OXYGEN OPTODE 4330, 4835, 4831, 5331

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1st Edition	February 2008 PRELIMINARY
2nd Edition	October 2008
3rd Edition	February 2009 Including description of Optode 4835
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5th Edition	February 2014 Updated text on page 17, 54 and 55
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INTRODUCTION

Purpose and Scope

This document is intended to give the reader knowledge of how to operate, calibrate and maintain the Aanderaa Oxygen Optodes 4330, 4835, 4831 and 5331. It also aims to give insight into how Oxygen Optode works.

All these sensors are covered in one single manual since the operation and configuration are identical. The main difference is housing and plug connection.

Individually calibrated commercially available optical dissolved oxygen Optodes for ocean and freshwater applications were introduced by Aanderaa Data Instruments in 2002. The proven long-term stability (years) and reliability of these sensors have revolutionized oxygen measurements and several thousand are now in use in applications ranging from streams to the deepest oceanic trenches on earth, from fish farms to wastewater, from polar ice to hydrothermal vents.

In 2002 the first MKI versions of these sensors, the models 3830 and 3835 went into service.

This manual deals with the more recent MKII Optode models 4330/4835/4831/5331. Compared to MKI the MKII Optodes' deliver improved electronics, optics, temperature compensation, formulas to calculate absolute oxygen and they are individually multipoint calibrated (in 40 points at 5 temperatures and 8 oxygen concentrations) to an enhanced accuracy.

With the release of Framework 3 in 2011 Aanderaa introduced a new firmware version to accommodate higher security and future expansion. Both the Smart Sensor Terminal protocol and the AADI Real Time protocol was updated with this version of the Smart Sensor firmware, (see appendix 11)

Aanderaa Smart Sensors utilize communication protocols at the RS232 interface where the Smart Sensor Terminal protocol is a simple ASCII command string-based protocol and the AADI Real Time is an XML based protocol.

Oxygen Optode 4330/4330F fits directly on the SeaGuard top-end plate and is interfaced by means of a reliable CANbus interface (AiCaP), using XML for plug and play capabilities. It can also be used as stand-alone sensor using RS-232 output. The sensor is available in three different depth ratings, 300 meter, 3000 meter and 6000 meter. Oxygen Optode 4330 is also available in a fast response version called 4330F.

Oxygen Optode 4835 is the shallow water version of 4330. The sensor housing is made of Hostaform and maximum depth rating is 300 meter. This version fits directly on the SeaGuard SW top-end plate and is interfaced by means of a reliable CANbus interface (AiCaP), using XML for plug and play capabilities. It can also be used as stand-alone sensor using RS-232 output.

Oxygen Optode 4831/4831F/5331 is a version built on the same platform as 4330 but with a wet mate connector for easy integration. This sensor has analog and RS-232 output. The sensor is available in three different depth ratings, 300 meter, 3000 meter and 6000 meter.5331 is rated as 11000 meter. Oxygen Optode 4831 is also available in a fast response version called 4831F.

Standard Oxygen Optode 4831 is equipped with an 8-pin Subconn while 4831U is equipped with a 6-pin Subconn and does not offer an analog output, only RS-232.

Oxygen Optode 5331 is equipped with an 8-pin Subconn while 5331HW is equipped with a 10-pin Subconn and does output via AiCaP or RS-232.

Document Overview

Chapter 1 is a short description of the sensors covered by this manual.

Chapter 2 is a description of measurement principles and parameters

Chapter 3 is a short description of how to use the sensor with SeaGuard.

Chapter 4 describes how to configure and use the sensor together with AADI Real-Time Collector.

Chapter 5 describes the connection to PC and the RS-232 communication protocol.

Chapter 6 describes maintenance, procedure for changing foil and functional test for the sensors.

The Appendix includes the principle behind the Oxygen Optodes, electronic and mechanical design, calibration procedures including the Stern-Volmer Uchida formula implemented with the new Optode framework 3 introduced in August 2012. The new firmware also allows an optional high accuracy multipoint calibration. The appendix also includes illustrations of all available cables, Frequently Asked Questions, a list of scientific publications in which Aanderaa Optodes have played a central role and the PCN covering the updates following introduction of framework 3.

Applicable Documents

V-9867	Assembly Drawing 4330/4330F
V-10362	Assembly Drawing 4835
V-11294	Assembly Drawing 4831
V-8700	Sensor Cable 3855, Sensor to PC, RS-232, for 4330/4835, laboratory use
V-10501	Sensor Cable 4865, Sensor to PC, RS-232, for 4330/4835, field use
V-10331	Sensor Cable 4762, Sensor to free end, for 4330/4835
V-10388	Sensor Cable 4793 for 4330/4835 remote sensor used on SeaGuard
V-11367	Sensor Cable 5280 for 4831, Sensor to IE55
DID-50042	Sensor Cable 5336 for 4831, Sensor to IE55 plus Mecca
DID-50041	Sensor Cable 5335, Sensor to PC, RS-232 for 4831
Form 712	Test & Specification Sheet, Oxygen Optode
Form 770	Calibration Certificate, O2 Sensing foil 3853
Form 710	Calibration Certificate, Oxygen Optode
D 378	Data sheet Oxygen Optode 4330/4330F
D 403	Data sheet Oxygen Optode 4831/4831F
D 385	Data sheet Oxygen Optode 4835

Abbreviations

O_2	Oxygen molecule
LED	Light Emitting Diode
ADC	Analogue to Digital Converter
DSP	Digital Signal Processor
EPROM	Erasable Programmable Read Only Memory
ASCII	American Standard Code for Information Interchange
MSB	Most significant bit
UART	Universal Asynchronous Receiver/Transmitter
RTC	Real Time Clock
FAQ	Frequently Asked Questions; documented in appendix of this OM
AiCaP	Automated idle line CANbus Protocol; A modified communication protocol developed by Aanderaa for a distributed network of smart sensors when connected to SeaGuard, SeaGuardII or SmartGuard loggers.

CHAPTER 1 **Short Description and Specifications**

1.1 Description

The AADI Oxygen Optode 4330, 4831, 5331 and 4835 are based on the ability of selected substances to act as dynamic fluorescence quenchers.

The fluorescent indicator is a special platinum porphyrin complex embedded in a gas permeable foil that is exposed to the surrounding water. Characteristic features of these foils and sensors are exceptional sensitivity, stability and robustness. Hundreds of examples exist of field stability for periods of 1-6 years (see summary of scientific publications appendix 11). In addition, the ability to withstand high temperatures, to have low and fully reversible pressure effects and minimal wet-dry cycling effects are benefits of the Aanderaa Optodes.

The 4330 and 4831 Optodes can be fitted with the standard or faster response foils. The “standard foil” is more robust and recommended in most applications. A black optical isolation coating protects the sensing complex from influences caused by direct incoming sunlight, exciting fluorescent particles in the water, and biofouling. The “faster response” foils are suitable if shorter response times are required however these foils do not have any protective optical isolation layer. Normally the foils have the same long-term stability, but the fast foils are slightly noisier. If exposed to direct sunlight they will bleach and drift towards lower responses. It is always recommended to store sensors and spare foils in the dark and to soak sensors in water at least 24 hours prior to calibration or deployment. Sensors are delivered with a reusable black rubber protection cap, and it is recommended to add a wet piece of natural sponge to keep the sensor foil wet at all times during storage.

The sensing foil is fixed against a sapphire window by two or four screws and a plastic securing plate, providing optical access to the foil by the measuring system from inside a watertight housing.

The foil is excited by modulated blue light, and the Optode measures the phase shift of a returned red light, ref Appendix 2. By linearizing and temperature compensating, with an incorporated temperature sensor located next to the sensing foil, the absolute O_2 concentration is determined.

The lifetime-based luminescence quenching principle, as used in AADI Oxygen Optodes, offers the following advantages over electrochemical sensors:

- Not stirring sensitive (does not consume oxygen; does not require pumps)
- Direct Measurement of absolute oxygen concentrations without repeated calibrations
- Better long-term stability (stable for years)
- Less affected by pressure; Pressure behavior is predictable and fully reversible
  - Repeatable
  - Low Noise
  - Exceptionally Low Drift

The Optode can be logged directly by a PC (via the RS232 protocol) and by most PLC’s, DCP’s, I/O devices, data loggers and systems.

The optical oxygen sensors described herein belong to the Aanderaa series of smart multi-parameter sensors.

Aanderaa produces other smart sensors to measure water Currents, Conductivity, Turbidity, Temperature, Wave, Tide and Pressure.

Features common to these sensors include:

- Internal Digital Signal Processor (DSP) to optimize data acquisition and improve accuracy, resolution and stability
- Multi-parameter outputs measured/calculated/presented within the sensor e.g. for oxygen O_2 in µM, O_2 in % saturation, Temperature and Raw data
- Calibration coefficients stored in sensor and unique sensor identification number
- Autonomous sampling, 1 second to 4-hour sampling interval
- AiCaP (CAN bus) communication which means that up to 20-25 sensors can be “plug and play” connected to Aanderaa SEAGUARD® or to a SMARTGUARD® logger that automatically detects and recognizes the sensor.
- RS232 serial communication so that these sensors can be connected directly to computers or third-party platforms e.g. data loggers from other manufacturers, gliders, floats, buoys, landers, cable operated and autonomous vehicles.
- Some sensors are also available in special versions with RS-422 for use on longer cables.
- Multipoint Calibration with increased accuracy.
- Analog 0-5 V, 4-20 mA only for 4831.
- Low power consumption
- Long-Time stable

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1.2 Sensor version

Each sensor and pin configuration is described in the following chapters.

1.2.1 Oxygen Optode 4835

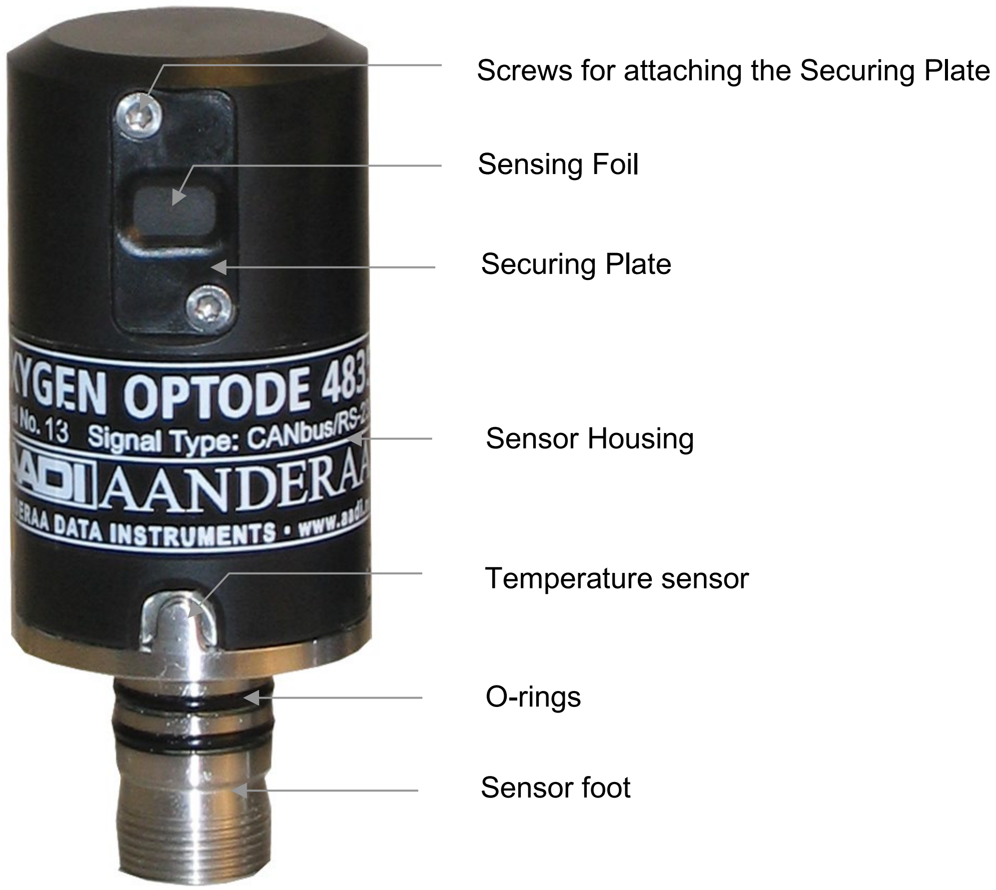

Figure 1-1: Illustration of Oxygen Optode Sensor 4835

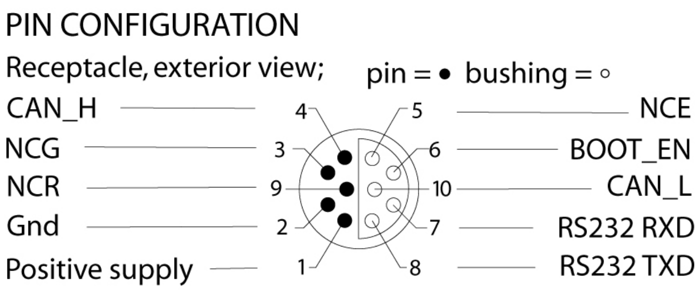

Figure 1-2: Oxygen Optode 4835 Pin Configuration

1.2.2 Oxygen Optode 4330

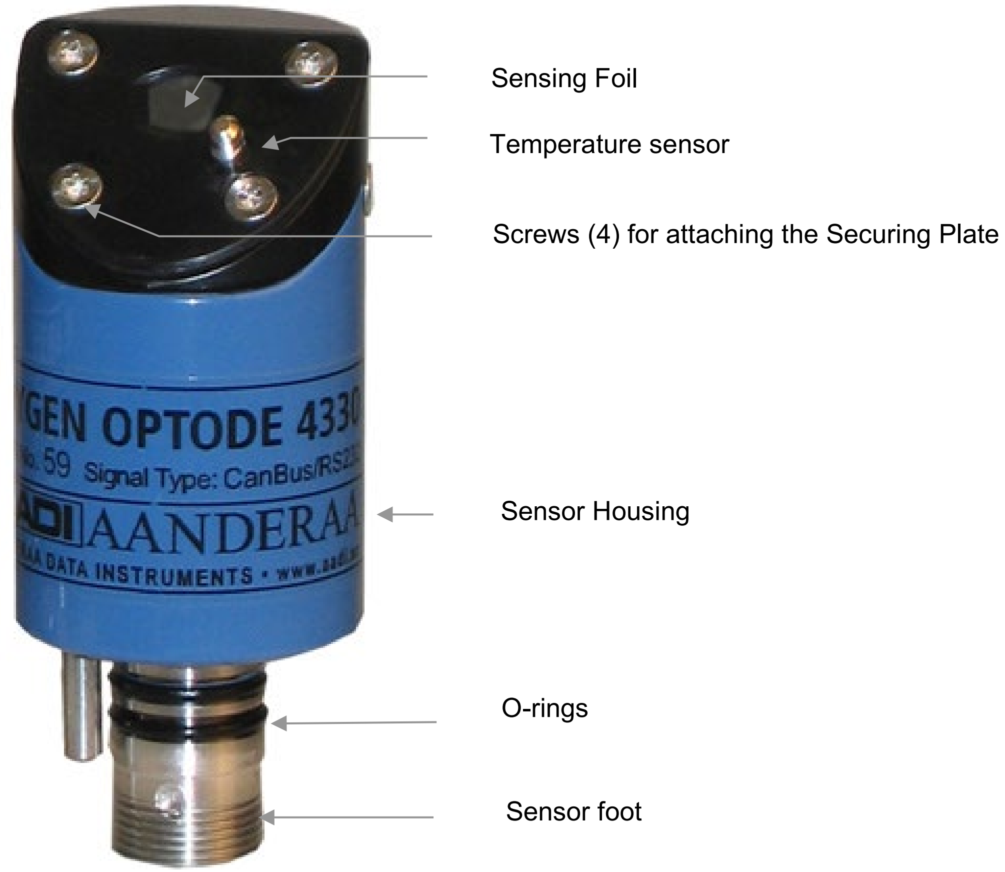

Figure 1-3: Illustration of the Oxygen Optode 4330.

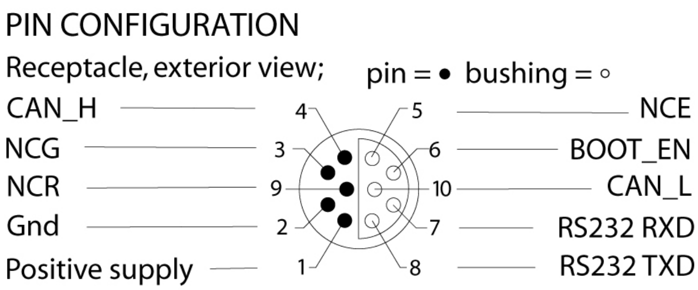

Figure 1-4: Oxygen Optode 4330 Pin Configuration

1.2.3 Lemo plug connection

The 4330 and 4835 sensors are using a lemo plug. This plug is not a 1 to 1 plug like eg. Subconn. See below for a complete list of connections between sensor and cable plug or hub card plug.

Table 1-1: 10-pinLemo plug Pin Configuration

Signal	Sensor pin	Cable pin
Positive supply / V+	1	8
Gnd	2	7
NCG	3	6
CAN_H	4	5
NCE	5	4
BOOT_EN / Boot Enable	6	3
RS232 RXD / RXD	7	2
RS232 TXD / TXD	8	1
NCR	9	10
CAN_L	10	9

1.2.4 Oxygen Optode 4831 and 5331

Figure 1-5 Illustration of the Oxygen Optode 4831/5331

1.2.5 Pin configuration 8 pin Subconn

Used with Standard 4831 and Standard 5331 with analog and Rs-232 Output

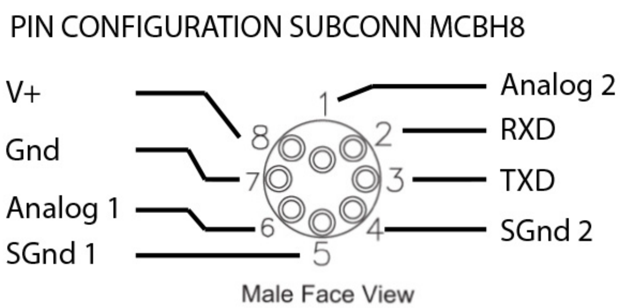

Figure 1-6: 8-pin Subconn pin configuration

Table 1-2: 8-pin subconn pin configuration

Signal	Cable pin
Positive supply / V+	8
Gnd	7
Analog 1	6
SGnd 1	5
Analog 2	1
SGnd 2	4
RS232 RXD	2
RS232 TXD	3

1.2.6 Pin configuration 6 pin Subconn

Used with 4831U with Rs-232 Output

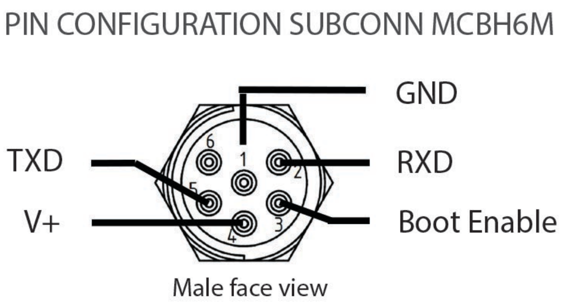

Figure 1-7: 6-pin subconn pin configuration

Table 1-3: 6-pin subconn pin configuration

Signal	Cable pin
Positive supply / V+	4
Gnd	1
Boot Enable	3
RS232 RXD	2
RS232 TXD	5

1.2.7 Pin configuration 10 pin Subconn

Used with 5331H with AiCaP and Rs-232 Output

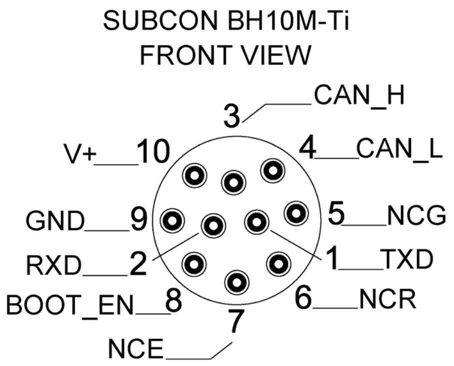

Figure 1-8: 10-pin subconn pin configuration

Table 1-4: 10-pin subconn pin configuration

Signal	Cable pin
Positive supply / V+	10
Gnd	9
Boot Enable	8
CAN_H	3
CAN_L	4
NCG	5
NCR	6
NCE	7
RS232 RXD	2
RS232 TXD	1

1.2.8 Oxygen Optode 4835

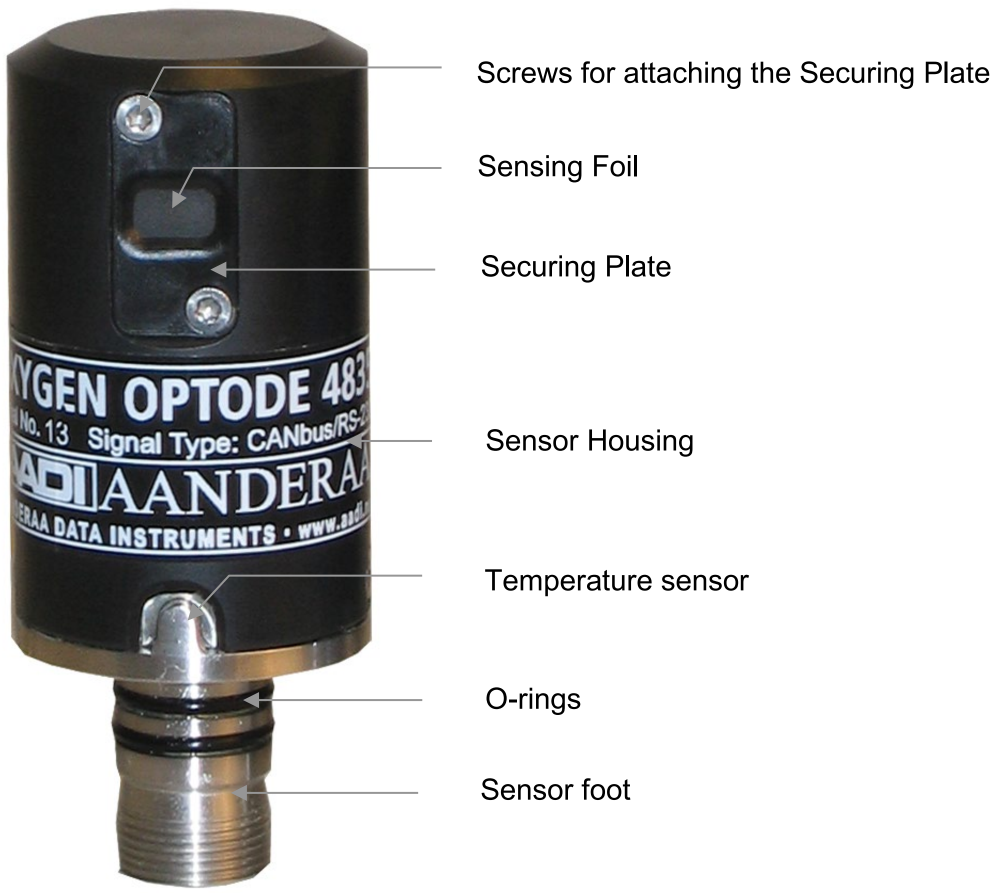

Figure 1-9: Oxygen Optode Sensor 4835

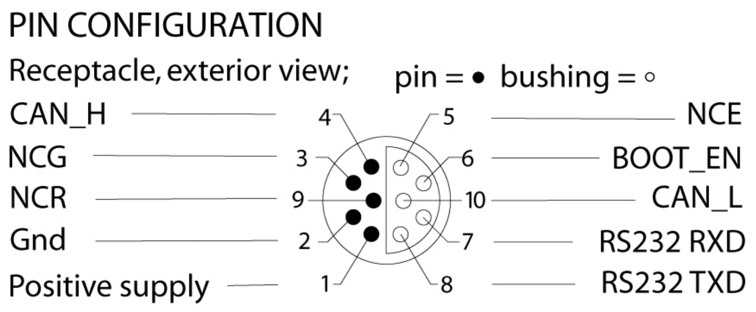

Figure 1-10: Oxygen Optode 4835 Pin Configuration

Please note that the lemo plug used for this sensor are not a 1 to 1 plug. This means that e.g. pin 1 on sensor are connected to pin 8 on cable. For more info, see chapter

1.3 Pin Configuration

The Oxygen Optode 4330, 4831, 5331 and 4835 pin configuration is given in ***Chapter 1.2*** . A description of the receptacle notation is given in ***Table 1-5.***

Table 1-5 Description of the Pin Configuration

Signal	Description
CAN_H	CANbus line (dominant high)
NCG	Node Communication Ground
NCR	Node Communication Request
Gnd	Ground
Positive supply / V+	5-14V positive supply
NCE	Node Communication Enable
BOOT_EN / Boot Enable	Boot Load Enable (do not connect)
CAN_L	CANbus line (dominant low)
RS232 RXD / RXD	RS232 Receive line
RS232 TXD / TXD	RS232 Transmit line
Analog 1	Analog output no. 1, 0-5V
SGnd 1	Signal ground for Analog output no. 1
Analog 2	Analog output no. 2, 0-5V
SGnd 2	Signal ground for Analog output 2

1.3.1 Lemo plug connection

The 4330 and 4835 sensors are using a lemo plug. This plug is not a 1 to 1 plug like eg. Subconn. See ***Table 1-6*** for a complete list of connections between sensor and cable plug or hub card plug.

