabled device (e.g. PC, Tablet, Mobile Device etc…) through Insight web page. The default Wi-Fi Hotspot IP address is **"192.168.4.1"**. This can also be accessed using the QR code on the label on the unit (Figure 22). The OQDe can also be connected to a local wireless network.

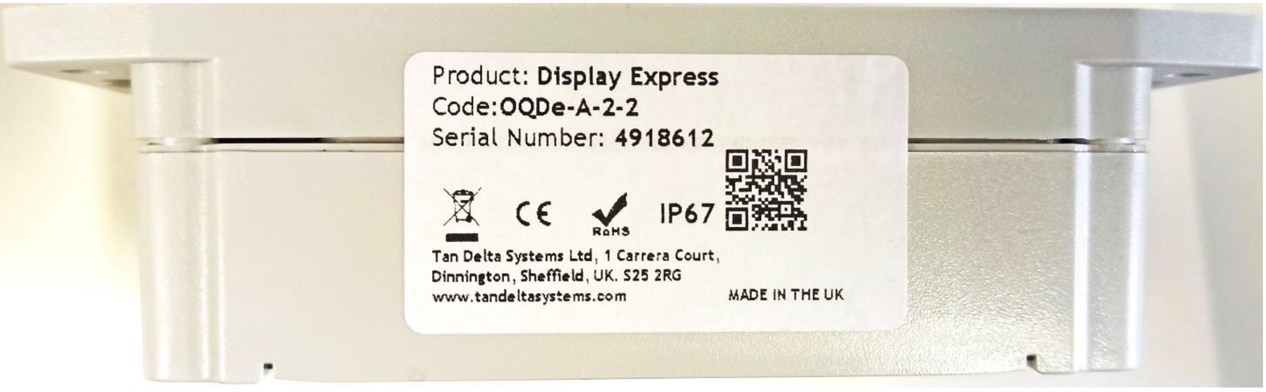


Figure 24 - Product Label with QR-Code

8.1.2 Analog outputs

The dual 4-20mA outputs from the OQSxG2 for oil quality and oil temperature are looped through the OQDe where they can be used separately to provide analog indication of the oil temperature and condition.

8.2 Configuration

The OQDe can be configured using either the Insight application or by using CADS on a windows PC. Configuration using Insight ca be done wirelessly when the display is installed. Configuration using CADS is done using a wired connection and can be done when the display is installed or with the display on the desk.

NOTE - You MUST configure the OQSxG2 Sensor for use with the OQDe *before* configuring the OQDe. This is done in CADS. See Section 6.1 of this User Guide for more information.

8.2.1 Connecting OQDe to Insight.

Insight is a web-based application allowing configuration of the OQDe and access to live and historic data, which can be downloaded via Wi-Fi. To connect to Insight, first power up the OQDe using the power & data cable (Cable M & Cable) or alternatively by connecting it to a Laptop or PC using Cable J and Cable M as shown in Figure 25. The device will power on automatically and the Power LED will illuminate green. Within a few seconds, the Wi-Fi Hotspot will start broadcasting and the Wi-Fi LED will also illuminate blue. You can now connect to the OQDe using Wi-Fi via any PC, Tablet or Mobile Device. Simply search for nearby devices. The default SSID of the OQDe is **"TanDelta OQDe"** and password is **"password"**. This will create a local network between the device and the display.

Once connected, use your preferred Internet Browser, and navigate to the IP address **"192.168.4.1"** which takes you to the web-based Insight application.

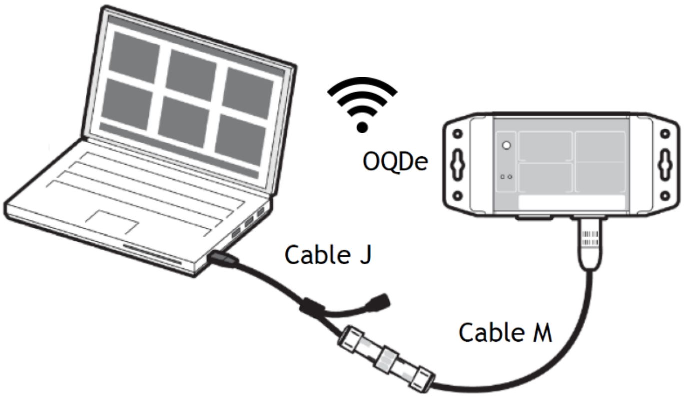


Figure 25 - Connecting to the OQDe via Wi-Fi Hotspot

8.2.2 Navigating Insight

On the top navigation bar, you can navigate to the different screens within Insight (Status, Data Log, Settings), and also change the units of Oil Temperature displayed on Insight (˚C or ˚F) and Oil Condition (TDN or %LF).

8.2.2.1 Status Screen

The first screen you will be presented with on Insight is the Status screen as shown in Figure 26. Each box displays different information regarding the state of the OQDe.

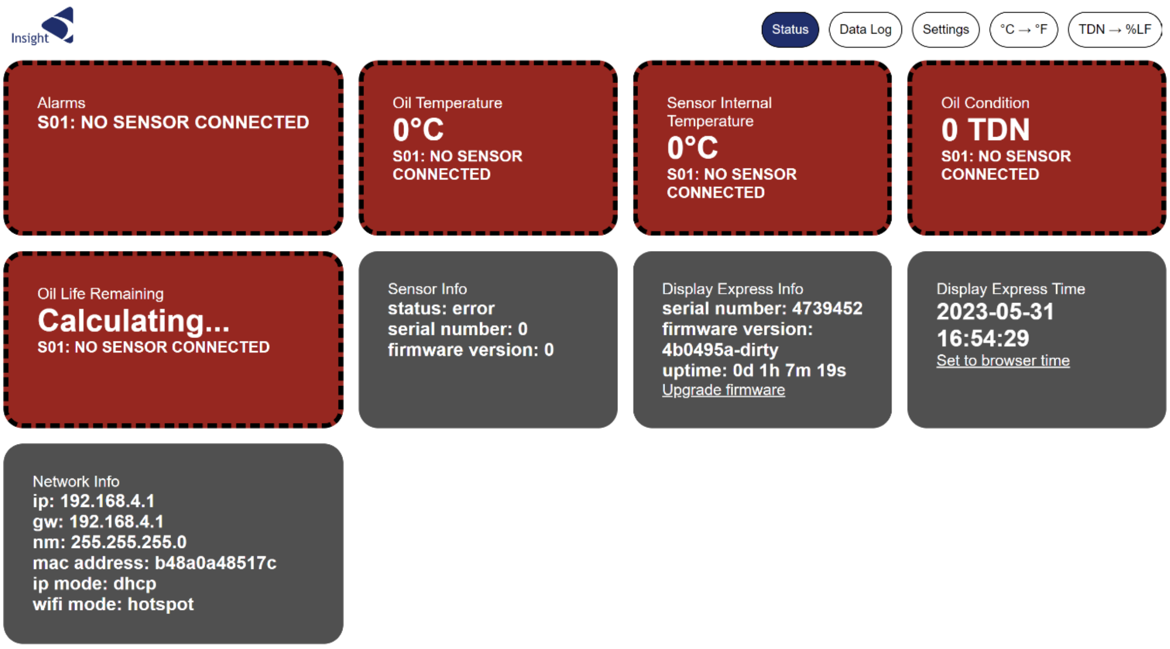


Figure 26 -Status Screen

8.2.2.1.1 Alarms

The Alarms box will display all Checks or Alerts corresponding to the Event Codes listed in Figure 36. If accessing for the first time, there may be an Alert triggered (S01) as there is still no sensor connected to the device. This can be ignored, or you may connect an OQSxG2 Sensor at this point which will remove the Alert.

8.2.2.1.2 Oil Temperature
Displays the temperature of the Oil as measured by the Sensor.

8.2.2.1.3 Sensor Internal Temperature
Displays the internal temperature of the Sensor.

8.2.2.1.4 Oil Condition
Displays the Oil Condition in either Tan Delta Number (TDN) or Loss Factor (%LF). With no Sensor connected to the device, the Oil Condition will display as 0 TDN or 45 %LF on Insight. On the OQDe unit the Oil Condition will display as '- - - -' until a configured Sensor is connected to the OQDe.

8.2.2.1.5 Oil Life Remaining
The Oil Life Remaining (OLR) will remain as 'Calculating…' on Insight for the first 14 days of the device being connected to a configured Sensor which is submerged in oil. On the OQDe unit the OLR will display as '- - -' during this period. After this point, both the OQDe and Insight will display the true OLR in days. This figure will get more accurate as the oil moves towards its end of life.

8.2.2.1.6 Sensor Info
If a Sensor is connected, you will see the Sensor Info box populated with the Serial Number and Firmware Version.

8.2.2.1.7 Display Express Info
Displays the Serial Number and Firmware version of the OQDe, along with Uptime, which is how long the OQDe has been powered on for. The OQDe firmware can be updated manually if required by selecting "Upgrade firmware" then selecting the firmware file from the PC / mobile device storage.

8.2.2.1.8 Display Express Time
Shows the time the OQDe clock is set to currently. It can be set to the time of the browser you are using to view Insight.

NOTE – this will affect the Timestamps on the Datalogs from the point it is changed.

8.2.2.1.9 Network Info
Displays IP/Gateway/Netmask, as well as the MAC address of the OQDe, the IP mode, and the Wi-Fi mode (Hotspot or WLAN).

8.2.2.2 Data log Screen
The OQDe has an internal clock and logs real-time oil quality readings. Data logs can be downloaded here as a CSV file. See Figure 27.

- <u>Warning: Do not disconnect the OQDe whilst downloading the Data Log file.</u>

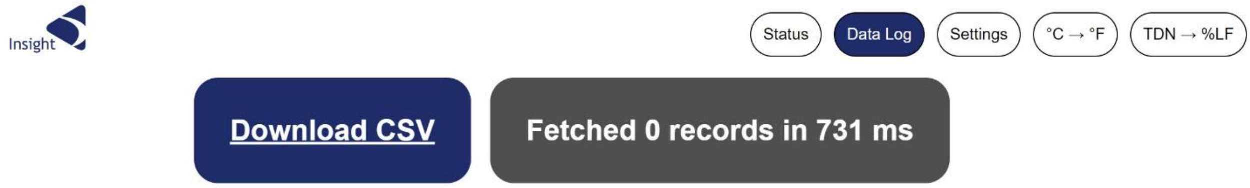


Figure 27 - Data Log Screen

To clear all historic Data Logs go to:

> Settings > Clear Datalog > set to TRUE > click Apply > Reboot device by disconnecting/reconnecting.

The Datalog will clear upon reboot and can take several minutes depending on the number of data logs.

8.2.2.3 Settings Screen – Configuring the OQDe

The Settings Screen (Figure 28) is where you can configure the OQDe.

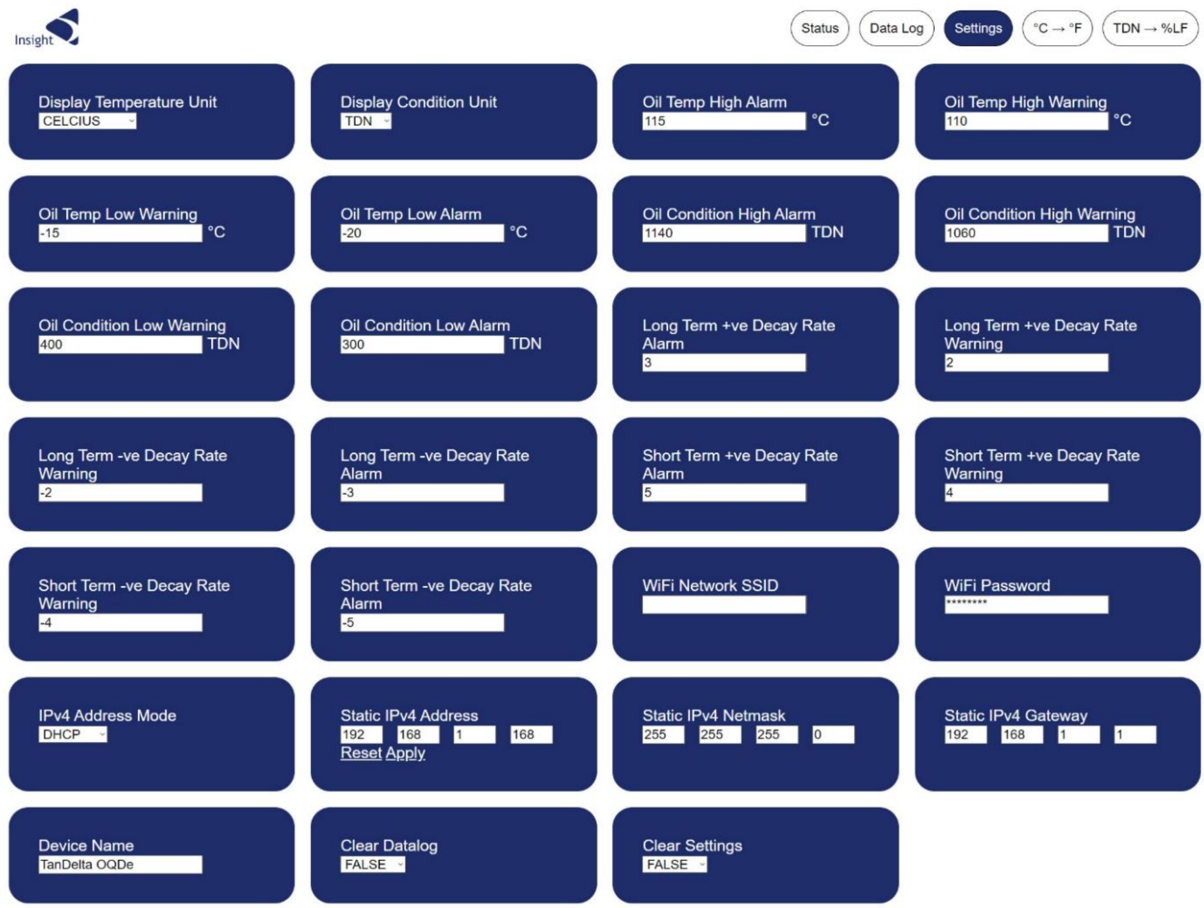


Figure 28 - Settings Screen

NOTE 1 – Configure the OQD prior to installation on site.

NOTE 2 - Configure the OQDe via Insight or using CADS. There are older Bluetooth versions of the OQDe product which are configurable via CADS only.

Figure 29 shows the parameters which are configurable on the OQDe, and the default values set on the device.

Parameter	Options	Default
Display Temperature Unit	°Celsius or °Fahrenheit	°Celsius
Display Oil Condition Unit	Tan Delta Number (TDN) or %Loss Factor (%LF)	Tan Delta Number (TDN)
Oil Temp High Alarm	Any numerical value – **Recommended to configure before first use**, however, can be adjusted at any time during operation.	115°C
Oil Temp High Warning		110°C
Oil Temp Low Warning		-15°C
Oil Temp Low Alarm		-20°C
Oil Condition High Alarm	**Recommended to configure before first use.** Recommended values depend on Application. See Figure 28. If your application is not listed, contact Tan Delta Support.	1140 TDN (Application: Diesel Engine)
Oil Condition High Warning		1060 TDN (Application: Diesel Engine)
Oil Condition Low Warning		400 TDN (Application: Diesel Engine)
Oil Condition Low Alarm		300 TDN (Application: Diesel Engine)
Long term +ve decay rate Warning	It is strongly recommended to discuss your application with Tan Delta Support before changing any of these default values.	3 TDN/day
Long term +ve decay rate Alarm		2 TDN/day
Long term -ve decay rate Warning		-2 TDN/day
Long term -ve decay rate Alarm		-3 TDN/day
Short term +ve decay rate Warning		5 TDN/day
Short term +ve decay rate Alarm		4 TDN/day
Short term -ve decay rate Warning		-4 TDN/day
Short term -ve decay rate Alarm		-5 TDN/day
Wi-Fi Network SSID	Any value	
Wi-Fi Password	Any value	password
IPv4 Address Mode	DHCP or Static	DHCP
Static IPv4 Address	Any numerical value	192 168 1 168
Static IPv4 Netmask	Any numerical value	255 255 255 0
Static IPv4 Gateway	Any numerical value	192 168 1 1
Device Name (also appears as SSID)	Numbers and letters	TanDelta OQDe
Clear Datalog	TRUE or FALSE	FALSE
Clear Settings	TRUE or FALSE	FALSE

Figure 29 – Default Parameters and Configuration Options

To clear all settings, go to:

Clear Settings > set to TRUE > click Apply > Reboot device by disconnecting/reconnecting.

The Settings will clear upon reboot. **NOTE: It is not recommended to clear settings.**

8.2.2.4 Application Settings

By default, the Oil Condition Warning and Alarm levels are set to that of a Diesel Engine. However, every application is unique, and some adjustments may help optimise the system. Tan Delta have recommended settings for several applications listed in Figure 30 which you can use for configuring the OQDe. Alternatively, if a bespoke solution is required, we recommend logging data for one oil change cycle, or six to eight weeks, and then sending the data to support@tandeltasystems.com. We can then advise you on your application settings.

	Engine (e.g. Diesel)	Gas Engine	Hydraulic	Compressor	Transmission
High Alarm	5.6mA (1140 TDN)	5.6mA (1140 TDN)	6.4mA (1060 TDN)	6.7mA (1050 TDN)	6mA (1100 TDN)
High Warning	6.4mA (1060 TDN)	6.4mA (1060 TDN)	7mA (1000 TDN)	7mA (1000 TDN)	7mA (1000 TDN)
Condition OK					
Low Warning	13mA (400 TDN)	9.4mA (760 TDN)	9.4mA (760 TDN)	10.5mA (650 TDN)	10mA (700 TDN)
Low Alarm	14mA (300 TDN)	10.4mA (660 TDN)	10.4mA (660 TDN)	11mA (600 TDN)	12mA (500 TDN)

Figure 30 - Oil Condition Values per Application

8.2.3 Connecting OQDe to Wireless Local Area Network (WLAN)

The OQDe supports connection to a Wireless Local Area Network. To connect to your WLAN, you must first connect to the OQDe via Wi-Fi Hotspot.

- Connect to the OQDe via Wi-Fi Hotspot as per 8.2.1.
- Navigate to Insight using the IP Address 192.168.4.1.
- Click on the Settings Screen
- In the "Wi-Fi Network SSID" box, type in the SSID of your WLAN, click Apply.
- In the "Wi-Fi Password" box, type in the Password of your WLAN, click Apply.
- Reboot the OQDe by disconnecting/reconnecting power. The OQDe is now connected to your WLAN.

8.2.4 Finding IP Address of OQDe on Wireless Local Area Network (WLAN)

Once connected to your WLAN, to access Insight, you will need the IP address of the OQDe to access settings or download datalogs. This will no longer be 192.168.4.1 because the device is no longer connected via Hotspot. To find the new IP address of the OQDe, connect via CADS:

- Connect OQDe to your Laptop/PC via Cables J and M (Figure 25).
- On the Laptop/PC launch CADS and wait for the home screen to load.
- Once the home screen has loaded, select 'Configure OQDe'
- You will now see a list of all connected devices. Under 'Available Devices', you will find the Serial Number and IP Address of the OQDe.
- Make a note of the IP Address, close CADS.
- Open Browser and navigate to the IP Address of the device to access Insight.

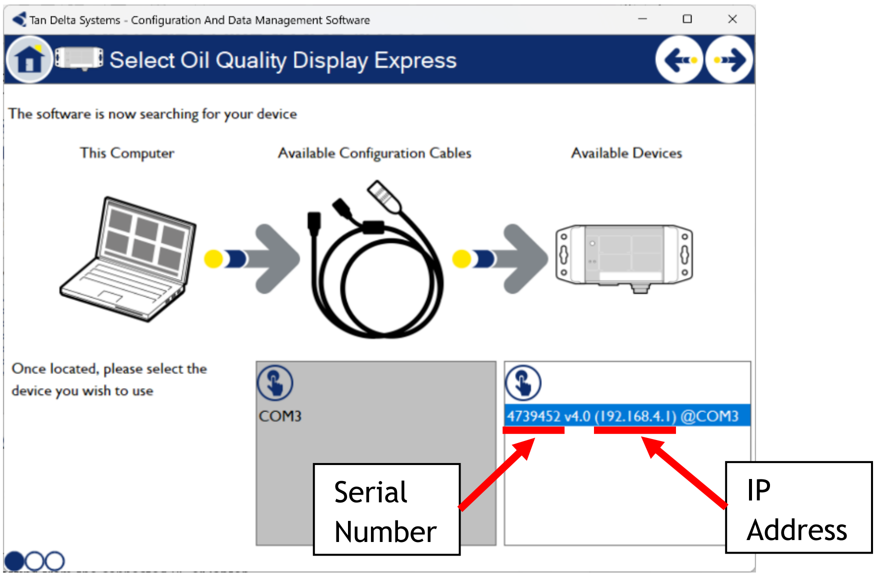


Figure 31 - Displaying IP Address of OQDe in CADS

NOTE – Further functionality through CADS will be released as part of further updates to this software package.

8.2.5 Upgrading Firmware

Insight provides the ability to upgrade the display firmware from a provided file. This can be done using a PC or mobile device, provided the firmware file is available on that device.

Firmware is upgraded from the Status screen by selecting "Upgrade firmware" then selecting the firmware file from the PC / mobile device storage.

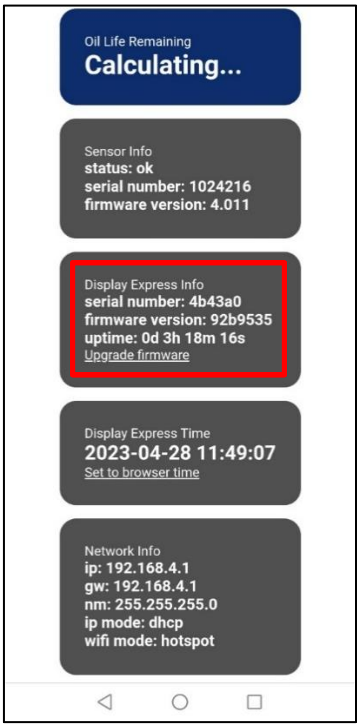


Figure 32 - Upgrading Firmware (1)

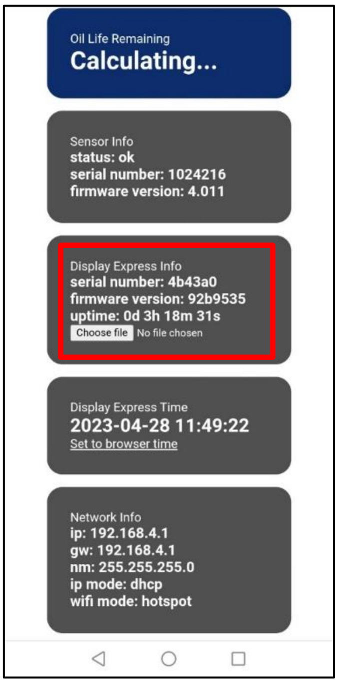


Figure 33 - Upgrading Firmware (2)

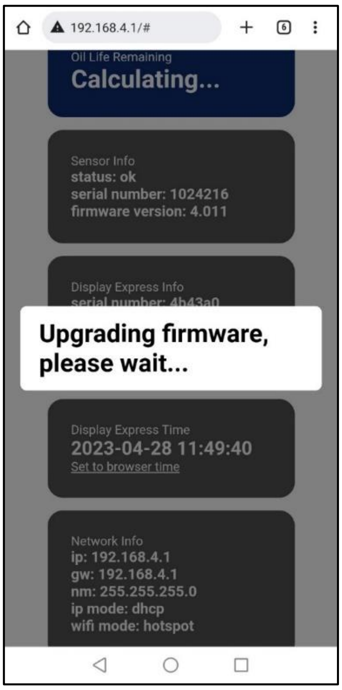


Figure 34 - Upgrading Firmware (3)

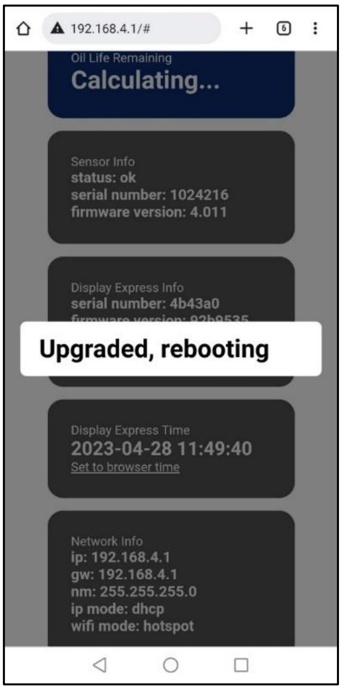


Figure 35 - Upgrade Reboot

Once the upgrade has completed, the display will reboot.

8.2.6 Configuring a display using CADS

CADS allows you to adjust the following OQDe parameters:

- Warning & Alarm Levels: the points at which the Status LED changes from Green to Amber to Red.
- Date/time.

8.2.6.1 Connect OQDe

First you must select ‘Configure Oil Quality Display Express’ from the Home Screen. Next, connect the OQDe to your computer using the configuration cable.

8.2.6.2 Select Device

You will now see a list of all connected devices, identified by serial number. Select the required device.

Click the arrow to proceed.

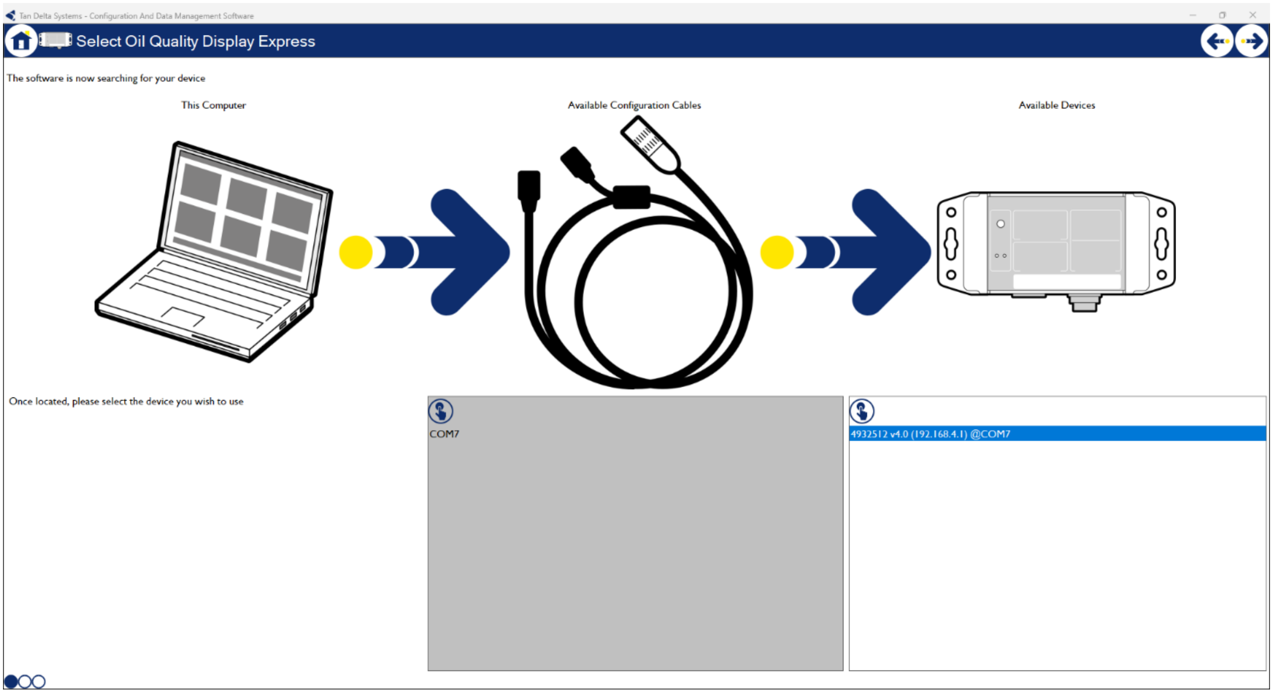


Figure 36 - CADS Identification Screen

8.2.6.3 Configuration Options

This section describes the various options presented on the OQDe configuration screen.