Table 1-6: Lemo plug Pin Configuration

Signal	Sensor pin	Cable pin
Positive supply / V+	1	8
Gnd	2	7
NCG	3	6
CAN_H	4	5
NCE	5	4
BOOT_EN / Boot Enable	6	3
RS232 RXD / RXD	7	2
RS232 TXD / TXD	8	1
NCR	9	10
CAN_L	10	9

1.4 Sensor Connection

Aanderaa offers a wide range of cables for different use of the sensors, both standard cables using AiCaP, RS-232 or analog but also special customer specified cables for use in project. See **Appendix 8** for an overview of standard cables or contact aanderaa.sales@xylem.com for more info. To configure the sensor, it either need to be connected to an Aanderaa logger using AiCaP, a real-time RS-232 cable or you need a RS-232 configuration cable.

1.4.1 Configure sensor using RS-232 configuration cable

The 3855 cable is a non-watertight 1.5 meter cable for laboratory use only used for connection between sensor and PC in the office/lab. This cable can also be used to configure all other Aanderaa Smart Sensors.

The cable is supplied with a USB port providing power to the sensor but since the USB port on a computer normally gives 5V power and the alalog output needs 6-14V the sensor cannot be powered from the computer like for most other Aanderaa Smart Sensors. A USB extension is supplied with the cable so we recommend connecting the free end to an external power (6-14V). An alternative solution is *to use a 9V alkaline battery (6LF22) to set the sensor up or log it in the laboratory.* Sensor Cable 3855 is also available in other lengths.

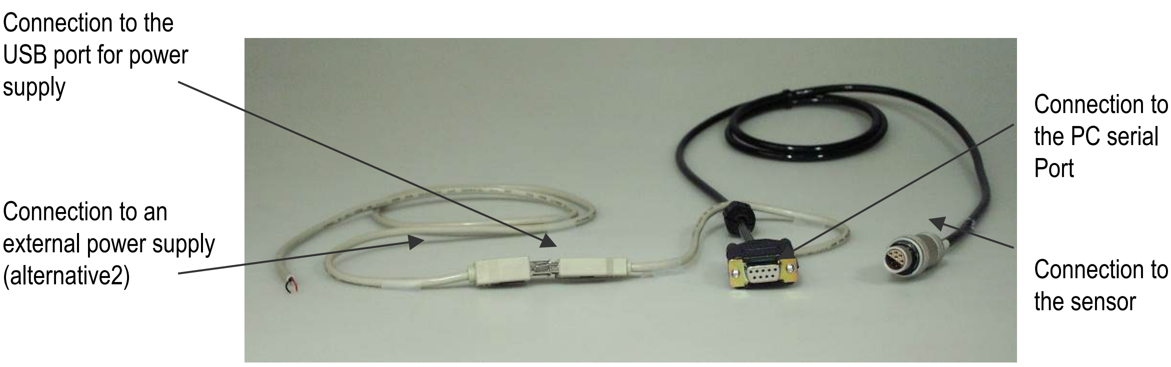

Figure 1-11: Configuration Cable 3855

Table 1-7: 3855 Cable pin configuration

Signal name	Sensor plug	9-p D-Sub	USB
TXD	1	2	
RXD	2	3	
Boot Enable	3		
BV	4		4 (black)
GND	7	5	1 (red)
Positive Supply	8		
RTS short to CTS		7-8	

1.5 User accessible sensor properties

All configuration settings that determine the behavior of the sensor are called properties and are stored in a persistent memory block (flash). One property can contain several data elements of equal type (Boolean, character, integer etc.). The different properties also have different access levels.

To read the value of certain properties you need to send ASCII string starting with the command ***get*** and then followed by the property name to the sensor, see example below.

To change the content of a property an ASCII string starting with ***set*** and then followed by the property name and new value in brackets need to be sent to the sensor.

Get Interval	//When sending this string to the sensor, it will then return the value stored in this property.
Interval 4330 17 1min	//Returned from sensor, where 4330 is the product number, 17 is the serial number of the sensor and 1min is the value stored as interval. To change the value you might send the following command:
Set Interval(10min)	//This will change the value for this property to 10 minutes
Save	//Always end with save to store setting in flash

The interval will now be changed to 10 minutes. For more details see CHAPTER 5

1.6 Passkey for writing protection

To avoid accidental change, most of the properties are write-protected. There are four levels of access protection, refer **Table 1-7** .

A special property called ***Passkey*** must be set according to the protection level before changing the value of properties that are write-protected, refer **Table 1-7**. After a period of inactivity at the serial input, the access level will revert to default. This period corresponds to the ***Comm TimeOut*** setting, or 1 minutes if the ***Comm TimeOut*** is set to ***Always On.***

Output	Passkey	Description
No		No Passkey needed for changing property
Low	1	The Passkey must be set to 1 prior to changing property
High	1000	The Passkey must be set to 1000 prior to changing property This Passkey value also gives read access to factory properties that usually are hidden
Read Only	Factory	The user have only read access

Table 1-8: Passkey protection

1.7 Sensor Properties

When using AADI Real-Time Collector you don't need to think about the command string sent to the sensor since this is fully controlled by the software.

Some properties of the 'AiCaP' sensor will not be applicable / visible when the sensor is connected to a SeaGuard, SeaGuardII or SmartGuard Datalogger, as these properties will be controlled by the instrument.

All sensor properties are listed in the following chapters .

1.7.1 Factory Configuration

All properties in this section are Read Only, not possible to overwrite for the user. Only certified Aanderaa service personal can alter these settings. The access level for reading the status of these properties are however different for each property, see table for more details. In this group we find information about Software and hardware settings, Production, Service and Calibration dates.

Table 1-9: Factory Configuration; Sensor Properties for Oxygen Sensor 4330, 4831, 5331 and 4835. ENUM=Enumeration, INT =Integer, BOOL=Boolean ('yes'/'no')

Property	Type	No of elements	Use	Category	Access Protection Read/Write
Product name	String	31	Aanderaa Product name	FC	No/ Read Only
Product Number	String	6	Aanderaa Product number		
Serial Number	INT	1	Serial Number		
SW ID	String	11	Software Identifier		
SW Version	INT	3	Software version (Major, Minor, Built)		
HW ID X	String	19	Hardware Identifier, X=1..3		High/ Read Only
HW Version X	String	9	Hardware Identifier, X=1..3		
System Control	INT	3	For internal use		
Production Date	String	31	AADI Production Date, format YYYY-MM-DD		
Last Service	String	31	Last service date, format YYYY-MM-DD, empty by default		
Last Calibration	String	31	Last calibration date, format YYYY-MM-DD		
Calibration Interval	INT	1	Recommended Calibration Interval in Days		

1.7.2 Deployment Settings

Deployment Settings contain settings for instruments metadata like position and owner, but also site dependent properties storing data that might influence the measurement.

Table 1-10: Deployment Settings; Sensor Properties for Oxygen Sensor 4330, 4831, 5331 and 4835. ENUM=Enumeration, INT =Integer, BOOL=Boolean ('yes'/'no')

Property	Type	No of elements	Use	Category	Access Protection Read/Write
Interval	Float	1	Sampling Interval in seconds	DS	No
Owner	String	31	Set the device owner		
Location	String	31	Set the location		
Geographic Position	String	31	Set the geographic position		
Vertical Position	Float	1	User value for describing sensor position		

1.7.3 System Configuration

This group is used to control the sensor via properties for configuring communication with logger, sensor setup, parameter enabling, analog setting and controlling the output from sensor. Some of the properties are only visible depending on the mode selected or if the function is enabled or not. These properties will either be grey or not visible at all.

Table 1-11: System Configuration; Sensor Properties for Oxygen Sensor 4330, 4831, 5331 and 4835. ENUM=Enumeration, INT =Integer, BOOL=Boolean ('yes'/'no')

Property	Type	No of elements	Use	Category	Access Protection Read/Write
Mode	ENUM	1	Operation Mode: 'AiCaP', 'Smart Sensor Terminal', 'AADI Real-Time', 'Analog Output' see chapter 5.7	SC	Low
Enable Sleep	BOOL	1	Enable sleep mode	SC	Low
Enable Polled Mode	BOOL	1	Enable Polled Mode (for RS232), when set to 'no' the sensor will sample at the interval given by the *Interval* property, when set to 'yes' the sensor will wait for the 'Do Sample' command.		
Enable Text	BOOL	1	Enable text, when set to 'no' the start up info and the parameter text is removed		
Enable Decimalformat	BOOL	1	Controls the use of decimal format in the output string		
Analog TempLimit	Float	2	Lower and upper ranger limits for analog temperature output (Output 2), default -5 to 35°C [*2)]		
Analog Output1	ENUM		Controls which parameter is presented at analog Output 1; O2Concentration, AirSaturation, CalPhase, Fixed1, Fixed2 [2)]		
Analog Coef	Float		Coefficients (offset,slope) used for trimming the analog outputs, default set to 0,1[2)]		
Enable AirSaturation	BOOL	1	Controls inclusion of air saturation(%) in the output		
Enable Rawdata	BOOL	1	Controls inclusion of raw data in the output string		
Enable Temperature	BOOL	1	Controls inclusion of Temperature in the output		
Enable HumidityComp	BOOL	1	Enable compensation for vapour pressure,-disable only for use in dry air or external humidity compensation		
Enable SVUformula	BOOL	1	Refer Appendix 7		

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1.7.4 User Maintenance

This group contains sensor settings that normally are not altered by the user. To access most of these properties you need to send passkey(1000) or with Real-Time Collector use password: 1000. These properties are used to configure serial port settings, communication to and from sensor, temperature and foil coefficients and properties used during calibration.

Table 1-12: User Maintenance; ; Sensor Properties for Oxygen Sensor 4330, 4831,5331 and 4835. ENUM=Enumeration, INT =Integer, BOOL=Boolean ('yes'/'no')

Property	Type	No of elements	Use	Category	Access Protection Read/Write
Node Description	String	31	User text for describing node, placement etc.	UM	High
Interface	ENUM	1	Sensor interface. Select either RS232 or RS422 (N/A for Oxygen Optode)		
Baudrate	ENUM	1	RS232 baudrate: 300,1200,2400,4800,9600,57600,115200 1)		
Flow Control	ENUM	1	RS232 flow control: None or Xon/Xoff		
Enable Comm Indicator	BOOL	1	Enable the Communication Sleep ('%') and Communication Ready ('!') indicators		
Comm TimeOut	ENUM	1	RS232 communication activation timeout: Always On,10 s,20 s,30 s,1 min,2 min,5 min,10 min		
Salinity	Float	1	Salinity (PSU) for use in salinity compensation of O_2 concentration	UM	High
TempCoef	Float	6	Curve fitting coefficients for the temp measurements.		
PhaseCoef	Float	4	Linearization coefficients for calculating compensated phase		
PTC0Coef	Float	4	Raw phase temperature compensation coefficients, normally not used (0,0,0,0)		
PTC1Coef	Float	4	Raw phase temperature compensation coefficients, normally not used (1,0,0,0)		
PhaseCoef	Float	4	Linearization coefficients for calculating compensated phase		
FoilID	String	9	Sensing Foil Identifier		
FoilCoefA	Float	14	Foil coefficients, general curve fit function, set A		
FoilCoefB	Float	14	Foil coefficients, general curve fit function, set B		
FoilPolyDegT	INT	28	Exponents for temperature, general curve fit function		

FoilPolyDegO	INT	28	Exponents for oxygen, general curve fit function		
SVUFoilCoef	Float	7	Foil coefficients for the 'Stern Volmer Uchida' formula		
ConcCoef	Float	2	Linear adjustments coefficients for final O_2 concentration calculation, nominal values 0 (offset) and 1 (slope).		
NomAirPress	Float	1	Nominal air pressure for use in O_2 concentration calculations		
NomAirMix	Float	1	Nominal O_2 percentage in air for use in O_2 concentration calculations		
CalDataSat	Float	2	Two point calibration data, raw phase and temperature @ 100% air saturation		
CalDataAPress	Float	1	Two point calibration data, air pressure (hPa)		
CalDataZero	Float	2	Two point calibration data, raw phase and temperature @ 0% air saturation		
Enable RedReference	BOOL	1	Controls the use of the red reference LED		
RedReference Interval	INT	1	Sample interval divisor for use of red reference. Examples: Value 1 for using red reference for each sample. Value 10 for using red reference for each 10th sample.		

1.8 Specifications

For product specifications refer Datasheet D378 for 4330/4330F, D385 for 4835 and D403 for 4831/4831F/5331 on our web site http://www.aaderaa.com or contact aanderaa.info@xylem.com

You will always find the latest versions of our documentation on the web.

On our website you will also find the latest versions of product manuals, technical notes and software. Please contact aanderaa.info@xylem.com for guidance.

1.9 Manufacturing and Quality Control

Aanderaa Data Instruments products have a record for proven reliability. With over 50 years' experience producing instruments for use in demanding environments around the globe, you can count on our reputation of delivering the most reliable products available.

We are an ISO 9001, ISO 14001 and OHSAS 18001 Certified Manufacturer. As a company we are guided by three underlying principles: quality, service, and commitment. We take these principles seriously, as they form the foundation upon which we provide lasting value to our customers.

CHAPTER 2 **Configuration on SeaGuard with display**

The Optode is equipped with a CANbus interface supporting AADI AiCaP (Automated idle line CANbus Protocol). This standard ensures easy plug and play connection to all Aanderaa SeaGuard, SeaGuardII and SmartGuard data logger. Make sure the sensor is set to AiCaP mode before you connect the sensor to the AiCaP bus. Default setting from factory is AiCaP.

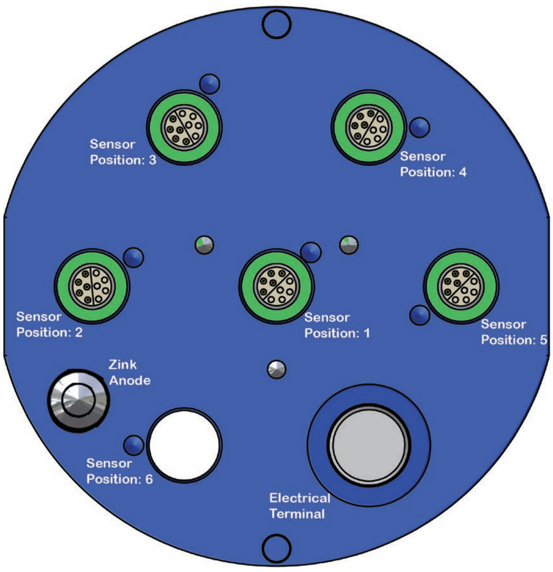
When connected to an AiCaP bus network the Optode will report its capabilities and specifications to the data logger at power up. The data logger assembles the information and provides the user with the possibility to configure the instrument based on the presented nodes. This solution provides for greater flexibility on both use and design of the different elements within the system.

Note! This chapter describes the configuration of the Oxygen Optode 4330 and 4835 when connected to an SeaGuard with display. Refer TD262a for a thorough description of configuring the SeaGuard Instrument, and to perform Node Identification and Recorder settings.

Note! Metal structures submerged in water (of e.g. Stainless Steel, Aluminium, Bronze) are often corrosion protected by sacrificial anodes. As the anode disintegrates oxygen is consumed at all "naked" exposed metal parts with which the anode is in electrical contact. The oxygen consumption can be significant e.g. during its lifetime, normally 1-2 years, a 130 g Zn anode mounted on a SeaGuard/RDCP/RCM pressure case can consume all oxygen in about 700 l of water. In areas where very low circulation conditions exist water parcels with lower oxygen concentrations will form and can surround the oxygen sensors and lead to artificial dips in the oxygen readings. These effects are detectable in environments in which oxygen is stable (e.g. less than 2 % variations over time periods of days-weeks) and when currents are low (e.g. below 10 cm/s). In a vast majority of applications these effects are of low/no significance. Detailed information about this can be found in the appendices.

2.1 Installation on SEAGUARD® Platform

The Oxygen Optode 4330 and 4835 can easily be installed on AADI SeaGuard or SeaGuardII data loggers. Power should be turned off before connecting the sensor. We recommend that you install the Oxygen Optode in sensor position 3, 4 or 6, refer ***Figure 2-1***. If mounted in position 6 use patch cable to connect the optode to the HUB card.



Refer SeaGuard Platform Operating Manual, TD262a, for an illustrated sensor installation guide.

TN309 holds an extract of sensor connection / disconnection given in the SeaGuard Operating Manual.

Note!

Always replace O-rings when removing, exchanging, or installing a new sensor or a sealing plug.

Figure 2-1: SeaGuard Top-end plate

2.2 Sensor Configuration

In this section we will show you how to configure the sensor connected to a SeaGuard with display. If you have a SeaGuard without display or a SeaGuard II please proceed to CHAPTER 4 . We will only cover the sections that are special for the oxygen sensor. Some of the screenshots might be different on your logger due to different setup and accessories connected. Some of the screenshots used are from other sensors but are then identical except from the sensor name.

Figure 2-2: Select Menu to start

After installing the sensor in one of the sensor positions turn power on and open the **System Configuration** from the **Menu** button. There are 3 submenus that contain properties for the Optode sensor.

- System Configuration
- Deployment Settings
- Administrative Tools
- User Maintenance

These menus are covered in this chapter. For information about the other menus see *SeaGuard Platform Operating Manual, TD262a.*

2.2.1 System Configuration

Figure 2-3: System Configuration menu

In ***System Configuration*** you will find two tabs. For more information about the Instrument tab and its submenus see *SeaGuard Platform Operating Manual, TD262a.*

Select the ***Sensors*** tab.

Figure 2-4: System Configuration Sensors selection

The ***System Configuration*** sensor tab holds a list of all Analog and AiCaP sensors connected to the logger. Select the newly installed Oxygen Optode which should appear in the list of sensors and tap Configure in the lower part of the window.

Alternatively, if you want to configure all sensors in the list you may select the Run Wizard button that will run you through all the individual sensor configurations.

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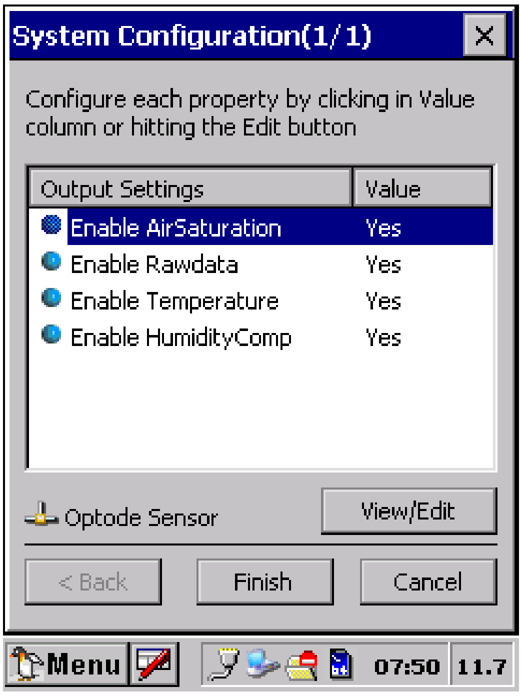


The ***System Configuration*** for the ***Optode Sensor*** holds a list of output parameters that can be enabled/disabled by the user. Enabled properties (*Yes*) are calculated and sent to the data logger:

- *Enable* Air Saturation in % saturation.
- *Enable* Raw data, refer chapter 5.4 .
- *Enable* Temperature in Deg. C.
- *Enable HumidityComp* property activates compensation of vapor pressure in the calculations of the output parameters. Enable HumidityComp can be set to *No* if measurements are performed in dry air conditions or if you like to perform the humidity compensation as a post-processing operation. Disabling this will typically lead to 1-3 % lower readings depending on the relative humidity of the air.

Figure 2-5: System Configuration parameter enabling

The ***Oxygen Concentration*** in ***µM***, is a default parameter and cannot be disabled.

To enable/disable a parameter:

Select the output parameter from the list, press ***View/Edit*** in the lower part of the window, and change the setting by clicking the box (box is now checked), press ***Save*** to save and close the window.

We recommend that you enable all parameters in case of later use. The memory card storage capacity is normally not a limitation for the SeaGuard. Raw data can be used e.g. to control calibration coefficients and perform quality control on the data.

2.2.2 Deployment Settings

Figure 2-6: Deployment Settings menu

In ***Deployment Settings*** you will find two tabs. For more information about the Instrument tab and its submenues see *SeaGuard Platform Operating Manual, TD262a.*

Select the ***Sensors*** tab.

Figure 2-7: Deployment Settings Sensor selection

*The **Sensors** tab holds a list of all Analog and AiCaP sensors connected to the logger. Select the newly installed **Oxygen Optode** which should appear in the list of sensors, and tap **Configure** in the lower part of the window.*

*Alternativly if you want to configure all sensors in the list you may select the **Run Wizard** button that will run you trough all the individual sensor configurations*

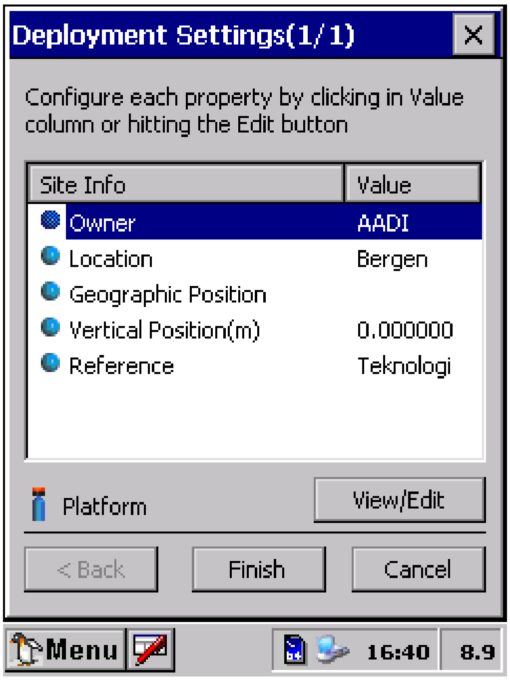


Figure 2-8: Deployment Settings properties

The ***Deployment Settings*** for the Oxygen Optode Sensor hold a list of user defined inputs: ***Owner***, ***Location, Geographic Position, Vertical Position*** and ***Reference***. These properties are not used by the sensor and therefor optional. Open ***Deployment Settings*** from the ***Menu*** button Select ***Optode Sensor*** from the sensor list.

To add information to one of these properties, select the property, press ***View/Edit*** and with the keyboard panel enter the text or numbers. Press ***OK*** and ***Finish*** storing the information.

2.2.3 User Maintenance

Special property settings and calibration coefficients are found in ***User Maintenance.***

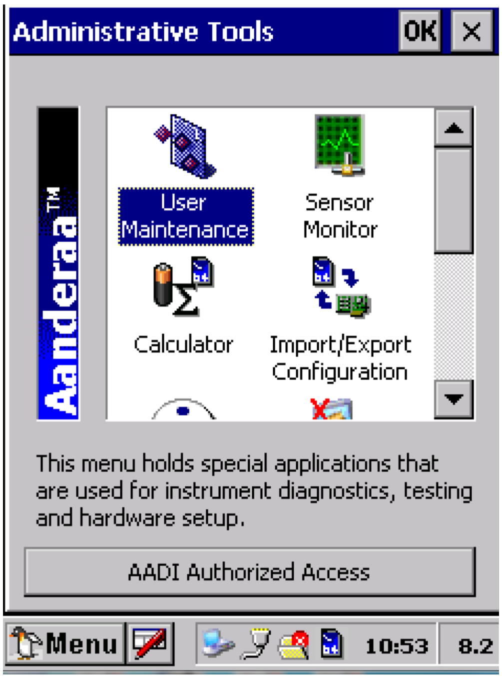


Figure 2-9: Administrative Tools

Open ***Administrative Tools*** from the ***Menu*** button Select ***User Maintenance*** and then ***Optode Sensor*** from the sensor list.

Figure 2-10: User Maintenance menu

In *User Maintenance* you find properties that are password protected, and are set/altered by the 'advanced user', ***note! the password is: 1000*** The properties in user maintenance are therefore not changed during normal operation. The user maintenance holds four submenus:

- ***Mandatory***
- ***Calculation Settings***
- ***Calibration***
- ***Sample Settings***

Select the ***Optode Sensor*** from the sensor list.

Select ***Configure*** *in the lower part of the window.*

Alternativly if you want to configure all sensors in the list you may select the ***Run Wizard*** *button that will run you trough all the individual sensor configurations.*

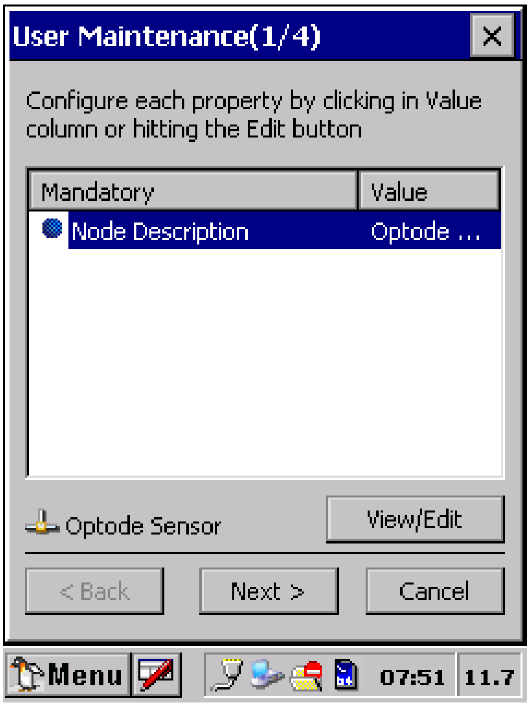


Figure 2-11 Mandatory

First submenu is the Mandatory. Select the ***Node Description*** property, press ***View/Edit*** in the lower part of the window, and change the setting. Press ***Save*** to store the setting when completed.

Node Description is a user entered text describing the sensor, placement etc. If using for example a SeaGuard sensor string with multiple sensors connected; renaming the sensor can facilitate analyzing data. The text is by default set to the product name followed by product- and serial number, e.g. ***Optode Sensor 4330#52.***

Press ***Next>*** to continue with the next submenu.

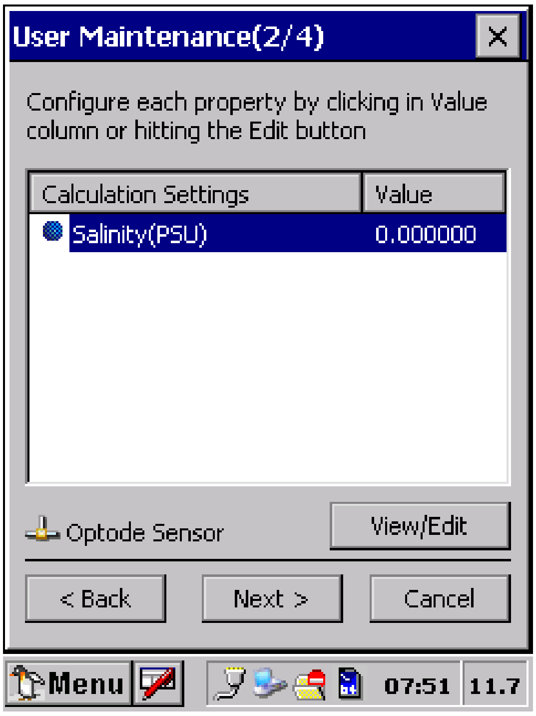


Figure 2-12 Calculation Settings

The second submenu in the ***Oxygen Optode User Maintenance*** is ***Calculation Settings*** and holds a setting for ***Salinity***:

Select the ***Salinity*** property, tap ***View/Edit*** and type the salinity value. Press ***Save*** to store the setting.

Note! If you are post compensating for the salinity, you should set the property value to 0. When sensors are delivered from the factory they are set to 0 salinity as factory default.

Salinity is only used when calculating the ***Oxygen Consentration*** and not when calculating ***Air Saturation***.

Press ***Next>*** to continue with the next submenu.

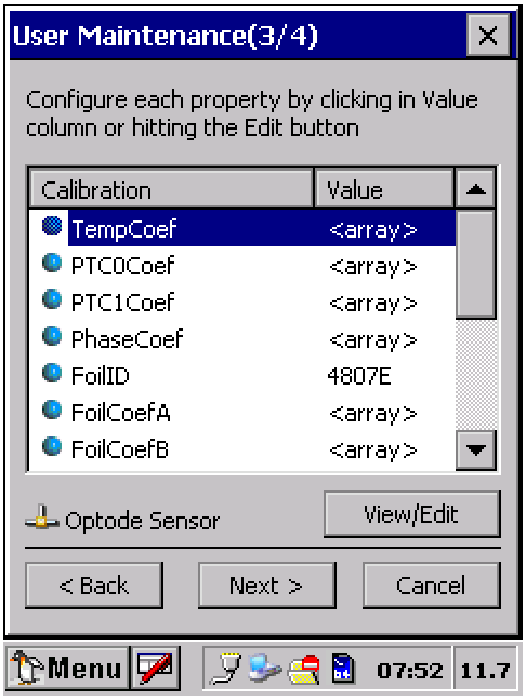


Figure 2-13 Calibration Coefficients

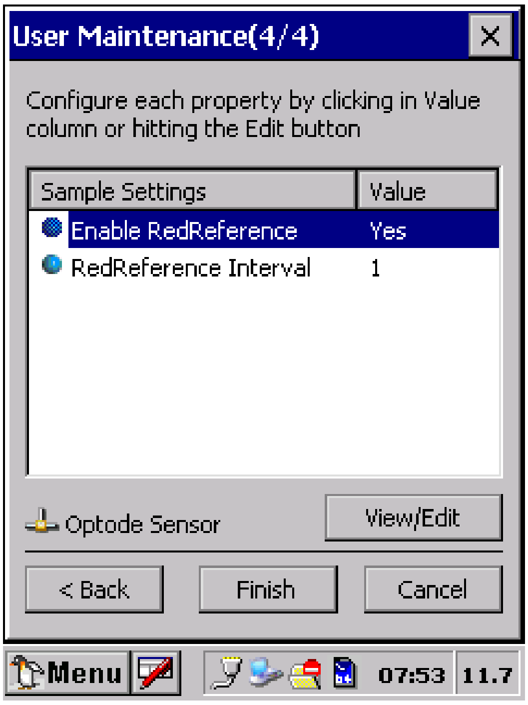
The third submenu are ***Calibration.*** For each calibration property to be set, you must first select the property then press ***View/Edit*** and type the correct value. Press ***Save*** to store the settings.

The foil coefficients must be updated when changing the sensing foil to a foil with different ***Foil ID***. Allways remember to also update the ***Foil ID*** when changing foil

Press ***Next >*** to continue with the next submenu.

Note! Foil coefficients can be entered and new calibrations can also be performed if connecting the sensor directly to a computer using a Terminal program, see below for detailed instructions.

The last submenu in the Oxygen Optode User Maintenance are Sample Settings and holds settings for:



- ***Enable RedReference***; should normally be enabled (***Yes***). The phase measurements are then performed with a zero-point set at the red reference (no fluorescence). The property can be set to ***(No)*** in special measurement situations; contact AADI service department.

- ***RedReference Interval***; this is a sample interval divisor for use of red reference. When the value is set to ***1*** (default) the red reference measurement is performed during each sample. The value can be increased to reduce power drain or to set a fast sampling interval, less than 2 sec. When the value is set to e.g. ***10***, the red reference measurement is only performed for each 10th sample. Avoid setting the RedReference Interval too long compared to temperature changes in the sensor, as the RedReference is used to compensate for temperature drift in the electronics.

Procedure to change the property:

Select the output parameter from the list, press ***View/Edit*** in the lower part of the window, and change the setting. Press ***Save*** to store the setting when completed.

Press ***Finish*** to complete and exit and store the changes made in the Oxygen Optode User Maintenance. Selecting Cancel exits without storing your changes.

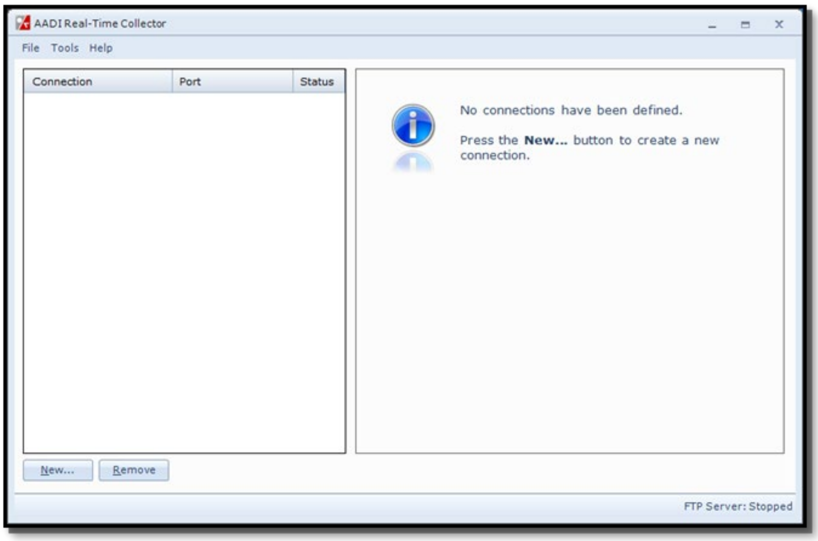
CHAPTER 3 Stand-alone Sensor configuration using Real-Time Collector

All sensors that are updated with Sensor Framework version 3 can be configured as stand-alone sensors using AADI Real-Time Collector.

This chapter describes the sensor configuration using AADI Real-Time Collector when the sensor is used as stand-alone sensor with serial communication RS-232 via the PC COM-port. The menus shown here are slightly different from the menus shown when the sensor is working in AiCaP mode and configured through an Aanderaa Datalogger via serial or USB connection to the PC (described in CHAPTER 4). It's also possible to use terminal software to configure a stand-alone sensor, refer CHAPTER 5 , but then you need to enter all the commands and send them to the sensor. With Real-Time Collector it's much easier since the software will then let you configure the sensor using the available choices in each category. Before connecting the sensor you need to install and start the AADI Real-Time Collector software on your PC. If using windows 10 please see **chapter 11.1**

For more information about the AADI Real-Time Collector, refer TD 268 AADI Real-Time Collector Operating Manual.

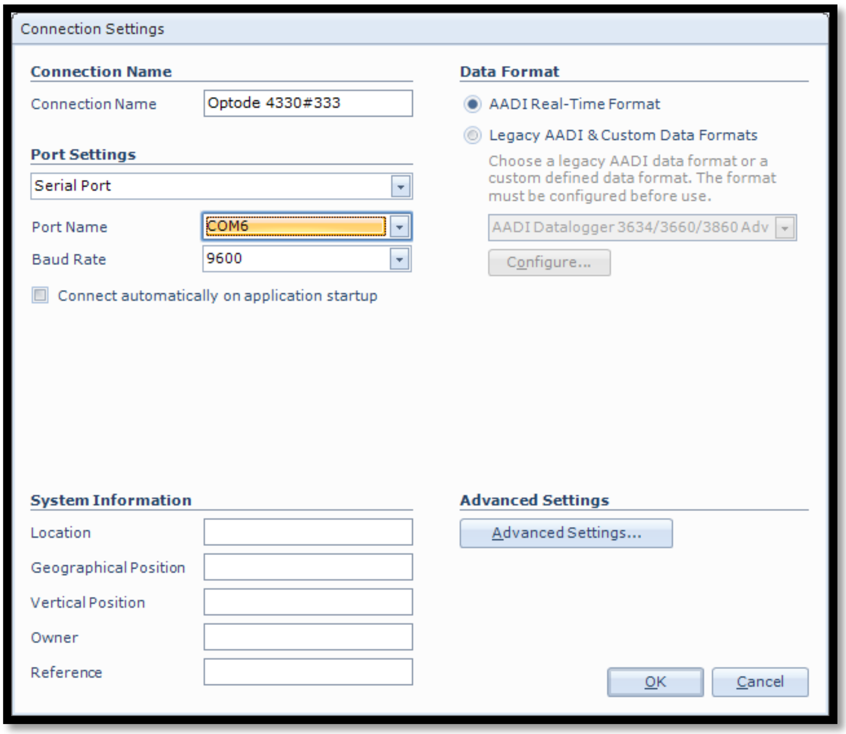
3.1 Establishing a new connection



If the AADI Real-Time Collector program is being used for the first time, the connection list will be empty. Click on the *New* button in the lower left corner to create a new connection (refer *Figure 2-1*).

NOTE: This only needs to be done once. AADI Real-Time Collector will keep the information for later use and next time you might select it from the connection list.

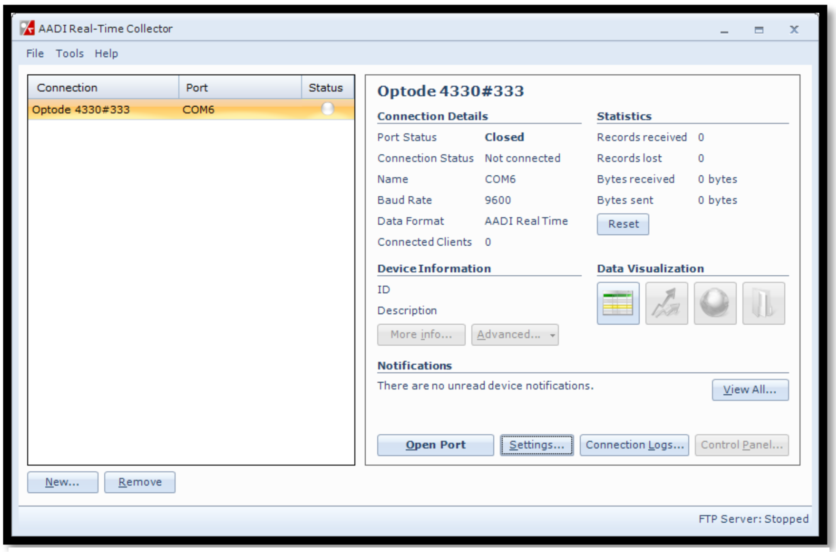
Figure 3-1 AADI Real-Time Collector start up menu



First enter a new ***Connection Name***, we recommend using name and serial number. Select **Serial Port** in the dropdown menu under ***Port Setting***, and choose the correct COM-port on your computer under ***Port Name***. Select ***9600*** as ***Baud Rate***. This is the default baud rate on all Optode sensors. The ***Baud Rate*** needs to match the baud rate set in ***User Maintenance***.

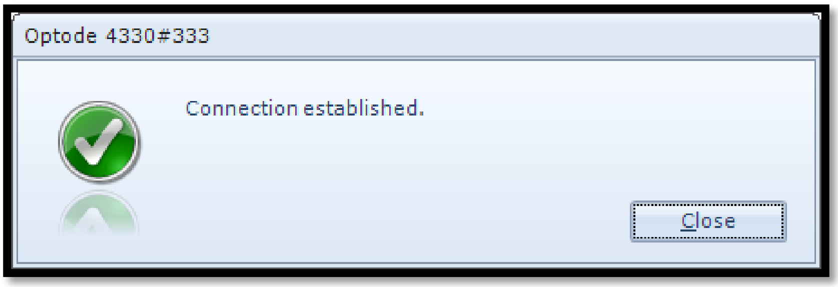
Figure 3-2: AADI Real Time Collector connection settings

3.1.1 Establish connection



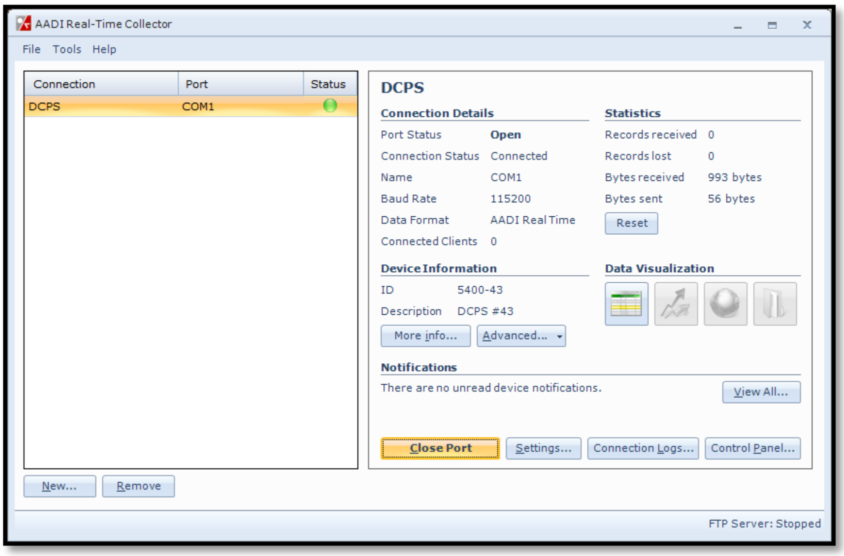
The new connection is now shown in the AADI Real-Time Collector connection list. Click on the line with the new connection to highlight the line and then click on the ***Open Port*** button.

Figure 3-3: New connection



When the connection is established a small window will show up confirming the connection

Figure 3-4: Connection established



The status changes to green when the port is open.

Then click on the ***Control Panel*** button on the lower right corner to continue.

Figure 3-5: Green Status

3.2 Control Panel

In the ***Control Panel*** window you will find two tabs, ***Recorder Panel*** and ***Device Configuration.*** Under ***Recorder Panel*** you can start and stop recordings. If the recorder is running first click on the ***Stop Recorder*** as you are not allowed to configure the sensor when recording. The recorder panel is dependent on the Sensor Mode. In ***AADI Real-Time*** mode you may start and stop the recorder. For ***AiCaP*** and ***Smart Sensor Terminal*** you can only refresh the status but not start the recording.

3.2.1 Recorder Panel

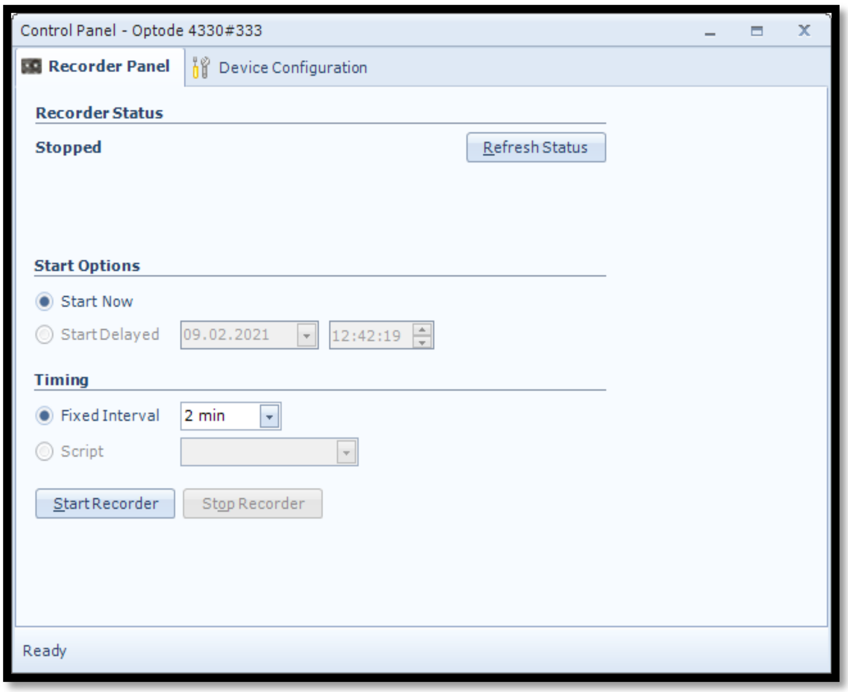


Figure 3-6: Recorder Panel

Under ***Start Option*** you can start sensor immediately by ***Start Now***. The ***Start Delayed*** option is not yet implemented.

In the ***Timing*** session you may select the recording interval using ***Fixed Interval***. The available interval will be dependent on the sensor configuration. If you change the configuration it might cause a change in the ***Fixed Interval*** so we recommend always checking the interval after configuration is finished.

The ***Script*** is not yet implemented.

The sensor will output one recording every interval.

3.2.2 Device Configuration

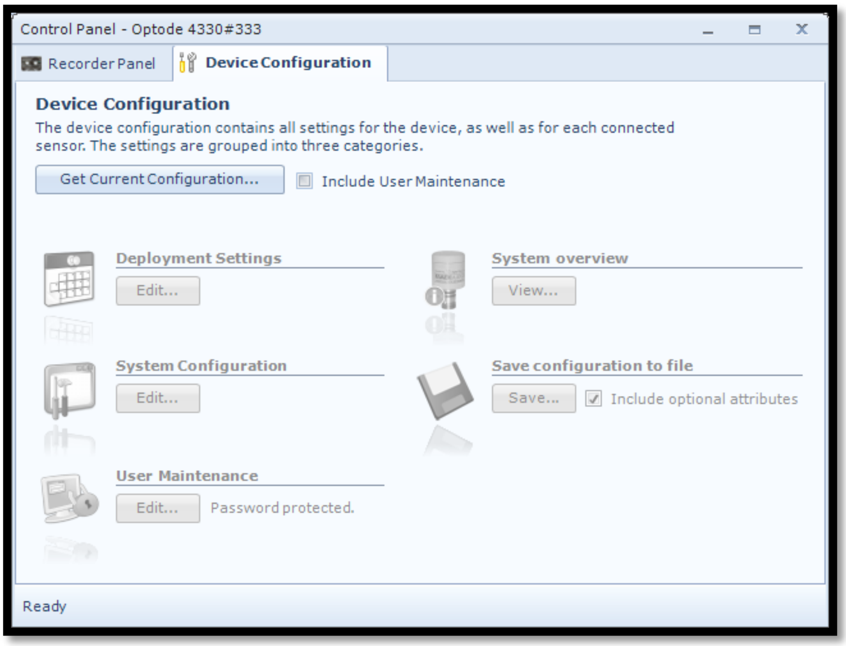


Figure 3-7 Device Configuration

Click on the ***Device Configuration*** tab to continue and access the sensor property menus.

Under the ***Device Configuration*** tab click on the ***Get Current Configuration...*** button in order to receive the current configuration from the sensor.

To include the ***User Maintenance*** settings tick off the ***Include User Maintenance*** box before clicking the ***Get Current Configuration…*** button.

The settings in ***User Maintenance*** are protected with a higher access level. To access this menu you will need to enter a ***password***. This ***password is 1000*** for all sensors.

The device configuration is separated into ***Deployment settings***, ***System Configuration***, ***User Maintenance***, ***System overview*** and ***Save configuration to file***.

You can save current settings to a backup file by pressing ***Save…*** under the heading ***Save configuration to file***. Edit the name for your file and press ***Save…*** to save the new configuration to file in .xml format.

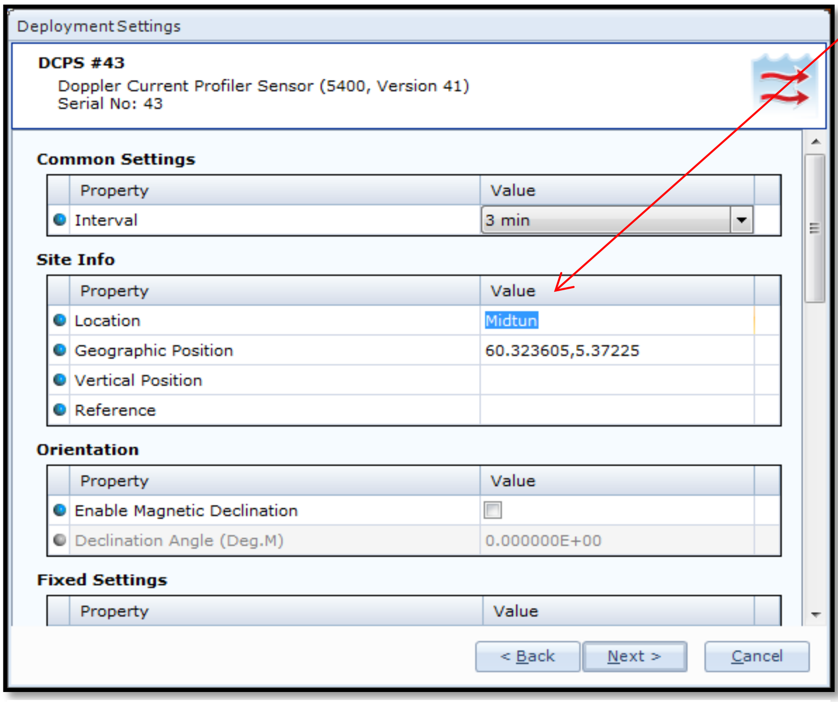
System overview shows a short list of sensor properties like product name, serial number and Software version.

User accessible sensor properties are found in ***Deployment settings, System Configuration and User Maintenance***. Refer **Table 1-5** *to* **Table 1-8** for an overview of the properties.

Note! The screen shots might show minor discrepancies compared to screen shots taken from your sensor due to sensor updates.

Note! We recommend that you verify the system settings prior to starting a recording session.

3.3 Changing Values



To change the content of a property first tick in the value box of the actual property and then enter the text or number before pressing *Next. See example in* **Figure 2-9** *where the text for* **Location** *has been changed.*

The value is not changed before you have finished the full process. If you press **Cancel** or turn of the power then *the changes will not be stored.*

Figure 3-8: Change value

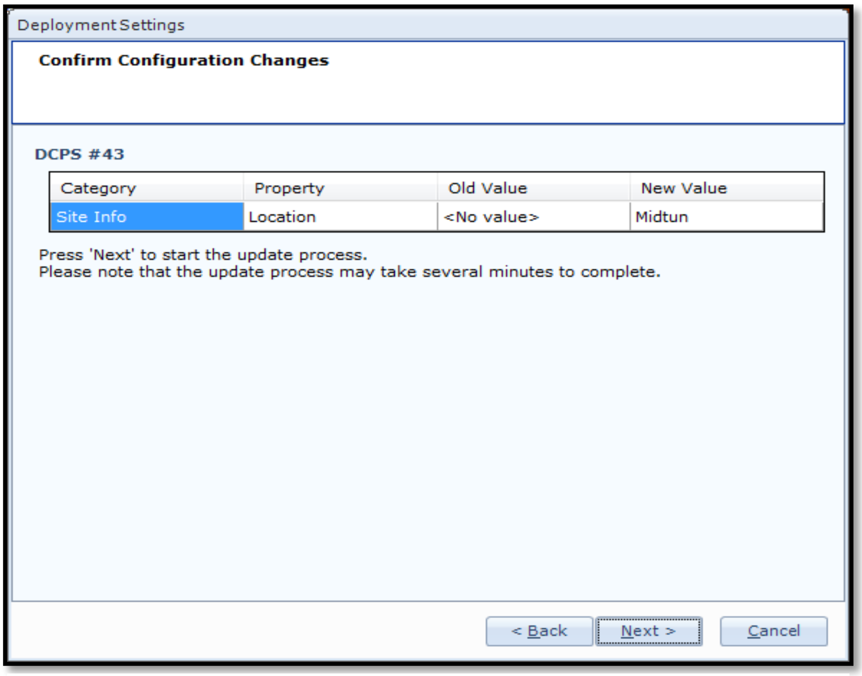


Figure 3-9: Confirm Configuration Changes

In the next picture a list of all properties that has been changed will show up.