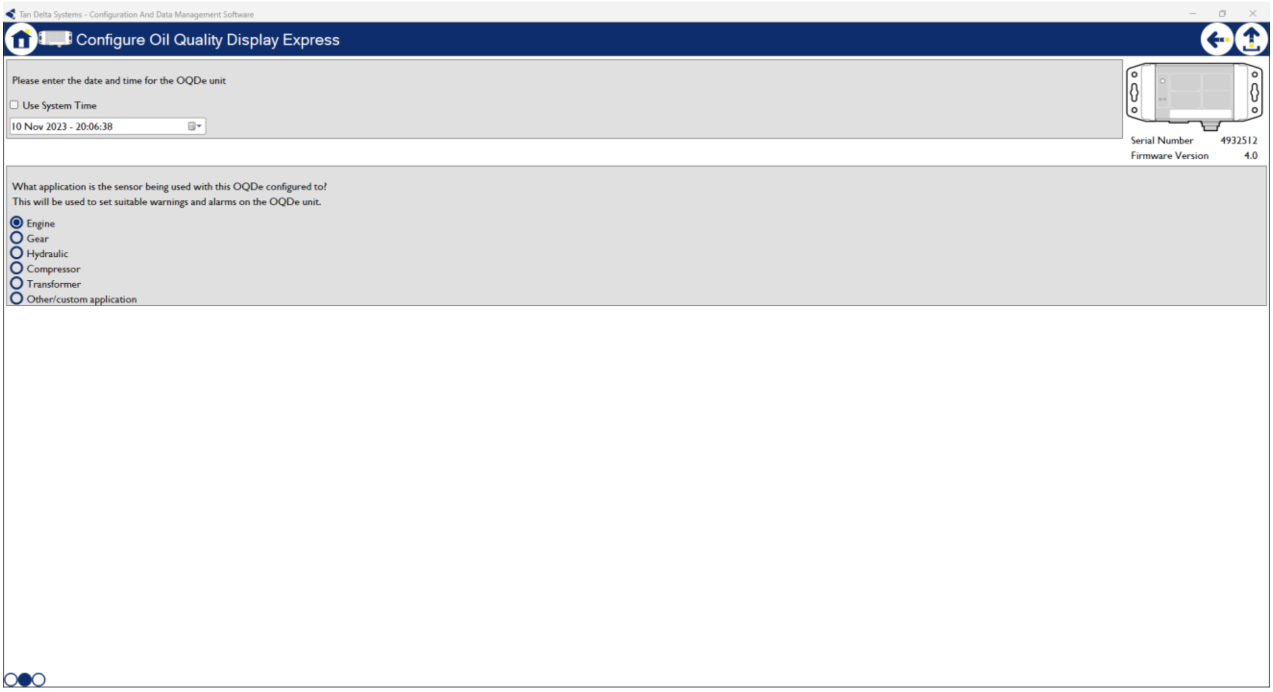


Figure 37 - CADS Default Configurations

8.2.6.4 Date & Time

Set the time for the display. This is used to time-stamp log files. You can set the time manually or take the setting from the connected PC or laptop.

8.2.6.5 Default Settings

If applicable, select the correct option from the list of default applications. These settings will generally be correct for most instances of the given application, however every application is unique and some adjustments may help optimise the system. We can consult with you over the weeks/months after installation to ensure the system is configured perfectly to reflect your environmental and operational parameters.

The values for each of the defaults is shown in the table at Figure 30.

8.2.6.6 Custom Settings

If the default settings are not suitable for your application, you can select other/custom application. This will display the configurable warning/alarm levels as shown below.

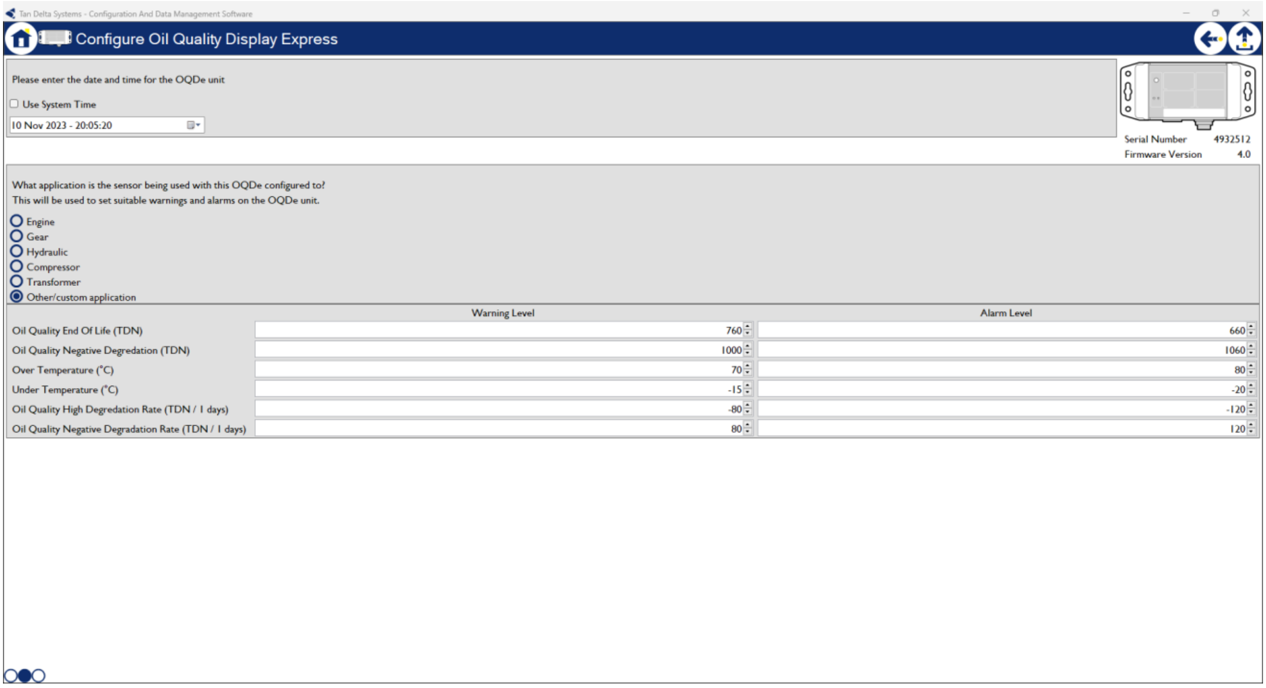


Figure 38 - CADS Custom Application Configuration

These warning and alarm level settings determine when the status will show, green, amber and red. You can set upper and lower limits for oil condition, temperature and rate of change. These warning and alarms levels are optional settings and you can set the levels according to your specifications. The correct levels will depend on your objectives and application, in order to create a bespoke solution we would recommend logging data for one oil change cycle or six to eight weeks and then sending the data to support@tandeltasystems.com so we can advise you.

8.2.6.7 Write Settings

Once your required settings are selected, use the arrow to proceed. A pop-up message will request confirmation that new settings should be sent to the device. Once confirmed, the settings will be written to the device.

Note: Do not disconnect device until CADS has displayed confirmation that the configuration has been successful.

8.3 Installation

8.3.1 Mounting

The OQDe has a flange on either side with mounting holes to allow it to be fixed to any suitable flat surface. Once your OQDe is correctly configured, you need to mount it using the flanges on the sides.

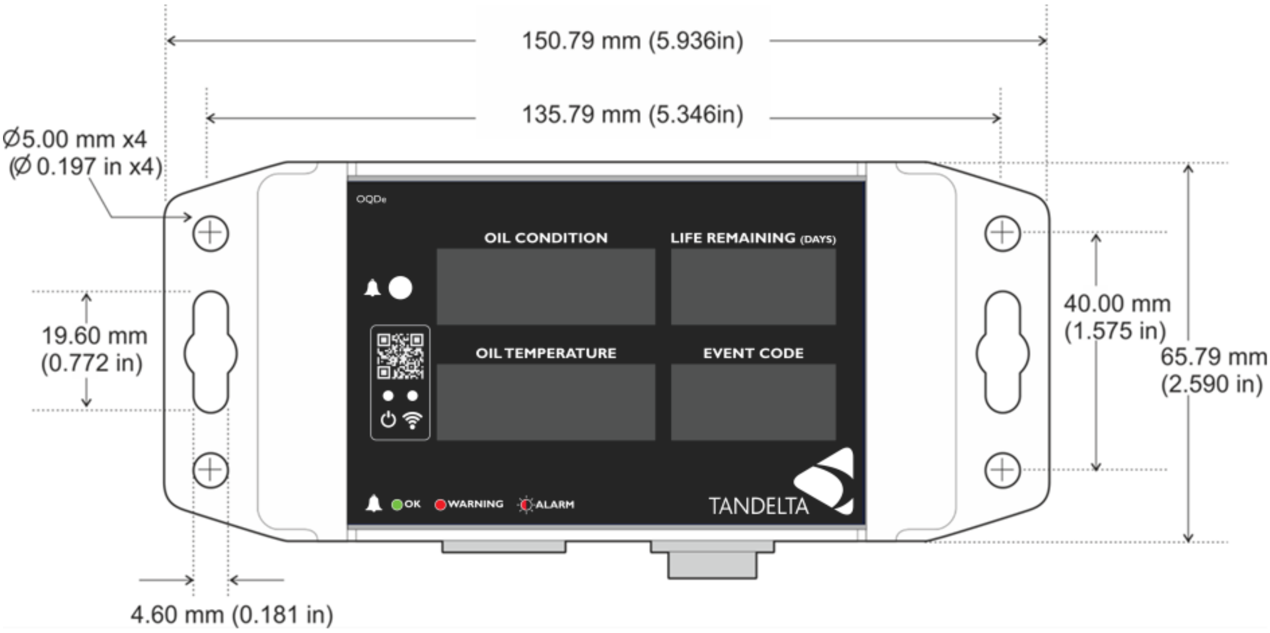


Figure 39 - OQDe Mounting Dimensions

Please ensure that the following environmental specifications are not exceeded by the proposed location.

Protection Rating:	IP67
Enclosure Type:	Rugged, polycarbonate machined housing with mounting flanges
Temperature (Operating)	-30C to +65C
Temperature (Storage)	-30C to +70C
Pressure (Ambient)	1 bar +/- 150mbar
Chemical Exposure (Splash)	Water, Mineral and Synthetic Oils

8.3.2 Connection

8.3.2.1 Connecting the Oil Quality Sensor

Connect the Oil Quality Sensor (OQSxG2) to the left-hand connector on the OQDe using a **Cable SD** (Sensor to Display Cable). 2m, 5m, 10m, 15m, 25m, 50m, & 100m lengths available as standard. Align and slot in the 6-pin connector and then tighten the connector screw-cap.

Please refer to the OQSxG2 section of the manual for further information about OQSxG2 setup and calibration.

NOTE. The right-hand connector can be used to connect an OQDe to a Laptop/PC by RS485 using Cables J & M in conjunction, or to other devices for remote monitoring purposes using a Cables M & SB combination or Cable DB (Display to Bare Ends).

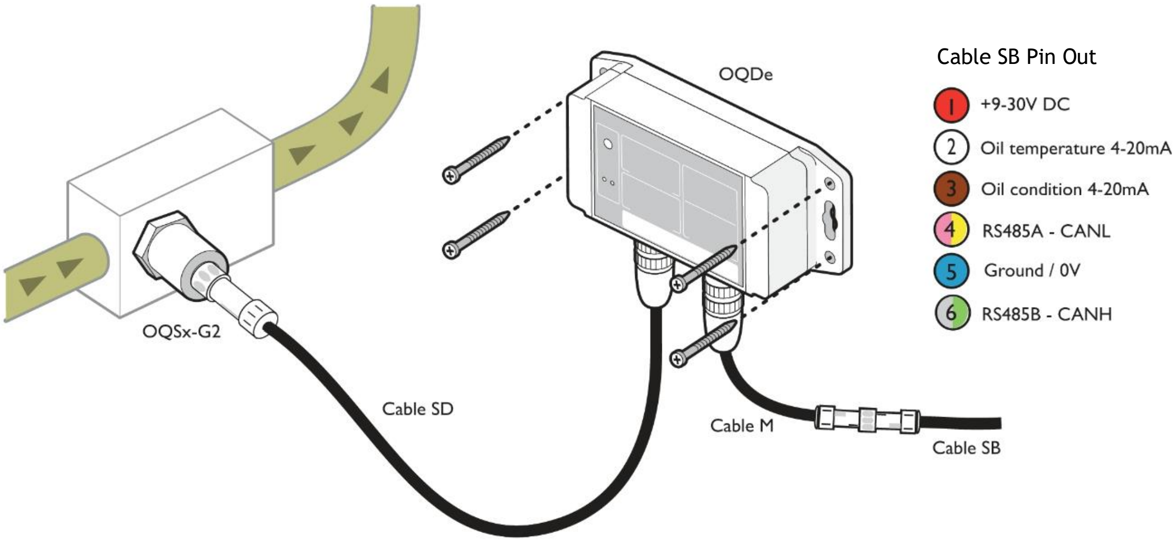


Figure 40 - OQDe Connection

8.3.2.2 Using Analog Output

Analog outputs measuring oil quality and oil temperature are looped through the OQDe from the OQSxG2. You can use these outputs to provide analog indication of the oil temperature and condition on other, third party, data acquisition and control systems.

If you wish to connect to the OQDe via 4-20mA in order to read the Oil Condition and Oil Temperature Data, connect a suitable power supply (9-30Vdc, at least 100mA) to the Red wire (power) & Blue wire (ground) on Cable SB / Cable DB.

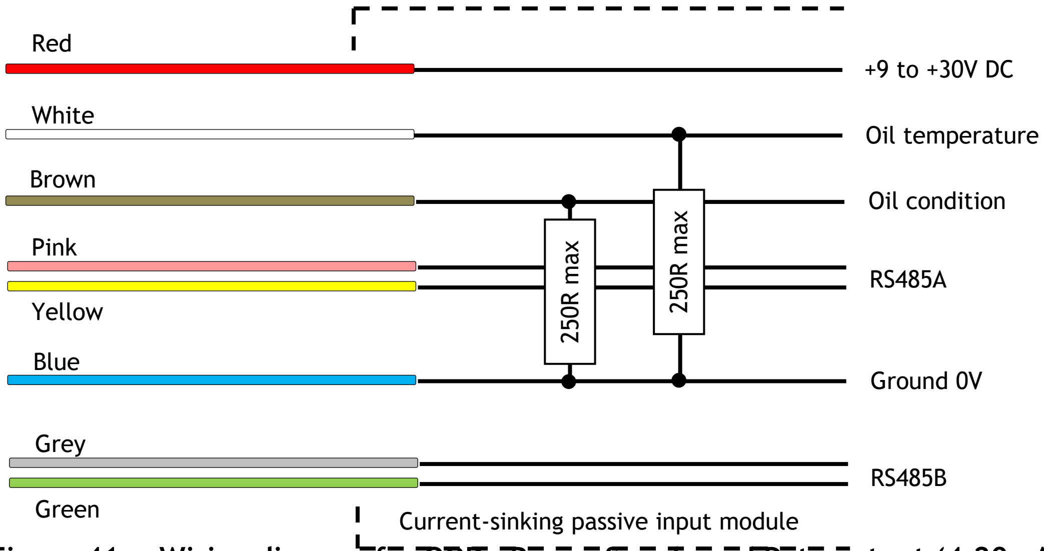


Figure 41 - Wiring diagram for OQDe Power Supply and Data output (4-20mA)

8.3.2.3 Using the Oil Condition analog output

Oil condition is output on the black wire and is linearly scaled from 4mA to 20mA. This can easily be converted to the TDN or % Loss Factor scale using the table at the Appendix (Section 13). A clean oil should provide an output of about 8mA. For some common applications we recommend the warning/alarm settings in Figure 30. Any value below 4mA indicates a fault.

8.3.2.4 Using the Oil Temperature analog output

The analog output on the white wire provides a linearly scaled measure of Oil Temperature in °C between -30°C (4mA) and +130°C (20mA) – see Appendix (Section 13).

8.4 Operation

8.4.1 Switching On

Ensure that you have configured the OQDe and OQSxG2 as described at section 8.2 and connected them correctly as described at section 8.3. To begin operation:

- Switch on the power supply. The green power LED is illuminated.
- The OQDe commences an initial self-test period lasting approximately one minute.
- On completing its self-test, the OLR will display as '- - -' for the first 14 days of operation. After this point, both the OQDe and Insight will display the true OLR in days. This figure will get more accurate as the oil moves towards its end of life.

NOTE: The OQDe MUST be connected to a configured Sensor which is submerged in oil otherwise the OQDe will not function as intended.

8.5 Product Specification

8.5.1 Environmental Specifications

Protection Rating	IP67 (When connected)
Enclosure Type	Rugged, polycarbonate machined housing with mounting flanges
Temperature (Operating)	-30C to +65C
Temperature (Storage)	-30C to +70C
Pressure (Ambient)	1 bar +/- 150mbar
Chemical Exposure (Splash)	Water, Mineral and Synthetic Oils

8.5.2 Connectivity

General	Two industrial 6 pin connectors, IP67
Power supply input	Two wire, universal 9 to 30V D.C.
Analog Interface	Dual 4-20mA outputs, single wire each plus ground
Serial Interface	Single RS485 interface, two wire
WiFi	WLAN or WiFi Hotspot using any internet-enabled device
Integration Options	JSON API

8.5.3 Functionality

- EMC Filtering and fuse protection on input power.
- Power distribution with individual fusing and EMC filtering on power output to one sensor.
- Datalog download facility via Wi-Fi to any internet-enabled device.
- Real time, continuous display of oil quality, oil temperature and Event Code on 7-segment LEDs.
- Simultaneous interface to either proprietary software via RS485 or Wi-Fi.
- Baud rates from 9600 (default) to 1Mbaud.
- Flash upgradeable firmware without return to manufacturer.
- Individual real-time clock with battery backup of 10 years.
- Auto power on when connected to power supply.
- Auto reboot at internal error condition.
- Internal fault-detection capability.
- Real-time oil quality readings from sensor every 2s.
- User defined parameters configurable using Insight via Wi-Fi.

8.5.4 Standards and Approvals

CE & UKCA marked RoHS Compliant:

- BS EN 60529:1992+A2:2013 IP67 Dust and Water Ingress.
- BS EN 60068-2-30:2005 Cyclic Humidity.
- BS EN 60068-2-6:2008 Sine Vibration.
- BS EN 60068-2-27:2009 Mechanical Shock.
- EN 61000-6-4:2007 Generic Emissions Standard for Industrial Environments.
- EN 61000-6-2:2007 Generic Immunity Standard for Industrial Environments.
- EN 300 328 v1.8.1. Transferable Electromagnetic Compatibility for Wideband Data Transmission Equipment operating in the 2.4GHz ISM Band and using Wideband Modulation Techniques.

8.5.5 Display

Real-time data is displayed on 14 digits of red color 7-segment LEDs. The display is readable in day-light at 120,000 Lux direct sunlight at 3 m/10 feet. Internal fault or no readings from sensor after 5 continuous requests are displayed as Event Codes until error condition solved.

Oil Condition	4 digits in 3 user selectable scales: oil quality loss factor (-20 to +60) and Tan Delta Number (0 to 1200).
Oil temperature	3 digits with user selectable scale in Celsius (default) or Fahrenheit indicated on 1 digit (°C or F).
Oil life remaining	Days.
Event Code	Up to 3 characters (alpha-numeric)
Oil status	Display oil condition comparison to user-programmable warning and alarm levels on a multicolor super-bright LED. Green color shows oil quality is OK, Red color shows Check level, and Flashing Red color shows Alert level.
Power	Green LED turns on when power is present.
Wi-Fi	Activity indicator, Blue LED.

8.5.6 Data Logging

Logging interval	5 minutes
Clock battery backup	10 years
Real time clock	Yes
Data download	Via Wi-Fi

8.5.7 Physical Characteristics

Enclosure material	Polycarbonate
Dimensions	120mm x 66mm x 42mm (L x W X H)
Weight	220g
Color	Grey
Top	Polyester Autotex XE V207 200um, UV stable
Mounting	Integrated Flanges
Usage	For indoor and outdoor use

8.5.8 Power

Input voltage	9-30V DC
Input current	0.55A typical, 1.8A maximum
Average power consumption	6W
RTC Battery capacity	CR1632 coin cell with 3V/120mAh capacity

8.5.9 Compatibility

- Tan Delta Oil Quality Sensor
- Tan Delta Configuration & Data Management Software (CADS)
- Tan Delta Accessories

8.5.10 Event Codes

The OQDe will analyse the data received from the OQSxG2 Sensor and based on the initial setup or amendments to the configurable parameters can provide a range of warnings or alarms.

In addition to the warnings and alarms determining the colour of the oil status LED, the display will also show an event code, identifying possible action required. Event codes can also identify potential issues with sensor connection as well as potential sensor and display configuration issues.

Event Code	Algorithm	Description	Check/ Alert
---	n/a	All OK	n/a
S01	n/a	No Sensor Connected – Please Connect the Sensor.	A
S02	n/a	Sensor Not Configured – Configure the Sensor via CADS.	A
S03	n/a	Display Not Configured – Configure the Display via Insight	A
S04	n/a	New Sensor Detected	n/a
E01	Current Temperature >= Temp High Warning Level	Oil Temperature High – Check Regularly.	C
E02	Current Temperature >= Temp High Alarm Level	Oil Temperature Very High – Immediate Action Required.	A
E03	Current Temperature <= Temp Low Warning Level	Oil Temperature Low – Check Regularly.	C
E04	Current Temperature <= Temp Low Alarm Level	Oil Temperature Very Low – Immediate Action Required.	A
E05	Current Oil Condition >= Oil Condition High Warning Level	Oil Condition Too High – Check Regularly.	C
E06	Current Oil Condition >= Oil Condition High Alarm Level	Oil Condition Very High – Immediate Action Required.	A
E07	Current Oil Condition <= Oil Condition Low Warning Level	Oil Near End Of Life – Check Regularly.	C
E08	Current Oil Condition <= Oil Condition Low Alarm Level	Oil At End Of Life – Immediate Action Required.	A
E09	Current Oil Condition >= 1200 TDN	Sensor In Air – Immediate Action Required	A
E11	Long Term +ve Decay Rate Warning (TDN/day)	Oil Quality degrading faster than expected – Check Regularly.	C
E12	Long Term +ve Decay Rate Alarm (TDN/day)	Oil Quality degrading much faster than expected – Immediate Action Required.	A
E13	Long Term -ve Decay Rate Warning (TDN/day)	Oil Quality improving faster than expected - Check Regularly.	C
E14	Long Term -ve Decay Rate Alarm (TDN/day)	Oil Quality improving much faster than expected - Immediate Action Required.	A
E15	Short Term +ve Decay Rate Warning (TDN/day)	Oil Quality degrading faster than expected - Possible Water/Coolant Contamination - Check Regularly.	C
E16	Short Term +ve Decay Rate Alarm (TDN/day)	Oil Quality degrading much faster than expected – Highly Likely Water/Coolant Contamination - Immediate Action Required.	A
E17	Short Term -ve Decay Rate Warning (TDN/day)	Oil Quality improved - Suspected oil top up / sweetening - Check Regularly	C
E18	Short Term -ve Decay Rate Alarm (TDN/day)	Oil Quality improved too much - Suspected Air or severe fluid contamination - Immediate Action Required.	A

Figure 42 - List of Event Codes

9 Oil Quality Gateway

9.1 Introduction

The Tan Delta Oil Quality Gateway is a comprehensive networking device. The OQTGateway — coupled with TD Online and/or another 3rd party service — provides remote visibility for all connected assets.

9.1.1 IMPORTANT SAFETY NOTES

Please pay attention to following safety notes:

- **Gateway is not IECEx certified.**
- **Never reassemble, repair or tamper with the gateway.**
- **Ensure that the supply voltage is within the specified range.**
- **Ensure the load currents do not exceed the rated value.**
- **Check all the wiring for correct connection before powering the unit.**

9.2 Gateway Configuration

9.2.1 Set up Configuration USB

Before you can use the OQTg it should be configured to work on the particular network which you have chosen to use. This is done by writing the configuration settings to a USB stick and uploading to the device. This section assumes you have sensors already configured and installed for use with the OQTg. If you have not yet configured or installed your sensors, please refer to Section 5.1.1.5.

9.2.1.1 *Run software*

Note: Complete the steps below prior to mounting device

1. Connect OQTg, Gateway Hub OQSxG2 sensors as per diagram below, for detailed wiring diagram, please see Installation section 9.3.

ID	Description
1	OQSxG2 Sensor to OQTh Gateway Hub Cable
2	OQTh Gateway Hub to OQTg Gateway Cable
3	OQSxG2 Sensor to OQTh Gateway Hub Cable
4	OQTh Gateway Hub Continuity Plug (1 required per unpopulated sensor slot)

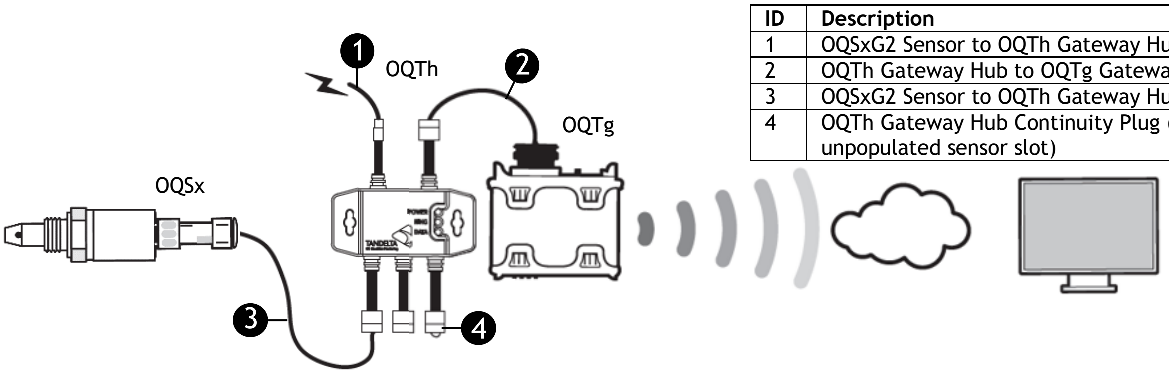


Figure 43 - OQTg System Architecture

2. Remove translucent clip-on cover at front of gateway.
3. Insert Tan Delta USB stick into a laptop or PC and navigate to OQGatewayConfigurator.exe (Application File) as shown below. Double click on file to launch program.

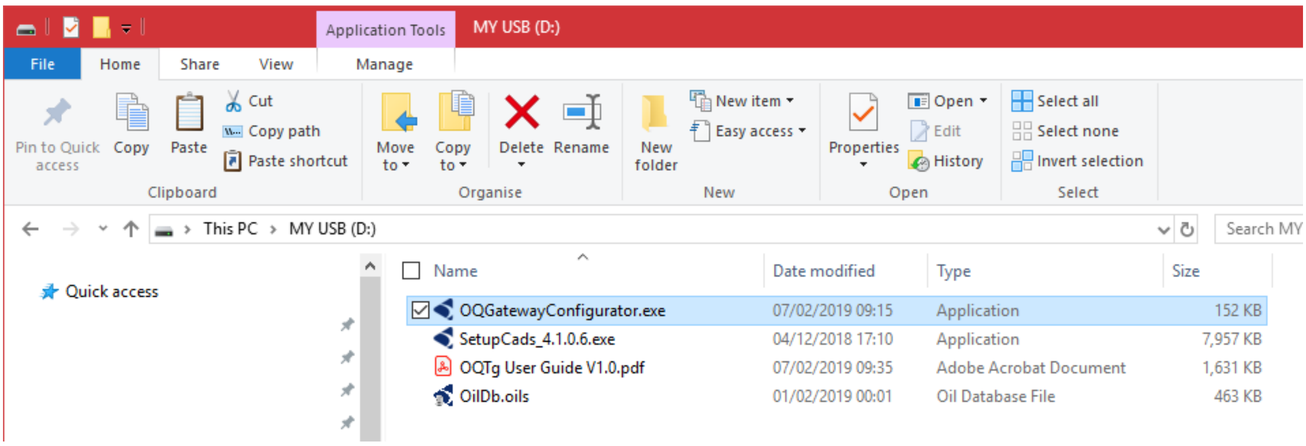


Figure 44 - OQTg Configurator

9.2.1.2 *Select required settings*

As shown in the screenshot below, the Configurator has 3 sections, and you just need to use the one which applies to your chosen network type.