If the list of configuration changes is correct press ***Next*** to start the update process.

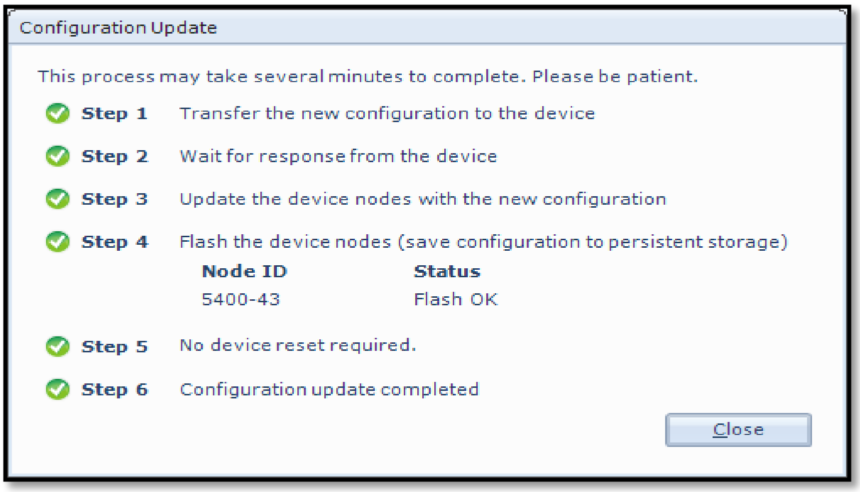


Figure 3-10 Configuration Update

An automatic process will start with 6 steps transferring and storing the new information/setting in the sensor Flash. If necessary a reset will be executed. Do not switch off before the entire process is completed.

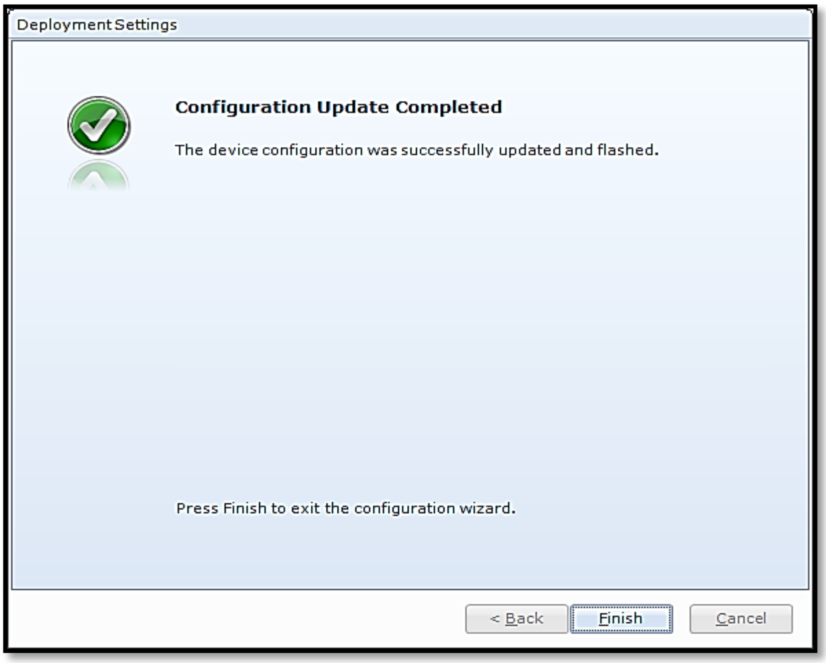


Figure 3-11 Configuration Update Completed

When the updating process is finished a confirmation will show up. Press ***Finish*** to continue.

3.4 Deployment Settings

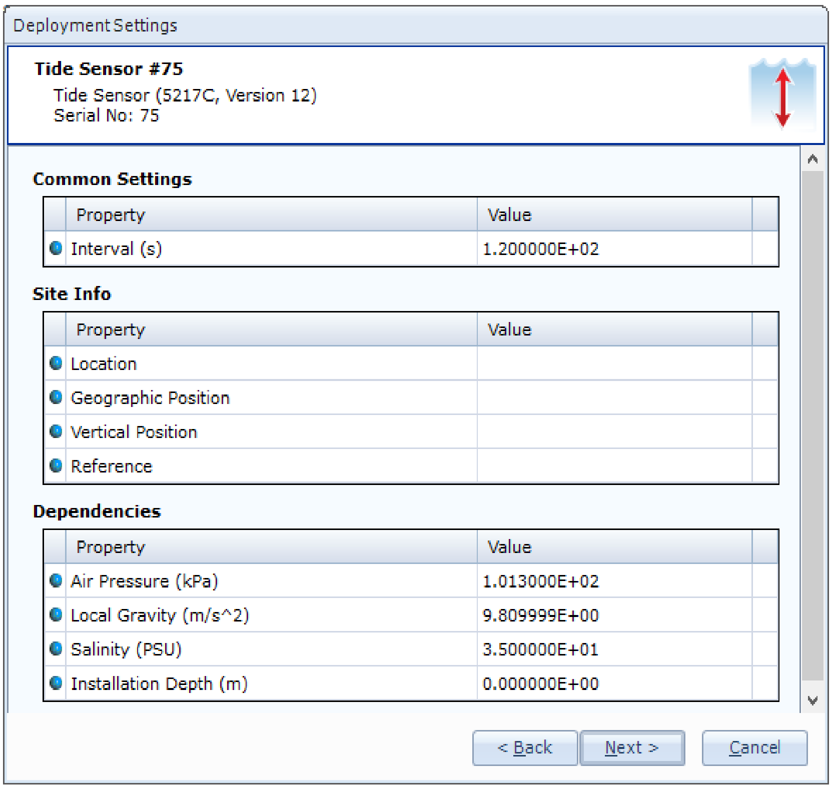


Figure 3-12: Deployment Settings

The ***Deployment Settings*** is separated in 5 groups. The settings in this groups are mainly used as information or values used in internal calculations.
Refer chapter **1.7.2** for more information on the properties in **Deployment Settings**.

When used as a stand-alone sensor without AiCaP Datalogger the fixed settings are used for calculations.
If the surface cell is enabled or the surface reference is enabled, this means that it uses the depth calculated from these fixed settings given in the **Deployment Settings**.

NOTE! We don't recommend using surface cell or surface referenced cell if no pressure sensor is used and connected via AiCaP.

In AiCaP mode more settings are available. See chapter **3.5**

3.5 System Configuration

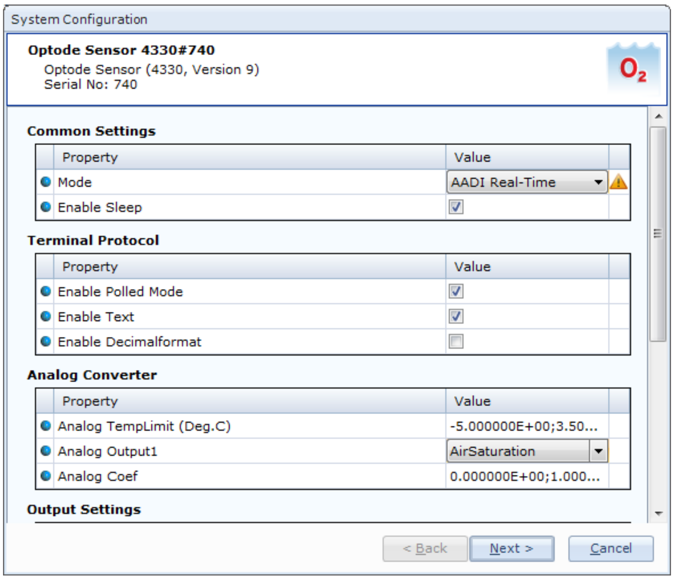


Figure 3-13 Sensor system configuration

3.6 User Maintenance

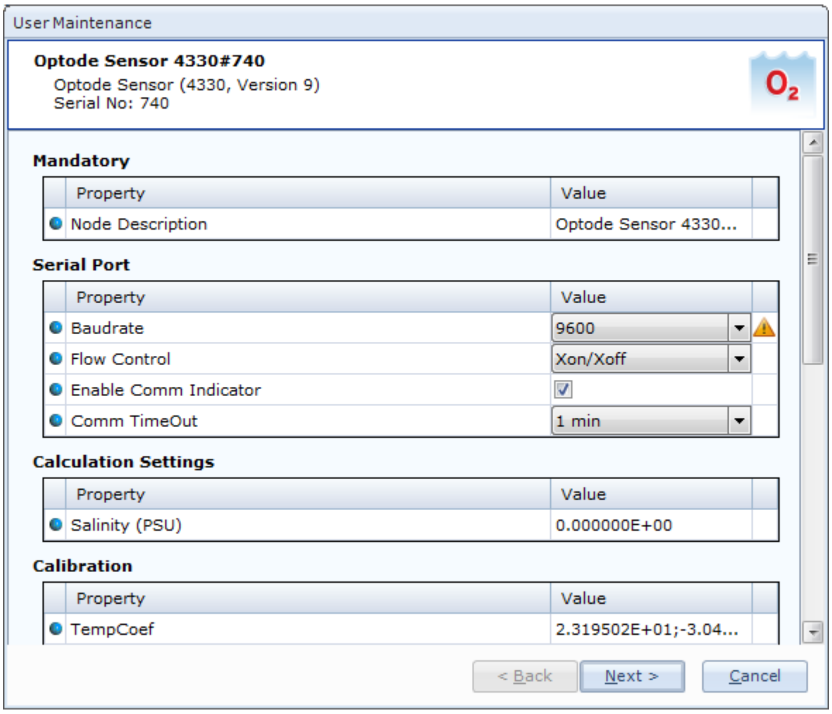


Figure 3-14 Sensor user maintenance

CHAPTER 4 Configuration via SmartGuard or SeaGuardII Datalogger

4.1 Introduction

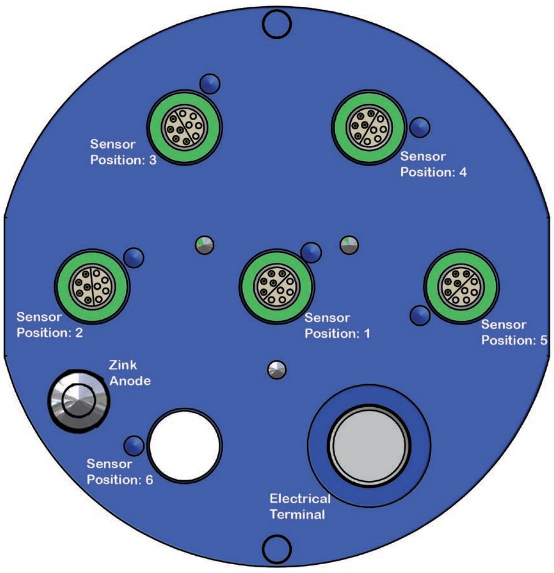
The Oxygen Optode 4835 and 4330 can easily be installed on the Aanderaa SeaGuardII platform or connected using a cable. For more information about the SeaGuardII, refer to the TD 303, Operating manual SeaGuardII.

It can also be used with the SmartGuard Datalogger using a cable for surface buoy applications or placed on land.

To be able to control the Optode via SeaGuardII or SmartGuard the sensor need to be in AiCaP mode.

4.2 Installation of the Oxygen Optode 4835 and 4330 on SeaGuardII

Power should be turned off before connecting the sensor. We recommend that you install the Oxygen Optode in sensor position 3, 4 or 6, refer ***Figure 2-1***. If mounted in position 6 use patch cable to connect the optode to the HUB card.



Important!

Refer SeaGuard Platform Operating Manual, TD262a, for an illustrated sensor installation guide.

TN309 holds an extract of sensor connection / disconnection given in the SeaGuard Operating Manual.

Note!

Always replace O-rings when removing, exchanging, or installing a new sensor or a sealing plug.

Figure 4-1: SeaGurdII Top End plate

4.3 Configuration with Real-Time collector

4.3.1 Connected via SeaGuardII

- Connect the micro USB configuration cable to the USB connector in front of the instrument and to the PC
- Install and start the AADI Real-Time Collector software on your PC. For more information about the AADI Real-Time Collector, refer TD 268 AADI Real-Time Collector Operating Manual
- Switch on the instrument by pressing the power button in the front of the instrument.
- Wait approximately 30 seconds before the instruments starts up and connection is established.

4.3.2 Connected via SmartGuard

- Connect the USB configuration cable to the USB connector on the left hand side of the SmartGuard and to the PC
- Install and start the AADI Real-Time Collector software on your PC. For more information about the AADI Real-Time Collector, refer TD 268 AADI Real-Time Collector Operating Manual
- Switch on the logger by turning the power to the “ON”- position.
- Wait approximately 30 seconds before the logger starts up and connection is established.

4.3.3 Establish connection

NOTE!

When using a USB connection, you also need to install Windows Mobile Device Center (Windows Vista, and Microsoft Windows 7) if not already installed on your computer. It can be downloaded from Microsoft website.

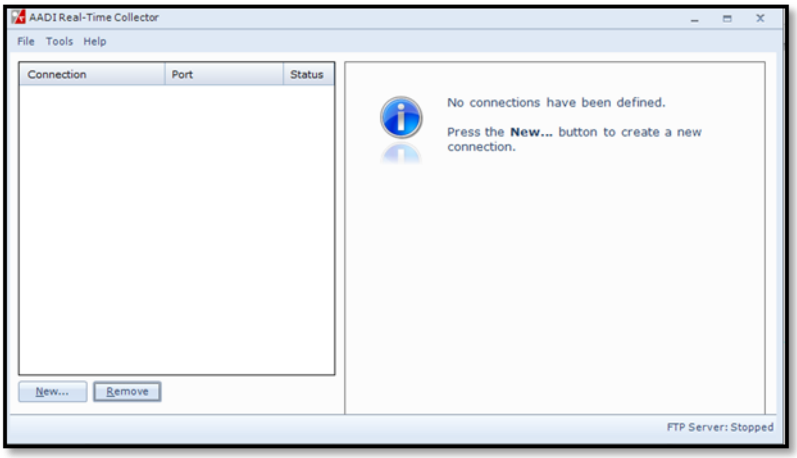
Windows Mobile Device Center acts as device management and data synchronization between a Windows Mobile-based device and a computer.

Once the USB connection has been established, Windows Mobile Device Center will start automatically:

If using windows 10 please see **chapter 11.1**

You may close this window after connection is established.

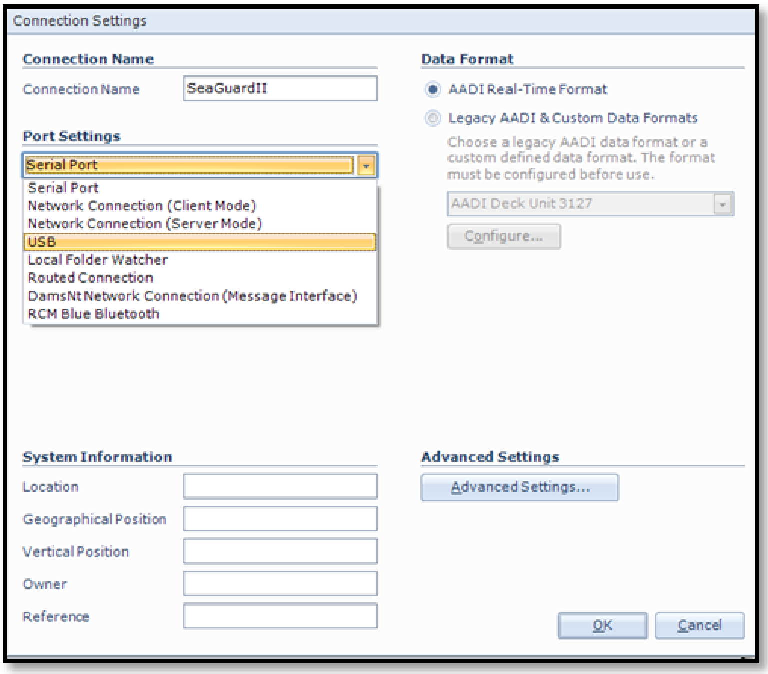
Figure 4-2: Windows Mobile Device Center



At first connection with AADI Real-Time Collector the connection list will be emty. Click on the ***New*** button in the lower left corner to create a new connection

NOTE: This only need to be done once. AADI Real-Time Collector will keep the information for later use and next time you might select it from the connection list.

Figure 4-3: AADI Real-Time Collector start up menu



Select ***USB*** from the ***Port Settings*** drop down menu (**Figure 3-4**); and write a name in the ***Connection Name*** box (for i.e. SeaGuardII). We recommend using product name and serial number if you want to connect multiple instruments to the same software.

Figure 4-4: AADI Real time Collector connection settings

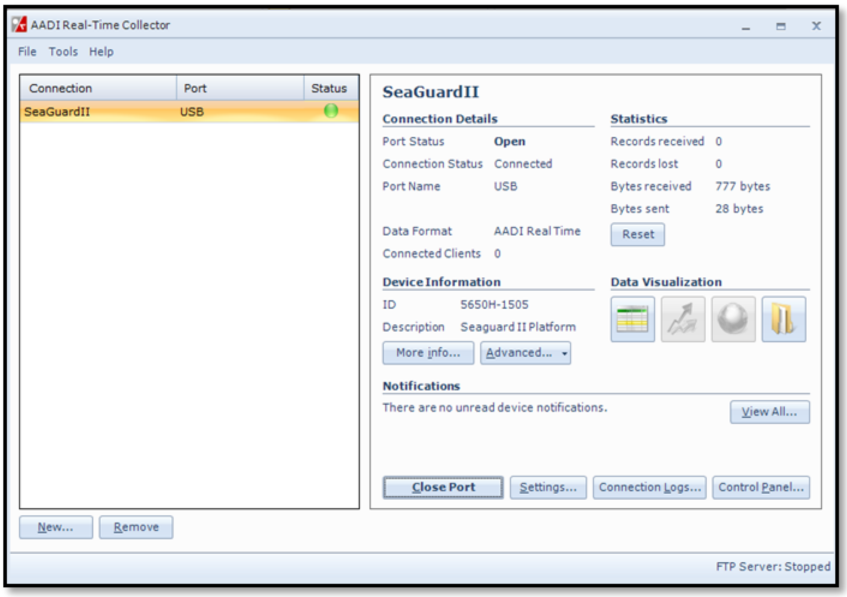


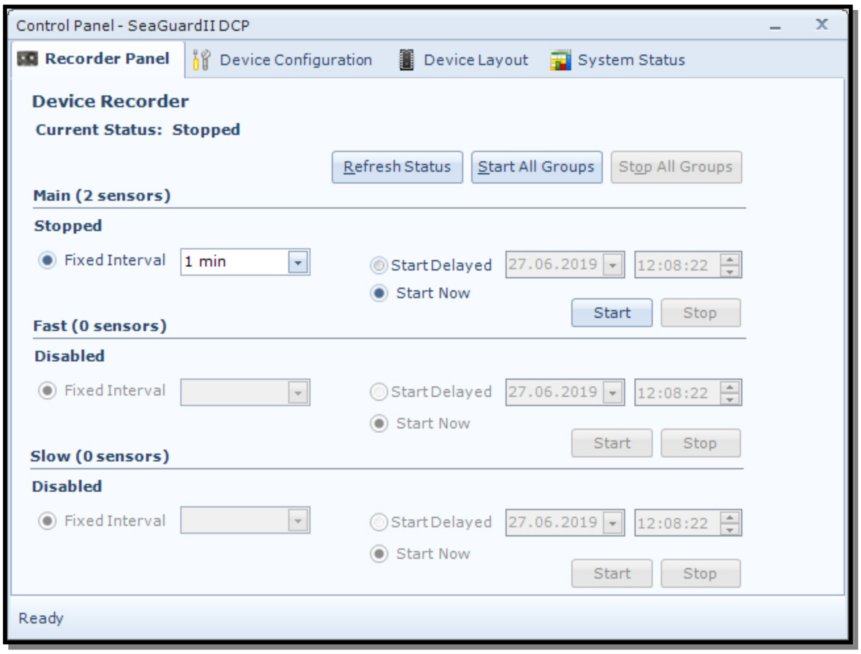
Figure 4-5: AADI Real-Time Collector main menu

The new connection is now shown in the AADI Real-Time Collector connection list. Click on the line with the new connection to highlight the line and then click on the ***Open Port*** button. The connection to the SeaGuardII/SmartGuard should be established within a few seconds and the status turn to green. After power up it will take approximately 30 seconds before the logger is ready.

Open ***Control Panel*** in the lower right corner (refer **Figure 3-7**).

4.3.4 Control Panel

In the ***Control Panel*** window you will find four tabs, ***Recorder Panel***, ***Device Configuration Device Layout*** and ***System Status.*** Under ***Recorder Panel*** you can start and stop recordings. If the recorder is running first click on the ***Stop Recorder*** as you are not allowed to configure the sensor when recording. For information about ***Device Layout*** and ***System Status*** see Manual for SeaGuardII Platform TD303 or SmartGuard TD293.



If the instrument is recording, under ***Recorder Panel,*** press ***"Stop All Groups"***.

The ***Control Panel*** is controlling the SeaGuardII/SmartGuard recorder and not individual sensors. However the Recorder Panel consist of three recording groups where you might put individual sensors in each group to run them on different recording interval. See Operation Manual SeaGuardII / SmartGuard for more info.

Under each group you can start the group immediately by ***Start Now***, or start at a later time using the ***Start Delayed*** option.

Figure 4-6: Recorder Panel

The ***Fixed Interval*** is the recording interval for each group. The configuration of sensors in each group will influence on the available recording interval. If you change the configuration of one sensor and this cause a longer processing time the ***Fixed Interval*** might be changed.

Each Sensor will do a calculation based on the configuration for each recording interval.

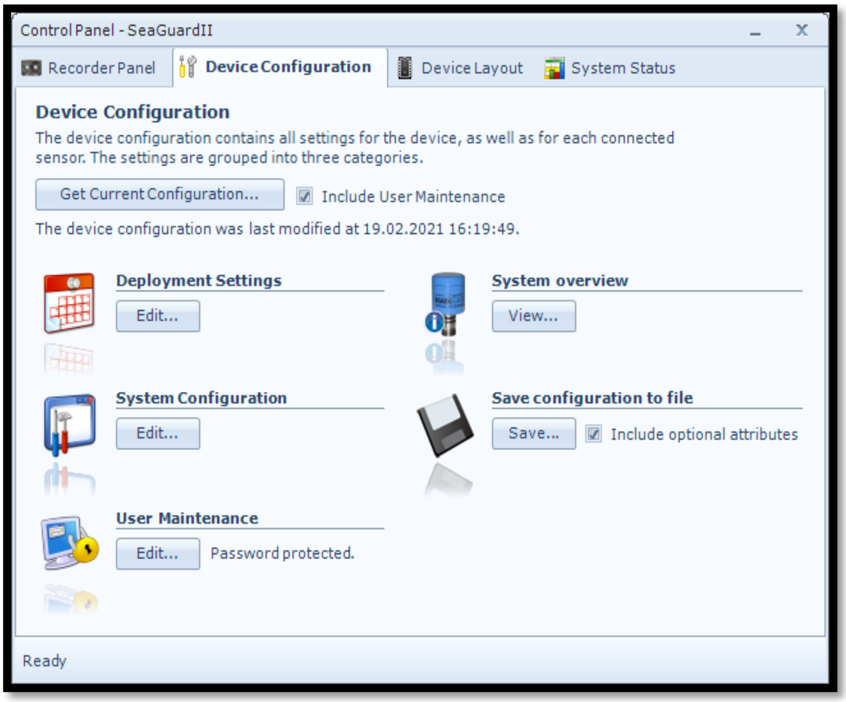


Figure 4-7: Device configuration

The device configuration is separated into ***Deployment settings***, ***System Configuration***, ***User Maintenance***, ***System overview*** and ***Save configuration to file***. Settings related to the Optode can be configured under **Deployment Settings**, **System Configuration** and ***User Maintenance. System overview*** shows a short list of sensor properties like product name, serial number and Software version. Under the heading

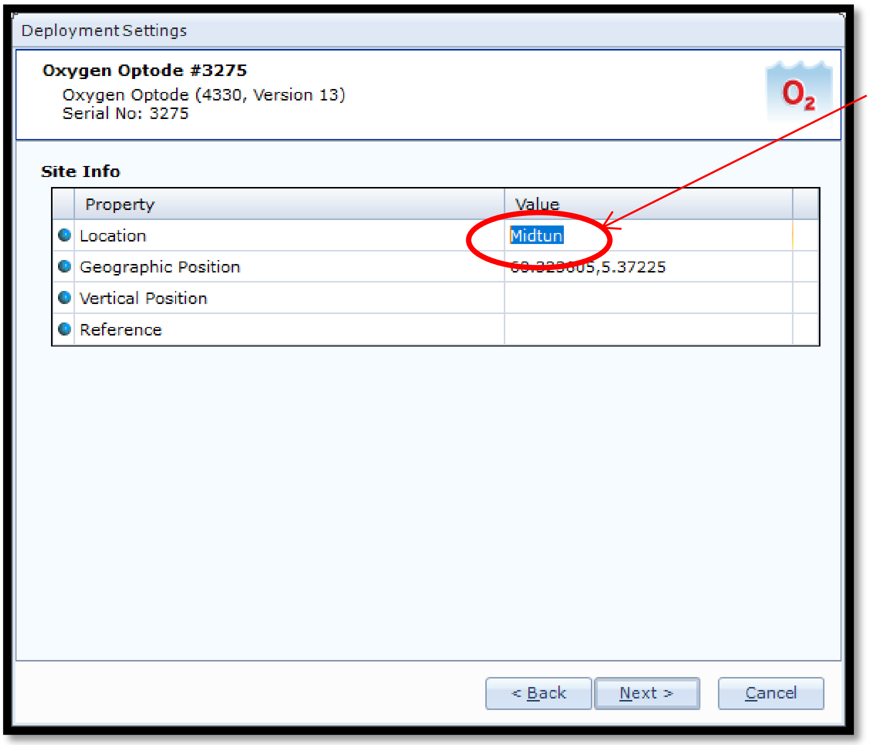
Save configuration to file you can save current settings to a backup file by pressing ***Save…***.Edit the name for your file and press ***Save…*** to save the new configuration to file in .xml format.