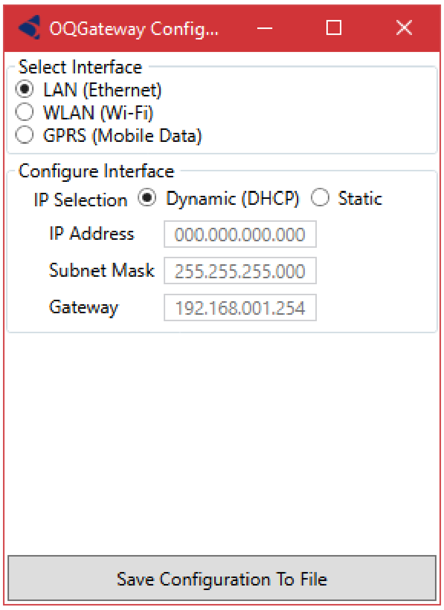


Figure 45 - OQTg Configurator Home Screen

9.2.1.2.1 Configure LAN (ethernet)

1. Select from either Dynamic (DHCP) or Static – Please consult with you network administrator to ensure correct option is chosen.
2. If static is used, please enter IP Address, Subnet Mask and Gateway

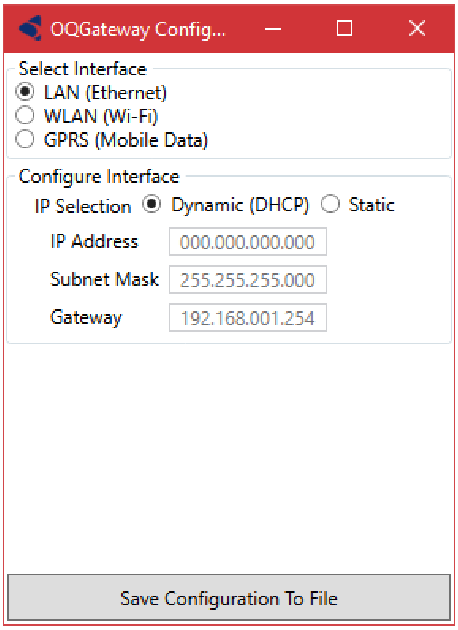


Figure 46 - LAN Settings

9.2.1.2.2 Configure WLAN (Wi-Fi)

1. Select from either Dynamic (DHCP) or Static – Please consult with your network administrator to ensure correct option is chosen.
2. If static is used, please enter IP Address, Subnet Mask and Gateway

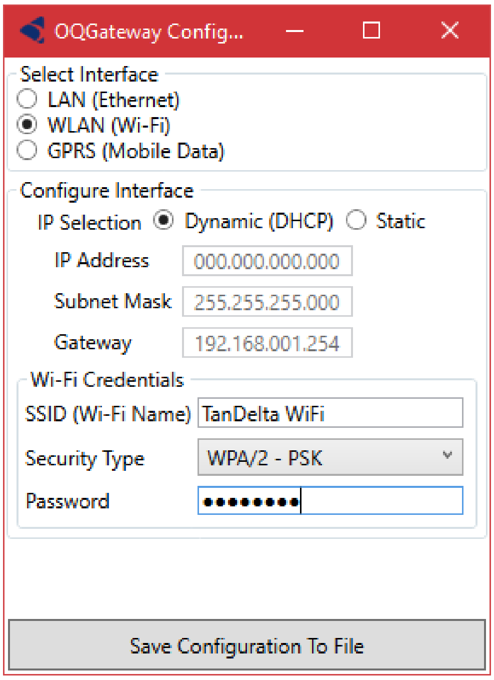


Figure 47 - WLAN Settings

3. Enter the details of Wi-Fi network to be connected to – Please consult with network administrator.
   a. SSID
   b. Security Type
   c. Password

9.2.1.2.3 Configure GPRS (mobile data)

1. List of pre-configured networks will be shown, if your required network is available, please go to step 4.1.3. If your network is not shown, proceed from step 2.

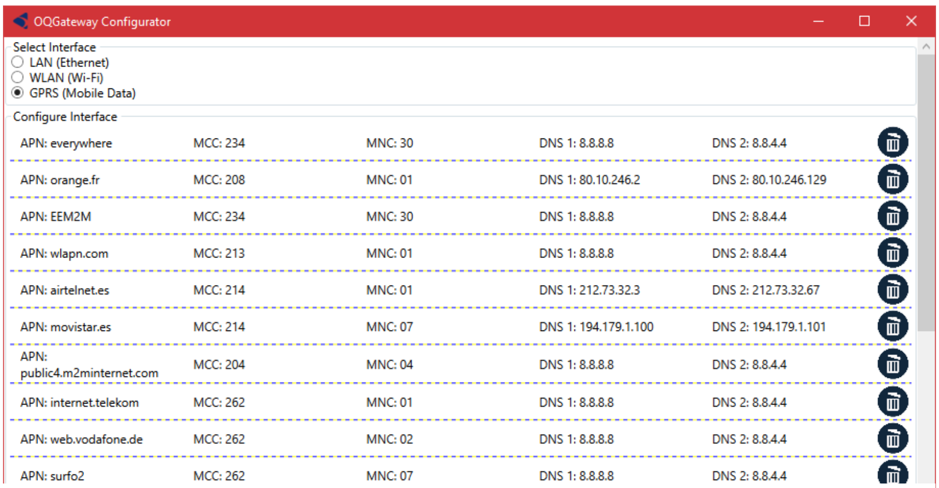


Figure 48 - Default Network

2. Delete all networks that will not be used from the list. Scroll to bottom of list and click '+' to add new network. List of required parameters is displayed, all information for your specific network will be available online, or from your carrier.

3. Click 'create'.

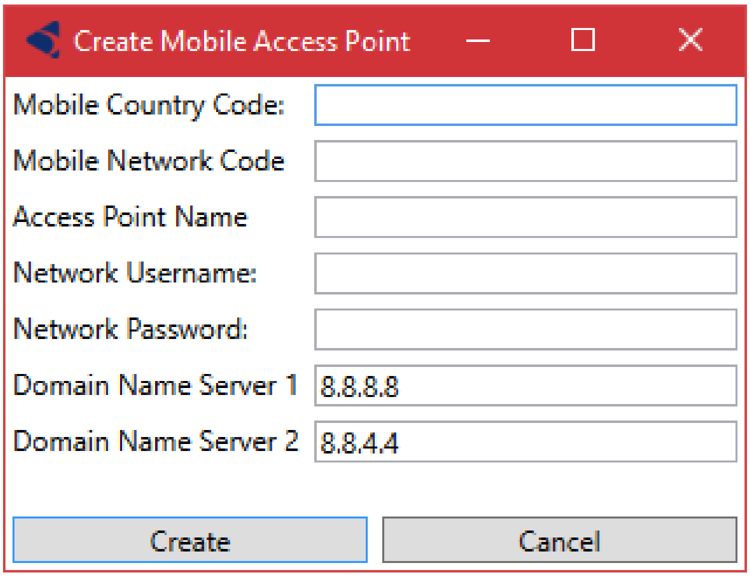


Figure 49 - Create New Network

9.2.1.3 *Save Settings*

Once configuration details are entered, click 'Save configuration To File'. This will automatically be saved to the USB stick.

Close OQTG Configurator and safely remove USB stick from computer.

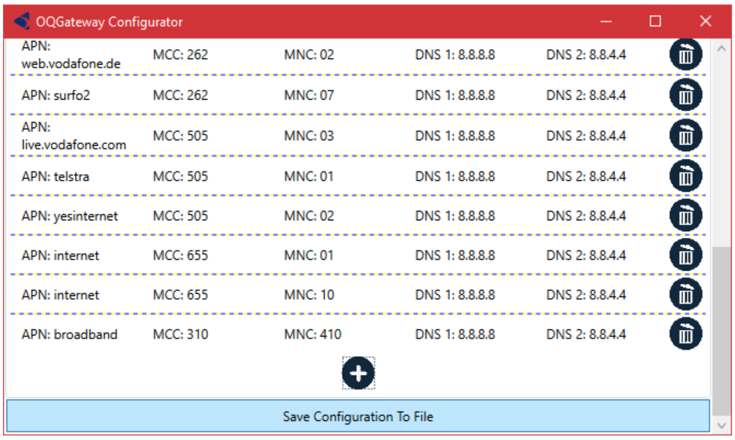


Figure 50 - Save Settings to USB

9.2.1.4 *Upload Settings to OQTg*

Turn on power to gateway.

Device will take a few minutes to boot up. A green LED will show once device is operational.

Insert memory stick into USB port of OQTg. Wait for the Amber LED to turn on and off again before removing USB memory stick.

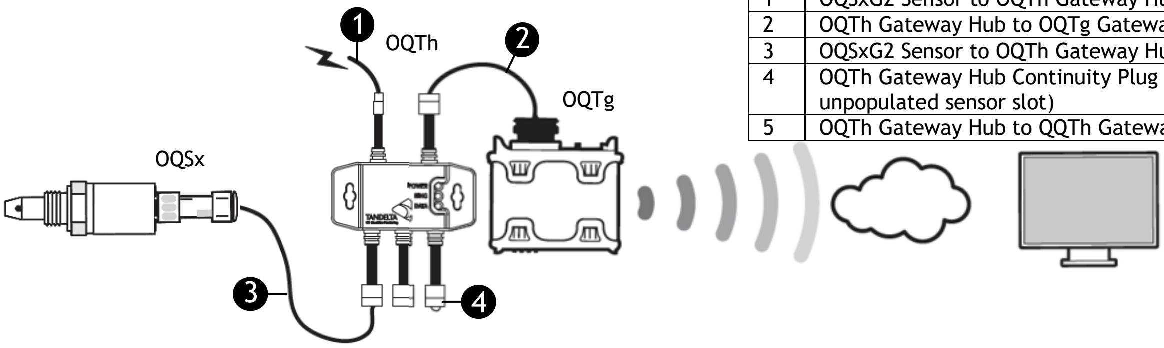
Once your network configuration has been loaded, the OQTg will reboot. Wait for green LED to turn on – may take several minutes.

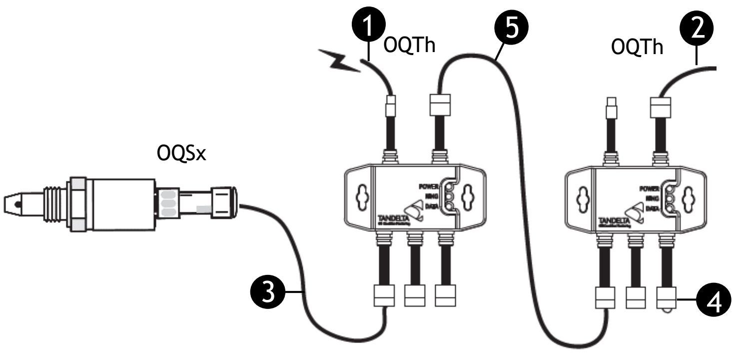
9.3 Gateway Installation

9.3.1 System Architecture

The diagram below shows the overall architecture of the Gateway system, when connected to a sensor, via the Gateway Hub. This configuration can support 1-3 sensors, with up to 10 sensors supported by adding additional Gateway Hubs. (See the table attached)

ID	Description
1	OQSxG2 Sensor to OQTh Gateway Hub Cable
2	OQTh Gateway Hub to OQTg Gateway Cable
3	OQSxG2 Sensor to OQTh Gateway Hub Cable
4	OQTh Gateway Hub Continuity Plug (1 required per unpopulated sensor slot)
5	OQTh Gateway Hub to QQTh Gateway Hub Cable





(Connect multiple OQTh Gateway Hubs with a single OQTg Gateway or bare ends cable)

No. of OQTh Gateway Hubs	No. of Sensors Supported (max)
1	3
2	5
3	7
N	2n+1

Figure 51 - System Architecture

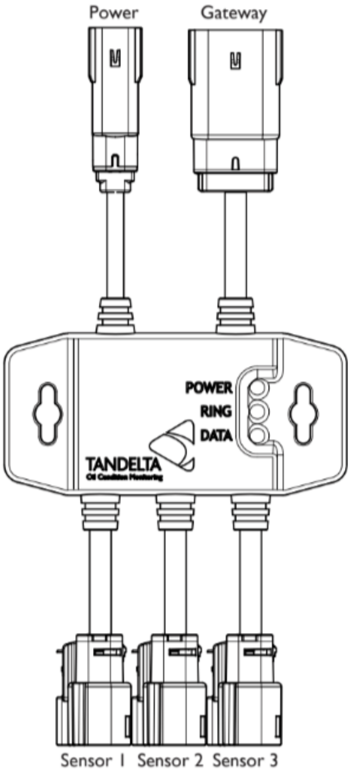
9.3.2 Mounting OQTg

The OQTg has mounting brackets allowing it to be mounted to any suitable surface. Please see the environmental and approvals specifications in Section 9.5 Product Specification and ensure the mounting location meets these requirements.

9.3.3 Wiring Gateway Hub

The table on the next page shows the Gateway Hub connectors and their wire allocations.

Please note this table shows our standard hub cable color scheme. If you have a previous version junction box the cable colours will be different, and the arrangement may reflect the legacy setup. Please refer to the correct manual for that product or contact support@tandaltasystems.com for further assistance.



	Power	Sensor 1	Sensor 2	Sensor 3	Gateway
Cable	45002 BK199	45008 BK199	45008 BK199	45008 BK199	45008 BK199
Molex Connector	33481-0201	33472-1206	33472-1206	33472-1206	33482-6201
Molex Contacts	33000-0003	33012-2003	33012-2003	33012-2003	33000-0003
Contact 1	Gnd	Vcc	Vcc	Vcc	Vcc
Contact 2	V+ (10-30VDC)	CAN1_Lo	CAN1_Lo	CAN1_Lo	CAN1_Lo
Contact 3	Not used	CAN1_Lo	CAN1_Lo	CAN1_Lo	CAN1_Lo
Contact 4	Not used	Not used	Not used	Not used	Not used
Contact 5	Not used	Ring Out	Ring Out	Ring Out	Ring Out
Contact 6	Not used	Not used	Not used	Not used	Not used
Contact 7	Not used	Gnd	Gnd	Gnd	Gnd
Contact 8	Not used	CAN1_Hi	CAN1_Hi	CAN1_Hi	CAN1_Hi
Contact 9	Not used	CAN1_Hi	CAN1_Hi	CAN1_Hi	CAN1_Hi
Contact 10	Not used	Not used	Not used	Not used	Not used
Contact 11	Not used	Ring In	Ring In	Ring In	Ring In
Contact 12	Not used	Not used	Not used	Not used	Not used

Figure 52 - Gateway Hub Wiring

9.4 Sensor Configuration

Before installation, configure the OQSxG2 to your specifications using the Tan Delta Configuration and Data Management Software (CADS) as described in section 5.1.1.5 of this manual.

9.5 Product Specification

9.5.1 Environmental Specifications

Protection Rating	IP67 When connected
Storage Temperature	-45C to +85C
Operating Temperature	-30C to +85C

9.5.2 Physical Characteristics

Material	Glass reinforced plastic
Dimensions	149mm x 135mm x 58mm
Weight	400g

9.5.3 Connectivity

Physical Connectors	FAKRA antenna connectors System connector: TE 776163-1 (35 pins) Micro SIM slot Ethernet (Under IP67 cover, requires a gland for use in installation) USB host 2.0 (Used for mass storage devices only)
GSM/GPRS	GSM850 + EGSM900 + GSM1800 + GSM1900 Class 4 (2W) GSM850/EGSM900 Class 1 (1W) GSM1800/GSM1900 GPRS Class B, Class 10 (4+2) HSPA+ (3G) and LTE (4G) support
WiFi	2.4GHz: 802.11 b/g/n/ac 5.0GHz: 802.11 a/n/ac

9.5.4 Electrical

Power Supply	10-30V DC
Power Consumption	approx. 15W – Plus Sensors ~0.6W each

9.5.5 System Specifications

CPU	ARM Cortex A8 @800MHz clock speed
Linux OS	Kernel 4.4
Memory	512MByte DDR3 NAND Flash 1GByte Allows 1-year internal datalogging
Sensor oil temperature normal operating range	-20C to +120C
Sensor oil temperature accuracy	+/-3% of full range (+/-4.2°C)
Sensor internal temperature operating range	-20C to +120°C
Sensor internal temperature accuracy	+/-3% of full range (+/-4.2°C)
Sensor 4-20mA accuracy	+/- 1% of full range (+/- 0.2mA)*

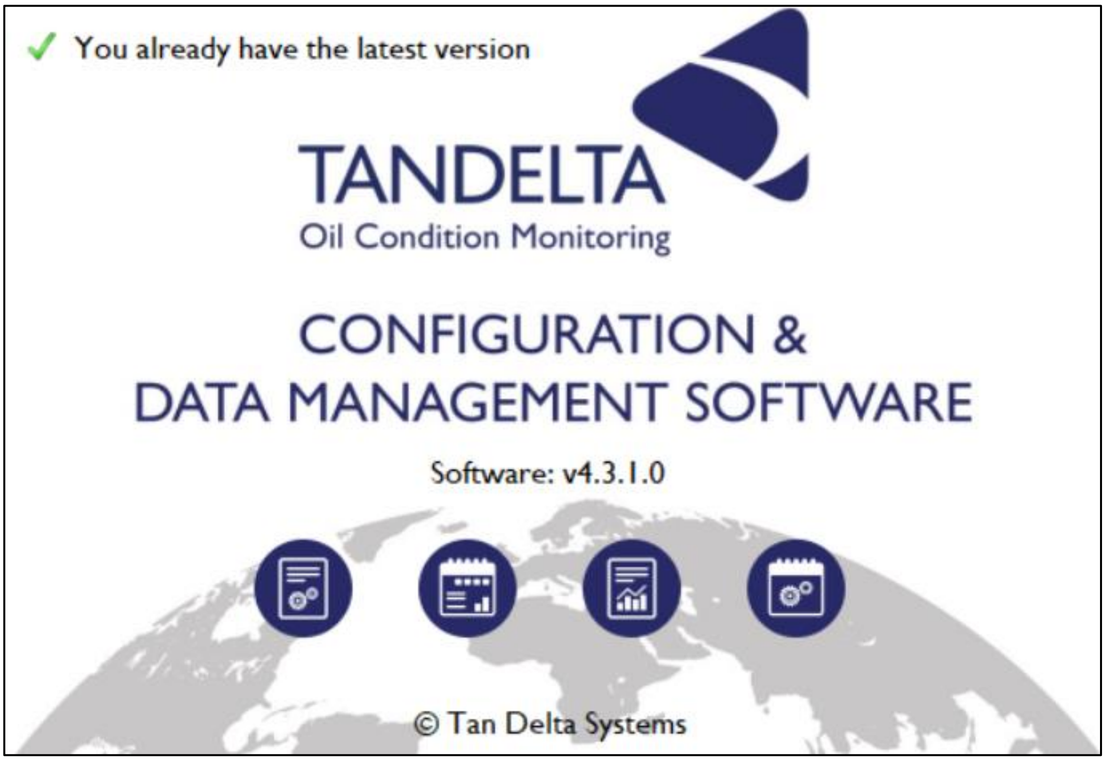
9.5.6 Gateway Hub

Material	Technomelt PA657
Temperature	-40C to +85C
Ingress Protection	IP67
Capacity	Connects up to 3 Sensors to Gateway Hub, or 2n+1 sensors where n equals the number of gateway hubs
Mounting	Mounting kit to gateway device, or by 2 screws direct to bulkhead / wall etc...
Size	114mm wide by 350mm long (incl. fly lead & connectors)

9.5.7 Standards and Approvals

- CE
- UKCA
- E - Automotive Zulassung entsprechend Kfz-EMV-Richtlinie
- R & TTE
- ROHS Directive

10 Configuration And Data Management Software (CADS)



10.1 Introduction

The Tan Delta Configuration and Data Software (CADS) is used to configure our core products, the Oil Condition Sensor (OQSxG2), EX GEN II (ATEX, IECEX, US/C, UKEX) Oil Quality Sensor and Oil Quality Display Express (OQDe). These products have a range of configurable parameters, allowing you to create a bespoke system for virtually any application.

10.2 Set Up

To install the software:

- Connect the memory stick supplied with your Tan Delta product to a USB port on your PC or laptop. Allow the PC/laptop to automatically update drivers, if needed.

- When prompted, select **Open folder** to view files.
- Double click the **setup** file and follow the instructions in the setup wizard.
- When prompted, click on **Install**.
- The first time you launch CADS you will be prompted to install the latest drivers for the Configuration cable. Select yes and follow the instructions in the set-up wizard.

Figure 53 - Driver Update

- You will also be prompted to select some basic set-up parameters, for oil temperature (Celsius or Fahrenheit) and condition (Tan Delta Number, Loss Factor.
- When installation is complete, *CADS* is displayed

10.3 Operation

The instructions on how to configure each product using CADS are contained within the sensor setup sections of this manual.

10.3.1 Oil Database

The oil database contains configuration profiles for different oils which can be programmed into any sensor. The software comes pre-loaded with the latest version and will automatically update periodically with the new oils we have added. If you have requested for a specific oil to be profiled, you may have been sent the database which will need to be loaded into the software manually.

- From the home screen click the cog icon ‘Application Settings’ to bring up the settings menu and select ‘Update From File’.
- Select ‘OilDb.oils’ from file location and select ‘Save’.

Note: At this point you can also select temperature (˚C/˚F) and oil condition units (Tan Delta Number/Loss Factor/Oil Quality Index)

10.4 Live Readings

10.4.1 Take Readings

Once on the live readings screen, as shown below, you need to select the required polling frequency, from 00:02 to 05:00. The correct frequency will generally depend on how long you intend to log data.

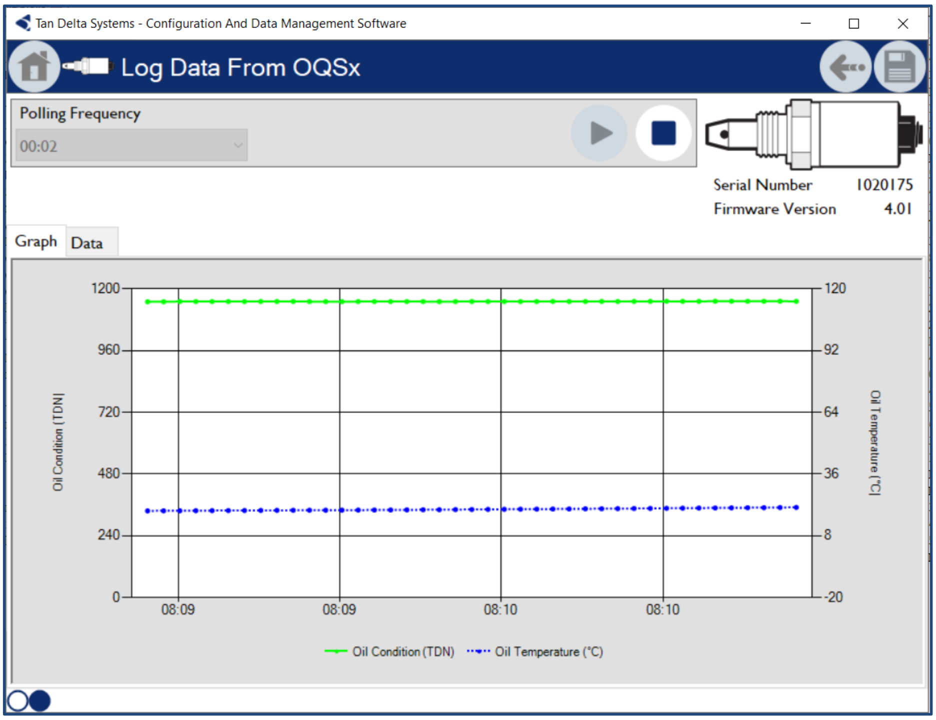


Figure 54 - Live Readings Screen

To begin taking readings, simply click the ‘Start’ button. The readings will then begin to log and can be displayed in a ‘Graph’ or ‘Data’ view using the 2 tabs.

We recommend waiting approx. 1 minute for the readings to stabilize and discarding any data before this point.

Once you are happy the data is reliable and consistent you can save the data by clicking the save icon in in top right corner. See the data graphing section below for how to view these log files in CADS.

10.4.2 Cleaning

If using the Live Readings function to compare different oil samples, please follow our OQSxG2 Cleaning Procedure between each sample.

10.5 Data Download

10.5.1 Download from OQDe (Legacy V1 Display ONLY)

Please note, this function is not yet available for the V2 of the Display Express.

From the home screen, select the 'Download Data from Oil Quality Display Express' option.

Once in the search screen, connect the OQDe with the configuration cable, select the correct device and click the arrow to proceed.

When prompted, select 'Download Datalogs'

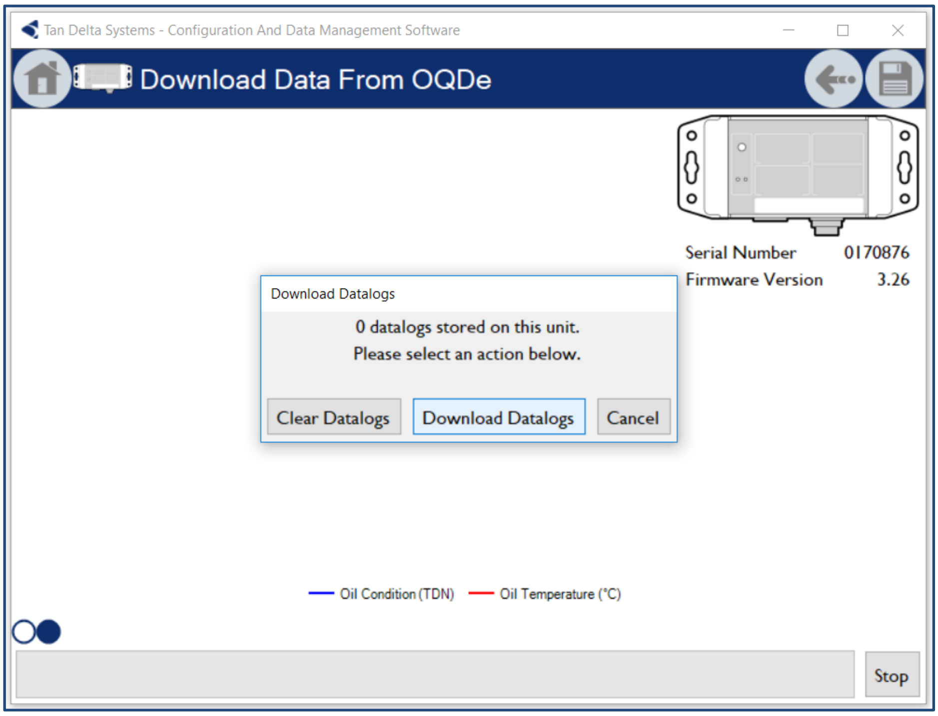


Figure 55 - CADS Data Download

As shown in **Figure 56**, the data being downloaded is displayed in a graph and you can stop the download at any point using the button in the bottom right corner.

Once the download is complete, click the Save icon and save to your chosen file location.

10.5.2 Data Graphing

CADS can be used to graph a log file from CADS or OQDe and show oil condition and temperature trends over time.

From the CADS home screen click ‘View Datalog File’ and select the .tsv file you wish to view.

Once graph is plotted you can view the Oil Condition and Oil Temperature data, plotted over time.