User accessible sensor properties are found in ***Deployment settings, System Configuration*** and ***User Maintenance***. Refer ***Table 1-6*** to ***Table 1-8*** for an overview of the properties.

Note! The screen shots might show minor discrepancies compared to screen shots taken from your sensor due to sensor updates.

Note! We recommend that you verify the system settings prior to starting a recording session.

4.4 Changing Values

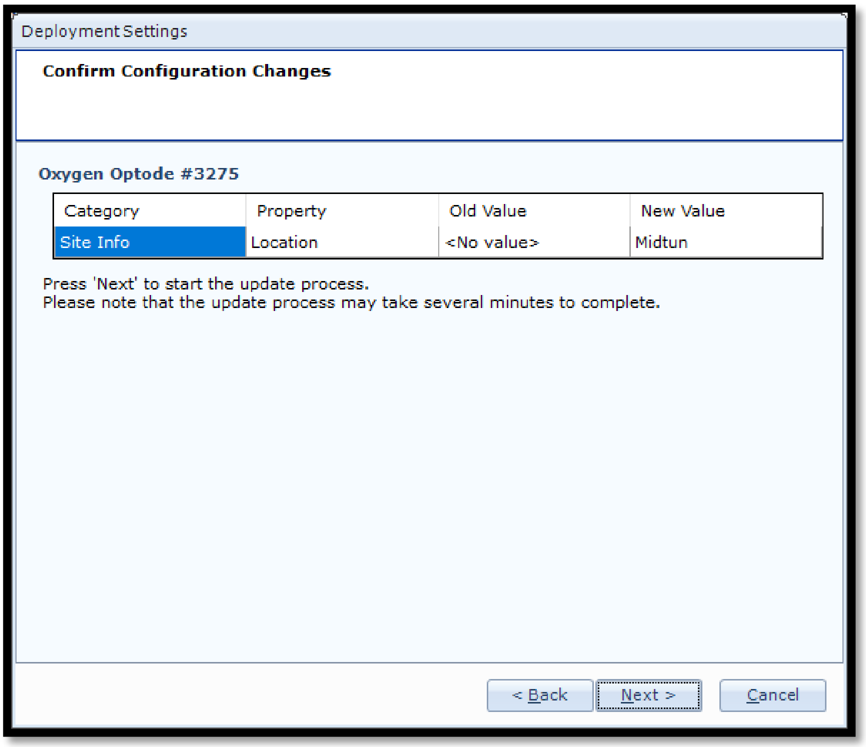


To change the content of a property first tick in the value box of the actual property and then enter the text or number before pressing ***Next.***

See example in ***Figure 4-8*** where the text for ***Location*** has been changed.

Please note that the new value is not stored before you have completed the sequence and received the ***Configuration update completed*** from sensor.

Figure 4-8 Change value

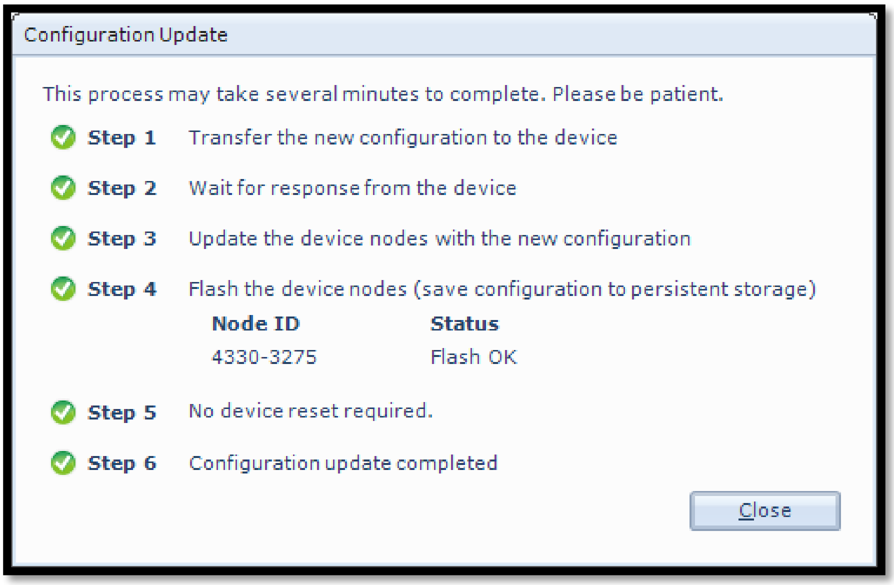


In the next screen a list of all properties that has been changed will show up.

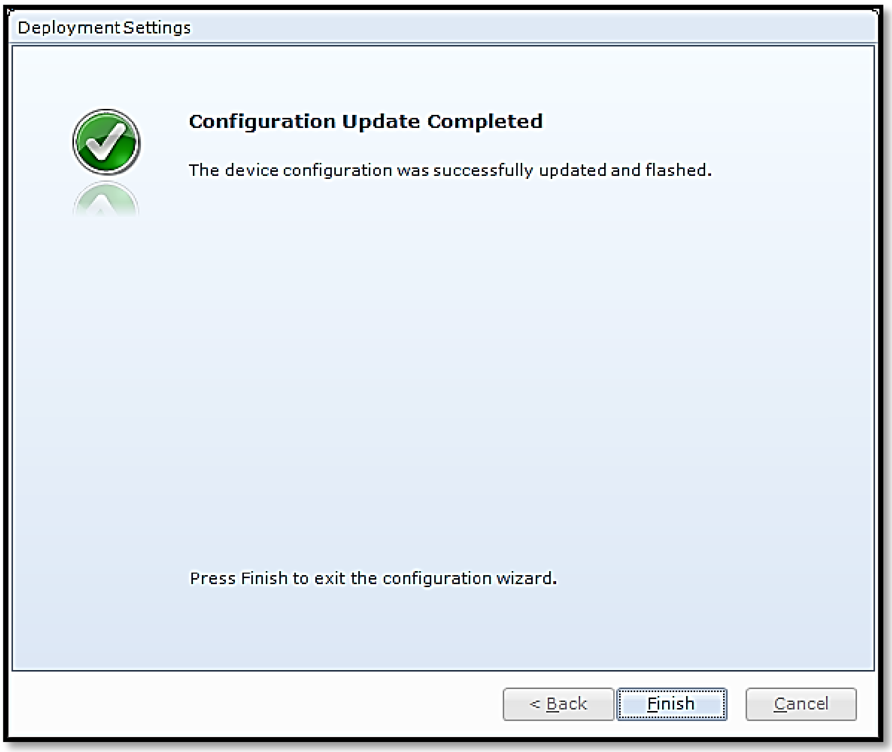
If the list of configuration changes is correct press ***Next*** to start the update process.

Press Back to return to the previous screen or Cancel to leave the menu.

Figure 4-9 Confirm Configuration Changes



An automatic process will start with 6 steps transferring and storing the new information/setting in the sensor Flash. If necessary a reset will be executed. Do not switch off before the entire process is completed.



When the updating process is finished a confirmation will show up. Press ***Finish*** to continue.

Figure 4-11 Configuration Update Completed

4.5 Deployment settings

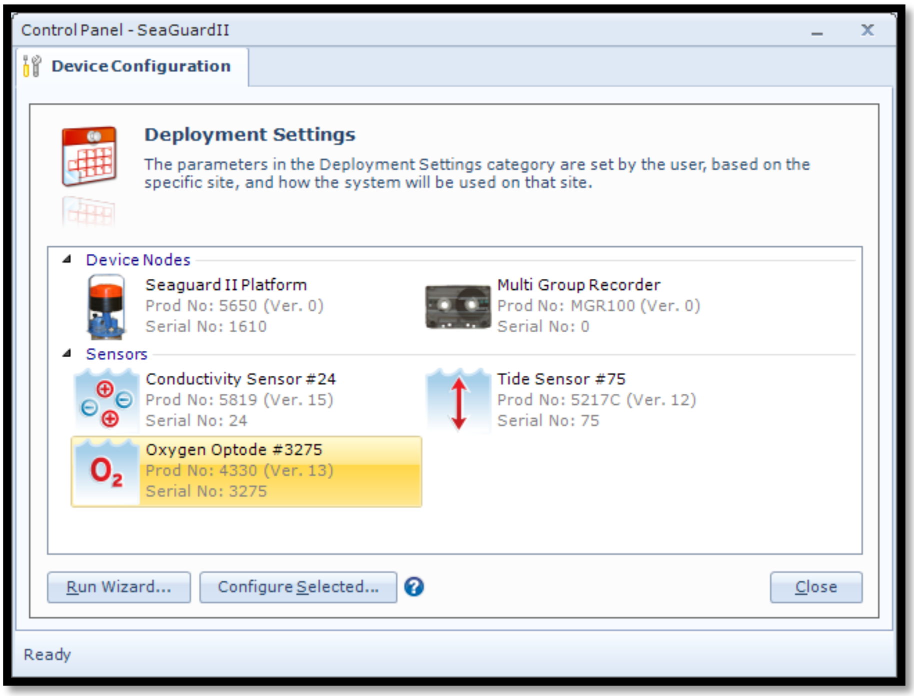


Figure 4-12: Deployment settings

Select ***Deployment Settings***. Under ***Sensors*** all connected sensors will show up. All AiCaP sensors connected to the bus will automaticly show up in the list after power-up.

Double-click on the **Optode Sensor** to select the sensor.

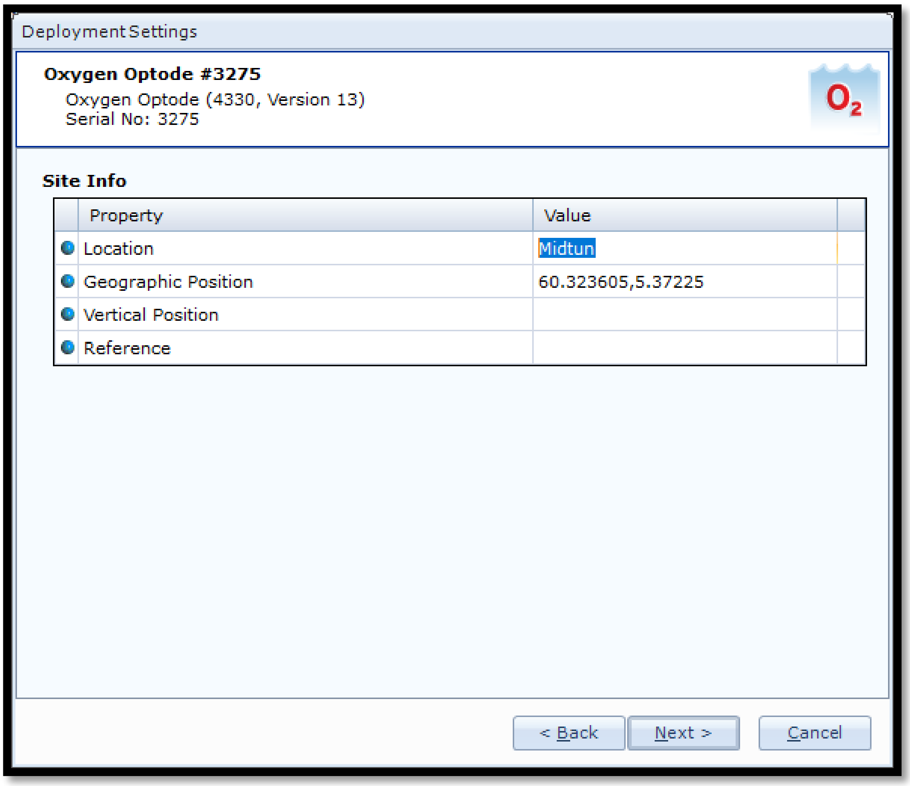


Figure 4-13: Deployment Settings

The ***Deployment Settings*** contains only one group. The settings in this group are mainly used as information and not used in any calculations.

Refer chapter **1.7.2** for more information on the properties in ***Deployment Settings***

.

4.5.1 Site Info

Site Info

Property	Value
Location	Midtun
Geographic Position	60.323605,5.37225
Vertical Position	
Reference	

Figure 4-14: Site Info

Site Info containing four properties:

- ***Location:*** Name of location where the instrument is deployed.
- ***Geographic Position:*** GPS potion for deployment format Latitude, Longitude.
- ***Vertical Position:*** Position in water column, e.g. 5 meter depth.
- ***Reference:*** Free text for additional information.

All these settings are optional information to be entered to store information about the deployment. These setting are not used in calculation. ***Geographical Position*** is used to give the map coordinates unless a GPS input is connected.

4.6 System Configuration

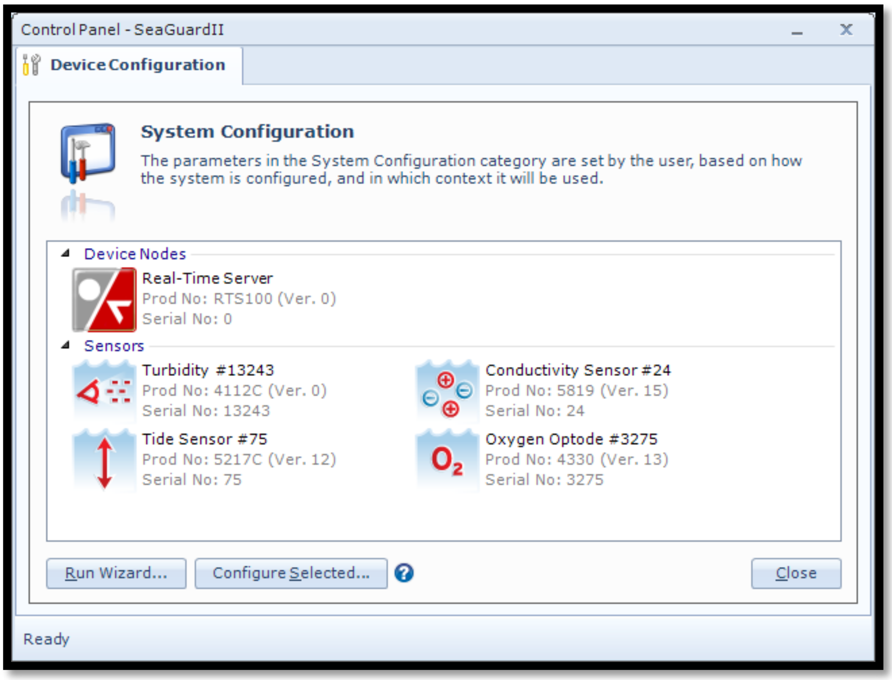


Figure 4-15: System configuration

Select ***System Configuration*** under ***Device Configuration*** (refer **Figure 4-7**). The different sensors connected to the same Datalogger will show up as selectable items,

Double-click on the Oxygen Optode to start configure

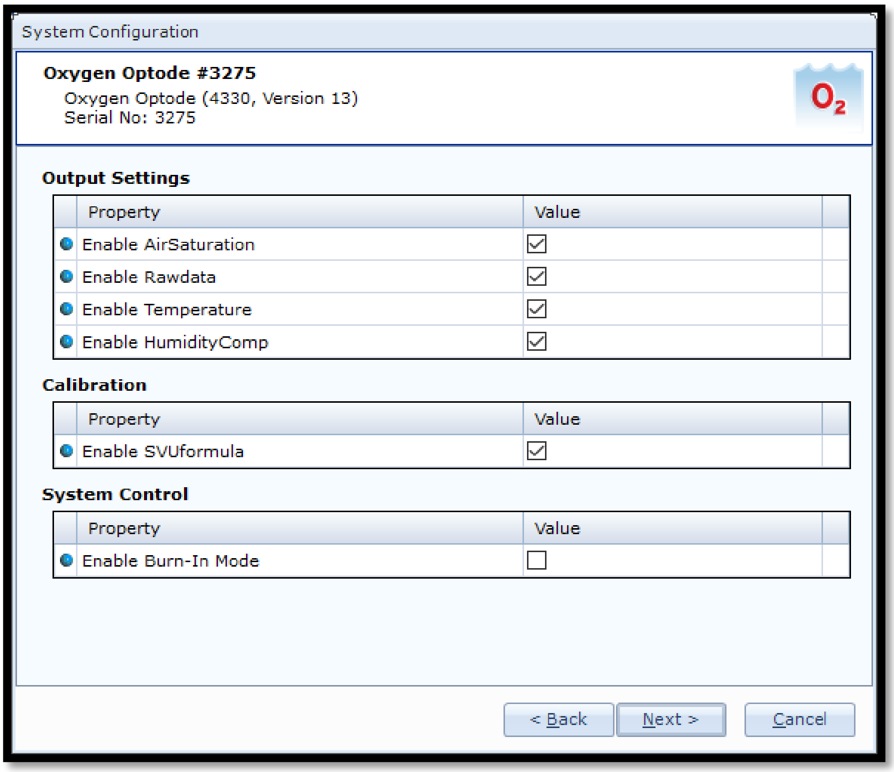


Figure 4-16: Sensor Configuration part 1

System Configuration is separated in 3 groups. The settings in these groups are mainly used to configure the sensor and control the output/ storage of data.

Refer chapter 1.7.3 for more information on the properties in ***System Configuration***.

For more information on each property see chapter ***4.6.1*** to
.

4.6.1 Output Settings

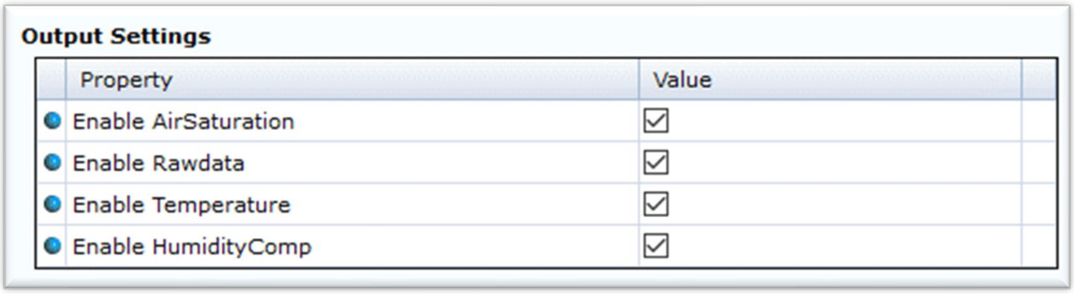


Figure 4-17: Output Settings

The ***Output setting*** group holds a list of output parameters that can be enabled/disabled by the user. Enabled properties (*Yes*) are calculated and sent to the data logger:

Enable Air Saturation is used to enable/disable the Air Saturation output in % saturation. Oxygen Concentration in µM is always enabled and cannot be switched off.

Enable Raw Data is used to enable raw data in the output string

Enable Temperature in used to enable Temperature Deg. C as a part of the output string.

Enable HumidityComp property activates compensation of vapor pressure in the calculations of the output parameters. Enable HumidityComp can be set to *No* if measurements are performed in dry air conditions or if you like to perform the humidity compensation as a post-processing operation. Disabling this will typically lead to 1-3 % lower readings depending on the relative humidity of the air.

The ***Oxygen Consentration*** in ***µM***, is a default parameter and cannot be disabled.

To enable/disable a parameter:

Select the output parameter from the list, press ***View/Edit*** in the lower part of the window, and change the setting by clicking the box (box is now checked), press ***Save*** to save and close the window.

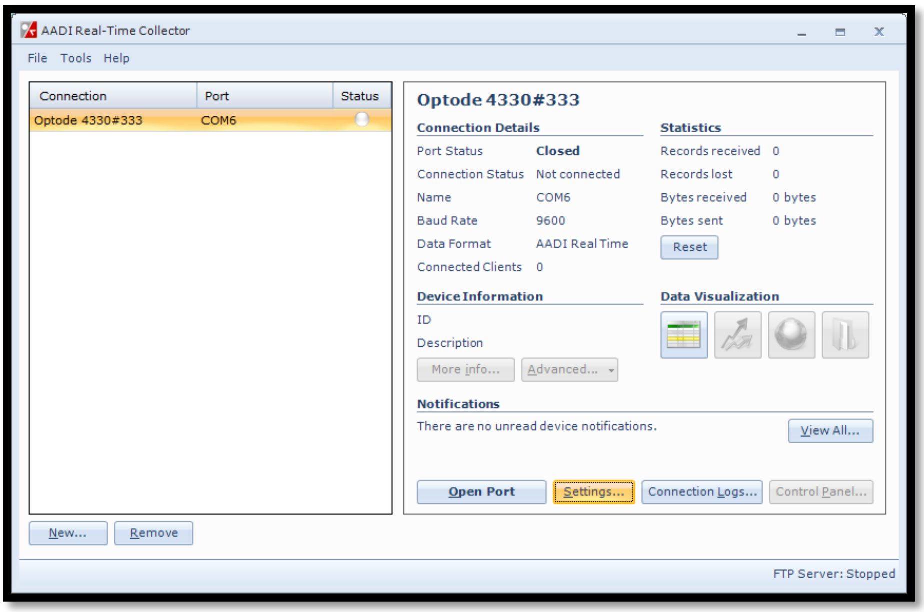
We recommend that you enable all parameters in case of later use. The memory card storage capacity is normally not a limitation for the SeaGuard. Raw data can be used e.g. to control calibration coefficients and perform quality control on the data.

CHAPTER 5 Logging data via AADI Real-Time Collector

5.1 Logging data on PC

The Real-Time Collector can save the incoming data to file if the sensor is in AADI Real-Time mode, either to a txt-file or to xml-files.

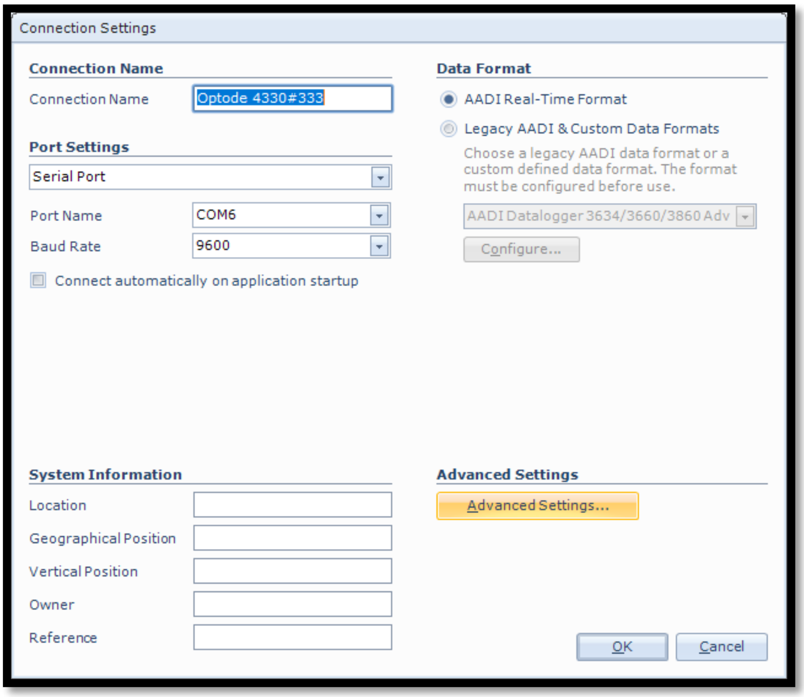
5.1.1 Enabling file output



If your connection is open,status is green in the AADI Real Time Collector main menu close the port first to be able to change the file output settings.

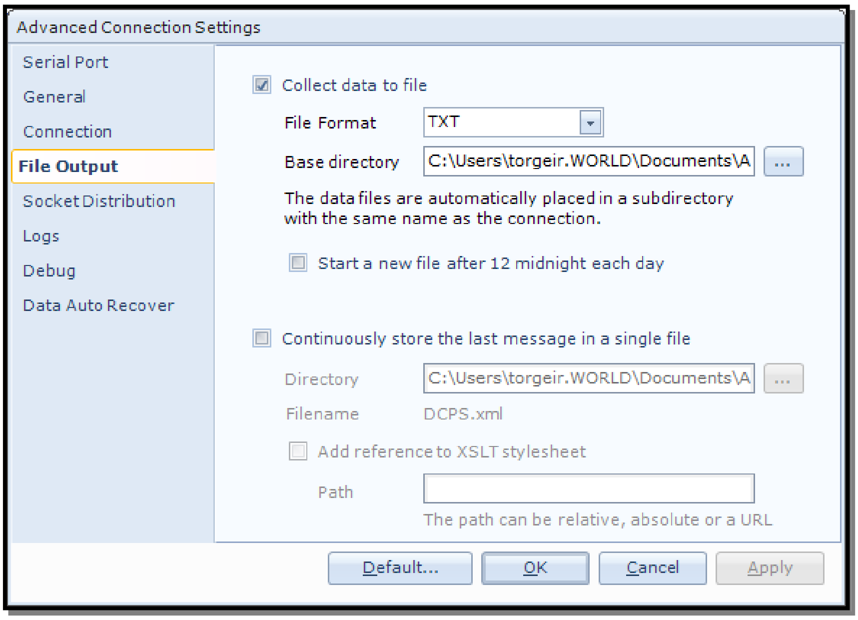
Click on the connection you are using. Then click on the ***"Settings..."*** button.

Figure 5-1: AADI Real-Time Collector start up menu



Then click on the "***Advanced Settings…"*** button in the Connection Settings window.

Figure 5-2: Connection settings menu



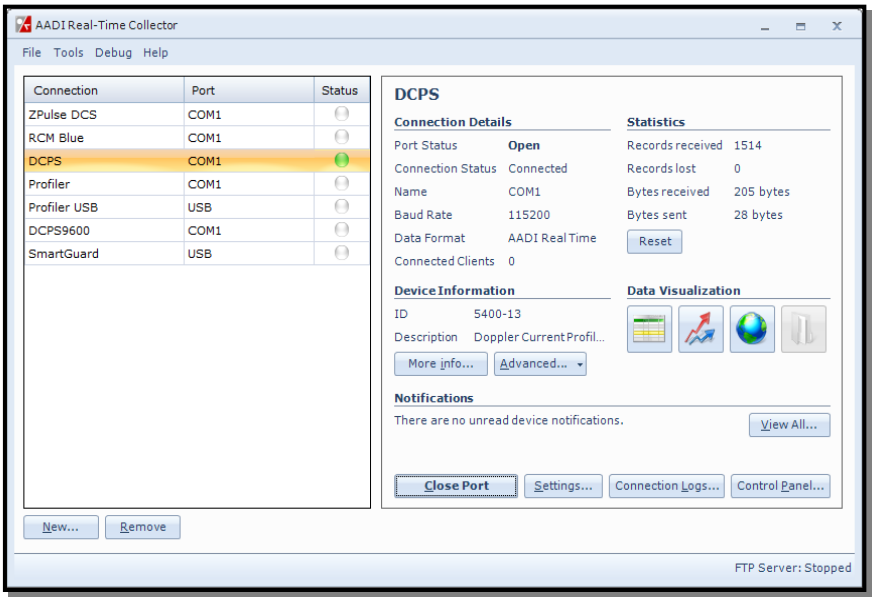
Choose ***File Output*** from the list on the left side. Check the "***Collect data to file"*** box to enable file output. Select a file format either XML or TXT and choose a base directory where you want the file to be saved.

Alternatively you may select "Continuously store the last message in a single file".

Click "**OK**" in the Advanced Connection Settings window, and "**OK**" in the Connection Settings window

Figure 5-3: Advanced connection settings / File Output

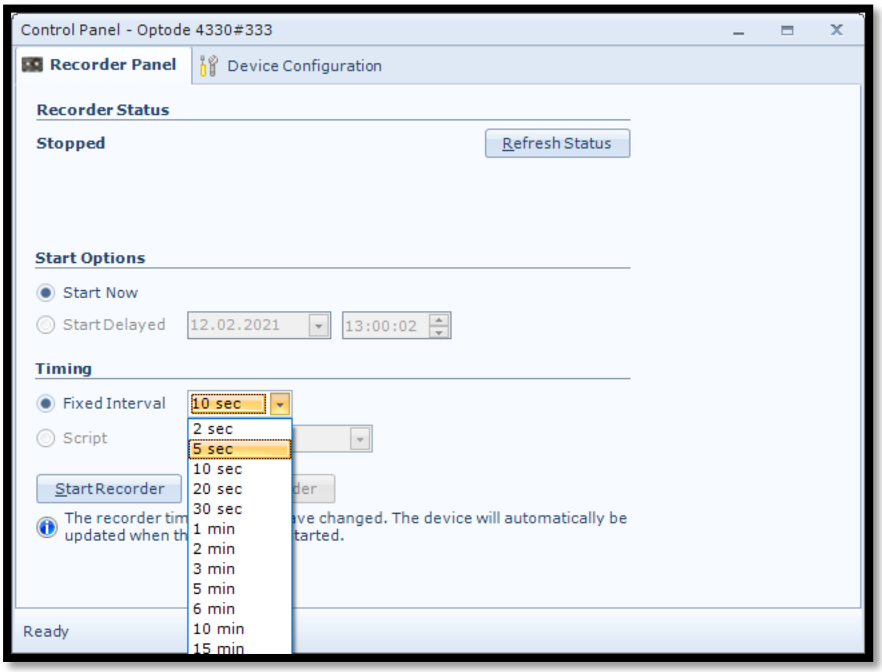
5.1.2 Starting the sensor and logging to file



Select your connection in th connection list and the press "*Open Port*". The Status turns green when the sensor is connected.

Click on the "**Control Panel…**" button in the lower right corner.

Figure 5-4: AADI Real-Time Collector start up menu



Select the interval duration and click the "***Start Recorder***" button. The shortest interval available depends on the sensor configuration. More cells give longer ping processing time and a higher minimum available recording interval.

This configuration is only available if the sensor is in ***AADI Real-Time*** mode.

Figure 5-5: Recorder panel

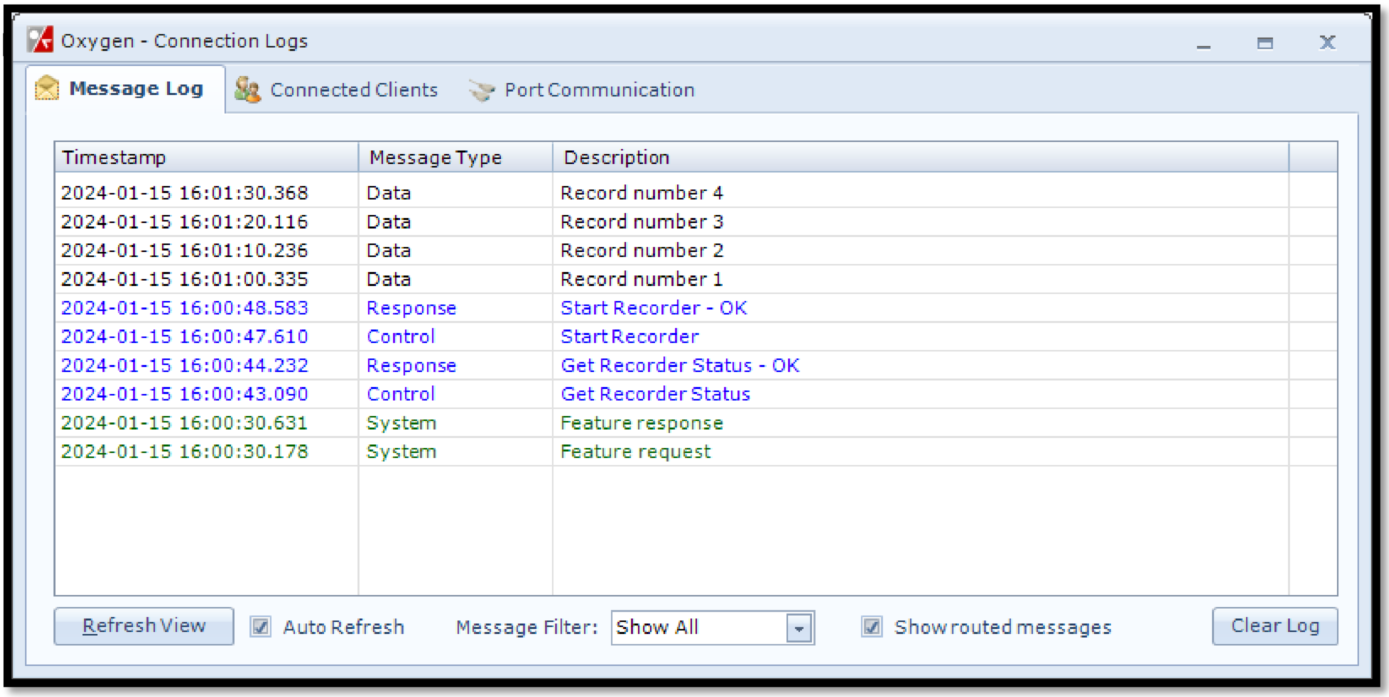
Data will start logging in the defined directory. If it is a txt-file, the easiest way to view it is using Excel. gives an example of an obtained data file. The different parameters are organized in columns.

Description	O2 Optode #2056									
Product Name	O2 Optode									
Product Number	4531									
Serial Number	2056									
Device ID	4531-2056									
Session ID	4531-2056-5.3.2-0-63									
Location										
Geographic Position	60.323605,5.37225									
Vertical Position										
Owner										
Reference										
		O2 Optode #2056								
Record Time	Record Nu	Sensor Sta	O2Concen	Status	O2Conten	Status	AirSaturat	Status	Temperat	Status
15.01.2024 14:30	1	(0) OK	2.521257E+02		8.068024E+00		9.597598E+01		2.401647E+01	
15.01.2024 14:30	2	(0) OK	2.520957E+02		8.067062E+00		9.597510E+01		2.402234E+01	
15.01.2024 14:31	3	(0) OK	2.521288E+02		8.068122E+00		9.599439E+01		2.402607E+01	
15.01.2024 14:31	4	(0) OK	2.520934E+02		8.066989E+00		9.599259E+01		2.403257E+01	
15.01.2024 14:31	5	(0) OK	2.520854E+02		8.066732E+00		9.599931E+01		2.403800E+01	
15.01.2024 14:31	6	(0) OK	2.521693E+02		8.069417E+00		9.603545E+01		2.404031E+01	
15.01.2024 14:31	7	(0) OK	2.521535E+02		8.068912E+00		9.603959E+01		2.404596E+01	

Figure 5-6: Data file example.

5.2 Viewing incoming data in real-time

When the sensor is running, the incoming data can be viewed under “**Connection Logs…**” in the main AADI Real-Time Collector menu. Double-click on one of the Record numbers to see data.



Click on the + signs to open and see all the data in the message.

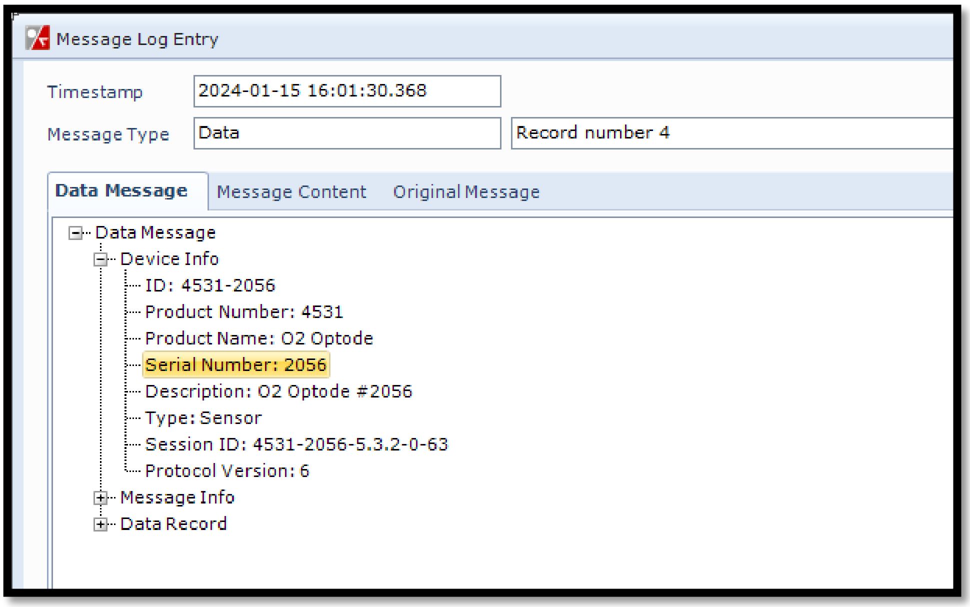


Figure 5-8: Message Log Entry

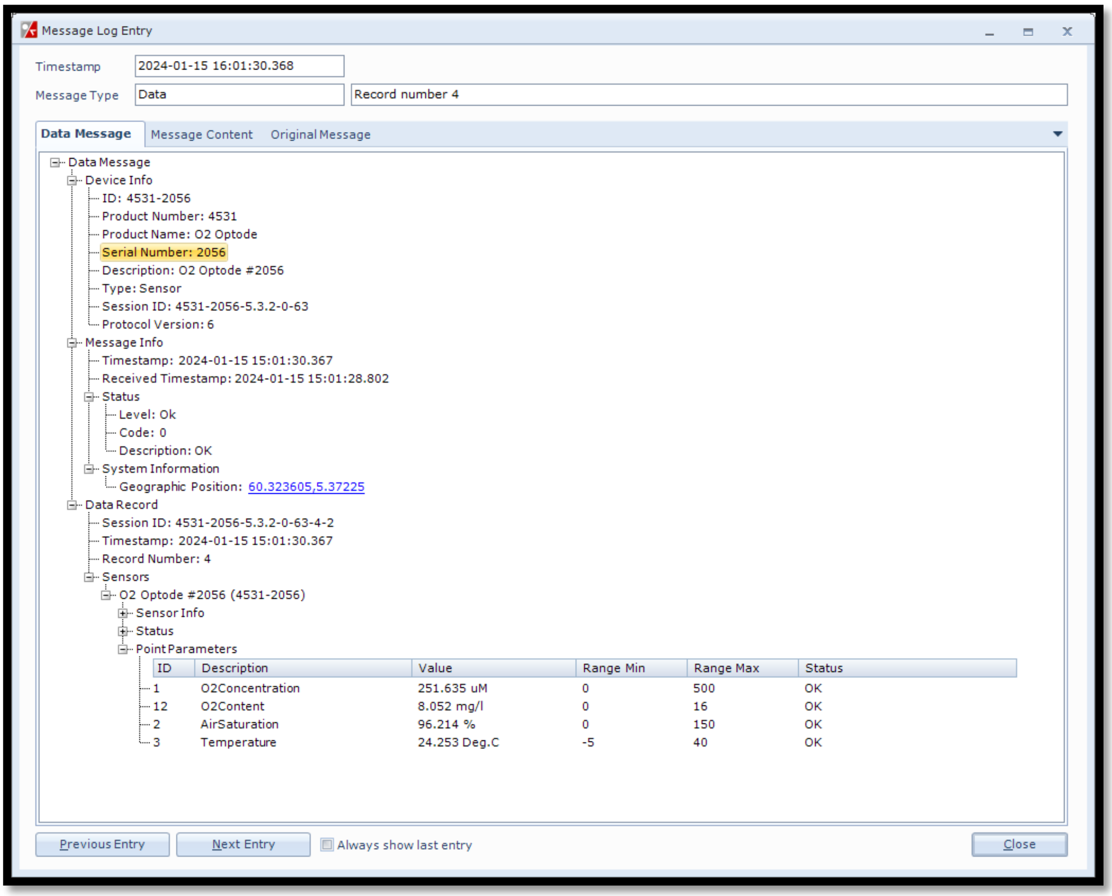


Figure 5-9: Visualization of incoming data from the sensor in real time

Previous records or newer records can be viewed by clicking on ***Previous Entry*** button or ***Next Entry button***. An automatic update to the last data message can be enabled by checking the Always show last entry check box.

The original message content can be seen if clicking on the Original Message tab.

CHAPTER 6 Stand-alone Sensor configuration using Smart Sensor Terminal

Refer to CHAPTER 3 for description how to connect the sensor to a PC.

6.1 Smart Sensor Terminal communication setup

Most third-party terminal programs, e.g. Tera Terminal Pro or Hyper Terminal can be used for RS-232 communication with the sensor when connected to a PC.

For sensors with default configuration the following Smart Sensor Terminal setup should be used:

9600 Baud

8 Data bits

1 Stop bit

No Parity

Xon/Xoff Flow Control

Note! If using Tera Terminal Pro, after setting up the com port according to settings above please select "Terminal" in the "Set up" menu and click "Local echo" also select "CR+LF" for both "Receive" and "Transmit" under "New line".

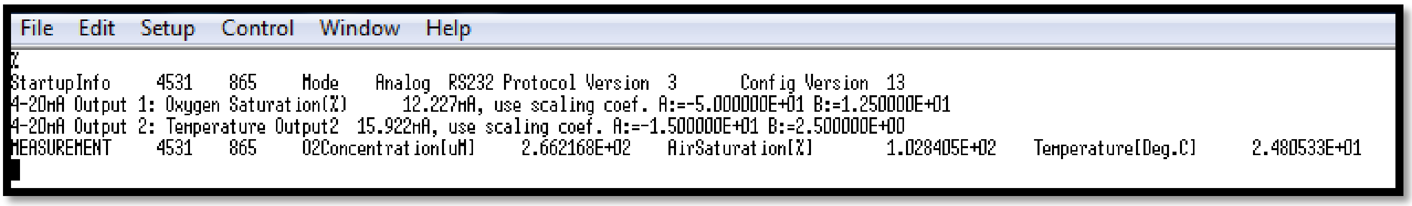
Note! If using Hyper Terminal, the options "Send line ends with line feeds" and "Echo line ends with line feeds" in the HyperTerminal ASCII setup must be selected.

Sensor startup

You will be able to communicate with the sensor via the Terminal software regardless of which mode the sensor is set to. However, the output string from the sensor will depend on the mode setting. The final structure of the output string will also depend on settings like Enable Text, Enable Decimal Format, Enable Raw Data, and so on. The sensor will continue to output measurements after the first startup info. The output frequency will be according to the interval setting. Some properties will not have any effects in all modes but they will still be available. Some properties may also have different effects depending on the mode.

6.2 Sensor Startup in Analog Output mode only 4831

Sensors in ***Analog Output*** mode and with default configuration will start by presenting a start-up message including the analog output settings, analog output level and scaling coefficients for both channels when powered up, see ***Figure 6-1***. Then the sensor will perform a sample (depending on the configuration) and then enter a power down mode. After this first startup info the sensor will act like a sensor in ***Smart Sensor Terminal*** mode, see ***chapter 6.3***.


```
File  Edit  Setup  Control  Window  Help
%
StartupInfo   4531   865   Mode   Analog  RS232 Protocol Version  3      Config Version  13
4-20mA Output 1: Oxygen Saturation(%)     12.227mA, use scaling coef. A:=-5.000000E+01 B:=1.250000E+01
4-20mA Output 2: Temperature Output2  15.922mA, use scaling coef. A:=-1.500000E+01 B:=2.500000E+00
MEASUREMENT   4531   865   O2Concentration[uM]   2.662168E+02   AirSaturation[%]   1.028405E+02   Temperature[Deg.C]   2.480533E+01
```

6.3 Sensor startup in Smart Sensor Terminal mode

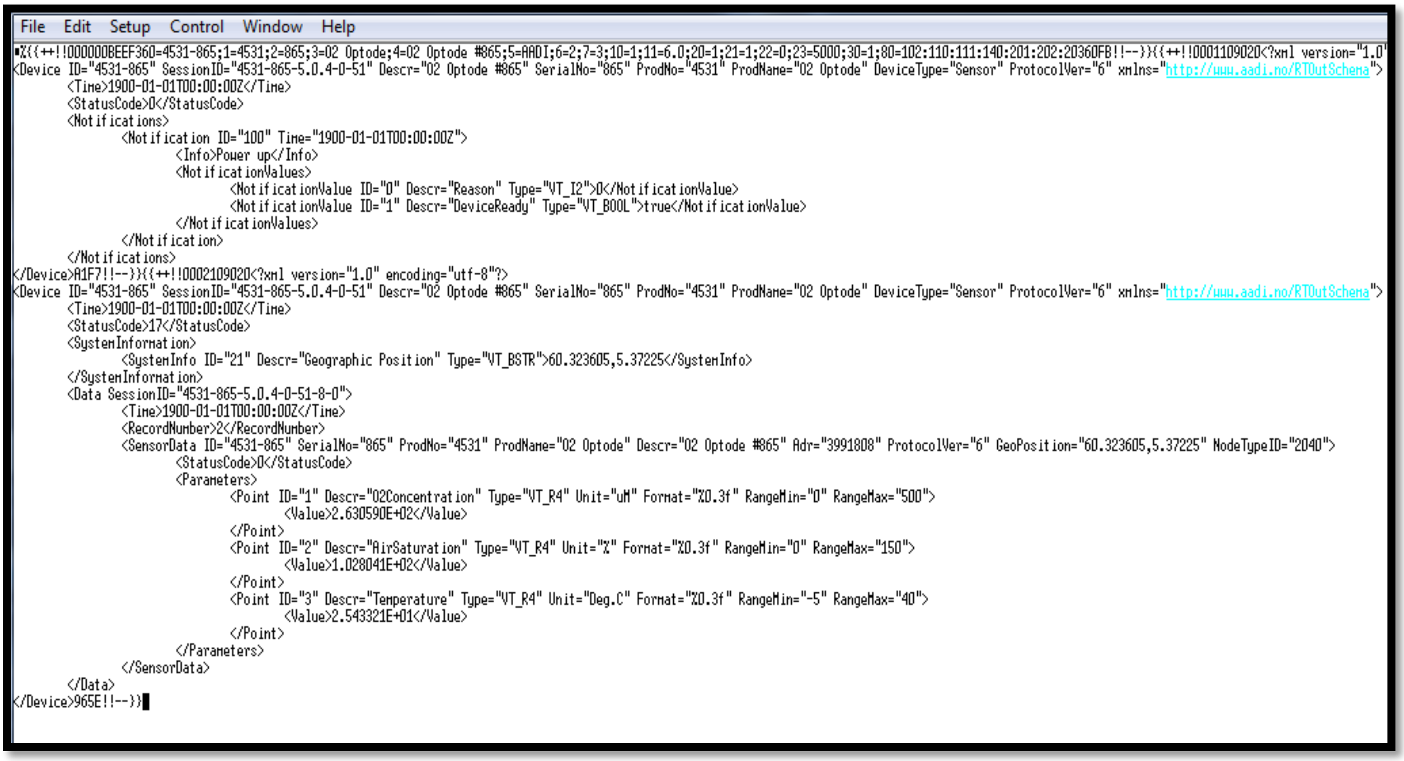
When used in ***Smart Sensor Terminal*** mode the sensor will always start by doing a sample that will be presented within 2 seconds from powering the sensor, see ***Figure 6-2***. This does not apply for Polled operations.

To minimize the power consumption, the sensor normally enters a power down mode after each sampling; the sensor can be awakened by any characters on the Smart Sensor Terminal input and will stay awake for a time set by the ***Comm TimeOut*** property after receiving the last character.


```
File  Edit  Setup  Control  Window  Help
%
StartupInfo   4531   865   Mode   AADI Smart Sensor Terminal Protocol   RS232 Protocol Version  3   Config Version  13
MEASUREMENT   4531   865   O2Concentration[uM]   2.641375E+02   AirSaturation[%]   1.029855E+02   Temperature[Deg.C]   2.530647E+01
```

6.4 Startup info in AADI Real-Time mode

When used in ***AADI Real-Time*** mode the sensor will always start by sending a startup XML, first 14 lines in ***Figure 6-3*** and then after first interval it will perform a measurement and display the xml message including sensor data and parameters.




```
File   Edit   Setup   Control   Window   Help
■%{{++!!000000BEEF360=4531-865;1=4531;2=865;3=02 Optode;4=02 Optode #865;5=AADI;6=2;7=3;10=1;11=6.0;20=1;21=1;22=0;23=5000;30=1;80=102:110:111:140:201:202:20360FB!!--}}{{++!!0001109020<?xml version="1.0"
<Device ID="4531-865" SessionID="4531-865-5.0.4-0-51" Descr="02 Optode #865" SerialNo="865" ProdNo="4531" ProdName="02 Optode" DeviceType="Sensor" ProtocolVer="6" xmlns="http://www.aadi.no/RTOutSchema">
        <Time>1900-01-01T00:00:00Z</Time>
        <StatusCode>0</StatusCode>
        <Notifications>
                <Notification ID="100" Time="1900-01-01T00:00:00Z">
                        <Info>Power up</Info>
                        <NotificationValues>
                                <NotificationValue ID="0" Descr="Reason" Type="VT_I2">0</NotificationValue>
                                <NotificationValue ID="1" Descr="DeviceReady" Type="VT_BOOL">true</NotificationValue>
                        </NotificationValues>
                </Notification>
        </Notifications>
</Device>A1F7!!--}}{{++!!0002109020<?xml version="1.0" encoding="utf-8"?>
<Device ID="4531-865" SessionID="4531-865-5.0.4-0-51" Descr="02 Optode #865" SerialNo="865" ProdNo="4531" ProdName="02 Optode" DeviceType="Sensor" ProtocolVer="6" xmlns="http://www.aadi.no/RTOutSchema">
        <Time>1900-01-01T00:00:00Z</Time>
        <StatusCode>17</StatusCode>
        <SystemInformation>
                <SystemInfo ID="21" Descr="Geographic Position" Type="VT_BSTR">60.323605,5.37225</SystemInfo>
        </SystemInformation>
        <Data SessionID="4531-865-5.0.4-0-51-8-0">
                <Time>1900-01-01T00:00:00Z</Time>
                <RecordNumber>2</RecordNumber>
                <SensorData ID="4531-865" SerialNo="865" ProdNo="4531" ProdName="02 Optode" Descr="02 Optode #865" Adr="3991808" ProtocolVer="6" GeoPosition="60.323605,5.37225" NodeTypeID="2040">
                        <StatusCode>0</StatusCode>
                        <Parameters>
                                <Point ID="1" Descr="02Concentration" Type="VT_R4" Unit="uM" Format="%0.3f" RangeMin="0" RangeMax="500">
                                        <Value>2.630590E+02</Value>
                                </Point>
                                <Point ID="2" Descr="AirSaturation" Type="VT_R4" Unit="%" Format="%0.3f" RangeMin="0" RangeMax="150">
                                        <Value>1.028041E+02</Value>
                                </Point>
                                <Point ID="3" Descr="Temperature" Type="VT_R4" Unit="Deg.C" Format="%0.3f" RangeMin="-5" RangeMax="40">
                                        <Value>2.543321E+01</Value>
                                </Point>
                        </Parameters>
                </SensorData>
        </Data>
</Device>965E!!--}}
```


Figure 6-3: Startup info in AADI Real-Time mode.