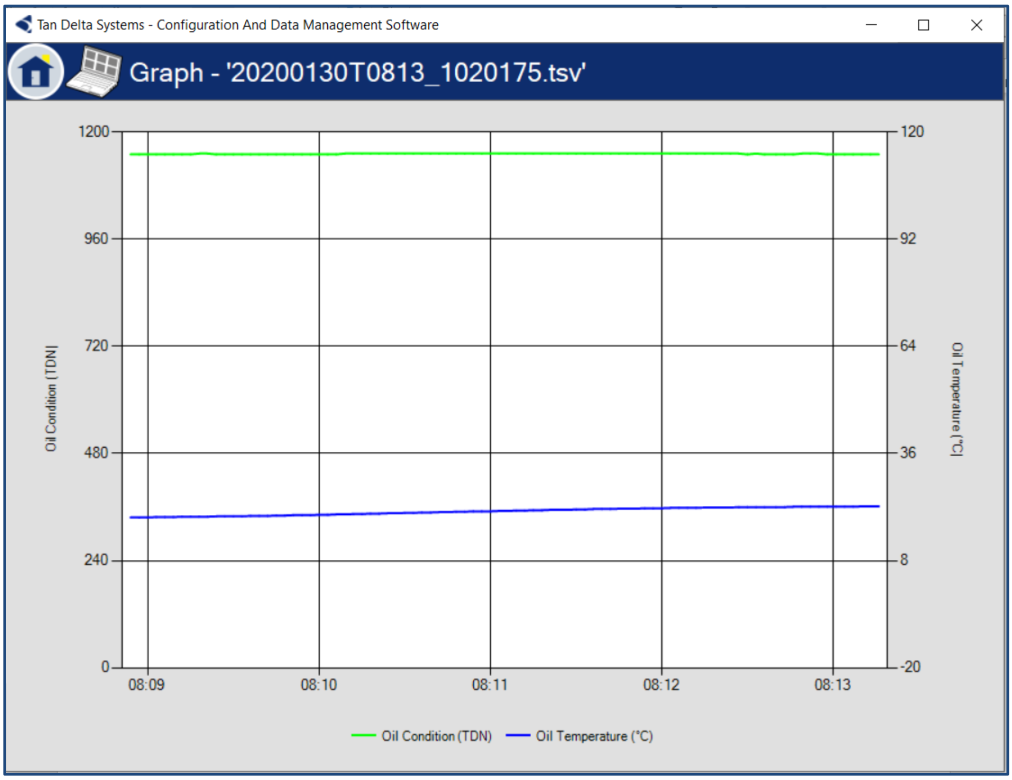


Figure 56 - CADS Graph

11 Interface Options

Note: Oil condition output in Loss Factor % can be converted to Tan Delta Number.

This can be converted to TDN using the following formula where T = TDN, L = Loss Factor %:

T = 900 - 20L

Temperature outputs in °C and can be converted to °F using the following formula:

T(°F) = T(°C) × 1.8 + 32

11.1 Tan Delta Communication Protocol

The command protocol and language for the Tan Delta serial communications uses a binary command format communicating over a half-duplex RS485 interface. The serial configuration must be set to 8 bits with no parity and one stop bit. The default baud-rate is 9600 bits per second. The Tan Delta unit operates in a slave mode, with the serial device which controls the communications (e.g. the monitoring computer) acting as master and issuing commands to which the slave will reply. Tan Delta will not transmit any data except in response to a command from the master and will expect no further commands until the last command has been replied to.

Commands are multiple sequences of bytes which must be interpreted as a complete data string before the correct action and response can be determined. Any command which is not interpreted and verified will cause the command interpreter to reset back to its initial state, and any interruption of communications of longer than 1s will cause the same result. The master must therefore check for correct response in all cases and re-send any commands which have been corrupted or misinterpreted.

Note that all hexadecimal bytes referred to here are physically sent on the RS485 bus as pair of ASCII characters. Thus the wake-up character “!”, which has an ASCII value of 0x21 is physically sent as the pair of ASCII bytes “2”, “1” (hex 0x32, 0x31). This provides further security as only valid ASCII characters are recognised and simplifies monitoring and debugging of command sequences. It is important to understand that all “bytes” and “byte-counts” referred to below comprise these pairs of ASCII characters when physically transmitted on the bus.

The detailed structure of commands is as detailed below.

The command structure is as follows:

Byte Number	Value	Description
Byte 0	“!”	acknowledge code
Byte 1	<count>	number of bytes to follow, including <cksm> and <count>
Byte 2	<iaddr>	Single byte instrument address
Byte 3&4	<cmd>	two byte command
Bytes 5 to n-1*	<data>	optional, depending on the command
Byte n, n+1*	<cksm>	16 bit inverse checksum of all preceding bytes including acknowledge

*n = <count-1>

The response structure is as follows:

Byte Number	Value	Description
Byte 0	“A”	wake-up code
Byte 1	<count>	number of bytes to follow, including <cksm> but excluding <count>
Byte 2 to n-1	<response>	optional, depending on the command
Byte n, n+1*	<cksm>	16 bit inverse checksum of all preceding bytes including acknowledge

*n = <count>

11.1.1 Checksum

The checksum is calculated by creating an unsigned 16 bit sum of all preceding data bytes, discarding any overflow and then subtracting the result from 65535.

11.1.2 Command Overview

(see below for detailed description of data and response strings)

Commands are divided into two categories:

- Read commands which read data from the Tan Delta unit, beginning “R”

<cmd>	Description	<data>	<response>
“Rc”	Read config settings	2 byte address plus 1 byte <length>	<length+2> bytes
“Rm”	Read system memory	2 byte address plus 1 byte <length>	<length+2> bytes
“Rr”	Read current readings	2 byte address plus 1 byte <length>	<length+2> bytes
“Rv”	Read version and serial no	2 byte address plus 1 byte <length>	<length+2> bytes

Note that <length> can exceed the data required: additional bytes will be returned but are redundant.

- Write commands which write data to the Tan Delta unit, beginning “W”

<cmd>	Description	<data>	<response>
“Wc”	Write channel settings	2 byte address plus 1 byte <length> plus <length> data	4 bytes

"Wm"	Write system memory	2 byte address plus 1 byte <length> plus <length> data	4 bytes

Note that <length> must be exact and must match the data sent.

1. Read commands allow access to current channel and system settings for confirmation and management of the unit's operation and current measurements (readings) acquired by the units. Note that all commands use exactly the same mechanism as "Read Memory", accessing system memory but adding the address onto a starting address appropriate to the command; thus "Read Channel Settings" with address 0x03 and length 0x06 reads six bytes, starting from the third byte of the Setup structure within system memory.
2. Write commands allow the remote configuration of current channel and system settings for management of the units' operation, and modification of the unit's system memory, for use in monitoring and debugging operations only.

11.1.3 Read Current Readings Command "Rr"

This command has two items of data, a two byte <starting address> and a single byte <length>. It commands the Tan Delta unit addressed by <iaddr> to transmit <length> bytes from <starting address> relative to the start of the current readings array for each of the three channels within the unit. Each reading comprises three bytes of data in 32 bit floating point format and must be interpreted as such by the receiving system. If the command is correctly interpreted, the Tan Delta unit addressed will acknowledge the command with the Ack code, echo the number of bytes it will transmit, and send a response containing the data requested, followed by a checksum. If the command is not correctly interpreted, the Tan Delta unit addressed will acknowledge with the Error code and a checksum. If the unit addressed cannot be found, there will be no reply.

The command string is 10 bytes long (no. of bytes in each field as subscript):

"!",<09$_1$>,<iaddr$_1$>,"R","r",<start address$_2$>,<length*$_1$>,<cksm$_2$>
(*length >= 0x0C)

The response string comprises the acknowledge character, the <count> of bytes to follow and then <length> bytes of data, followed by a 16 bit checksum. In its most common usage as used to download all three channel readings, this will comprise 12 bytes of data, as follows:

Bytes 0-3 32 bit floating point representation of Oil Temp value, in C (unless otherwise scaled)
Bytes 4-7 32 bit floating point representation of Ambient Temp value, in C (unless otherwise scaled)
Bytes 8-11 32 bit floating point representation of Oil Condition value, in %

Thus the response string is <length> + 4 bytes long (no. of bytes in each field as subscript):

"A",<length+2$_1$>,<length bytes of data>,<cksm$_2$>

Or, in case of error:"E",<021>,< FFB82>

11.1.4 Read Memory Command "Rm"

This command has two items of data, a two byte starting <address> and a single byte <length>, allowing a read of up to 256 addresses from system memory. It commands the Tan Delta unit addressed by <iaddr> to transmit <length> memory bytes starting at <address>. If the command is correctly interpreted, the Tan Delta unit addressed will acknowledge the command with the Ack code, echo the number of bytes it will transmit, and send a response containing all the data requested, followed by a checksum. If the command is not correctly interpreted, or the starting <address> is outside the range of system memory, the Tan Delta unit addressed will acknowledge with the Error code and a checksum. If the unit addressed cannot be found, there will be no reply.

The command string is 10 bytes long (no. of bytes in each field as subscript):

“!”,<09$_1$>,<iaddr$_1$>,“R”,“m”,<record no$_2$>,<length$_1$>,<cksm$_2$>

The response string comprises the acknowledge character, the <count> of bytes to follow and then <length> bytes, followed by a 16 bit checksum.

Thus the response string is (4 + <length>) bytes long (no. of bytes in each field as subscript):

“A”,<length+2$_1$>,<byte 1>,<byte 2>,...,<byte n*>,<cksm$_2$>
(*n = length)

or, in case of error: **“E”,<02$_1$>,< FFB8$_2$>**

11.1.5 Read Config Data Command “Rc”

This command has two items of data, a two byte <starting address> and a single byte <length>. It commands the Tan Delta unit addressed by <iaddr> to transmit <length> bytes from <starting address> relative to the start of the channel settings and alarm array for each of the three channels within the unit, and the two relays and eight alarm definitions. Config settings are as defined below and must be correctly interpreted by the receiving system. If the command is correctly interpreted, the Tan Delta unit addressed will acknowledge the command with the Ack code, echo the number of bytes it will transmit, and send a response containing the data requested, followed by a checksum. If the command is not correctly interpreted, the Tan Delta unit addressed will acknowledge with the Error code and a checksum. If the unit addressed cannot be found, there will be no reply.

The command string is 10 bytes long (no. of bytes in each field as subscript):

“!”,<09$_1$>,<iaddr$_1$>,“R”,“c”,<start address$_2$>,<length$_1$>,<cksm$_2$>

The response string comprises the acknowledge character, the <count> of bytes to follow and then <length> bytes of data, followed by a 16 bit checksum. The data returned will be dependent on the particular parameters specified by the start address.

Thus the response string is <length> + 4 bytes long (no. of bytes in each field as subscript):-

“A”,<length+2$_1$>,<length bytes of data>,<cksm$_2$>

or, in case of error:- **“E”,<02$_1$>,< FFB8$_2$>**

11.1.6 Read Version and Serial Number Command “Rv”

This command has two items of data, a two byte <starting address> and a single byte <length>. It commands the Tan Delta unit addressed by <iaddr> to transmit <length> bytes from <starting

address> relative to the software Version No. variable. Version and Serial No. information is as defined below and must be correctly interpreted by the receiving system. If the command is correctly interpreted, the Tan Delta unit addressed will acknowledge the command with the Ack code, echo the number of bytes it will transmit, and send a response containing the data requested, followed by a checksum. If the command is not correctly interpreted, the Tan Delta unit addressed will acknowledge with the Error code and a checksum. If the unit addressed cannot be found, there will be no reply.

The command string is 10 bytes long (no. of bytes in each field as subscript):

“!”,<09$_1$>,<iaddr$_1$>,“R”,“v”,<start address$_2$>,<length$_1$>,<cksm$_2$>

The response string comprises the acknowledge character, the <count> of bytes to follow and then <length> bytes of data, followed by a 16 bit checksum. The start address should be 0000 to return:-

Software Version No: 4 byte floating point version no.

Thus the response string is <length> + 4 bytes long (no. of bytes in each field as subscript):-

“A”,<length+2$_1$>,<length bytes of data>,<cksm$_2$>

or, in case of error: **“E”,<02$_1$>,< FFB8$_2$>**

11.1.7 Parameter Addresses

Parameter	Start Addr	Access
Cal Zero	0x0000	R/W
Instrument Address	0x002C	R/W
Serial Type	0x002D	R/W
Max Temp	0x002E	RO
Serial No.	0x004E	RO
Oil Data String	0x0056	R/W
Hardware Version No.	0x007B	RO
CAN Transmission Type	0x00A4	R/W
CAN Event Timer	0x00A5	R/W
CAN TPDO settings	0x00A7	R/W
Filter TC	0x00EF	R/W (V2.10+)
Baud Rate	0x00F0	R/W (V2.10+)
CAN Bit Rate	0x00F1	R/W (V2.10+)

11.2 CANopen

The OQS-CAN Oil Quality Sensor measures the Oil Condition, Oil Temperature and Ambient (Sensor) Temperature. The range is from a nominal -20% to +60% Oil Condition units and -30 to +130C. The measured value is transmitted on the CAN-bus using the CANOpen protocol based on the CAN in Automation standard profile CiA DS 404 V1.2. The Sensor samples at 100 samples per second, filters and converts the raw signal to a conditioned output signal.

TANDELTA

The CAN interface uses a default bit rate of 125 kb/s with 11 bit identifiers.

The CAN protocol complies with the CANOpen specification DS301 and the Oil Quality Sensor conforms to CANOpen device profile DS404. Node Guarding and Emergency messages are implemented to ensure high reliability.

11.2.1 CAN Interface

The Sensor uses a full CAN controller specified to conform with CAN 2.0B. The physical layer of the 2 wire interface is specified according to ISO 11898. The wires are protected against short circuit and noise emission is minimized. No bus termination resistors are included within the sensor.

11.2.2 OQS-CAN Specification

Supply voltage:	+9 to +30 Vd.c.
Current consumption:	50mA max. when quiescent, 100mA max. with CAN active 30-40mA typical
CAN physical layer:	2 wire interface @ 5V d.c. voltage levels a/c to ISO 11898 Short circuit protected
CAN bitrate:	125kbit/s
Bus termination:	External
Protocol:	CANOpen DS301, Device Profile DS404
Environment:	noise emission according to EN 50 081-2 Noise immunity according to EN 50 082-2
Operating temperature:	-20 to +120C
Storage temperature:	-40 to +150C

11.2.3 Connection Details

The sensor uses a Bulgin 4000 series male connector with the following pin assignments: -

P1:	+9 to +30V d.c. power supply
P2:	Analog 4-20mA Oil Temp output (active, current sourcing)
P3:	Analog 4-20mA Oil Condition output (active, current sourcing)
P4:	CANL/RS485A
P5:	0V
P6:	CANH/RS485B

11.2.4 CANOpen Communication

11.2.4.1 *Summary of the CANOpen functions*

CANOpen type:	NMT slave
Network bootup:	Minimum bootup
COB ID:	pre-defined connection set, SDO
Node ID:	object (specific entry – read/write, **default 1**)

Bitrate: object (specific entry - read only, **fixed 125kbit/s**)

Number of PDOs: PDO1 synchronous or asynchronous configurable

Emergency message: supported

Node Guarding: supported

Device Profile: DS404

11.2.4.2 *Object Dictionary Communication Profile*

Index (HEX)	Sub Index	Name	Type	Access	Default	Comment
1000	00	Device Type	U32	RO	0x000E0194	DSP404 analog output, input & digital output
1001	00	Error Register	U8	RO	0x00	

Error Register definition (index 0x1001); 0 = no error, 1 = error:

B0: Global Error
B1: unused
B2: unused
B3: Temperature Error
B4: CAN Communication Error
B5: Oil Quality Error
B6: unused
B7: unused

Index (HEX)	Sub Index	Name	Type	Access	Default	Comment
1005	00	COB-ID SYNC	U32	RO	0x80	
1008	00	Manufacturer Device Name	VIS STR	RO	“Oil Quality Sensor”	Sales Code
1009	00	Manufacturer Hardware Version	VIS STR	RO	“V19”	Build Version
100A	00	Manufacturer Software Version	VIS STR	RO	“3.101”	Software Version
100C	00	Guard Time	U16	RO	20000	
100D	00	Life Factor	U16	RO	1	
1018		Identity Object				
	00	Number of entries	U8	RO	0x4	
	01	Vendor ID	U32	RO	0x32F	Vendor ID
	02	Product Code	U32	RO	111021	Sales Code
	03	Revision No.	U32	RO	0900	
	04	Serial No.	U32	RO		S/No.

Index (HEX)	Sub Index	Name	Type	Access	Default	Comment
1800		Transmit PDO parameter				
	00	Number of entries	U8	RO	0x5	
	01	COB-ID used by PDO	U32	RO	0x180	0x180 + Node-ID
	02	Transmission Type	U8	RW	0x1	0x01 = every SYNC, 0x02 to 0xF0 = every 2nd to 240th SYNC, 0xFF = ASYNC according to Event Timer
	03	Inhibit Time	U16	RO	0x0	
	04	Reserved	U8	RO	0x0	
	05	Event Timer	U16	RW	0x3E8	Interval in ms, 1s default
1A00		Transmit PDO1 mapping				
	00	Number of entries	U8	RO	0x02	
	01	PDO mapping for the 1st application object to be mapped	U32	RW	0x91300320	Oil Condition as I32: 0x91300320 Oil Condition as F32 0x61300320
	02	PDO mapping for the 2nd application object to be mapped	U32	RW	0x91300120	Oil Temperature as I32: 0x91300120 Oil Temperature as F32: 0x61300120

Index (HEX)	Sub Index	Name	Type	Access	Default	Comment
1F80	00	NMT startup	U32	RW	0x0x	0x0x = Follow standard 0x1x = Self-starting Typically, a CANopen slave will launch into pre-op mode and a network master must setup the device. With the self-starting bit enabled the sensor will launch into operational mode when ready during bootup, this allows the sensor to communicate on a simplified CANopen network that may not have a master present. Note: The low nibble of this byte is used for serial type. See 0x4000:00

Index (HEX)	Sub Index	Name	Type	Access	Default	Comment
4000	00	Serial Type	U8	RW	0x01	**0x01** = TanDelta via RS485 **0x02** = CANopoen via CANbus 0x03 = Modbus RTU via RS485 0x05 = J2939 via CANbus Note: The high nibble of this byte is used for flags which influence the serial communications. See 0x1F80:00
4001	00	Sensor Address	U8	RW	0x01	Node ID for CAN, Sensor Address for other serial interfaces
4002	00	RS485 Baudrate	U8	RO	0x00	9600 Baud ONLY
4003	00	CANbus Bitrate	U8	RW	0x05	0 = 1 Mbps 1 = 800 kbps 2-3 = 500 kbps 4 = 250 kbps

						5 = 125 kbps (default) 6 = 50 kbps 7 = 20 kbps
4004	00	Sensor ID String	VIS STR	RO	0x05	Writable externally to CAN
	01	Sensor ID String bytes 0 - 6	VIS STR	RO	"Sensor ID string"	First 7 bytes of ID string
	02	Sensor ID String bytes 7 - 13	VIS STR	RO	"Sensor ID string"	Next 7 bytes of ID string
	03	Etc.	Etc.	Etc.	Etc.	Etc.
	04	Etc.	Etc.	Etc.	Etc.	Etc.

11.2.4.3 *Object Dictionary Device Profile - Analogue Input Function Block*

Index (HEX)	Sub Index	Name	Type	Access	Default	Comment
6110		AI Sensor Type				
	00	Number of entries	U8	RO	0x3	
	01	AI Sensor Type 1	U16	RO	0x64	100 = Temperature sensor
	02	AI Sensor Type 2	U16	RO	0x64	100 = Temperature sensor
	03	AI Sensor Type 3	U16	RO	0x2710	10000 = Oil condition sensor (Manufacturer defined)
6124		AI Input Offset				
	00	Number of entries	U8	RO	0x1	
	01	AI Input Offset 3	F32	RW		Oil Condition Cal. Zero voltage
6125		AI Autozero				
	00	Number of entries	U8	RO	0x01	
	01	AI Input Autozero 3	U32	WO		Autozero Oil Condition
6126		AI Scaling Factor				
	00	Number of entries	U8	RO	0x01	
	01	AI Input Scaling 3	F32	RO		Oil Condition Gain %
6127		AI Scaling Offset				
	00	Number of entries	U8	RO	0x05	
	01	AI Scaling Offset 1	F32	RW		Oil Normalisation Param 1
	02	AI Scaling Offset 2	F32	RW		Oil Normalisation Param 2
	03	AI Scaling Offset 3	F32	RW		Oil Normalisation Param 3
	04	AI Scaling Offset 4	F32	RW		Oil Normalisation Param 4
	05	AI Scaling Offset 5	F32	RW		Oil Normalisation Param 5
6130		AI Input PV				
	00	Number of entries	U8	RO	0x03	
	01	AI Input PV1	F32	RO		Oil Temp. Value
	02	AI Input PV2	F32	RO		Sensor Temp. Value
	03	AI Input PV3	F32	RO		Oil Condition Value/Alarm State
	04	AI Input PV4	F32	RO		Oil Temp. Value in F
	05	AI Input PV5	F32	RO		Sensor Temp. Value in F
	06	AI Input PV6	F32	RO		**RESERVED**
	07	AI Input PV7	F32	RO		Encrypted RUL
6132		AI Decimal Digits PV				0: integer scaled as is 1: integer scaled *10 2: integer scaled *100 etc.
	00	Number of entries	U8	RO	0x03	
	01	AI Dec. Digits PV1	U8	RW	0x02	Oil Temp. Integer Scaling
	02	AI Dec. Digits PV2	U8	RW	0x02	Sensor Temp. Integer Scaling

	03	AI Dec. Digits PV3	U8	RW	0x02	Oil Condition Integer Scaling
6135		AI Interrupt Upper Limit I/P PV				
	00	Number of entries	U8	RO	0x03	
	08	AI Interrupt Upper Limit IP PV8	F32	RW	0d30	End of Life Value (LF units)
6148		AI Span Start				
	00	Number of entries	U8	RO	0x03	
	01	AI Span Start 1	F32	RO		Oil Temp. Min Range
	01	AI Span Start 2	F32	RO		Sensor Temp. Min Range
	01	AI Span Start 3	F32	RO		Oil Cond. Min Range
6149		AI Span End				
	00	Number of entries	U8	RO	0x03	
	01	AI Span End 1	F32	RO		Oil Temp. Max Range
	01	AI Span End 2	F32	RO		Sensor Temp. Max Range
	01	AI Span End 3	F32	RO		Oil Cond. Max Range
61A0		AI Filter Type				0: unfiltered 1: exponential average
	00	Number of entries	U8	RO	0x01	
	01	AI Filter Type 1	U8	RO	0x01	Exponential average
61A1		AI Filter Constant				
	00	Number of entries	U8	RO	0x01	
	01	AI Filter Const. 1	U8	RO	0x07	1/(2^<Filter Const)* new sample
6F20						
	00	Number of entries	U8	RO	0x01	
	01	AI Oil Data String	STR	RW		Oil Data String
9130		AI Input PV				
	00	Number of entries	U8	RO	0x03	
	01	AI Input PV1	I32	RO		Oil Temp. Value
	02	AI Input PV2	I32	RO		Sensor Temp. Value
	03	AI Input PV3	I32	RO		Oil Condition Value/Alarm State
	04	AI Input PV4	I32	RO		Oil Temp. Value in F
	05	AI Input PV5	I32	RO		Sensor Temp. Value in F
	06	AI Input PV6	I32	RO		**RESERVED**
	07	AI input PV7	I32	RO		Encrypted RUL
9148		AI Span Start				
	00	Number of entries	U8	RO	0x03	
	01	AI Span Start 1	I32	RO		Oil Temp. Min Range
	01	AI Span Start 2	I32	RO		Sensor Temp. Min Range
	01	AI Span Start 3	I32	RO		Oil Cond. Min Range
9149		AI Span End				
	00	Number of entries	U8	RO	0x03	
	01	AI Span End 1	I32	RO		Oil Temp. Max Range
	01	AI Span End 2	I32	RO		Sensor Temp. Max Range
	01	AI Span End 3	I32	RO		Oil Cond. Max Range

11.2.5 CAN Communication without CANOpen Functionality

11.2.5.1 *Basic Configuration - examples of common settings*

The OQS-CAN Sensor can be used successfully in CAN networks without full CANOpen functionality. Before using the Sensor within the network the following should be noted and configured where necessary. Note that you will need to know the current Node ID to communicate with the sensor; if you are unsure of this value and it has been changed from the default, you can identify it from the boot-up message issued by the sensor on startup. This will be

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7

Message	0x700+ NodeID	1	0x00	NA	NA	NA	NA	NA	NA	NA

Thus a startup message from a COB-ID of 0x71C indicates that the sensor has a Node ID of 0x1C, or 28 decimal.

Bitrate: Object 0x4003, subindex 0. This is, by default, 125kbits/s (CAN bitrate 5) but can be changed – see Section 5.2 above for details.

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	8	0x40	0x03	0x40	0x00	NA	NA	NA	NA
Reply	0x580+ NodeID	8	0x40	0x03	0x40	0x00	0x05	0x00	0x00	0x00

To change the bitrate to <Bitrate> use the following command. Note that the number to be entered in this field is the bitrate code, from 0 to 7, not the actual bits/s. Note that you must restart the sensor to make this change active.

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x2F	0x03	0x40	0x00	<bitrate>	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x60	0x03	0x40	0x00	NA	NA	NA	NA

Node ID: Object 0x4001, subindex 0. This is 0x01 by default and can be changed. Valid values are between 1 and 127 (0x7f). To read use the following command

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x01	0x40	0x00	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x40	0x01	0x40	0x00	<NodeID>	0x00	0x00	0x00

To change the Node ID to New ID use the following command

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x2F	0x01	0x40	0x00	<NewID>	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x60	0x01	0x40	0x00	NA	NA	NA	NA

The sensor will need restarting (powering off and then on again) before the change becomes effective and the new ID is valid. Any changes made are saved automatically in non-volatile memory.

Transmission Type: Object 0x1800, subindex 2. This is 0x00 (send PDO response every SYNC command) by default and can be changed. Values from 0x00 to 0xF0 represent synchronous response every <TType>+1 SYNC commands and 0xFF represents an asynchronous (timed) response every <Event Timer> ms (default 1000ms). See below to change the Event Timer value. To read use the following command

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x00	0x18	0x02	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x4F	0x00	0x18	0x02	<TType>	NA	NA	NA

To change the Transmission Type to New Type use the following command

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x2F	0x00	0x18	0x02	<NewType>	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x60	0x00	0x18	0x02	NA	NA	NA	NA

Event Timer: Object 0x1800, subindex 5. This is 0x3E8 (1000 ms) by default and can be changed. Values from 0x0064 to 0xFFFF (decimal 100 to 65535) will generate a Timer Event every <Timer> ms, which can be used to generate a timed PDO response – see above to select Timed PDO responses. To read use the following command:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x00	0x18	0x05	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x40	0x00	0x18	0x05	<Timer LSB>	<Timer MSB>	NA	NA

To change the Event Timer value to <NewTime> use the following command

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x2E	0x00	0x18	0x05	<NewTime LSB>	<NewTime MSB>	NA	NA
Reply	0x580+ NodeID	0x08	0x60	0x00	0x18	0x05	NA	NA	NA	NA

PDO Data Selection and Format: Object 0x1A00, subindex 1 and 2. These values are 0x61300320 (Oil Condition, F32 format) and 0x61300120 (Oil Temperature, F32 format) by default and can be changed. New variables, in different formats can be selected from the Object Dictionary as detailed above. To read use the following command.

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x00	0x1A	0x01(2)	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x40	0x00	0x1A	0x01(2)	<Variable LSB>	<Variable byte1>	<Variable byte2>	<Variable MSB>

The Variable bytes for the default configuration would be 20, 03, 30, 61 for the oil condition value in F32 format, and 20, 01, 30, 61 for the oil temperature in F32 format.

To change the PDO Data Selection and Format to <NewPDO> use the following command

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x23	0x00	0x1A	0x01(2)	<Variable LSB>	<Variable byte1>	<Variable byte2>	<Variable MSB>
Reply	0x580+ NodeID	0x08	0x60	0x00	0x1A	0x01(2)	NA	NA	NA	NA

For example, the Variable bytes needed to set the two values returned by the PDO to Oil Condition in I32 format (0x91300120) and Oil Temperature in I32 format (0x91100120) would entail writing 20, 03, 30, 91 to subindex 01, and 20, 01, 30, 91 to subindex 02 – see above in the Object Dictionary.

11.2.5.2 *Network Operation without CANOpen Master*

After connecting the Sensor to the network and applying power, the Sensor will enter the pre-operational state and issue the boot-up message as described above. In normal operation with a CANOpen Master present, the Master will then issue a command to set the Sensor into a fully operational mode and take over control. If the Master is not present this same operation can be done by setting the Sensor to Self-Starting mode. This is done by setting NMT Startup, Object 0x1F80, to 0x12 and then restarting the Sensor, as follows

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x2F	0x80	0x1F	0x00	0x12	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x60	0x80	0x1F	0x00	NA	NA	NA	NA

The Sensor will now be in Self-Starting mode and will automatically enter full Operational mode after every startup. SYNC commands can then be issued by any other CANOpen device to elicit the Sensor's normal PDO response which is to send the Oil Condition and Temperature in 32-bit floating point format. This will be as follows:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7

Command	0x080	0x00	NA	NA	NA	NA	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	<Tb0>	<Tb1>	<Tb2>	<Tb3>	<Cb0>	<Cb1>	<Cb2>	<Cb3>

Where Tb3 to Tb0 are the most significant to least significant bytes of the 32 bit floating point Oil Temperature value and Cb3 to Cb0 similarly for the Oil Condition. Thus values of 0A,D7,D5,41,7B,14,AE,3F in databytes B0 to B7 equates to hexadecimal values of 41D5D70A and 3FAE147B (byte order rearranged) and floating point values of 26.73C and 1.36%. The Node ID of the sensor returning this data can be inferred from the ID byte as defined in the CAN Open specification for TPDO transmissions. This means that multiple sensors may be connected to the same CAN-bus as long as they have different Node IDs, and if they are all configured in this way, each will return the above response to a single SYNC command

11.2.5.3 *Reading and Writing Parameters and Values*

Individual parameters may be read or written according to the RO,WO or RW) or equivalent) setting of that object using the standard SDO format as defined within the CAN Open specification. The following examples show the process of reading a value, and both reading and writing a parameter.

11.2.5.4 *Reading the Ambient (Sensor) Temperature I32 format*

The Sensor Temperature may be read as a 32 bit integer by performing an SDO read of the object at index 0x9130, sub-index 02 as specified in the Object Dictionary (see section 5.2, Analogue Input Function Block). The command is as follows:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x30	0x91	0x02	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x43	0x30	0x91	0x02	<Tb0>	<Tb1>	<Tb2>	<Tb3>

The value is returned as a signed integer number in bytes Tb0 to Tb3, where Tb3 is the MSB and Tb0 the LSB. The value is multiplied by the power of ten specified in PV Decimal Digits at index 0x6132, sub-index 02. Thus with a default PV Decimal Digits value of 2, the floating point value is multiplied by 10^2, or 100 so that the last two decimal digits are fractional after an implied decimal point so a decimal value of 3214 would translate to 32.14C.

11.2.5.5 *Reading the Oil Condition Cal Zero Voltage*

The Oil Condition Cal Zero Voltage may be read as a 32 bit floating point number by performing an SDO read of the object at index 0x6124, sub-index 01 as specified in the Object Dictionary (see section 5.2, Analogue Input Function Block). The command is as follows:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x24	0x61	0x01	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x43	0x24	0x61	0x01	<Zb0>	<Zb1>	<Zb2>	<Zb3>

The value is returned as a floating point number in bytes Zb0 to Zb3, where Zb3 is the MSB and Zb0 the LSB.

11.2.5.6 *Writing the Oil Condition Cal Zero Voltage*

The Oil Condition Cal Zero Voltage may be changed by performing an SDO write of the object at index 0x6124, sub-index 01 as specified in the Object Dictionary (see section 5.2, Analogue Input Function Block). The command is as follows:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x2F	0x24	0x61	0x01	<Zb0>	<Zb1>	<Zb2>	<Zb3>
Reply	0x580+ NodeID	0x08	0x60	0x24	0x61	0x01	NA	NA	NA	NA

The value to be written is formatted as above. In this way the calibration of the sensor may be adjusted.

11.2.5.7 *Reading the Oil Data String from the Oil Database*

The Oil Condition Cal Data String may be read by performing an SDO read (Domain Upload) from the object at index 0x6F20, sub-index 01 as specified in the Object Dictionary (see section 5.2, Analogue Input Function Block). The command is as follows:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x20	0x6F	0x01	0x00	0x00	0x00	0x00
Reply	0x580+ NodeID	0x08	0x41	0x20	0x6F	0x01	0x25	NA	NA	NA
Command	0x600+ NodeID	0x08	0x60	0x20	0x6F	0x01	0x00	0x00	0x00	0x00
Reply	0x580+ NodeID	0x08	0x60	0x31	0x43	0x5E	0xB8	0xDB	0x00	0x43
Command	0x600+ NodeID	0x08	0x70	0x20	0x6F	0x01	0x00	0x00	0x00	0x00
Reply	0x580+ NodeID	0x08	0x70	0x17	0xA4	0x35	0x7B	0x00	0x35	0x43
Command	0x600+ NodeID	0x08	0x60	0x20	0x6F	0x01	0x00	0x00	0x00	0x00
Reply	0x580+ NodeID	0x08	0x60	0x00	0x00	0x50	0xA0	0x8A	0x1F	0x87
Command	0x600+ NodeID	0x08	0x70	0x20	0x6F	0x01	0x00	0x00	0x00	0x00
Reply	0x580+ NodeID	0x08	0x70	0xFA	0x0A	0xBA	0xAD	0x81	0x00	0xF1
Command	0x600+ NodeID	0x08	0x60	0x20	0x6F	0x01	0x00	0x00	0x00	0x00
Reply	0x580+ NodeID	0x08	0x60	0xD1	0x17	0x00	0x3E	0xB7	0xAA	0xA8
Command	0x600+ NodeID	0x08	0x70	0x20	0x6F	0x01	0x00	0x00	0x00	0x00
Reply	0x580+ NodeID	0x08	0x70	0x00	0x3E	NA	NA	NA	NA	NA

The Oil String Data comprises bytes B1 to B7 successively for each Reply message, plus B1 and B2 of the last message, in that order. The example shown above corresponds to Generic Mineral 15W40, which has string:

31435EB8DB004317A4357B003543000050A08A1F87FA0ABAAD8100F1D117003EB7AAA8003E.

11.2.5.8 *Writing the Oil Data String to the Oil Database*

The Oil Condition Cal Data String may be changed by performing an SDO write (Domain Download) to the object at index 0x6F20, sub-index 01 as specified in the Object Dictionary (see section 5.2, Analogue Input Function Block). The command is as follows:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x20	0x20	0x6F	0x01	0x00	0x00	0x00	0x00
Reply	0x580+ NodeID	0x08	0x60	0x20	0x6F	0x01	0x25	NA	NA	NA
Command	0x600+ NodeID	0x08	0x00	0x03	0x66	0xEE	0xEF	0x6E	0xC4	0x41
Reply	0x580+ NodeID	0x08	0x20	0x20	0x6F	0x01	0x25	NA	NA	NA
Command	0x600+ NodeID	0x08	0x10	0xE6	0xBD	0x08	0x1C	0xB6	0x19	0x00
Reply	0x580+ NodeID	0x08	0x30	0x20	0x6F	0x01	0x25	NA	NA	NA
Command	0x600+ NodeID	0x08	0x00	0x6F	0x77	0x5A	0x3F	0x66	0x3A	0xF0
Reply	0x580+ NodeID	0x08	0x20	0x20	0x6F	0x01	0x25	NA	NA	NA
Command	0x600+ NodeID	0x08	0x10	0x03	0x66	0x06	0x3F	0x12	0xA7	0x49
Reply	0x580+ NodeID	0x08	0x30	0x20	0x6F	0x01	0x25	NA	NA	NA
Command	0x600+ NodeID	0x08	0x00	0xA3	0x03	0x02	0x1B	0x6F	0x12	0x66
Reply	0x580+ NodeID	0x08	0x20	0x20	0x6F	0x01	0x25	NA	NA	NA
Command	0x600+ NodeID	0x08	0x1B	0x3F	0xBF	NA	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x30	0x20	0x6F	0x01	0x25	NA	NA	NA

The value to be written is formatted as above. In this way the calibration of the sensor may be adjusted. The Oil String Data comprises bytes B1 to B7 successively for each Reply message, plus B1 and B2 of the last message, in that order. The example shown above has string 0366EEEF6EC441E6BD081CB619006F775A3F663AF00366063F12A749A303021B6F12663FBF which corresponds to Avia Bantleon Synto.

11.2.5.9 *Reading the Hardware Version No. from the sensor*

The Hardware Version No. may be read as a 3 byte string by performing an SDO read (Expedited Upload) of the object at index 0x1009, sub-index 00 as specified in the Object Dictionary (see section 5.2, Communication Profile). The command is as follows:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x09	0x10	0x00	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x43	0x09	0x10	0x00	<HVb0>	<HVb1>	<HVb2>	NA

The value is returned as a string value in bytes HVb0 to HVb2, where HVb0 is the first character in the string and HVb2 the last character.

11.2.5.10 *Reading the Software Version No. from the sensor*

The Software Version No. may be read as a 5 byte string by performing an SDO read (Domain Upload) of the object at index 0x100A, sub-index 00 as specified in the Object Dictionary (see section 5.2, Communication Profile). The command is as follows:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x0A	0x10	0x00	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x41	0x0A	0x10	0x00	0x05	NA	NA	NA
Command	0x600+ NodeID	0x08	0x60	0x0a	0x10	0x00	0x00	0x00	0x00	0x00
Reply	0x580+ NodeID	0x08	0x05	<SVb0>	<SVb1>	<SVb2>	<SVb3>	<SVb4>	NA	NA

The value is returned as a string value in bytes SVb0 to SVb4, where SVb0 is the first character in the string and SVb4 the last character.

11.2.5.11 *Reading the Serial No. from the sensor*

The Serial No. may be read as a 32-bit unsigned integer by performing an SDO read (Expedited Transfer) of the object at index 0x1018, sub-index 04 as specified in the Object Dictionary (see section 5.2, Communication Profile). The command is as follows:

	ID	DLC	B0	B1	B2	B3	B4	B5	B6	B7
Command	0x600+ NodeID	0x08	0x40	0x18	0x10	0x04	NA	NA	NA	NA
Reply	0x580+ NodeID	0x08	0x43	0x18	0x10	0x04	<SNb3>	<SNb2>	<SNb1>	<SNb0>

The value is returned as a 32 bit unsigned integer value in bytes SNb3 to SNb0, where SNb3 is the MSB of the value and SNb0 the last character.

11.3 Modbus

To select Modbus as the preferred communication method, please use the PC/Laptop Software and refer to the appropriate manual.

11.3.1 Hardware

The Tan Delta serial communication uses an RS485 multi-drop interface.

11.3.2 Configurable Parameters

The serial configuration must be set to 8 bits with no parity and will communicate at 9600 baud. The OQS operates in a slave mode with a default ID of 1 which can be preset to suit on register 11 (0x0B), with the serial device which controls the communications (e.g. the monitoring computer) acting as master and issuing commands to which the slave will reply. OQS will not transmit any data except in response to a command from the master, and will expect no further commands until the last command has been replied to.

11.3.3 Communication Mode

OQS supports communication using the OQS proprietary protocol which uses RS485 in ASCII mode (not covered by this document), and Modbus RTU protocol which uses RS485 in Hex mode. The suitable method of communication can be set by presetting register 12 (0x0C) to:

- TDS RS485 1
- ModBus RTU 2

11.3.4 Message Framing

Message start with a silent interval of at least 3.5 character times then the first field transmitted is assumed to be the device address.

Following the last transmitted character, a similar interval of at least 3.5 character times marks the end of the message. A new message can begin after this interval.

The entire message frame must be transmitted as a continuous stream. If a silent interval of more than 1.5 character times occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte will be the address field of a new message.

Similarly, if a message starts earlier than 3.5 character times following a previous message, the receiving device will consider it a continuation of the previous message. This will set an error, as the value in the final CRC field will not be valid for the combined messages.

A typical message format is shown below:

Start	3.5 Characters
Address	8 Bits
Function	8 Bits
Data	16 Bits
CRC	16 Bits

End	3.5 Characters Time

11.3.5 Function Codes
04 (0x04) Read Input Registers

11.3.5.1 *Data format*
Tan Delta returns all real (non-integer) values as 16 bit signed integers with the value multiplied by 100 (decimal).

For example, a temperature reading of 34.14 degrees C would be returned as 3414 decimal (0D56 hex).

Negative values follow the usual signed format, so -12.34 would be returned as -1234 decimal (Fb2E hex).

11.3.5.2 *Query*
This reads the contents of input registers in the slave. The query message specifies the starting register and number of registers to be read. Information needed to be read from the probe is kept in registers:

Parameters	Registers Decimal	Registers Hex	Access
Oil Temperature *100	0	00	RO
Ambient Temperature * 100	1	01	RO
Oil Condition * 100	2	02	RO
Cal Zero * 100	3	03	RO
Oil Temperature deg F * 100	4	04	RO
Ambient Temperature deg F * 100	5	05	RO
Oil Condition TDN * 10	6	06	RO
Alarm State	7	07	RO
Encrypted RUL	8	08	RO
End of Life Value	10	0A	R/W
Instrument/Node Address	11	0B	R/W
Serial Type (Modbus/CANbus/J1939)	12	0C	RO
Maximum Ambient Temp * 100	13	0D	RO
Serial No.	14	0E	RO
Hardware Version Number	15	0F	RO
Software Version Number * 100	16	10	RO
Serial No. High Digit	17	11	RO
Oil Serial No. 0 (Low)	18	12	RO
Oil Serial No. 1	19	13	RO
Oil Serial No. 2	20	14	RO
Oil Serial No. 3 (High)	21	15	RO
Oil Serial No. 4 (RESERVED)	22	16	RO
Oil Serial No. 5 (RESERVED)	23	17	RO
Oil Serial No. 6 (RESERVED)	24	18	RO

Oil Data String characters 1 & 2	32	20
Oil Data String characters 3 & 4	33	21
Oil Data String characters 5 & 6	34	22
Oil Data String characters 7 & 8	35	23
Oil Data String characters 9 & 10	36	24
Oil Data String characters 11 & 12	37	25
Oil Data String characters 13 & 14	38	26
Oil Data String characters 15 & 16	39	27
Oil Data String characters 17 & 18	40	28
Oil Data String characters 19 & 20	41	29
Oil Data String characters 21 & 22	42	2A
Oil Data String characters 23 & 24	43	2B
Oil Data String characters 25 & 26	44	2C
Oil Data String characters 27 & 28	45	2D
Oil Data String characters 29 & 30	46	2E
Oil Data String characters 31 & 32	47	2F
Oil Data String characters 33 & 34	48	30
Oil Data String characters 35 & 36	49	31
Oil Data String characters 37 (MSB)	50	32

Here is an example of a request to read a single register starting at register 1 (ambient temperature) of device slave 1.

Field Name	Example (Hex)
Slave Address	01
Function	04
Starting Address Hi	00
Starting Address Lo	00
No. of Registers Hi	00
No. of Registers Lo	01
CRC Check	600A

11.3.5.3 *Response*

The register data in the response message are packed as two bytes per register, with the contents right justified within each byte. For each register, the first byte contains the high order bits and the second contains the low order bits.

Here is an example of a response to above query to read a single register, starting at register 0, ambient temperature.

Field Name	Example (Hex)
Address	01
Function	04
Byte Count	02
Data Hi	4E

Data Lo	5A
CRC	0CAB

06 (0x06) Write Single Register

11.3.5.4 *Query*

The Write command specifies the register reference to be preset and allows the remote configuration of channel and system settings for management of the unit's operation, and modification for use in monitoring. The registers which hold the configuration parameters are:

Parameters	Registers Decimal	Registers Hex
Instrument Address	11	0B
Serial Type	12	0C

Here is an example of a request to preset register 11 (instrument address) of device slave 1 to change it to devices slave 4. Note that changing the instrument address or serial type will only take effect after the sensor is shut down and restarted:

Field Name	Example (Hex)
Slave Address	01
Function	06
Starting Address Hi	00
Starting Address Lo	0B
No. of Registers Hi	00
No. of Registers Lo	04
CRC Check	F9CB

11.3.5.5 *Response*

The normal response is an echo of the query, returned after the register contents have been preset.

Here is an example of a response to above query to preset register 11, instrument address to 4.

Field Name	Example (Hex)
Slave Address	01
Function	06
Starting Address Hi	00
Starting Address Lo	0B
No. of Registers Hi	00
No. of Registers Lo	04
CRC Check	F9CB

17 (0x11) Report Slave ID

Returns information about the slave device. Currently returns only the Version No. of the probe firmware.

11.3.6 Troubleshooting

If you are experiencing a communication issue with a Tan Delta sensors following a ModBus installation, please carefully review the following points;

1) Does whatever monitoring system you are using (Monitoring System) use an RS485, 2 wire, half duplex serial interface?

2) Does the Monitoring System use Modbus RTU, not ASCII?

3) Is the Monitoring System set to use the correct COM port (that is connected to the sensor)?

4) Is the Monitoring System set to use 9600 baud, 8 bits, 1 stop bit with no parity?

5) Is the Monitoring System trying to communicate with the correct Node ID for the sensor (Sensor Node ID 0 will be forced to Node ID 1)?

6) Has the sensor been set to Modbus using Tan Delta Configuration & Data Software, or register 12 (zero based) to 0x03 or 0x13 (decimal 3 or 19) by other means?

7) Has the sensor been powered off and restarted after setting to Modbus?

8) Is the sensor firmware V2.28 or V3.xx? If not, please ask TD for confirmation.

If no response whatsoever is being received….

1) Does the Monitoring System use zero-based register addresses? The sensor registers are listed as zero based (starting from register zero); some Modbus master devices start from register 1 – if this is the case, add 1 onto every register address listed in the manual. Check that the sensor Serial Type has been set correctly, if set using other than Tan Delta Configuration and Data Software, as a typical test, try to read the value back from any (or all) of Registers 0 to 2 (zero based) or 1 to 3 (one based). These are the three live readings.

2) Does your Monitoring System give communications errors? If so, check these to see if they give any further indication of the issue. (eg. time-out errors, CRC errors, overrun errors…)

3) What time-out is set within the Monitoring System? If this is too short the system may be timing out before the sensor can respond. Time-outs of less than 50ms may cause problems; 500ms to 1s are good starting points. If you are configuring the oil type via Modbus then a timeout of 2000ms is recommended.

4) What polling rate is being used by the Monitoring System? If this is too short the system may be asking for the next response before the sensor can respond to the first. Again polling rates of something like 1s are a good starting point.

5) Does the Monitoring System use a standard Modbus 16 bit CRC for error checking? If not the system will not communicate correctly.

6) Does the Monitoring System use any non-standard data formats, e.g. inverted data? If so, the system will not communicate correctly.

7) Is the GND lead of the sensor shared with the GND of the Monitoring System? If either part is driven by a completely different power supply, there may be significantly different voltages between the two and they will not communicate. If they are commoned or either is floating or isolated they should “float” back together. If in doubt, check with a meter and unless there are persistently high voltages (more than a few volts) between the two, connect the two GND lines together with a third wire, ideally with a fuse in line in case they are driven to different voltages and not just floating apart. CHECK YOUR POWER CONNECTION SCENARIO FIRST TO ENSURE THIS WILL NOT HARM THE SENSOR OR YOUR EQUIPMENT.

8) Try swapping the RS485 A and B lines over. The A line should go to the blue wire (pin 5 on the sensor connector) and the B line should go to green (pin 6) but these lines are sometimes marked the opposite way round on the Monitoring System. (A should be the non-inverted data line and B the inverted data line but the whole RS485 communications system is active-low so inverted and non-inverted sometimes get confused.) This will not cause any damage so is worth trying if all else fails!

9) If this still does not work, please feel free to contact Tan Delta for more support;

Telephone: +44 (0)845 094 8710

Email: support@tandeltasystems.com

If you are receiving replies but they do not make sense….

1) Check that you are reading the correct Register as detailed in 2) at the top of page 20.

2) Check that you are reading in the correct number format. Most value readings are in signed 16-bit integer decimal format and multiplied by 100, so a reading of +1234 means +12.34 and a reading of -5678 means -56.78. If you are reading in unsigned format, any negative values will look wrong. If you are reading in binary, octal or hexadecimal formats the values will look very strange. Other readings are generally in simple integer format so should be straightforward.

3) Check that you are using the correct baud rate and number of bits as detailed in 4) at the top of page 20. If your Monitoring System gives communications errors, check these to see if that gives any clue.

4) If this still does not work, please feel free to contact Tan Delta for more support;

Telephone: +44 (0)845 094 8710

Email: support@tandeltasystems.com

11.4 J1939 on CANbus

The OQSx Oil Quality Sensor measures the Oil Condition, Oil Temperature and Ambient (Sensor) Temperature. The range is from a nominal -20% to +60% Oil Condition units and -30 to +130C. The measured value is transmitted on the CAN-bus using the J1939 protocol based on the SAE J1939 standards J1939-DA August 2018, J1939-21 October 2018 and J1939-82 June 2015. The Sensor samples internally at 100 samples per second, filters and converts the raw signal to a conditioned output signal and outputs the Oil Condition and Oil Temperature periodically every 10s.

The CAN interface uses a default bit rate of 250 kb/s with 29 bit identifiers. 500 kb/s is also available.

The CAN protocol complies with the SAE J1939 standard and the Oil Quality Sensor implements 2 PGNs for transmission of process values. PGN 65262 (0xFEEE) is used for Oil Temperature and PGN 65279 (0xFEFF) is used for Oil Condition. The sensor is Single Address Capable (not Arbitrary Address Capable) with Command Configurable Addressing; it does not support Service Configurable or Self-Configurable Addressing.

11.4.1 CAN Interface

The Sensor uses a full CAN controller specified to conform with CAN 2.0B. The physical layer of the 2 wire interface is specified according to ISO 11898. The wires are protected against short circuit and noise emission is minimized. No bus termination resistors are included within the sensor.

11.4.2 OQS-CAN Specification

Supply voltage:	+9 to +30 Vd.c.
Current consumption:	50mA max. when quiescent, 100mA max. with CAN active 30-40mA typical
CAN physical layer:	2 wire interface @ 5V d.c. voltage levels a/c to ISO 11898 Short circuit protected
CAN bitrate:	250kbit/s default
Bus termination:	External
Protocol:	J1939-DA August 2018, J1939-21 October 2018 and J1939-82 June 2015
Environment:	noise emission according to EN 50 081-2 Noise immunity according to EN 50 082-2
Operating temperature:	-20 to +120C
Storage temperature:	-40 to +150C

11.4.3 Connection Details

The sensor uses a Bulgin 4000 series male connector with the following pin assignments: -

P1: +9 to +30V d.c. power supply

P2: Analog 4-20mA Oil Temp output (active, current sourcing)

P3: Analog 4-20mA Oil Condition output (active, current sourcing)

P4: CANL/RS485A

P5: 0V

P6: CANH/RS485B

11.4.4 J1939 Communication

11.4.4.1 *Summary of the J1939 functions and settings*

J1939 type: J1939 Node

Bitrate: Default 250 kb/s, can be configured to 500 kb/s using CADS

Industry Group: 5

Function: 46 (decimal)

Manufacturer Code: 952 (decimal)

Available PGNs: PGN 65262 (0xFEEE) Engine Temperature: here used for Oil Temperature
PGN 65279 (0xFEFF) Operator Indicators: here used for Oil Condition
PGN 65240 (0xFED8) Commanded Address

J1939 Name/Address: The sensor's J1939 Name/Address is constructed as follows:

TABLE 1: CONTROLLER APPLICATION NAME/ADDRESS FORMAT

Arbitrary Address Capable	Industry Group	Vehicle System Instance	Vehicle System	Reserved	Function	Function Instance	ECU Instance	Manufacturer Code	Identity Number
1 Bit	3 Bits	4 Bits	7 Bits	1 Bit	8 Bits	5 Bits	3 Bits	11 Bits	21 Bits

Arbitrary Address Capable = 0
Industry Group = 5 decimal = 0x05
Vehicle System Instance = 0 for single instance
Vehicle System = 0
Reserved = 0
Function = 46 decimal = 0x2E
Function Instance = 0 for single instance
ECU Instance = 0 for single instance
Manufacturer Code = 952 decimal = 0x3b8
Identity Number = Complete Serial No. of the sensor reduced to 21 bits

e.g for a serial no. of 1003834 decimal = 0xF513A, the Identity Number is (0)F513A where (0) represents 1 single bit.

For all practical purposes, the above means that the J1939 Name/Address will be 0x50002E0077000000 plus the sensor serial number.

11.4.4.2 *Sensor Operation and Messages*

On Start up, the sensor will broadcast its J1939 Name/Address as shown below. The J1939 Node Address will be, by default, the sensor's Node ID + 0x80, so a Node ID of 1 will yield a J1939 Node Address of 0x81, or 129 decimal.

State	ID (hex)	DLC	Data (hex)
E	CEEFF81	8	3A 51 0F 77 00 2E 00 50

Data is usually shown as little-endian so the bytes need to be reversed to get the J1939 Name/Address of 50002E00770F513A as discussed above.

The sensor will then begin its automatic asynchronous data transmission, sending both Oil Temperature and Oil Condition PGNs every 10s as below.

E	18FEEE81	8	FF FF 00 2E FF FF FF FF
E	18FEFF81	8	FF FF FF FF FF 01 50 FF

These values may be requested over the J1939 bus as well as using the periodic transmission.

PGN 65262 (0xFEEE) reports Oil Temperature in bytes 3 and 4 according to J1939_DA201808 and PGN 65279 (0xFEFF) reports Oil Condition in byte 6. These values are reported as unsigned integers, with an offset of +30 on the temperature and 10* scaling on the oil condition (reported in TDN) so 0x002E = 0d46 reports an oil temperature of 46-30 = 16C. 0x01 reports a TDN value of 10,

Sensor Readings may also be requested on demand using the two PGN messages as shown below. This may be useful if data capture synchronous to a particular event is required. To request Oil Temperature and Oil Condition consecutively, send a message requesting PGN 65262 with 3 bytes of data set to 00, FE, FF, and PGN 65279 with 3 bytes of data set to 00, FE, EE. If these are sent back-to-back the bus traffic would look something like this.

```
E    18EA8180    3    EE FE 00
E    18EA8180    3    FF FE 00
E    18FEEE81    8    FF FF 00 2E FF FF FF FF
E    18FEFF81    8    FF FF FF FF FF 01 50 FF
```

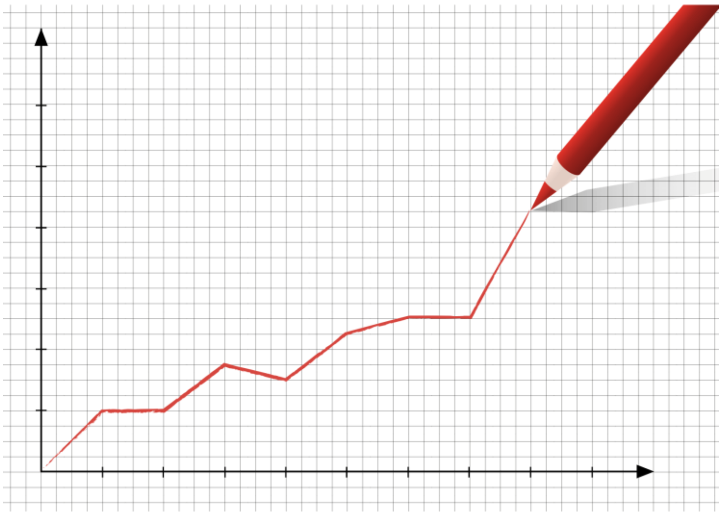
Finally the J1939 Node Address may be changed by an external node by sending 3 messages to PGN 65240, using the Commanded Address function. Here three commands are sent:-

1) The first message has Priority 0x1C sent in the first byte, PDU format EC in the second byte, Destination Address of 0xFF (broadcast) and Source Address of 0x80 are used for the remaining two bytes. The first command data is fixed at 0x00, 0xFE, 0xD8, 0xFF 0x02, 0x00, 0x09, 0x20 in little-endian (reversed) order.
2) the second has the same message with command data holding a packet number of 0x01 followed by the upper 7 bytes of the J1939 Name/Address.
3) the third again has the same message with command data holding a packet number of 0x02 followed by the last byte of the J1939 Name/Address, the new J1939 Node Address to which this Node is to be set, here shown as 0x84 or Node 132 in decimal. The rest of the bytes in the third data group are set to 0xFF.

```
E    1CECFF80    8    20 09 00 02 FF D8 FE 00
E    1CEBFF80    8    01 3A 51 0F 77 00 2E 00
E    1CEBFF80    8    02 50 84 FF FF FF FF FF
E     CEEFF84    8    3A 51 0F 77 00 2E 00 50
```

This command changes the Node with J1939 Name/Address 50002E00770F513A to Node Address 0x84, as shown in the last line above which displays the node at the new address 0x84 broadcasting the same J1939 Name/Address as was previously at node 0x81.