6.5 Communication sleep

To minimize the power consumption, the sensor normally enters a power down mode after each sampling; the sensor can be awake by any characters and will stay awake for a time set by the ***Comm TimeOut*** property after receiving the last character.

If the property ***Comm TimeOut*** is set to other than ***'Always On'*** the serial interface will not be activated after power-up (or the ***Reset*** command). Any character will activate the serial interface, but a Carriage Return (CR or CR+LF), ***'/'*** or ***';'*** are often preferred since these characters do not interfere with the command syntax. The serial interface will then be active until a period of input inactivity specified by the ***Comm TimeOut*** value.

The ***Communication Sleep Indicator***, ***'%',*** will be transmitted when the serial communication is deactivated, and the ***Communication Ready Indicator, '!'*** is outputted after activation (electronics require up to 500ms start up time). When ***Comm TimeOut*** is set to '***Always On'*** the communication (and microprocessor) will be kept active all time.

The ***Communication Sleep Indicator '%'*** and the ***Communication Ready Indicator '!'*** are not followed by Carriage Return and Line Feed.

Any character will cause the electronics to return to normal operation; when the sensor has responded with the character ***'!'***, new commands may be entered.

When communicating with the sensor, you must start by pressing *Enter*. The sensor will respond in two ways (***Comm TimeOut*** is 1 minute by default in the following description):

- If the sensor is ready for communication, it will not send any response indicator. The sensor will stay awake and ready to receive commands for 1 minute.
- If the sensor is in sleep mode and not ready for communication, the sensor will send a 'communication ready' indicator ***(!)*** when awakened (within 500ms). The sensor will then be ready for communication.

6.6 Smart Sensor Terminal protocol

All inputs to the sensor are given as commands with the following format:

- ***MainCmd SubCmd*** or ***MainCmd Property(Value.., Value)***

All configurations of sensors in RS-232 operation are the same regardless of mode setting.

Description of ASCII coded communication rules:

- The main command, ***MainCmd,*** is followed by an optional subcommand (***SubCmd)*** or sensor property (***Property***).
- The ***MainCmd*** and the ***SubCmd/Property*** must be separated with the space ' ' character.
- When entering new settings the ***Property*** is followed by parentheses containing comma-separated values.
- The command string must be terminated by ***Carriage Return*** and ***Line Feed*** (ASCII code 13 and 10).
- The command string is not case ***sensitive (UPPER***/lower-case).
- A valid command string is acknowledged with the character '***#***' while character '*******' indicates an error. Both are followed by ***Carriage Return/ Line Feed (CRLF).***
- For most errors a short error message is also given after the error indicator.
- There are also special commands with short names and dedicated tasks, as ***save***, ***reset***, and ***help.***
- All names and numbers are separated by tabulator spacing (ASCII code 9).
- The output string is terminated by ***Carriage Return*** and ***Line Feed*** (ASCII code 13 & 10).

6.7 Passkey for write protection.

To avoid accidental change of the sensor configuration, most of the properties are write-protected. There are five levels of access protection, refer ***Table 6-1***.

A special property called *Passkey* must be set according to the protection level before changing the value of properties that are write-protected, refer ***Table 6-1***. E.g.:

Set passkey(1000)

Table 6-1 Access protection levels

Output	Passkey	Description
No		No Passkey needed for changing property.
Low	1	The Passkey must be set to 1 prior to changing property.
High	1000	The Passkey must be set to 1000 prior to changing property. This Passkey value also give read access to factory properties that usually are hidden
Read Only		The user has only read access, no passkey needed.
Factory Write	XXXX	Sensor specific code for factory level access.

After a period of inactivity at the serial input, the access level will revert to default. This period corresponds to the ***Comm TimeOut*** setting, or 1 minute if the ***Comm TimeOut*** is set to Always On.

6.8 Save and Reset

When the required properties are set, you must send a *Save* command to make sure that the new configuration are saved internally in the flash memory. The Oxygen Optode always reads the configuration from the internal flash memory after reset and power up.

When changing the *Mode* and *Baudrate* property a reset is required for the change to take effect. This can be done by recycling power or entering the Reset command. At start-up/reset the sensor normally presents a start-up information string as shown Figure 5-2.

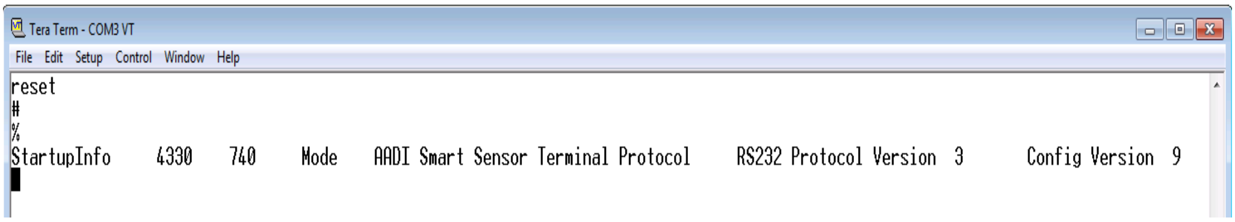


Figure 6-4 Sensor start-up/reset.

6.9 Communication Sleep

If the property *Comm TimeOut* is set to other than 'Always On' the serial interface will not be activated after power-up (or the Reset command). Any character will activate the serial interface, but a Carriage Return (CR or CR+LF), '/' or ';' are often preferred since these character do not interfere with the command syntax. The serial interface will then be active until a period of input inactivity specified by the *Comm TimeOut* value (10 s,20 s,30 s,1 min,2 min,5 min,10 min). The Communication Sleep Indicator, '%', will be transmitted when the serial communication is deactivated, and the Communication Ready Indicator, '!' is outputted subsequent to activation. When *Comm TimeOut* is set to 'Always On' the communication (and microprocessor) will be kept active all time.

The Communication Sleep Indicator '%' and the Communication Ready Indicator '!' are not followed by Carriage Return and Line Feed.

6.10 Available Commands for the Oxygen Optodes

Available commands and properties for the Oxygen Optode are given in Table 5-2 and Table 1-2 respectively.

Table 6-2 Main RS232 commands available for the Oxygen Optode.

Command	Description
Do Sample	Execute an oxygen measurement and presents the result
Start	Start a measurement sequence according to current configuration
Stop	Stop a measurement sequence
Do CollectCalDataSat[1)]	Collect and save calibration data for 100% saturation
Do CollectCalDataZero[1)]	Collect and save calibration data for 0% saturation
Do Calibrate[1)]	Execute a two point internal calibration function
Do Test	Internal use
Do AdjustGain	Optimize internal amplification to foil type, only used when changing between standard foil and fast response foil. Refer chapter 6.1 .
Get *ConfigXML*	Outputs info on available properties on XML format
Get *DataXML*	Outputs info on available(enabled) parameters on XML format
Get *Property*	Output Property value (refer Table 1-2)
Get All	Output all property values
Set *Property(Value,.. Value)*	Set Property to Value,… Value
Set *Passkey(Value)*	Set passkey to change access level
Save[1)]	Store current settings
Load	Reloads previous stored settings
Reset	Resets the sensor with new configuration
Help	Print help information
;	Comment string, following characters are ignored
//	Comment string, following characters are ignored

1) Note that the Save procedure might require up to 20 seconds. Losing power during this period will cause loss of latest configuration change. Wait for acknowledge, '#', before powering down the sensor. The save procedure is also executed when running the Do CollectCalDataSat, Do CollectCalDataZero and Do Calibrate –commands.

6.10.1 The Get Command

The *Get* command is used for reading the value/values of a property and for reading the latest value of a parameter.

The command name *Get* followed by a *Property* returns a string on following format:

Property ProductNo SerialNo Value, ..Value

The string starts with the name of the property, the product number and serial number of the sensor, and finally the value of the property, refer example in Figure 5-3.

The command name *Get* followed by a parameter returns the name and unit of the parameter, the product and serial number of the sensor, and finally the latest parameter reading, refer example in Figure 5-3.

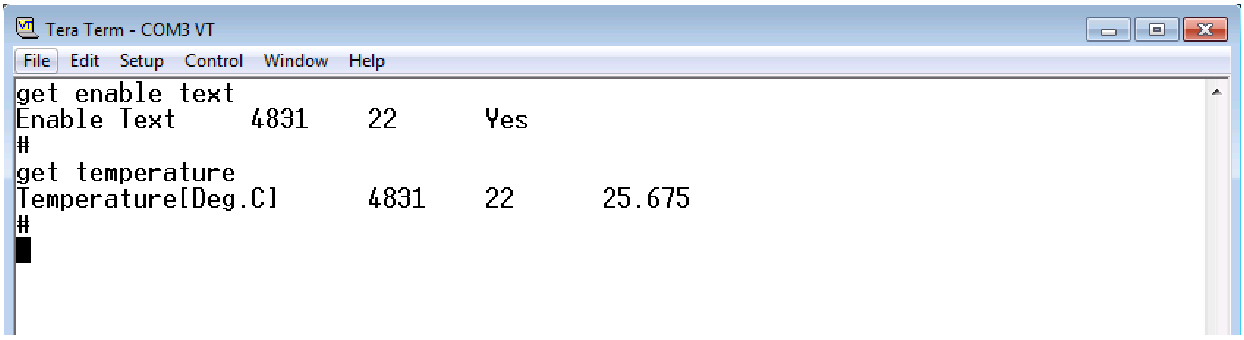


Figure 6-5 Examples of the Get command.

A special version, *Get All*, reads out all available properties in the sensor.

6.10.2 The Set Command

The *Set* command is used for changing a property. Type the corresponding *Get* command to verify the new setting, refer example in Figure 5-4.

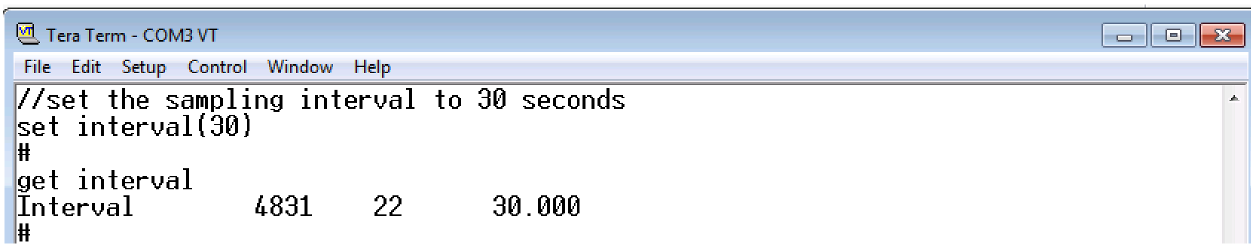


Figure 6-6 Example of the Set command.

Use the *Save* command to store the new property value. Some properties will require a *Reset* before the change is executed.

6.10.3 Formatting the Output String

The property called ***Enable Text*** controls the presentation of measured data. When the property is set to ***(Yes)*** the output string includes the descriptive parameter name. When the property is set to ***(No),*** the output parameters are presented without descriptive parameter names; the parameter order is the same, refer Figure 5-5 for an example.

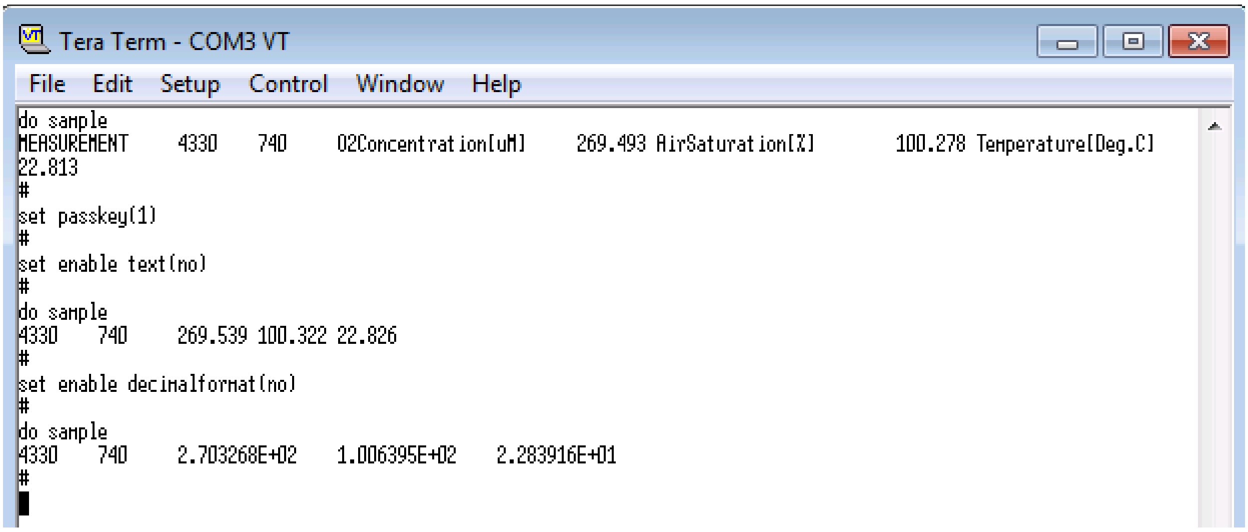


Figure 6-7 Example of output string: enable/disable text/decimal format

The property called ***Enable DecimalFormat*** controls the format of the output values, either as decimal numbers ***(Yes),*** or in exponential format ***(No).*** Refer Figure 5-5 for an example.

6.10.4 XML Commands

Get *ConfigXML* presents the configuration of all the sensor properties in XML format.

Get *DataXML* presents all of the enabled parameters in XML format.

6.11 Scripting -sending a string of commands

Often it may be usefully to collect more than one command in a text file. For example the instructions below can be written in an ordinary text editor and saved as a text file, which can be sent to the sensor. In HyperTerminal click *send text file* in the *Transfer* menu, and select the correct file. In Tera Terminal click “Send File” under “File” in main menu and select the file to be transferred.

Example of text file:

```
// Set sampling interval to 30 seconds
Set Passkey(1)
Set Interval(30)
Save
Get All
```

NOTE! The last line, Get All, reads out available properties for the sensor.

The first line is a comment line that is disregarded by the sensor. Strings starting with either '//' or ';' are ignored by the software, and do not produce errors or acknowledgements.

When sending text file the sensor can be awakened from sleep mode by sending a string of comment leads characters:

```
/////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
/////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
/////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
// Wake up test
Get All
```

This will provide time for the optode to wake up and be ready before the next string appears. Note that higher baud rates might require more lines of '/' to provide sufficient delay. Communication wake up will normally require less than 100mS.

6.12 Sensor Configuration

The sensor configuration consists of sensor settings and customized presentation of data. Refer Table 1-2 for a list of all sensor properties and the input format; below follows a description of the properties that are typically set by the user prior to a deployment (RS232 application). Description of properties regarding the sensing foil and calibration are given in CHAPTER 6 .

The ***Mode*** property is used to set the operation mode. Available modes are AiCaP, Smart Sensor Terminal, AADI Real-Time and Analog Output.

- Set ***Mode*** to ***'AiCaP'*** when connected to AADI SeaGuard or to a SmartGuard logger that automatically detects and recognices the sensor on CANbus(AiCaP).
- Set ***Mode*** to ***'AADI Real-Time'*** for use with AADI Real-Time Data Collector or third party software that can handle XML based protocol
- Set ***Mode*** to '***Smart Sensor Terminal'*** for a simple ASCII command string based protocol when connected to PC or third party serial interface
- Set ***Mode*** to '***Analog Output'*** when interfacing 4330 or 4835 sensors to optional Analog 0-5 V, 4-20 mA adaptors, or enabling the build in analog output of the 4831

Note! As default the 4330 and 4835 sensors are set to AiCaP communication while 4831 is set to Smart Sensor Terminal (RS232). Please select the correct Output according to which type of logger/interface you plan to use.

Set the **Enable AirSaturation, Enable Temperature**, and ***Enable Rawdata*** to (***Yes)*** to include these parameters in the output string.

Set the ***Enable Text*** to (***Yes)*** for the optode to output a detailed text string with the measurements, or (***No)*** to output the measured values without the descriptive text.

Set the ***Enable Decimalformat*** to (***Yes)*** to output the measured values in decimal format. Set the property to (***No)*** to output the values in exponential format (higher resolution in the output parameter value).

The ***Interval*** property describes the measurement interval in seconds; the Optode provides a set of measured data for every measurement interval.

The ***Salinity*** property is set to 0 at the factory and the measurements must be post processed to compensate for the salinity variations at the measurement site. If the salinity is known at the site and relatively stable, you can set the Salinity property according to the known value and the measurements will be salinity compensated inside the sensor before presentation (useful for Real-Time measurements).

The ***Enable HumidityComp*** property describes compensation of vapour pressure in the calculations of the output parameters. **Enable HumidityComp** can be set to (***No)*** if measurements are performed in complete dry conditions (dry air) or if you like to perform the humidity compensation as a post-processing operation. Measurements in dry conditions are more accurate when the ***Enable HumidityComp*** is set to (***No)***. The property is set to (***Yes)*** at the factory.

When ***Enable Redreference*** is set to (***Yes)***, the phase measurements are performed with a zero-point set at the red reference (no fluorescence). The property can be set to (***No)*** in special measurement situations; contact AADI service department. ***Enable Redreference*** is set to (***Yes)*** at the factory before calibration; if the property is set to (***No)*** the Optode must be recalibrated.

Set the ***Enable Sleep*** to (***Yes)*** for the Optode to go to sleep between recordings, or (***No)*** for the optode to stay continuously switched *on* between recordings (drains more power).

CHAPTER 7 **Maintenance**

The Oxygen Optode requires very little maintenance.

When the membranes on traditional oxygen consuming sensors (based on electrochemical principles), often called Clark sensors, are fouled the water mixing in front of the sensor membrane becomes poorer, which influences the measurement directly.

Since the Optode consumes no oxygen, the ability to diffuse gas has no influence on the measurement accuracy. However, if the fouling is in the form of algae that produce or consume oxygen, the measurement might not reflect the oxygen concentration in the surrounding water correctly.

Also the response time of the measurements might increase if the sensing foil is fouled. Therefore, the sensor should be cleaned at regular intervals depending on the fouling condition at the site.

Field experiences have demonstrated that AADI Optodes typically are a factor of 2-4 more fouling resistant than electrochemical oxygen sensors from other manufacturers and then the AADI conductivity sensors.

The Optode housing can be cleaned using a brush and clean water. Carefully, use a wet cloth to clean the sensing foil.

Fouling consisting of calcareous organisms (e.g. barnacles), can be dissolved by dipping the sensor/instrument in a weak acid solution (e.g. 7% Vinegar).

If the sensing foil is scratched or if the protective black layer on the foil is removed the sensor will still work as long as there is enough Fluorophore on the foil.

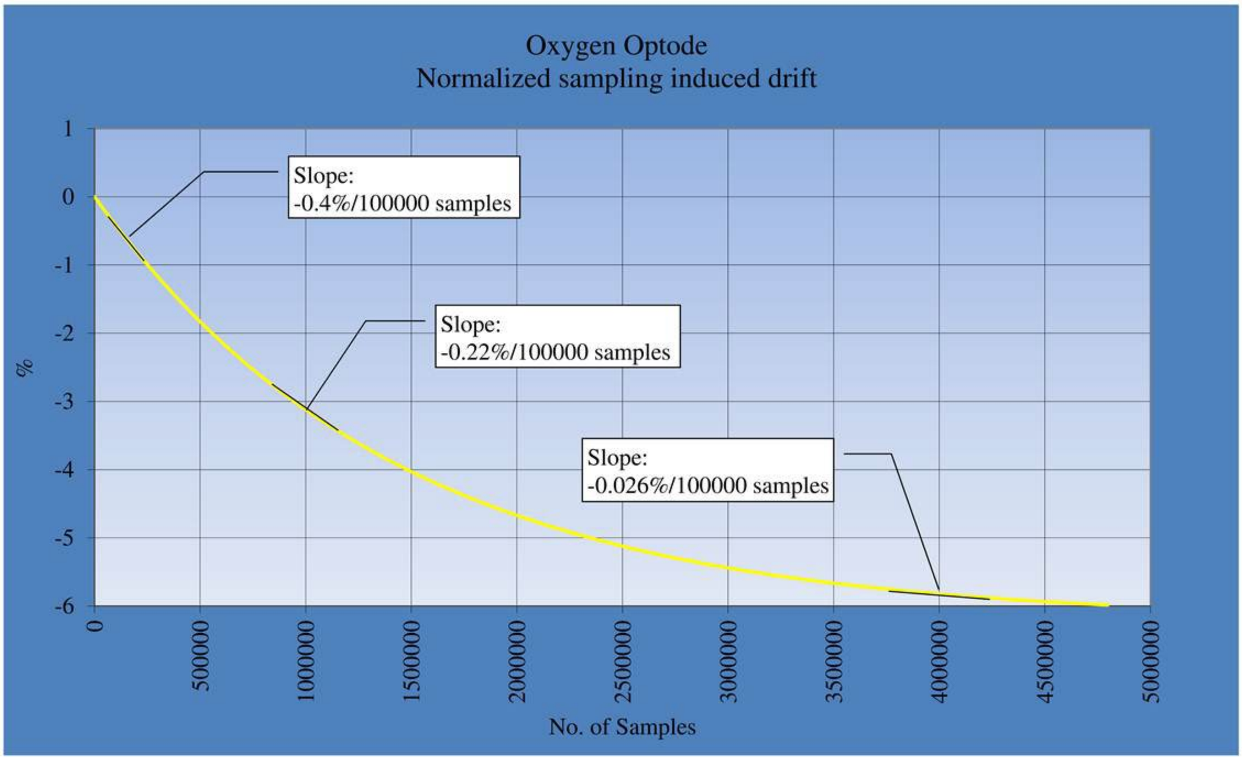
If severely damaged (so that the sensor gives unrealistic readings) the sensing foil must be replaced (Sensing Foil Kit) and the sensor recalibrated.

NOTE! Enter new calibration coefficients and perform a new two point calibration when changing the sensor foil.

The fluorescence life time measurement technology provides for very good long term stability. There is however a minor bleaching (break down) of the luminophore for every excitation of the foil. For the AADI Optodes this change is minimized by use of exceptional stable foil chemistry and careful excitation. Experience show that the foils have very good durability and generally become more stable over time. In figure 5-2 typical drift versus the number of excitations (samples) is depicted.

Figure 7-1: Example of fouling on an RCM 9 with an Oxygen Optode 3830 (Optode version with SR-10 output) mounted to it: The Optode was still giving correct readings.

In order to maintain optimum accuracy it is recommended that user select the sampling frequency required for the application and to not over sample in order to minimize potential drift. Annual recalibration is optimal and recommended by the factory (refer next section) although for many applications this may not be possible. In case where longer calibration intervals are expected use of a controlled reference can be adequate to QC the data.



The standard foil is equipped with a black optical isolation layer to protect it from ambient light. The fast response foil is not equipped with this layer and is therefore more susceptible to bleaching from external light. While stored all foils and Optode must be shielded from ambient light. Optodes equipped with the fast response foil will normally require more frequent calibration but this is highly dependent on the amount of ambient light.

When saturated with moisture the polymer of the sensing foil will swell a little. This will cause a minor, approximately 2%, change in the response of the Optode. For optimum accuracy the foils should be wetted for 48 hours prior to use. The protecting cap supplied with the 4330 and 4831 style Optodes can be used for keeping the foil both wet and shielded from ambient light.

NOTE! It is not recommended to change standard foils (with the black isolation layer) unless they have serious mechanical damages. Faster response transparent foils can be bleached by light therefore these foils require greater care in handling and application. Indications for when you will need replace an otherwise undamaged foils are:

- *Increasing levels of mesausrement noise*
- *TCPhase(deg) vales below 10*

AADI Service department can perform a cost-effective performance check and recalibration. Please fill out our Service Order Form, form no. 135, for this purpose (refer Services page at www.aanderaa.com)

7.1 Changing the Sensor Foil

If the sensor foil gets damaged it can easily be changed. For the 4330 and the 4831 models it is possible to change between the standard foil and fast response foil. The *Sensor Foil Kit 4733* for Optode 4330, 4831 and 4835 and Semnsor Foil Kit 5551 for Optode 5551 contains 1 standard foils while *Sensor Foil Kit 4794* for Optode 4330 and 4831 contains 1 fast response foils. The content of Kit 4733/4794/5551 is given in Table 6-1, and a procedure for changing the foil is given below the table.