12 Data Analysis Guide



12.1 Tan Delta Full Spectrum Holistic (FSH) Data

Dynamic Maintenance Optimisation (DMO) is the method by which the data can be used to optimise the maintenance intervals for the lubricating oil in the application.

Changing the oil at an interval determined by the Display Express means you are only changing the oil when you need to, not at a predetermined schedule when the oil may still be in a useable condition.

In this section we will demonstrate the methods by which Tan Delta FSH data can be presented.

12.1.1 Display Express (OQDe)

The Display Express is a powerful tool for instant data display, providing a "Red, Amber, Green" traffic light display of the holistic oil condition as well as the current Oil Condition value, Oil Temperature and Oil Life Remaining (OLR).

Using the display alone to review the oil condition is simple. If the oil status indicator is green, then the oil is still in a good useable condition. If the oil status indicator is amber, you should be planning to carry out an oil change at the earilest opportunity. If the oil status indicator is red, the machine should not be used, and the oil should be changed immediately.

Figure 57 - Oil Status Indicator

In addition to the oil status indicator, the Oil Condition value can be viewed and checked to see the current oil condition against the standard table shown at appendix 10.1

Oil temperature and OLR are also viewable on the Display Express.

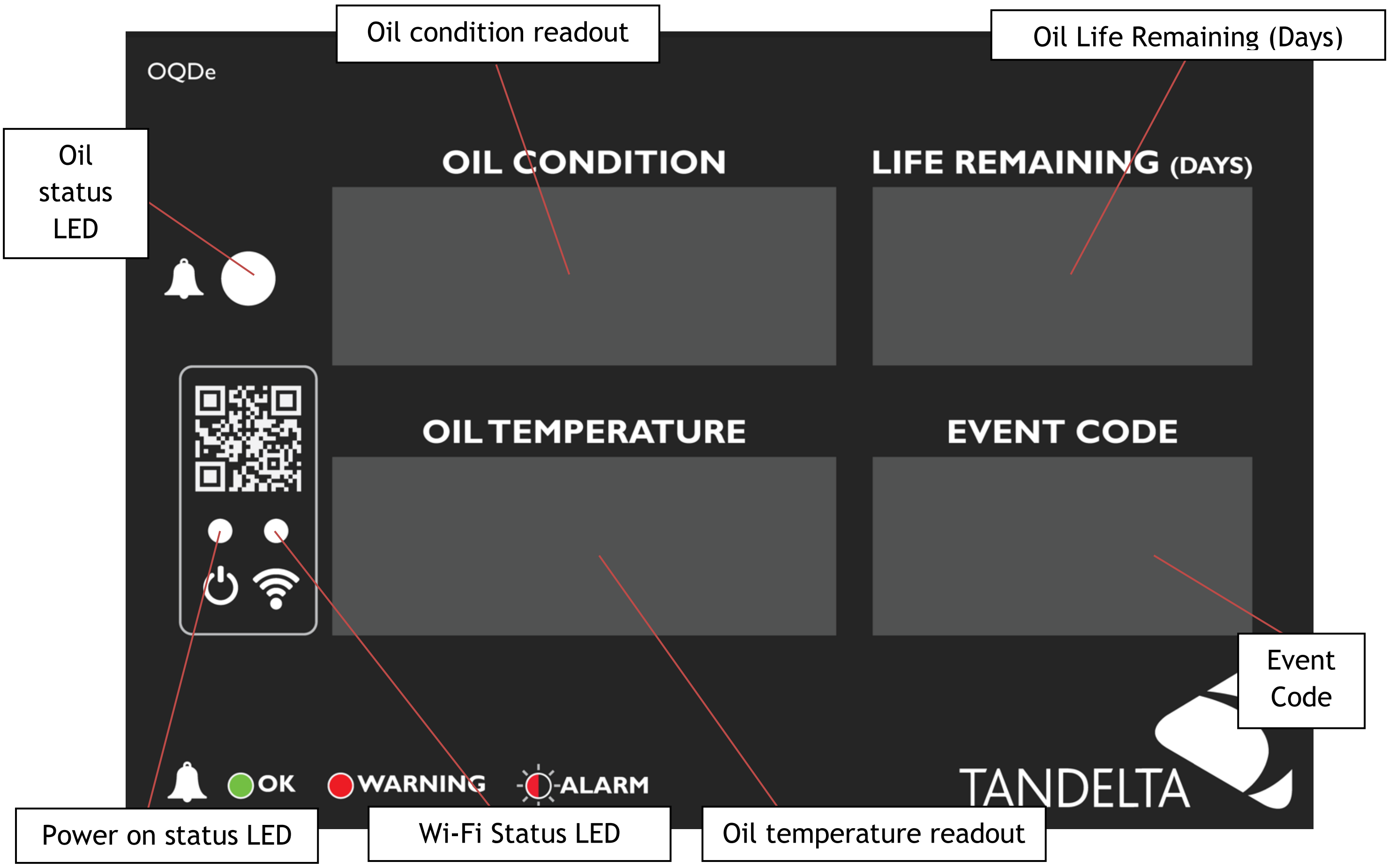


Figure 58 - Tan Delta OQDe Display Express

12.1.2 CADS application

Data can also be accessed from the Display Express using CADS to either view whilst connected to the display through the in-built graphing screens, or to download to analyse and interrogate offline.

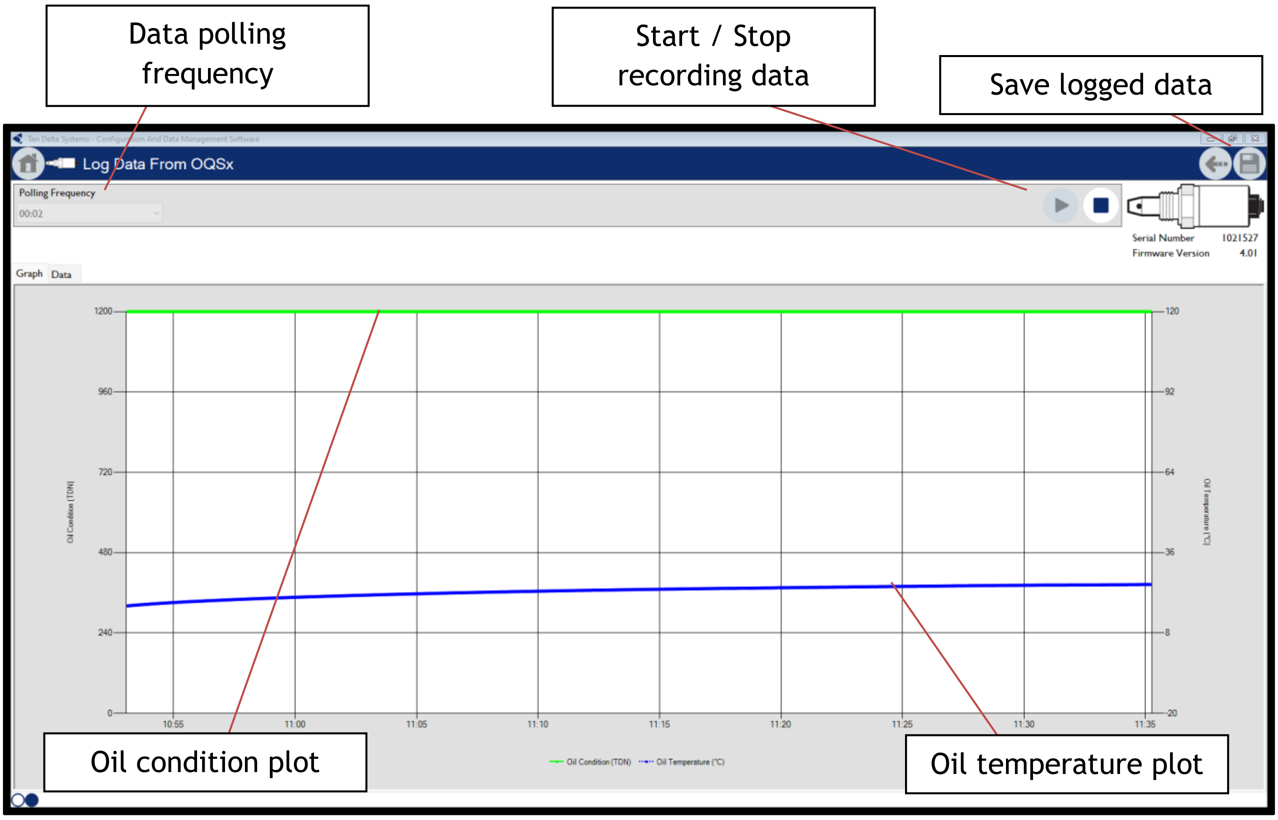


Figure 59 - CADS data (Note: data shown for a sensor tested out of oil)

12.1.3 Insight

Insight provides access to the data collected by the Display Express using any internet-enabled device via Wi-Fi. Live data can be viewed in Insight in real time, or historical data logs can be downloaded as a CSV file.

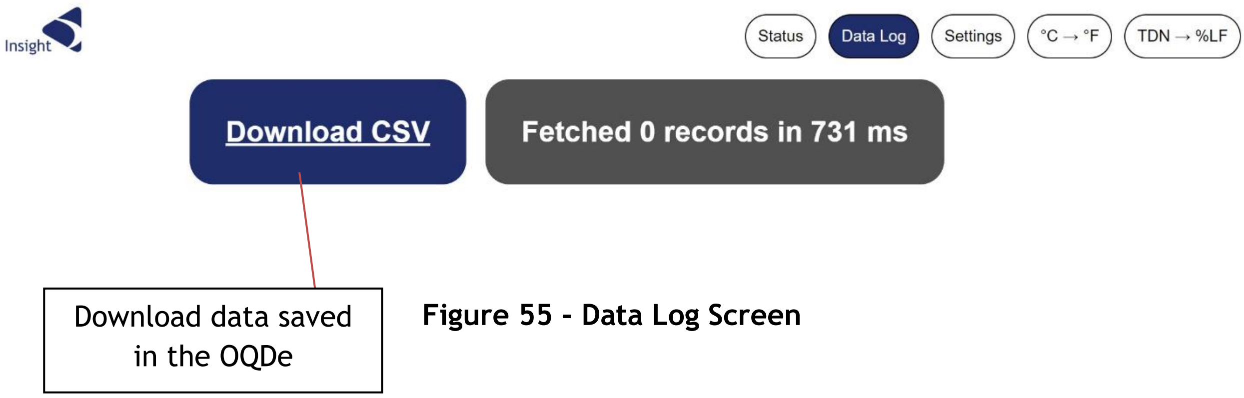


Figure 55 - Data Log Screen

12.1.4 TD Online

TD Online is a cloud-based Internet of Things (IoT) solution that uses a Gateway device connected to the internet to send data from either one or a multiple sensors to a cloud-based viewing platform.

TD Online allows live reading of oil condition and oil temperature.

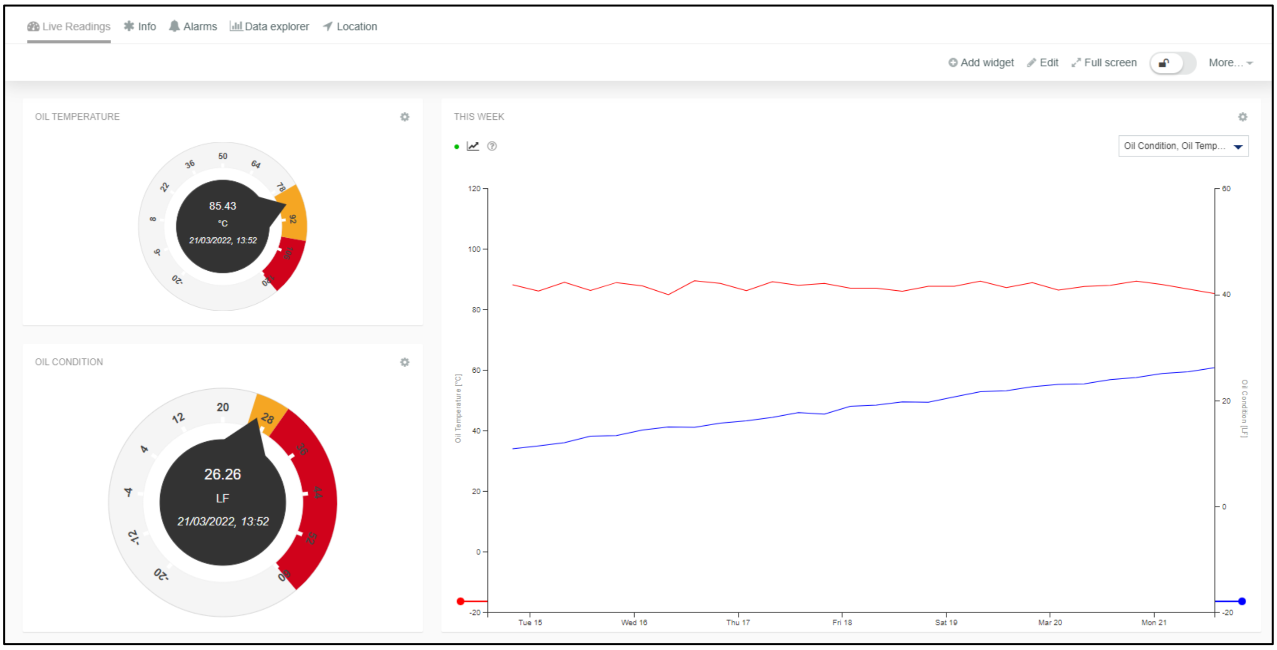


Figure 60 - TD Online Live Readings Display

The TD online platform allows the user to simply view the data live, or alternatively set alerts and alarms for oil condition in a similar manner to the Display Express, essentially replicating the live-data reading functions of the OQDe but from a remote online portal.

Alerts and alarms can be configured to show in the online dashboard or to email relevant personnel to take action.

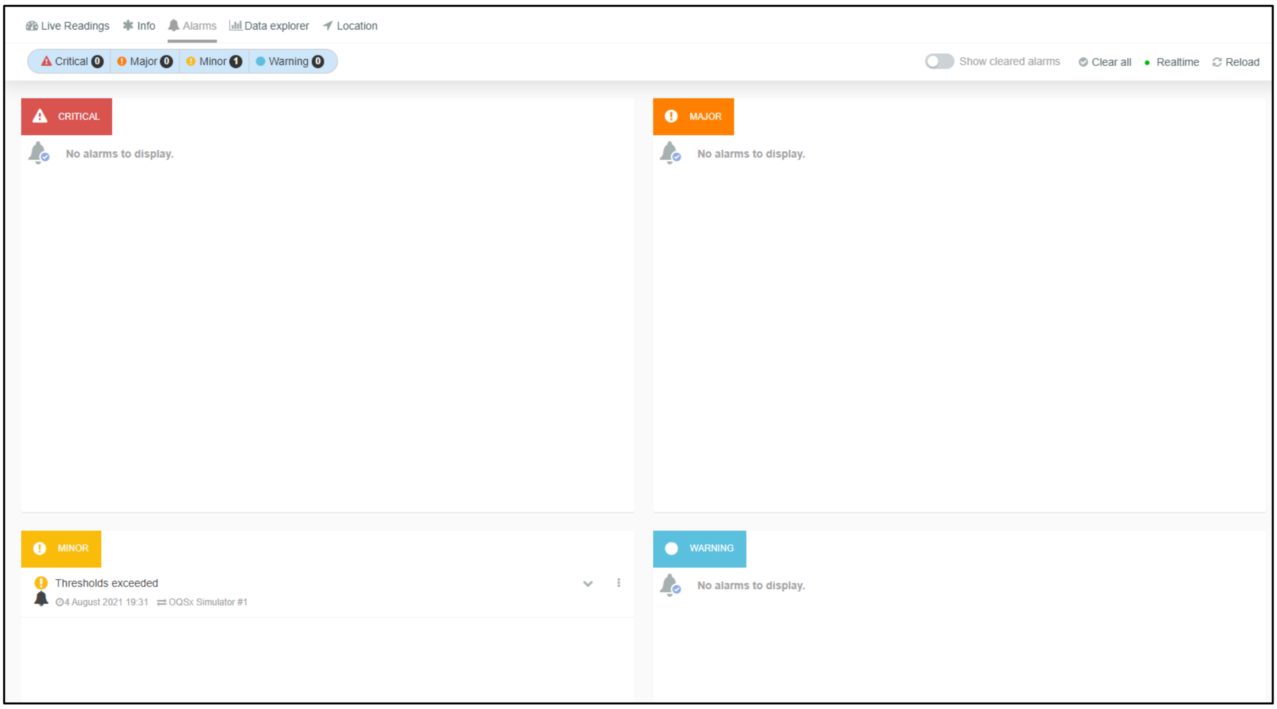


Figure 61 - TD Online Alerts & Alarms Dashboard

Historic data collected from the sensor and presented on TD Online can also be viewed through the Data Explorer menu, including viewing pre-set date ranges or setting a custom period to review.

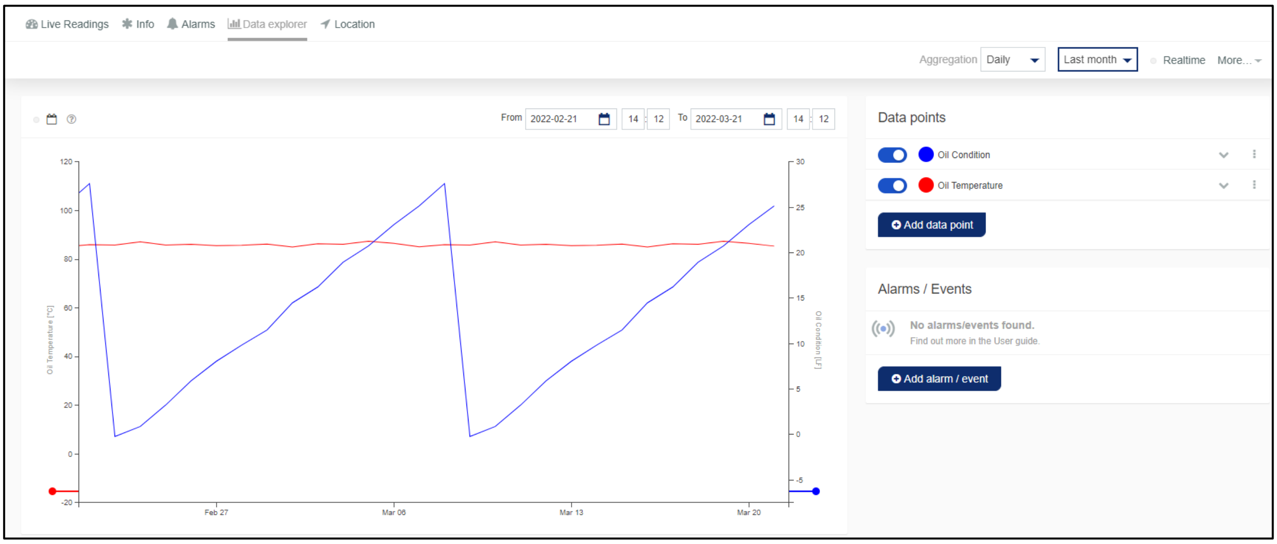


Figure 62 - TD Online Data Explorer Menu

NOTE: Oil condition data reported in TD Online is presented in % Loss Factor (%LF) rather than in TDN. This will mean that oil condition data patterns presented as graphs on TD Online will be an inverted image of data graphed from TDN values. Oil temperature in TD Online is always presented in Degrees Celsius (°C)

12.1.5 Digital Data

When not used with a Tan Delta preparatory display or gateway solution, the sensor can be configured to communicate by a number of different communication protocols:

- Tan Delta Protocol on RS485
- CAN Open on CANbus
- Modbus RTU on RS485
- J1939 on CANbus

For full details of all of these communication protocols, please refer to section 11 of this manual or contact Tan Delta Support for further assistance.

12.1.5.1 *J1939 on CANbus*

J1939 is commonly used on data logger equipment. Raw data may be presented with a variety of header detail associated to the CAN logging device you are using. This is not needed for interpreting the data.

CAN data will be returned in a format similar to as shown below (example is from a J1939 data logger on CANbus):

```
Timestamp;Type;ID;Data
2022-03-01 08:49:54.765;1;18feee85;ffff4000ffffffff
2022-03-01 08:49:54.765;1;18feff85;ffffffffff1c39ff
2022-03-01 08:50:05.989;1;18feee85;ffff4000ffffffff
2022-03-01 08:50:05.990;1;18feff85;ffffffffff1c39ff
```

Figure 63 - Example Raw CAN Data

Plain text can be imported into a spreadsheet to process as shown:

Column1	Column2	Column3	Column4
2022-03-01 08:49:54.765	1	18feee85	ffff4000ffffffff
2022-03-01 08:49:54.765	1	18feff85	ffffffffff1c39ff
2022-03-01 08:50:05.989	1	18feee85	ffff4000ffffffff
2022-03-01 08:50:05.990	1	18feff85	ffffffffff1c39ff

Figure 64 - Example Raw CAN Data (2)

Data ID of 18feff85 represents the TDN value, whilst data ID of 18feee85 represents the temperature value returned from the sensor.

The following formulae may be useful to use on the data (column 4 in the example) in a spreadsheet to turn the raw J1939 CAN data into a useable number for reporting or graphing:

For 18feff85 (TDN) values: =HEX2DEC(MID(D2,11,2))*10

For 18feee85 (Temperature) values: =HEX2DEC(MID(D1,7,2)&MID(D2,5,2))-30

Once converted into useable data, the values can be plotted as per the instructions provided in 11.7. **(Note, "D2" refers to the cell reference containing the data)**

12.1.6 Example Good Sensor Output Readings

The graph shown below is a classic “sawtooth” representation of an engine in operation illustrating when oil changes have taken place at checkpoints F, L and R. The green lettered checkpoints are where oil samples would normally be sent for analysis to ensure oil condition is acceptable, with the OQSxG2 installed the need for oil sampling prior to checkpoints F, L and R is not required.

Figure 65 - Example Sensor Output Readings

12.2 Dynamic Maintenance Optimisation (DMO)

Dynamic Maintenance Optimisation (DMO) is the method by which the data can be used to optimise the maintenance intervals for the lubricating oil in the application.

Changing the oil at an interval determined by the Tan Delta Sensor means you are only changing the oil when you need to, not at a predetermined schedule when the oil may still be in a useable condition.

In this section we will demonstrate the methods by which DMO can be implemented.

12.2.1 Display Express (OQDe)

The Display Express (OQDe) will display DMO through displaying a an LED indicator when the oil reaches a low condition warning (red) value and when the oil reaches a low condition alert (flashing red) value.

When the oil condition reaches a red warning status, a maintenance intervention should be planned.

When the oil condition reaches a flashing red alarm status, the oil is at its end of useable life and the machine should not be used until the oil has been changed.

Figure 66 - OQDe DMO Alert Examples

12.2.2 TD Online

TD Online presents oil condition data in percentage loss factor (%LF) values.

DMO can be reported as an alert on TD Online and also via email. Alerts can be set up using values input into the online platform manually and are shown on the cockpit main page upon logging in.

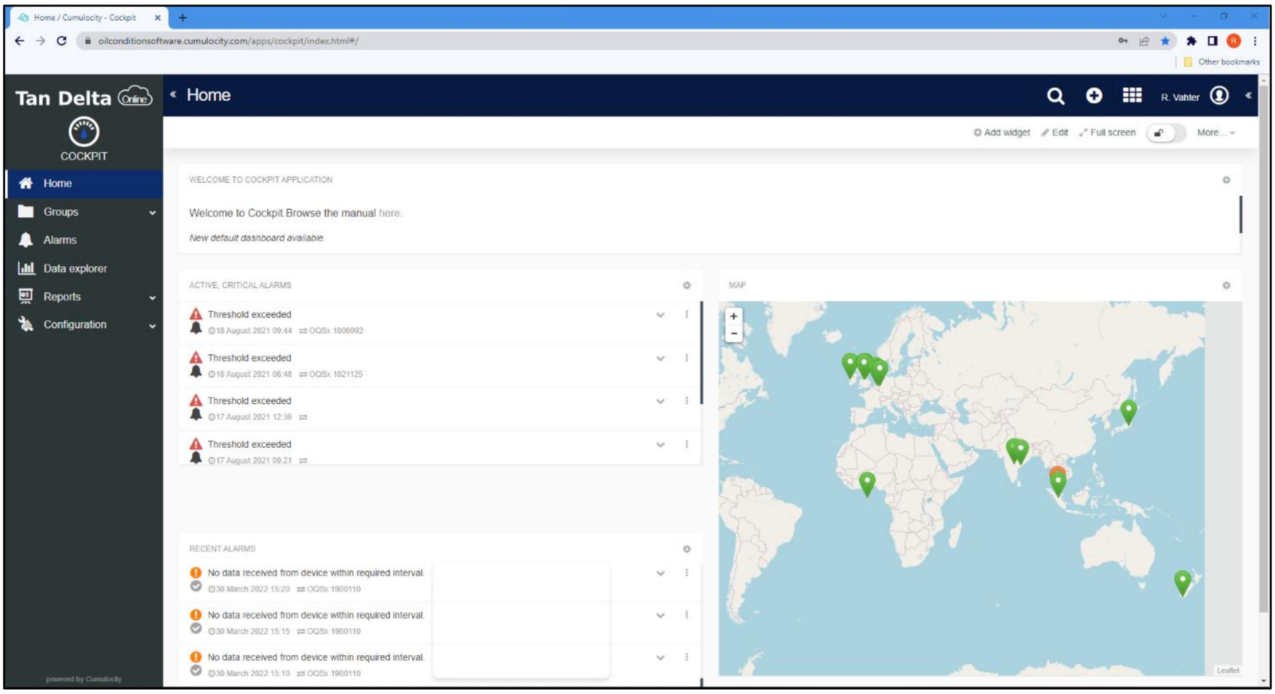


Figure 67 - TD Online Alerts

To set up an alert, navigate to a device or group within the TD online cockpit. Click on the "Info" tab.

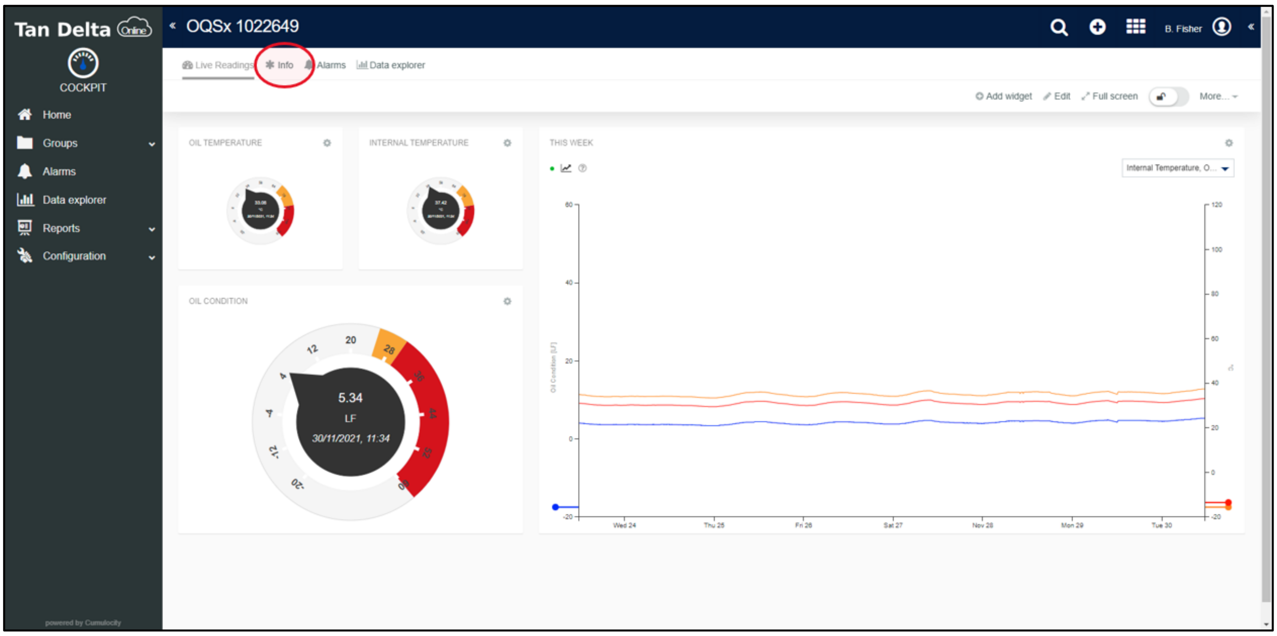


Figure 68 - TD Online Setting an Alert

Click to "Add Smart Rule". Select "On measurement explicit threshold create alarm"

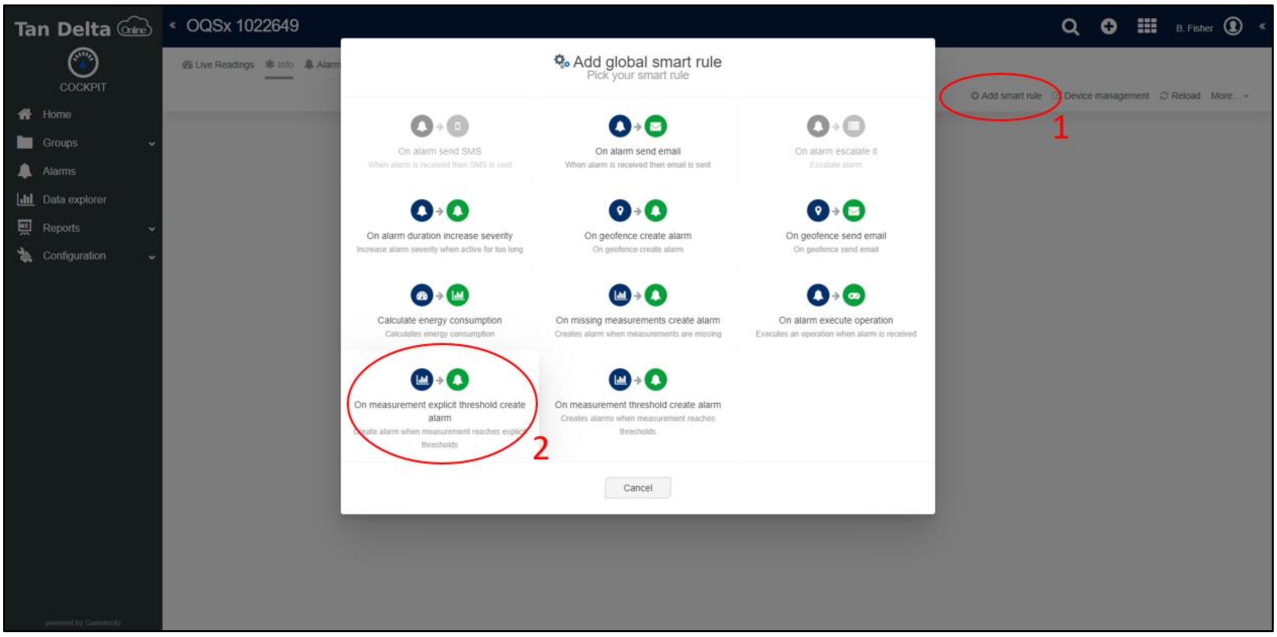


Figure 69 - Adding a Smart Rule

Select datapoint (ambTemp / oilTemp / oilCond only). This will autofill fragment & series. Enter the warning and alarm values you wish to trigger a warning and an alarm, then enter an alarm name and click "Create"

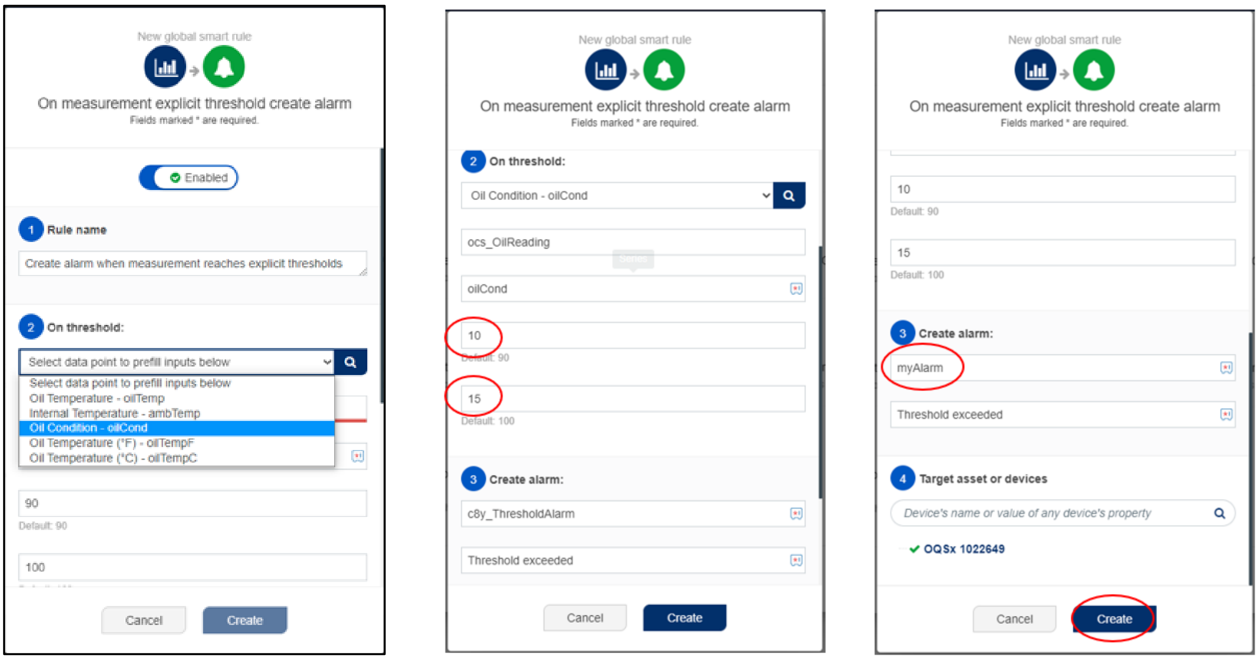


Figure 70 - Entering Smart Rule Values

This smart rule will now appear in the info tab in the TD Online Cockpit.

To set up an email alert from the platform, click “Add Smart Rule” and this time select the option to “On alarm send email”.

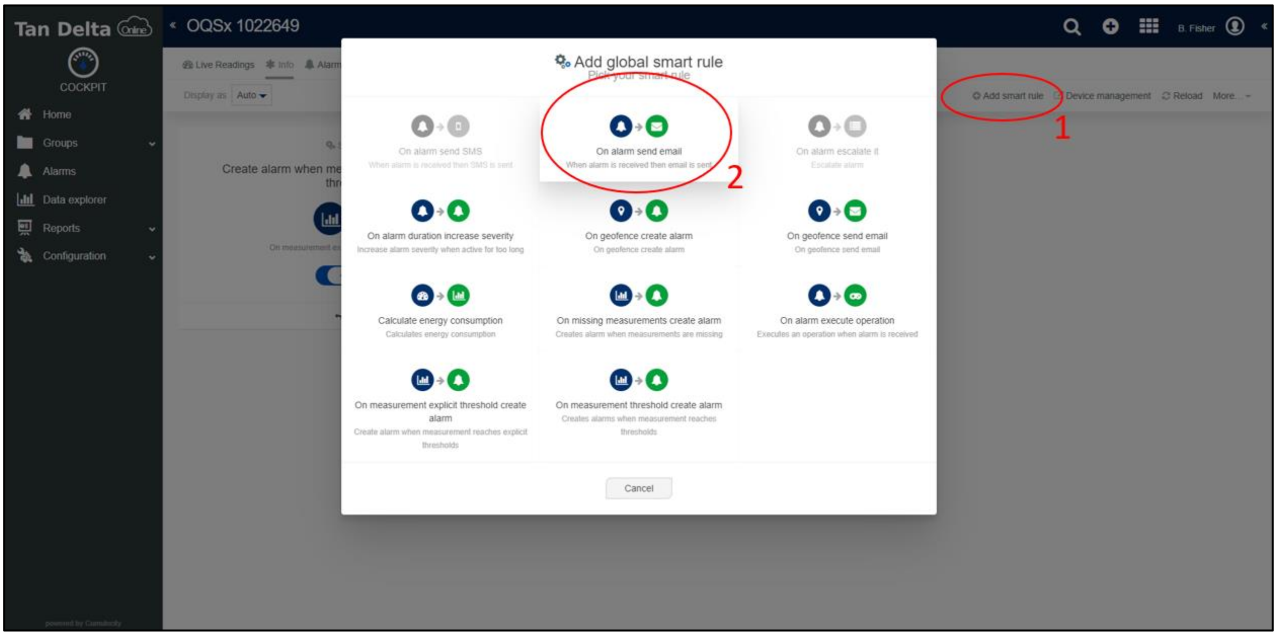


Figure 71 - Setting an Email Alert

Enter the name of the alarm you wish to trigger the email, enter the email address to send the email to and complete the message you wish the email to contain. When you have completed click on “create”

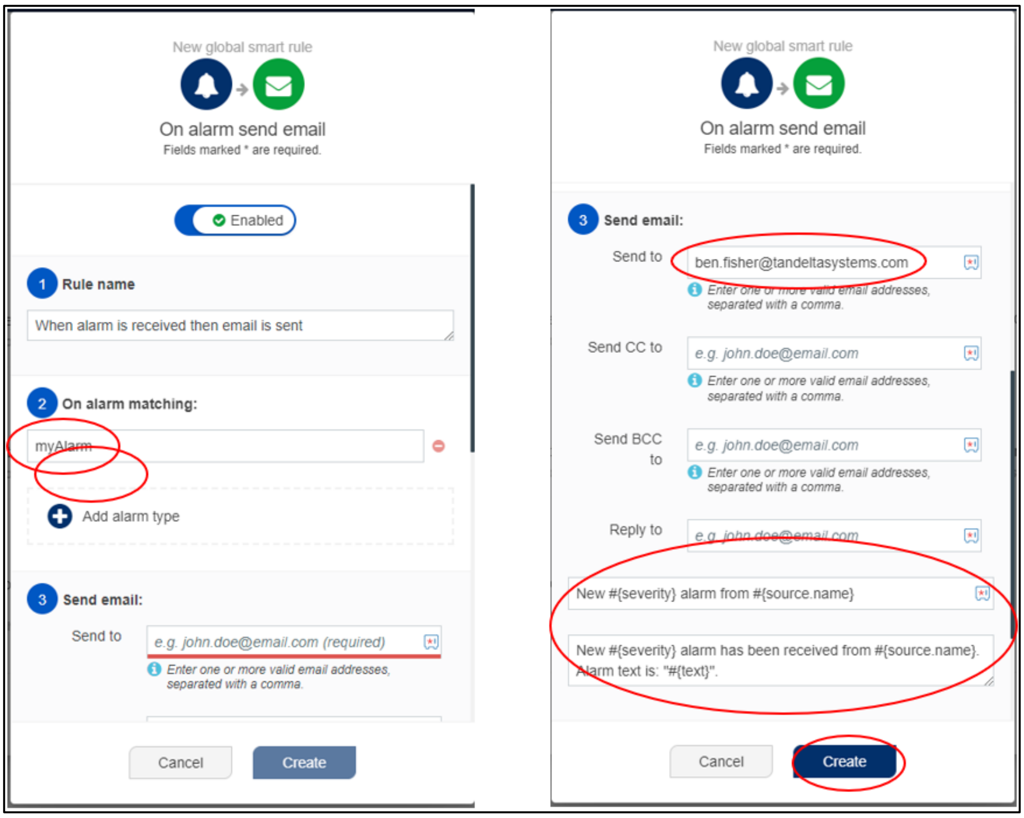


Figure 72 - Completing Email Alert Details

The alert is now set up and will show in the Info tab on TD Online.

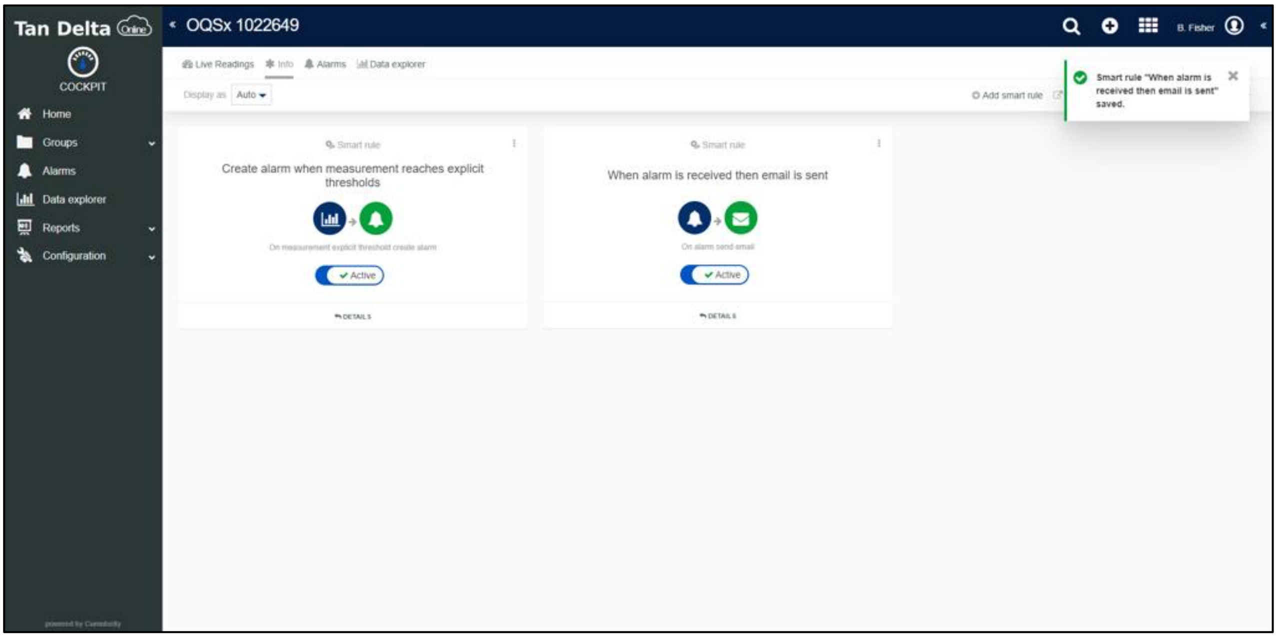


Figure 73 - Alerts Set Up

12.2.3 Partially / Fully Integrated Sensors

Sensors integrated into third party solutions can feed data directly into these systems either using Analog signals or Digital Signal protocols. For more information on the available communication protocols, please contact Tan Delta Support.

Oil condition is output in analog format on Pin 3 and is linearly scaled from 4mA to 20mA. This can easily be converted to the TDN or Loss Factor scale using the table provided in appendix 10.1. A clean oil should provide an output of about 8mA. For some common applications we recommend the warning/alarm settings in the table below. Any value below 4mA indicates a fault. The analog output on pin 2 provides a linearly scaled measure of Oil Temperature in °C between -30°C (4mA) and +130°C (20mA) – See appendix 10.2

	Engine (e.g. Diesel)	Gas Engine	Hydraulic	Compressor	Transmission
High Alarm	5.6mA (1140 TDN)	5.6mA (1140 TDN)	6.4mA (1060 TDN)	6.7mA (1050 TDN)	6mA (1100 TDN)
High Warning	6.4mA (1060 TDN)	6.4mA (1060 TDN)	7mA (1000 TDN)	7mA (1000 TDN)	7mA (1000 TDN)
Condition OK					
Low Warning	13mA (400 TDN)	9.4mA (760 TDN)	9.4mA (760 TDN)	10.5mA (650 TDN)	10mA (700 TDN)
Low Alarm	14mA (300 TDN)	10.4mA (660 TDN)	10.4mA (660 TDN)	11mA (600 TDN)	12mA (500 TDN)

Figure 74 - Generic Warning / Alarms (inc 4-20mA)

The third-party systems using a 4-20mA analog signal should be configured using the above table as a guide and may subsequently be fine-tuned with the assistance of Tan Delta Support.

The following Table details the logic that can be applied to installations into third-party systems to determine various event variables. If your Display Express or third-party device allows this level of customisation, you may wish to utilise some of the detailed algorithm logic to provide warnings or alarms through the third-party display / system:

Event Code	Algorithm	Description	Check/ Alert
---	n/a	All OK	n/a
S01	n/a	No Sensor Connected – Please Connect the Sensor.	A
S02	n/a	Sensor Not Configured – Configure the Sensor via CADS.	A
S03	n/a	Display Not Configured – Configure the Display via Insight	A
S04	n/a	New Sensor Detected	n/a
E01	Current Temperature >= Temp High Warning Level	Oil Temperature High – Check Regularly.	C
E02	Current Temperature >= Temp High Alarm Level	Oil Temperature Very High – Immediate Action Required.	A
E03	Current Temperature <= Temp Low Warning Level	Oil Temperature Low – Check Regularly.	C
E04	Current Temperature <= Temp Low Alarm Level	Oil Temperature Very Low – Immediate Action Required.	A
E05	Current Oil Condition >= Oil Condition High Warning Level	Oil Condition Too High – Check Regularly.	C
E06	Current Oil Condition >= Oil Condition High Alarm Level	Oil Condition Very High – Immediate Action Required.	A
E07	Current Oil Condition <= Oil Condition Low Warning Level	Oil Near End Of Life – Check Regularly.	C
E08	Current Oil Condition <= Oil Condition Low Alarm Level	Oil At End Of Life – Immediate Action Required.	A
E09	Current Oil Condition >= 1200 TDN	Sensor In Air – Immediate Action Required	A
E11	Long Term +ve Decay Rate Warning (TDN/day)	Oil Quality degrading faster than expected – Check Regularly.	C
E12	Long Term +ve Decay Rate Alarm (TDN/day)	Oil Quality degrading much faster than expected – Immediate Action Required.	A
E13	Long Term -ve Decay Rate Warning (TDN/day)	Oil Quality improving faster than expected - Check Regularly.	C
E14	Long Term -ve Decay Rate Alarm (TDN/day)	Oil Quality improving much faster than expected - Immediate Action Required.	A
E15	Short Term +ve Decay Rate Warning (TDN/day)	Oil Quality degrading faster than expected - Possible Water/Coolant Contamination - Check Regularly.	C
E16	Short Term +ve Decay Rate Alarm (TDN/day)	Oil Quality degrading much faster than expected – Highly Likely Water/Coolant Contamination - Immediate Action Required.	A
E17	Short Term -ve Decay Rate Warning (TDN/day)	Oil Quality improved - Suspected oil top up / sweetening - Check Regularly	C
E18	Short Term -ve Decay Rate Alarm (TDN/day)	Oil Quality improved too much - Suspected Air or severe fluid contamination - Immediate Action Required.	A

Figure 75 - Data Logic Table

12.3 Advanced Fault Detection (AFD)

Advanced fault detection is the identification of potential issues in a piece of machinery that present themselves as a fault or anomaly in the oil condition. As the Oil Quality Sensor sends back a holistic full spectrum analysis of the oil condition in the form of a condition number (TDN or %LF), the trend of these returned numbers can be analysed to identify an emerging issue or concern, which may require further investigation or rectification.

By downloading and interrogating data collected by the sensor, it is possible to identify different types of degradation of the oil, including water ingress, wear metals, TBN decrease and soot increase.

Water and wear metals have very distinct characteristics and are therefore very easy to identify. Whereas with TBN decrease (TAN increase) and soot, during the very early stages of wear they will both give a small deviation, however as they progress soot will remain linear and TBN will become exponential, therefore we are able to differentiate.

The following graphs give examples of different oil degradation patterns allowing you to identify the specific reasons for oil degradation when compared to the expected degradation.

12.3.1 Oil Degradation

The example graph below shows a steady fall in TDN as the oil deteriorates. Generally, a steady and consistent change like this is representative of normal time-based oil wear that occurs within any machinery.

There are some obvious spikes within this data – which is often the case. Here the spikes are showing 'improved' oil condition, which will generally be caused by either erratic temperature or air. In this example, the spikes coincide with sudden temperature spikes, and so we can conclude that this is the cause.

The sensors do have temperature corrections which should reduce the amount of condition change that results from variation in temperature, however there will still be some correlation. If there is too much noise, then the smoothing function on the sensor can be enabled or increased. For further guidance on how to adjust the smoothing, please refer to CADS User Guide for further assistance with Advanced Settings.

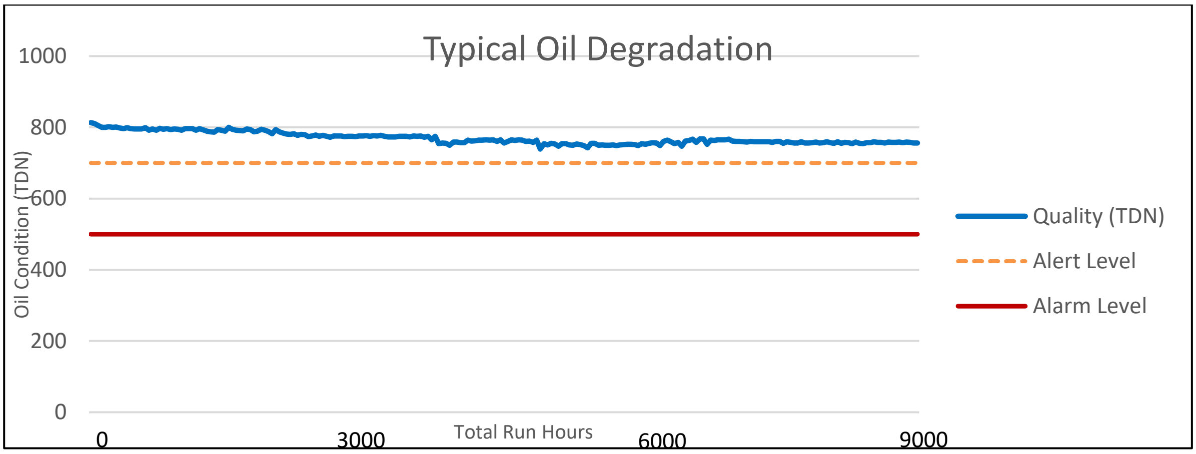


Figure 76 - Normal Behaviour

12.3.2 Contamination (Water / Coolant)

The graph below demonstrates what water or coolant contamination can look like in an engine. The graph begins with a steady trace showing the oil in working condition following an oil change interval (1). However after a period of time, when the engine is re-started after being shut down, we see a sudden spike drop in oil condition (2). This then disappears as the water is thoroughly mixed throughout the oil and then evaporates off. The process is repeated with varying degrees of severity, while the overall condition of the oil is degrading significantly (3) which highlights the effect the water is having on the oil.

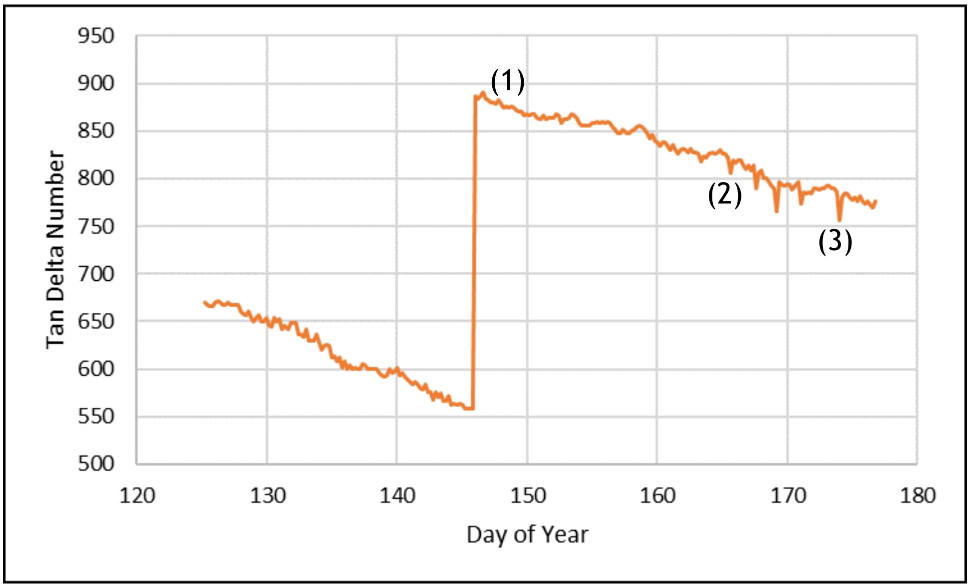


Figure 77 - Water Ingress

It's often difficult to identify water in oil using lab analysis, because as the data above shows, it is only present in the oil at low temperatures. Often sampling will occur after equipment has been running and so water will have been evaporated. If your sensor shows data similar to this, we recommend waiting until the equipment has been shut down and cooled to ambient, and then running it for several minutes before taking a sample for analysis. Coolant will often leave chemicals in the oil, which can be detected using lab analysis, we recommend conducting lab analysis on the coolant itself, so you know exactly what chemicals it contains, and makes it easier to detect in the oil.

12.3.3 Wear Metal Contamination

Wear metal contamination can be indicated by fluctuations in the oil condition values happening over a shorter period of time (peaks are progressively closer together than they have been previously) as shown in the below example graph (1).

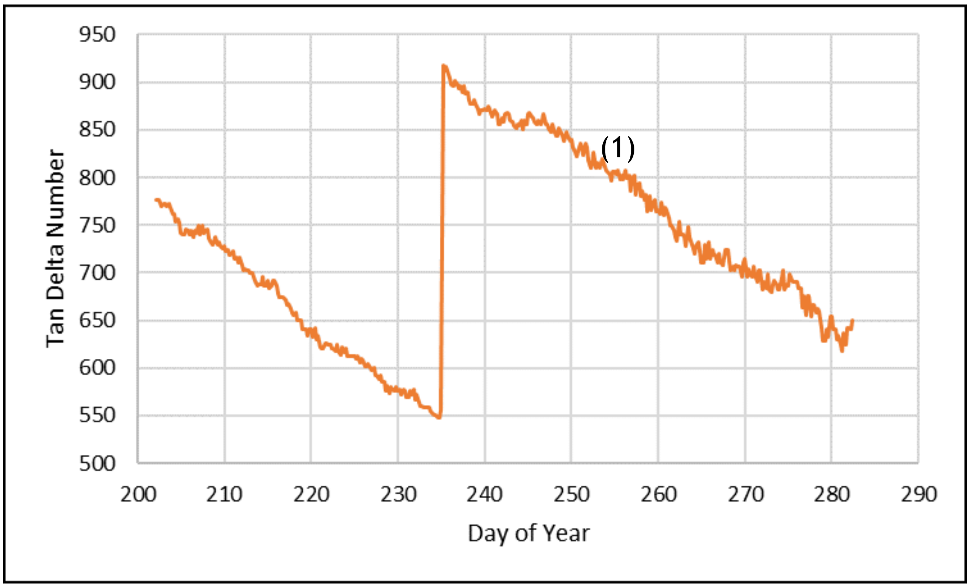


Figure 78 - Wear Metal Contamination

12.3.4 Fuel Dilution

This is indicated with either a lower decrease in the oil condition over time (ROC) than expected in comparison to the assets usual ROC, or even by an increase in the oil condition that is not directly related to a fluctuation in the oil temperature.

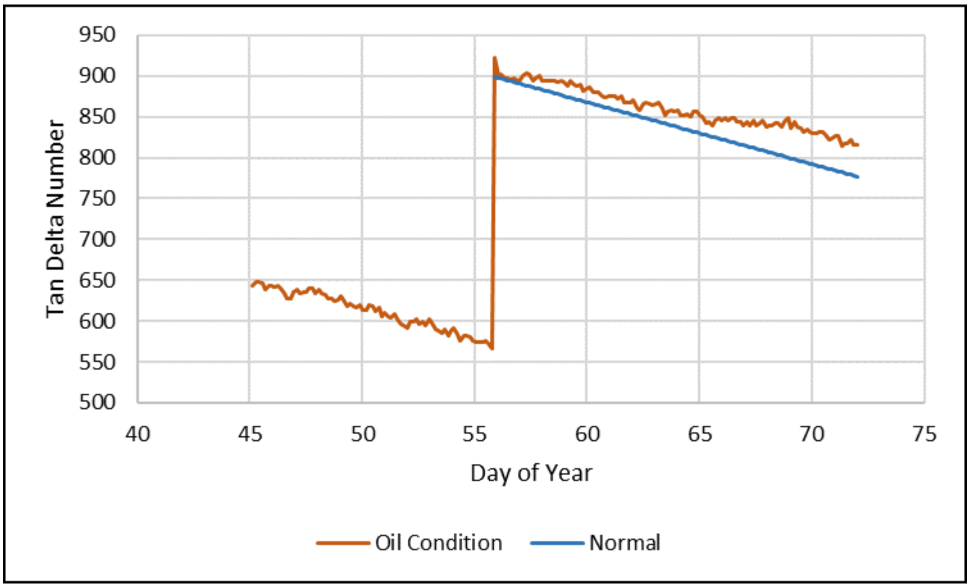


Figure 79 - Fuel Dilution

In the graph example shown, we have added a comparison line of how a condition such as fuel dilution would look compared to the normal path of oil degradation over time.

12.3.5 Soot Contamination

Contamination from soot in oil is indicated by a greater change in the oil condition (decrease in TDN) over time (ROC) than expected in comparison to the assets usual ROC.

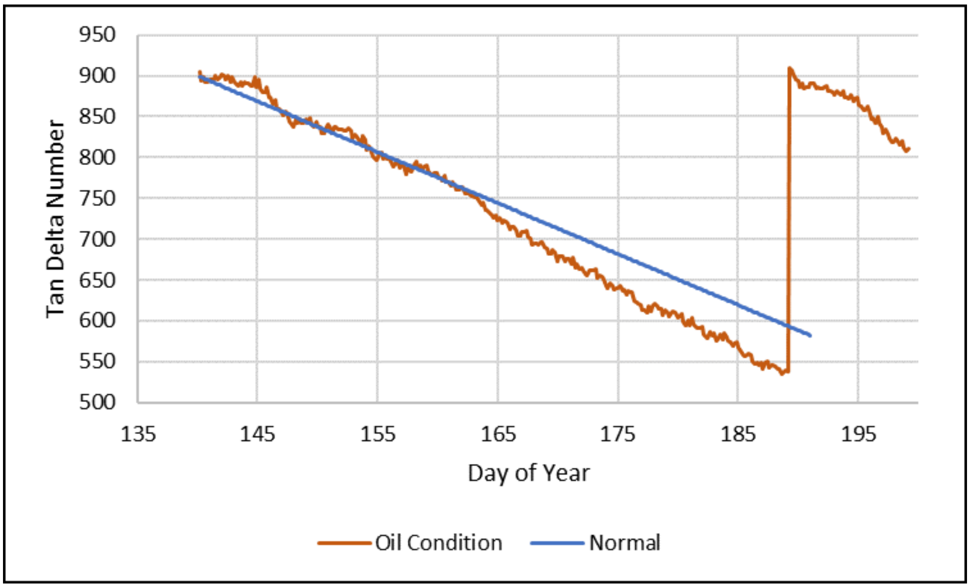


Figure 80 - Soot Contamination

The example graph provided shows how the oil is degrading faster than expected (the blue line representing the normal expected behaviour) and a point where this contamination becomes evident as the oil condition deteriorated further.

12.3.6 TBN Decrease

A decrease in Total Base Number (TBN) is indicated by the exponential decrease in TDN value with time, also described by the downward curve of the plot.

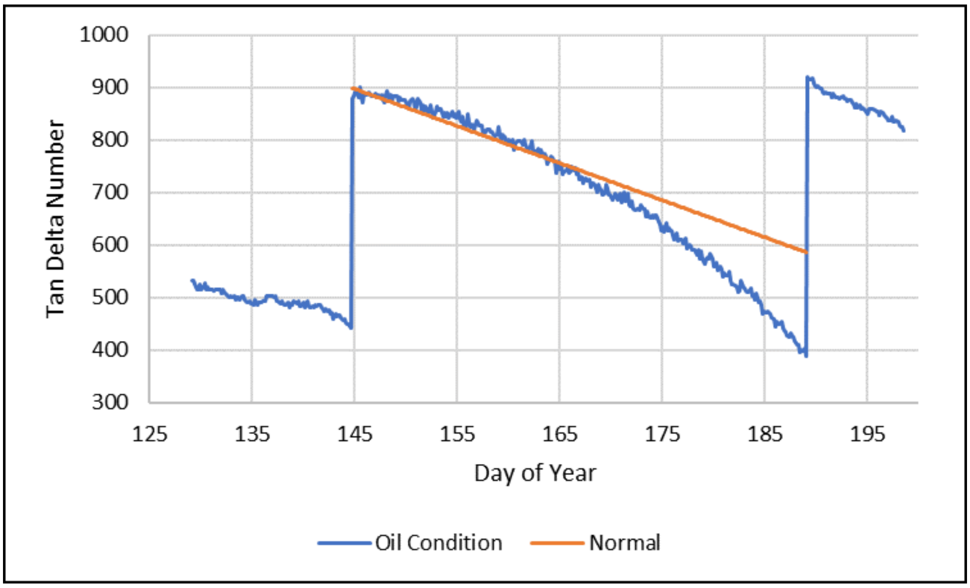


Figure 81 - TBN Decrease

In the example graph provided, you can see the downward curve in the data clearly emerging indicating an issue.

12.4 Event Identification & Validation (EIV)

Data returned from the Oil Quality Sensor can be used to identify and validate key events such as oil changes and oil top-ups. As the Oil Quality Sensor sends back a holistic full spectrum analysis of the oil condition in the form of a condition number (TDN), the trend of these returned numbers can be analysed to identify an event such as a maintenance interval or intervention.

Complete oil changes will show as a direct linear change in the reported oil condition, if the TDN value returns to the point expected of a new clean oil (1), then the oil change can be validated as being carried out correctly.

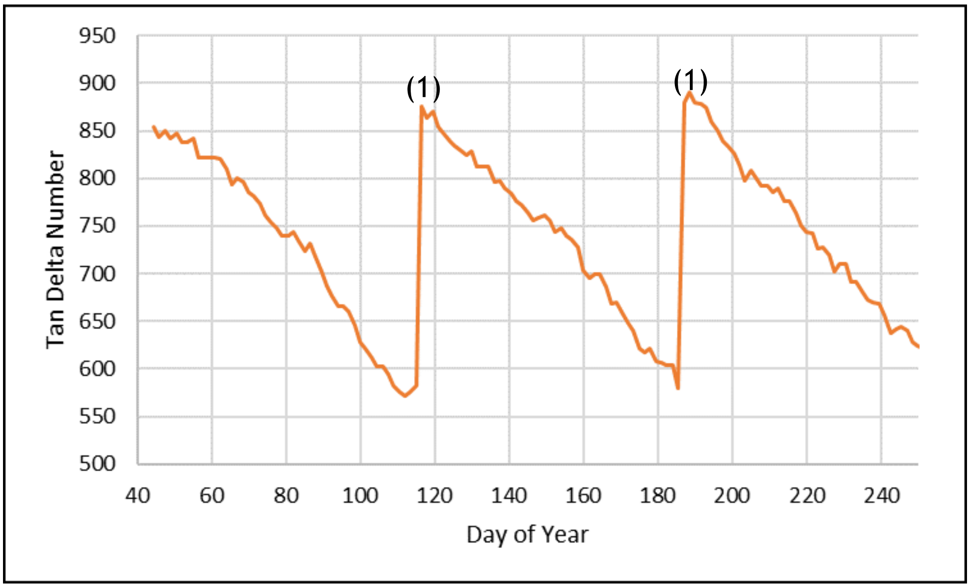


Figure 82 - Oil Change Carried Out Correctly

If the TDN value does not return exactly to the same point expected of a new clean oil (2), then it is likely that there was some residual amount of used oil remaining in the system which has mixed with the new clean oil.

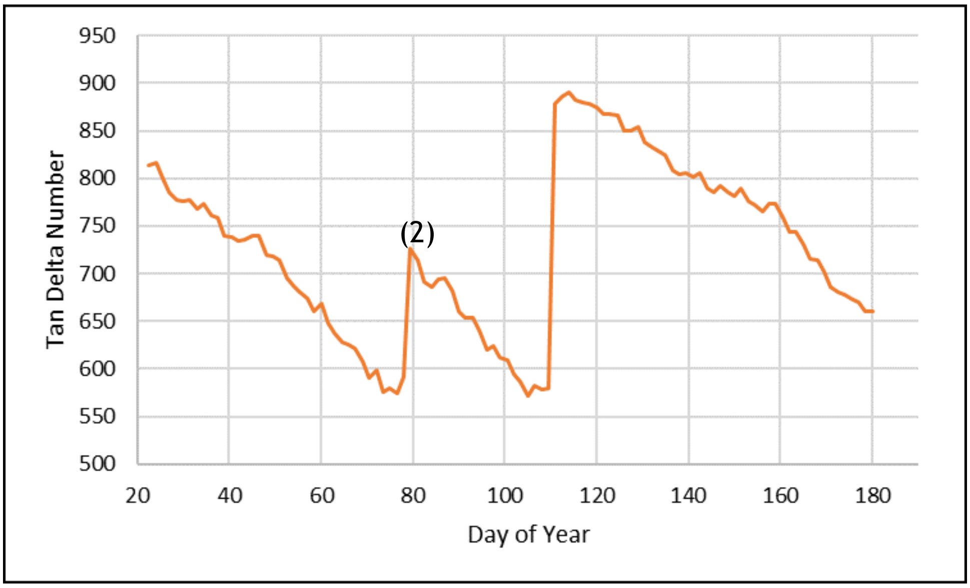


Figure 83 - Oil Change Not Carried Out Correctly

Small linear improvements in the TDN value are not expected to be seen in normal operation and are not indicative of a contamination event, therefore a linear increase in oil condition in a shorter time scale (3) would validate an oil top-up intervention.

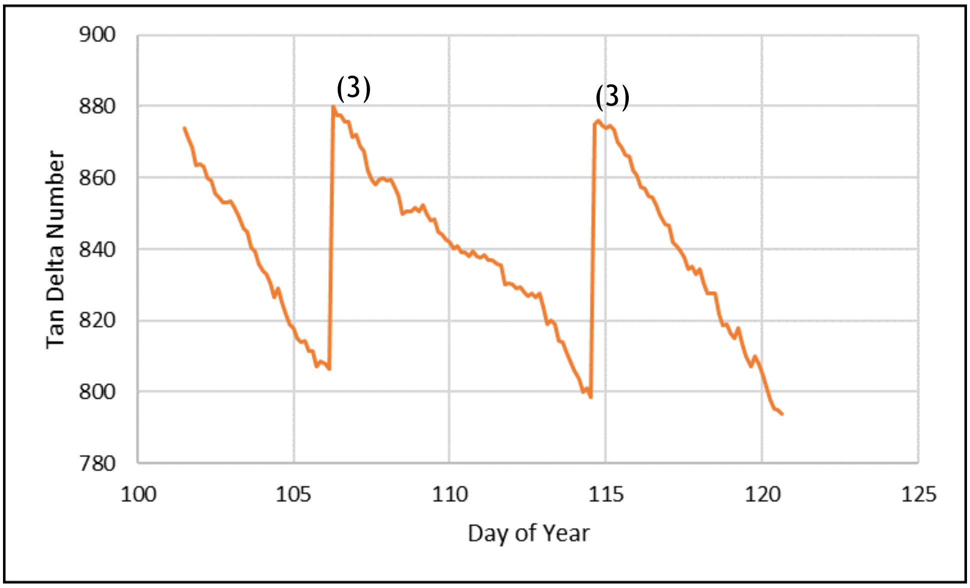


Figure 84 - Oil Top-Up Intervention

12.5 Rate of Change (ROC)

Calculating Rate of Change (RoC) of oil condition is necessary to utilise some of the more advanced algorithms for integrated oil condition logic.

You can use the following logic to set up a third-party device to show the rate of change in the oil condition:

- Instant RoC = Average change in oil condition for last 5 minutes.
- Median RoC = Average change in oil condition for last 6 hours. (Should cover at least 60 data points)
- Lifetime RoC = Average change of all oil condition readings. (Should cover at least 60 data points)

This equation is a relatively expensive task on small processors, so may not be possible for all devices. Below is the RoC implementation which is mathematically correct to the definition of "rate of change over time".

$$R = \frac{\sum_{i=c}^{c+I}(t_i - \bar{T})(o_i - \bar{O})}{\sum_{i=c}^{c+I}(t_i - \bar{T})^2}$$

R	Rate of change	Rate of change value
i	Iterator	Value iterator
I	IterMax	Number of records to consider (ROC time period in minutes / log interval in minutes)
c	Clock	Current time in minutes / log interval in minutes
t	Time	Time at record i

$\bar{T}$	AvgTime	Average time at records $[t_c, t_{c+I}]$
o	OilCond	Oil condition at record i
$\bar{O}$	AvgOilCond	Average oil at records $[o_c, o_{c+I}]$

With the following variable definitions.

12.6 Remaining Useful Life (RUL)

Remaining Useful Life is determined as the number of days that the oil can be used until it is considered as being at the end of its useable life.

To establish the RUL at any point as a snapshot in time, we must first understand and establish what is referred to as the "Median Rate of Change", which is the rate of change in TDN over the previous 6 hours (usually presented as a negative number).

We should also know the End of Life (EOL) TDN value for the oil in use (this is typically 300 TDN).

We can then use the following equation to calculate the Remaining Useful Life of the oil:

RUL = ((Oil EOL – Current Oil Condition) / Median RoC) / 4

For example:

Oil EOL = 300TDN
Current Oil Condition = 582TDN
Median rate of change over the last 6 hours = -2

13 Cleaning Guide

13.1 Cleaning the Tan Delta Sensor

13.1.1 Health & Safety

Solvents and Kerosene can be harmful if inhaled and/or ingested. Eye protection and gloves should be worn and products should be used in a well ventilated area. Always follow usage instructions on the packaging.

It is always prudent to ensure the COSHH datasheet from the manufacturer is always readily available when using dangerous substances.

13.1.2 Introduction

If using the sensor in the Tan Delta Mobile Oil Test Kit or if the sensor is being used for bench testing, it is important to always clean the sensor properly between samples. In a fixed installation it is not necessary to clean the sensor due to the sensor being in a live oil zone, however in a situation where you have experienced a very heavy contamination we do recommend that you clean the sensor prior to refilling with oil.

13.1.3 Selecting a solvent cleaner

We recommend Loctite 7063 aerosol solvent to clean the sensor as this has excellent degreasing properties and leaves little or no residue on the sensor, it also widely available, although Loctite 7063 is not available in all territories you can determine whether an alternative cleaner is suitable by following the procedure on the latter pages of this guide.

Please take care in selecting an alternative as many claim to be low residue when they still leave significant residue which will affect the sensors capability and resultant outputs.

Additionally, you can also use odourless kerosene to clean the sensor, in which case please follow the procedure on page 4.

13.1.4 Cleaning Procedure – Loctite 7063 or Similar Solvent

- Unplug and remove the sensor then use absorbent paper to wipe off the excess oil from the sensor tip and thread.

- While rotating the sensor, force a short blast of solvent up into each of the holes in the sensor nose, and then give the general exterior a wash on both sides as shown in the pictures below:

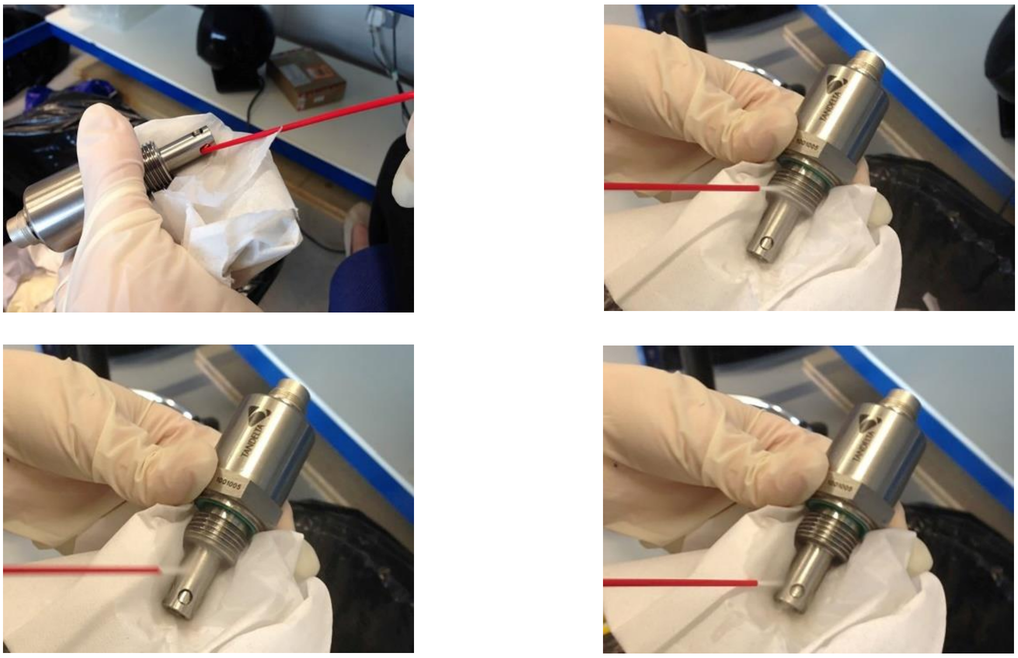


Figure 85 - Cleaning the Sensor (1)

- Then give a slightly longer spray up the centre hole (2 seconds).

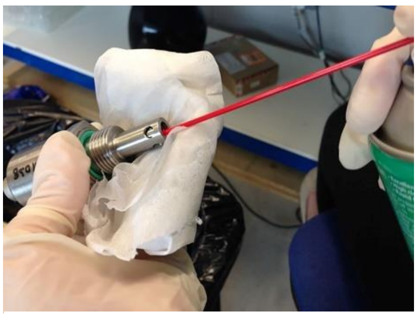


Figure 86 - Cleaning the Sensor (2)

- Shake sensor over the absorbent paper to dislodge any solvent remaining around the electrode.

- Leave to dry for a few minutes.

13.1.5 Cleaning Procedure - Odourless Kerosene

- Unplug and remove the sensor then use absorbent paper to wipe off the excess oil from the sensor tip and thread.
- Attach a bottle adaptor to a sample bottle and pour in approximately 15ml of kerosene.
- Screw in the sensor and shake vigorously for 2 minutes to ensure the kerosene washes up around the tip of the sensor.

Figure 87 - Cleaning the Sensor (3)

- Remove the sensor from the adaptor and shake rigorously over the absorbent paper to dislodge any excess kerosene.
- Leave to dry for a few minutes.

13.1.6 Cleaning Procedure - Deep Cleaning

Some oil testing, generally where there are extremely high levels of carbon deposits and where the sensor has not been cleaned and has been allowed to dry, can result in the sensor being difficult to clean using our standard methods, in this case we recommend a more thorough deep cleaning process cleaning process as follows:

- Clean sensor using one of the 2 methods described above.
- Clean the sensing head only in an ultrasonic bath for 5 minutes, using a solvent which is suitable for stainless steel and nickel-plated brass, rigorously shake the sensor over absorbent paper, rinse the sensor tip in distilled water, and then rigorously shake the sensor again over absorbent paper.
- Allow to dry for a few minutes.
- Then repeat the steps above.

13.1.7 Cleaning Procedure – Alternative Solvent Test

- Clean the sensor using one of the following two methods:

- Rinse the sensor tip thoroughly in odourless kerosene, as described at 13.1.5.
  Or
- Use the deep cleaning method described at 13.1.6.

- Test a clean oil sample, repeat the cleaning method used above and then re-test a clean oil sample, the readings from both tests should be the same (or very similar), this proves that using one of the failsafe cleaning methods is working.

- Clean the sensor using the new cleaner and re-test a clean oil sample and if the results are the same as for the failsafe cleaning method then the new cleaner works, if not try a different cleaner.

14 Appendix

14.1 Oil Condition Conversion Chart

Oil condition is output as a Loss Factor Percentage and the output is linearly scaled between -20% (4mA) and +60% (20mA). The Loss Factor Percentage can easily be converted to the TDN scale using the following table. **(NOTE: The colour scales and alert levels used are set for a typical diesel engine setup.)**

4-20mA	Loss Factor	TDN	Alarm Setting
<4			
4 mA	-20.0 %	1200 TDN	
	-19.0 %	1200 TDN	
	-18.0 %	1200 TDN	
	-17.0 %	1200 TDN	
	-16.0 %	1200 TDN	
5 mA	-15.0 %	1200 TDN	
	-14.0 %	1180 TDN	
	-13.0 %	1160 TDN	
	-12.0 %	1140 TDN	High Alarm
	-11.0 %	1120 TDN	
6 mA	-10.0 %	1100 TDN	
	-09.0 %	1080 TDN	
	-08.0 %	1060 TDN	High Warning
	-07.0 %	1040 TDN	
	-06.0 %	1020 TDN	
7 mA	-05.0 %	1000 TDN	
	-04.0 %	0980 TDN	
	-03.0 %	0960 TDN	
	-02.0 %	0940 TDN	
	-01.0 %	0920 TDN	
8 mA	000.0 %	0900 TDN	
	001.0 %	0880 TDN	
	002.0 %	0860 TDN	
	003.0 %	0840 TDN	
	004.0 %	0820 TDN	
9 mA	005.0 %	0800 TDN	
	006.0 %	0780 TDN	
	007.0 %	0760 TDN	
	008.0 %	0740 TDN	
	009.0 %	0720 TDN	
10 mA	010.0 %	0700 TDN	
	011.0 %	0680 TDN	
	012.0 %	0660 TDN	
	013.0 %	0640 TDN	
	014.0 %	0620 TDN	
11 mA	015.0 %	0600 TDN	
	016.0 %	0580 TDN	
	017.0 %	0560 TDN	
	018.0 %	0540 TDN	
	019.0 %	0520 TDN	

4-20mA	Loss Factor	TDN	Alarm Setting
12 mA	020.0 %	0500 TDN	
	021.0 %	0480 TDN	
	022.0 %	0460 TDN	
	023.0 %	0440 TDN	
	024.0 %	0420 TDN	Low Warning
13 mA	025.0 %	0400 TDN	
	026.0 %	0380 TDN	
	027.0 %	0360 TDN	
	028.0 %	0340 TDN	
	029.0 %	0320 TDN	
14 mA	030.0 %	0300 TDN	Low Alarm
	031.0 %	0280 TDN	
	032.0 %	0260 TDN	
	033.0 %	0240 TDN	
	034.0 %	0220 TDN	
15 mA	035.0 %	0200 TDN	
	036.0 %	0180 TDN	
	037.0 %	0160 TDN	
	038.0 %	0140 TDN	
	039.0 %	0120 TDN	
16 mA	040.0 %	0100 TDN	
	041.0 %	0080 TDN	
	042.0 %	0060 TDN	
	043.0 %	0040 TDN	
	044.0 %	0020 TDN	
17 mA	045.0 %	0000 TDN	
	046.0 %	0000 TDN	
	047.0 %	0000 TDN	
	048.0 %	0000 TDN	
	049.0 %	0000 TDN	
18 mA	050.0 %	0000 TDN	
	051.0 %	0000 TDN	
	052.0 %	0000 TDN	
	053.0 %	0000 TDN	
	054.0 %	0000 TDN	
19 mA	055.0 %	0000 TDN	
	056.0 %	0000 TDN	
	057.0 %	0000 TDN	
	058.0 %	0000 TDN	
	059.0 %	0000 TDN	
20 mA	060.0 %	0000 TDN	

Number Format
Loss Factor = Always 4 characters (including -) to 1
TDN = Always 4 digits
Conversion
4-20mA to Loss Factor = (mA - 4) * 5 - 20
4-20mA to TDN = (mA -17) * -100

14.2 Oil Temperature Analog Output

The table below shows how the oil temperature output (4-20mA) converts to temperature.

OQS Output 4.20mA value		Temperature Conversion °C		°F	
min	max	min	max	min	max
20		130		266	
19.5	19.99	125	129	257	264.2
19	19.49	120	124	248	255.2
18.5	18.99	115	119	239	246.2
18	18.49	110	114	230	237.2
17.5	17.99	105	109	221	228.2
17	17.49	100	104	212	219.2
16.5	16.99	95	99	203	210.2
16	16.49	90	94	194	201.2
15.5	15.99	85	89	185	192.2
15	15.49	80	84	176	183.2
14.5	14.99	75	79	167	174.2
14	14.49	70	74	158	165.2
13.5	13.99	65	69	149	156.2
13	13.49	60	64	140	147.2
12.5	12.99	55	59	131	138.2
12	12.49	50	54	122	129.2
11.5	11.99	45	49	113	120.2
11	11.49	40	44	104	111.2
10.5	10.99	35	39	95	102.2
10	10.49	30	34	86	93.2
9.5	9.99	25	29	77	84.2
9	9.49	20	24	68	75.2
8.5	8.99	15	19	59	66.2
8	8.49	10	14	50	57.2
7.5	7.99	5	9	41	48.2
7	7.49	0	4	32	39.2
6.5	6.99	-5	-1	23	30.2
6	6.49	-10	-6	14	21.2
5.5	5.99	-15	-11	5	12.2
5	5.49	-20	-16	-4	3.2
4.5	4.99	-25	-21	-13	-5.8
4	4.49	-30	-26	-22	-14.8
<4		Fault			

14.3 Software License Agreements

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anstyle-parse

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anstyle-query

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anstyle-wincom

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async-channel

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base64

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bytes

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cfg-if

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chrono

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clap

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concurrent-queue

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const_format

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const_format_proc_macros

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crossbeam-channel

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crossbeam-utils

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csv

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csv-core

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cxxopts

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encoding_rs

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env_logger

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event-listener

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fnv

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form_urlencoded

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futures

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futures-channel

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futures-executor

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futures-io

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futures-sink

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futures-task

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futures-timer

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futures-util

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hashbrown

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idna

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is-terminal

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lazy_static

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libc

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log

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mime

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num_cpus

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num-traits

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once_cell

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pin-utils

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thiserror-impl

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time

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tokio-native-tls

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tower-service

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tracing

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tracing-core

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try-lock

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unicode-bidi

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unicode-normalization

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unicode-xid

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url

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utf8parse

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winapi

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winapi-util

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windows_x86_64_msvc

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winreg

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