NOTE! If you use a foil from a different batch, new foil coefficients must be entered.

NOTE! After changing the foil and entering new foil coefficients a new two or multipoint calibration should be performed (see below). Table 7-1 Contents of Sensor Foil Kit 4733/4794/5551

Part no.	Pieces	Description	Foil Kit 4733	Foil Kit 4794	Foil Kit 5551
1206005A	1	Standard Sensing Foil packed in aluminium foil	X		
1206020	1	Fast Response Sensing Foil packed in aluminium foil		X	
1206019	1	Standard Sensing Foil packed in aluminium foil			X
1913042	1	Torx key no. T9	X	X	X
1642223	4	M3 x 6mm screw torx a4 Din 965a (4330/4831)	X	X	X
1642222	2	M2.5 x 6mm screw torx a4 Din 965a (4835)	X		X
Form No. 721	Calibration Sheet for Sensing Foil (each batch of foils is calibrated)		X	X	

7.1.1 Procedure for Oxygen Optode 4330 and 4831

Procedure for changing the sensor foil using kit 4733 or 4794:

- The sensor foil is changed by unscrewing the 4 torx screws in the securing plate, refer Figure 7-2. Remove the securing plate and the old foil.
  - Rinse clean the sapphire window with DI water
  - If the removed foil will be used in the future it should also be pre-cleaned and rinsed then packed in a light blocking package marked with the foil type and batch number.

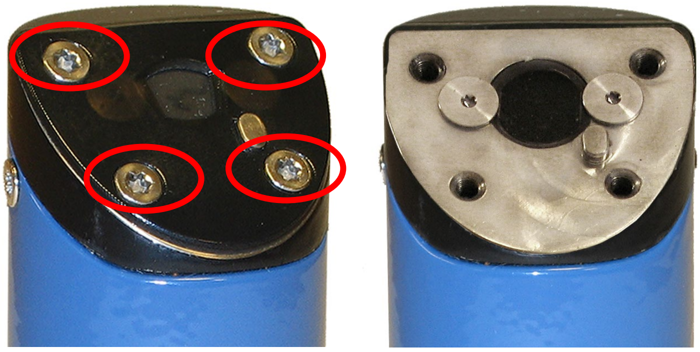


Figure 7-2 Removing the securing plate and change the sensing foil.

- Center the new foil to fit the optical window. It is important that the standard foil is mounted with the black side out, and the fast response foil with the *non-glossy* side out.
- Remount the securing plate.
- Figure 6-3 optical signal levels of the fast response foil are quit different from the standard foil. If changing from a standard foil to a fast response foil our vice versa, the internal amplification should be optimized to the new foil. This is done by executing the command ***Do AdjustGain*** (refer Figure 6-3). This should be done at room-temperature in air or saturated water. Ensure that the sensor is connected until the new amplification settings are stored (10-15 seconds)
- Control and if necessary update the sensing foil coefficients according to the foil certificate, refer chapter 0.
- Recalibrate the sensor, refer chapter 6.2.2.

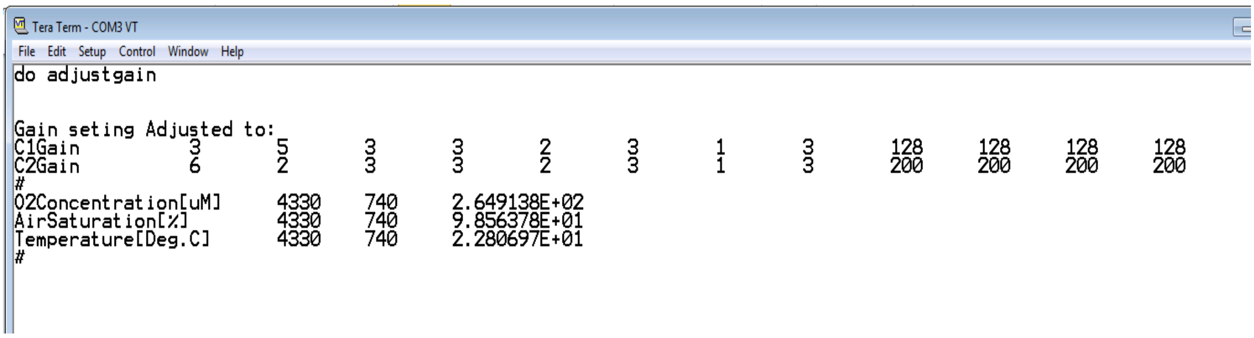


Figure 7-3 Adjust Gain.

7.1.2 Procedure for Oxygen Optode 4835

Procedure for changing the sensor foil using kit 5551:

- The sensor foil is changed by unscrewing the 2 torx screws in the securing plate, refer Figure 6-4Remove the securing plate and the old foil.
  - Rinse clean the sapphire window with DI water
  - If the removed foil will be used in the future it should be pre-cleaned and rinsed then packed in a light blocking package marked with the foil type and batch number.
- Center the new foil to fit the optical window. It is important that the standard foil is mounted with the black side out.
- Remount the securing plate.
- Control and if necessary update the sensing foil coefficients according to the foil certificate, refer chapters:3.2;4.1;5.1
- Recalibrate the sensor, refer chapter 6.2.2.

Figure 7-4 Removing the securing plate and change the sensing foil.

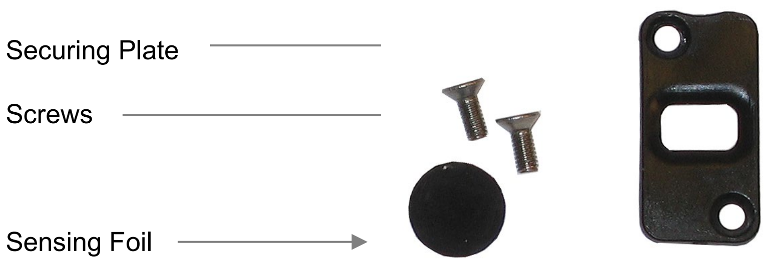


Figure 7-5 Illustration of parts, Optode 4835

7.2 Function Test

We recommend that you perform a function test of the sensor operating in air to verify the sensor readings. Refer chapter 6.2.1 and chapter 6.2.2 , for a description of the function test procedure.

At sea level the oxygen saturation should be approximately 100% in air (90-110 %, depending on air pressure, local oxygen production/consumption and if the temperature sensor measurements are representative for the temperature of the foil). The saturation will be significantly lower when you breathe on or near the sensing foil.

The measured temperature should also agree with the ambient temperature.

7.2.1 SEAGUARD® Applications

Leave the Oxygen Optode 4330/4835 mounted onto the SEAGUARD® Platform. Power the instrument; refer TD262a and TD262b for operating instructions.

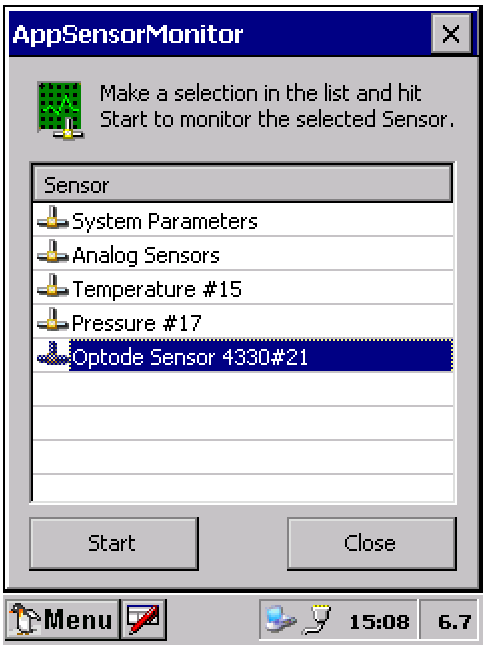


Figure 7-6 Select sensors to monitor

Open ***Administrative Tools-> Sensor Monitor***

Sensor Monitor can be used as a direct reading of the sensor; the function is mainly used for test purposes.

Select the Optode from the list and press ***Start***, refer Figure 6-6.

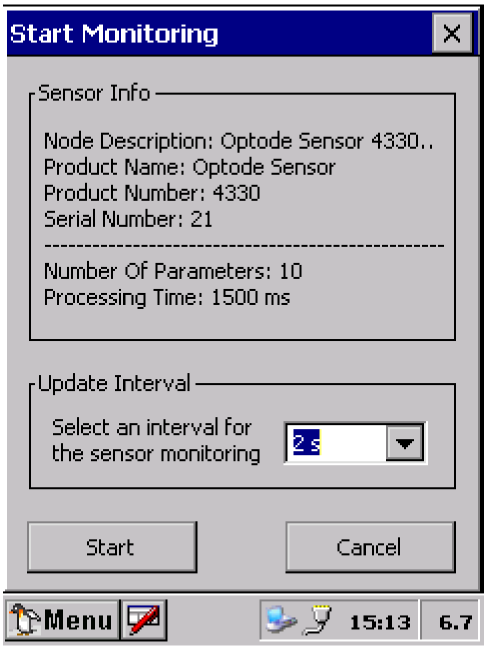


Figure 7-7 Set the Update Interval

The next window shows sensor information like the Node Description, Product name and number, and Serial number, refer Figure 6-7.

The number of sensor parameters and the processing time can be viewed in the window.

Select an ***Update Interval*** for the sensor monitoring. Press ***Start*** to start monitoring the sensor readings.

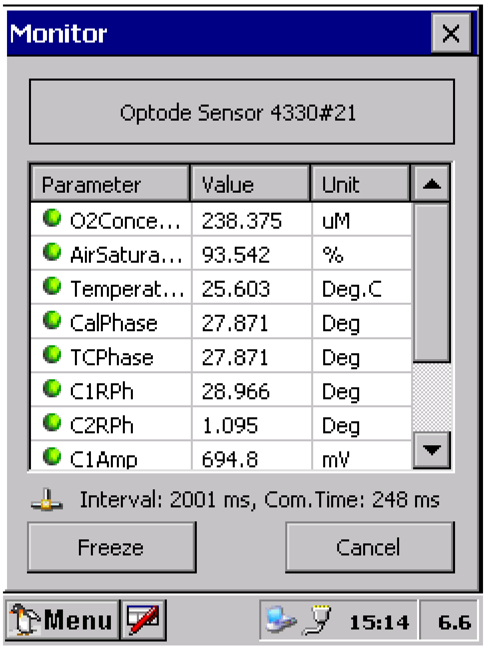


Figure 7-8 Monitor Sensor Readings

The parameter reading in engineering units is shown as illustrated in Figure 6-8. The reading updates according to the update interval.

Press ***Freeze*** to temporarily stop the update; press *Start* to restart monitoring (Start is the same button as Freeze).

Press ***Cancel*** to stop monitoring.

The sensor readings should be according to the description in chapter 6.2 .

Calibration

AADI has discovered that an after-curing occures in the foils during the first 1-3 months after the foil was manufactured which typically leads to 1-4 % lower readings if the sensors are calibrated before the after-curing has stopped. As of today methods are in place to cure all foils before they are mounted on the Optodes and calibrated.

Each batch of sensing foils is delivered with calibration data describing the behaviour with respect to oxygen concentration and temperature. When changing the sensing foil the following 28 coefficients must be updated:

FoilCoeffA$_{0\text{-}13}$

FoilCoeffB$_{0\text{-}13}$

These coefficients are found in the Calibration Certificate for the Sensing Foil 3733/4793, refer enclosed documentation. Refer chapter 6.2.2 for changing foil coefficients.

In addition to the above mentioned coefficient update at a minimum a two point calibration must be done. This calibration compensates for individual sensor and foil variations.

Two controlled oxygen concentrations are relatively easy to obtain, one in air saturated water, and one in a zero-oxygen solution.

An air-saturated solution is obtained by inserting freshwater in a glass and bubble it with a standard aquarium pump. For a more efficient bubbling it is recommended to use an air stone bubble dispenser. The water should be allowed to achieve temperature stability for at least 1 hour. Take care to not have air bubbles on the foil. We recommend the zero oxygen solution to be obtained by preparing another glass of the same water (as for air saturation) and dissolving 5g of sodium sulphite (Na_2SO_3) in 500ml water.

7.2.2 Calibration Procedure using a Terminal Program

NOTE! To obtain the highest accuracy the sensor(s) to be calibrated should be submerged into water at least 24-48 hours prior to the calibration. If a sensor is allowed to dry out this could lead to a bias in the readings of up to 2 %. This effect disappears when the sensor is submerged into the water.

Prepare a suitable container with freshwater. Aerate (apply bubbling) to the water using an ordinary aquarium pump together with an air stone, and let the temperature stabilize (might take hours).

Prepare a zero oxygen solution by dissolving 5 grams of sodium sulphite (Na2SO3) in 500 ml of water. Other substances that remove oxygen can also be used.

NOTE! Stripping of the oxygen with e.g. N_2 gas is also possible, but not recommended, since it is uncertain when and if ever an absolute zero oxygen level is/can be reached using this method.

Connect the sensor to a PC by use of the Sensor Cable 3855 (see above RS232 communication).

Start a terminal program, i.e. the HyperTerminal by Hilgraeve Inc (included in Microsoft operating systems) or Tera Terminal with the following set-up:

9600 Baud

8 Data bits

1 Stop bit

No Parity

Xon/Xoff Flow Control

NOTE! Select one of the options 'Sent line ends with line feeds' or 'Echo line ends with line feeds' in the Hyper Terminal.

Note! If using Tera Terminal Pro, after setting up the com port according to settings above please select "Terminal" in the "Set up" menu and click "Local echo" also select "CR+LF" for both "Receive" and "Transmit" under "New line".

Control, and if necessary update, the *FoilID*, *FoilCoefA*, *FoilCoefB, FoilPolyDegT, FoilPolyDegO* properties accordingly to the Calibration Certificate for the sensing foil in use (refer CHAPTER 5 for communication with the sensor).

Example of changing foil coefficients:

Set Passkey(1000)

Set FoilID(1707)

Set FoilCoefA(1.71404376E-04,3.04290906E-04,-6.39414910E-02,5.14270106E+00,-2.84638794E-02,3.88090809E-05,-1.92200149E+02,1.66135018E+00,-5.18448297E-03,1.22642972E-05,2.89178945E+03,-3.48247963E+01,2.03067907E-01,-1.72740886E-03)

Set FoilCoefB(1.23230336E-05,0,0,0,0,0,0,0,0,0,0,0,0,0)

Set FoilPolyDegT(1,0,0,0,1,2,0,1,2,3,0,1,2,3,4,0,0,0,0,0,0,0,0,0,0,0,0,0)

Set FoilPolyDegO(3,4,3,2,2,2,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0)

Save

Type *Get All* to verify the new coefficients.

Script files for entering the foil coefficients via text terminal programs will be available from the factory.

1. Submerge the Optode into the aerated water. Set the *Interval* property to e.g. 30 seconds. Enter the *save* command and wait until both the temperature and the phase measurements have stabilized:

   Set Passkey(1000)

   Set Interval(30)

   Save

2. Store calibration values by typing:

   Set Passkey(1000)

   Do CollectCalDataSat

   The *save* command is automatically performed when you type *Do* CollectCalDataSat*.*

3. Set the CalDataAPress property to the actual air pressure in hPa at the site.

   Set Passkey(1000)

   Set CalDataAPress (..)

   Save

NOTE! For maximum accuracy do not compensate the air pressure for height above sea level.

Submerge the Optode in the zero solution. ***Make sure that the sensing foil is free from air bubbles***. Wait until both the temperature and the phase measurements have stabilized.

4. Enter the *Do* CollectCalDataZero command to store calibration values. The *save* command is automatically performed.

   Set Passkey(1000)

   Do CollectCalDataZero

5. Enter the *Do Calibrate* command to effectuate the new calibration and store the new coefficients in the sensor memory. The *save* command is automatically performed.

   Set Passkey(1000)

   Do Calibrate

Check that the sensor is working properly by taking it up into the air and rinse off, flush the sensor well to remove all of the Zero Oxygen water to not have cross contamination of your saturated sample. In dry air, the sensor should show close to 100% oxygen saturation at sea level. Put the sensor back into the anoxic water; the reading should drop to zero.

7.3 Sensor Integrated Firmware

The main tasks of the sensor's integrated firmware are to control the transmitter, sample the returned fluorescent signal, extract the phase shift of this signal, and convert it into oxygen concentration and/or Air Saturation value.

All the user configurable properties that can be changed for each individual sensor, i.e. calibration coefficients, are called sensor properties. The properties can be displayed and changed using the Smart Sensor Terminal protocol via an RS232 port, refer CHAPTER 5 for communication with the sensor using a terminal communication program. Examples of typical terminal emulation programs are Hyper Terminal and Tera Term

The Oxygen Optode will perform a measurement sample and present the result within the first 1.5 seconds after the Optode has been powered up.

7.4 Sensor Parameters

Engineering data are calculated by firmware in the sensor based on measured raw data and sets of calibration coefficients stored in the sensor:

- The Oxygen content is presented in µM (1 Molar = 1 mole/litre). Conversions to other commonly used engineering unit values are:
  - 1 ml/l = 44.66 µM, (real gas STP)
  - 1 mg/l = 31.25 µM.

  Please observe that to obtain absolute concentrations of oxygen these values needs to be salinity and pressure compensated (see below).
- The relative Air Saturation is presented in % relative to the nominal air pressure (1013.25 hPa). These values do not need to be salinity compensated.
- The ambient Temperature is presented in ºC.

The optode raw data are the phase and amplitude of the returned signal after the luminophore quenching:

CalPhase(deg):	Calibrated phase
TCPhase(deg):	Temperature compensated phase
C1RPh(deg):	Phase measurement with blue excitation light
C2RPh(deg):	Phase measurement with red excitation light
C1Amp(mV):	Amplitude measurement with blue excitation light
C2Amp(mV):	Amplitude measurement with red excitation light
RawTemp(mV):	Voltage from thermistor bridge.

The 4831 analog channel 1 may be set to output either; µM or %Saturation or CalPhase.

Calibration coefficients are stored in the sensors flash and are updated when recalibrated. If raw data are not needed the user can select to turn off the delivery and logging of these.

7.5 Salinity Compensation of Data

The O_2 concentration sensed by the Optode is the partial pressure of dissolved oxygen in water.

Since the foil is only permeable to gas and not water, the optode cannot sense the effect of salt dissolved in the water, hence the optode always measures as if immersed in fresh water.

If the salinity variation on site is minor (less than ±1ppt), the O_2 concentration can be compensated in real-time inside the sensor by setting the internal property '*Salinity*' to the average salinity at the measuring site.

If the salinity varies significantly, you should simultaneously measure the salinity externally and perform a more accurate correction by a post compensation of the data. An Excel spreadsheet containing the equations for post compensation of the measurements is available for download at the document download site at the Aanderaa Global Library, refer www.aanderaa.com.

If the *Salinity* property in the sensor is set to zero, the compensated O_2 concentration, O_{2c} in *µM*, is calculated from the following equation:

$$O_{2C} = [O_2] \cdot e^{S\left(B_0 + B_1 T_S + B_2 T_S^2 + B_3 T_S^3\right) + C_0 S^2}$$

where:

O_2 is the measured O_2 concentration

S = measured salinity in ppt or PSU

T_s = scaled temperature $= \ln\left[\dfrac{298.15 - t}{273.15 + t}\right]$

t = temperature, °*C*

B_0 = -6.24097e-3 C_0 = -3.11680e-7

B_1 = -6.93498e-3

B_2 = -6.90358e-3

B_3 = -4.29155e-3

If the *Salinity* property in the optode is set to other than zero (zero is the default value), the equation becomes:

$$O_{2C} = [O_2] \cdot e^{(S-S_0)\left(B_0 + B_1 T_S + B_2 T_S^2 + B_3 T_S^3\right) + C_0 (S^2 - S_0{}^2)}$$

Where S_0 is the internal salinity setting.

7.6 Depth Compensation of Data

The response of the sensing foil decreases to some extent with the ambient water pressure (3.2% lower response per 1000 m of water depth or dbar –investigated in detail by Uchida et al., 2008, for full reference see publication list in appendix 11). This effect is the same for all AADI oxygen Optodes and is totally and instantly reversible and easy to compensate for.

The depth compensated O_2 concentration, O_{2c}, is calculated from the following equation:

$$O_{2c} = O_2 \cdot \left(1 + \frac{0.032 \cdot d}{1000}\right)$$

where:

d is depth in meters or pressure in dbar.

O_2 is the measured O_2 concentration in either µM or %.

The unit of the compensated O_2 concentration, O_{2c}, depends on the unit of the O_2 input

NOTE! Depth compensation is not performed within the Optode.

Examples of depth compensation:

At normal atmospheric pressure (1013 mbar) the measured O_2 concentration should not be pressure compensated. As the sensor is submerged you must perform pressure compensation of 0.0032% per dbar or for every meter increase of the relative pressure.

The relative pressure = absolute pressure (measured with the optode) – atmospheric pressure (normally set to 1013 mbar).

Example 1: The measured O_2 concentration with an Optode is 400 µM. The measurement was performed at 1m depth, which is 1dbar relative pressure.

O_{2c}= *400×1.000032= 400.012 µM*

Example 2: The measured O_2 concentration with the Optode is 400 µM. The measurement was performed at 1000m depth, which is 1000dbar relative pressure.

O_{2c}=*400×1.032= 412.8 µM*

Appendix 1 **Theory of Operation**

The Oxygen Optode is based on a principle called dynamic luminescence quenching.

This phenomenon is the ability of certain molecules to influence the fluorescence of other molecules. Fluorescence is the ability of a molecule to absorb light of certain energy and later emit light with lower energy (longer wave length). Such a molecule, called a luminophore, will after absorbing a photon with high enough energy, enter an exited state.

After a while the luminophore will emit a photon of lower energy and return to its initial state. Some types of luminophores might also return to the initial state when colliding with certain other molecules.

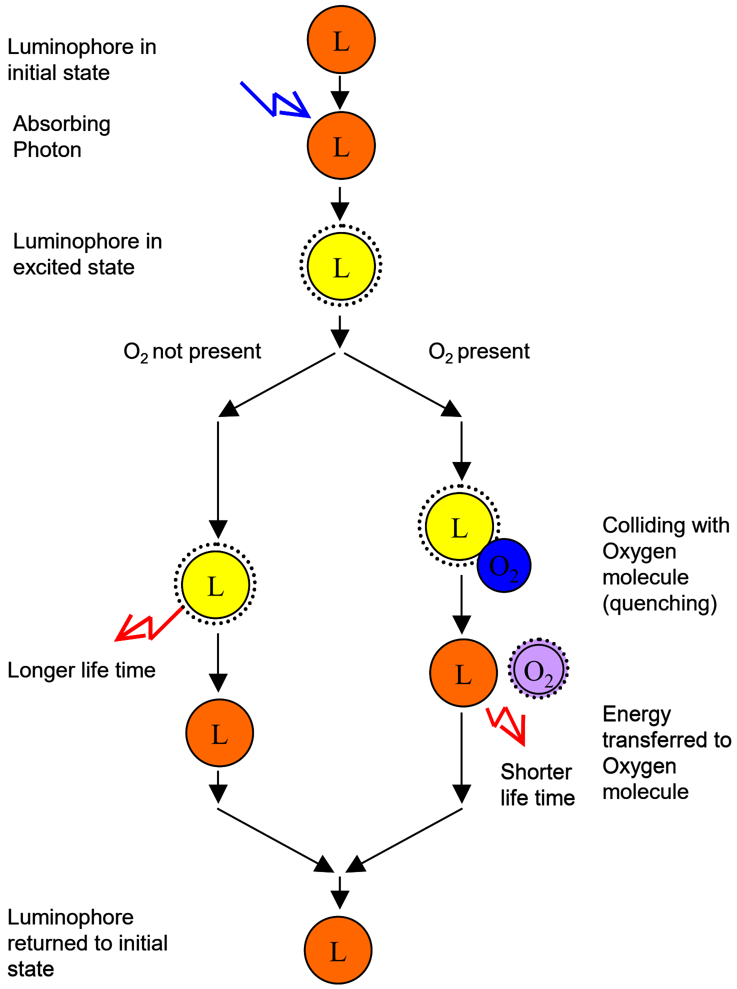


Figure A 1 Dynamic Luminescence Quenching

The luminophore will then transfer parts of its excitation energy to the colliding molecule, with the result that less photons (giving a shorter lifetime) are emitted from the luminophore. This effect is called dynamic luminescence quenching, and in the Oxygen Optode the colliding molecules are O_2.

The luminophore used in the Oxygen Optode is a special molecule called platinum porphyrine. These luminophores are embedded in a polymer layer, called the indicator layer (coated on a thin film of polyester support).

To avoid potential influence from fluorescent material surrounding the sensor or direct incoming sunlight when measuring in the photic zone, the normal monitoring foil is also equipped with a black gas permeable coating.

The coating gives optical isolation between the indicator layer and the surroundings. For faster response time foils also exist without the optical isolation layer, transparent foils, through which the blinking blue and red light can be seen. The transparent foils are only available for 4330 and 4831 optodes.

Sensing

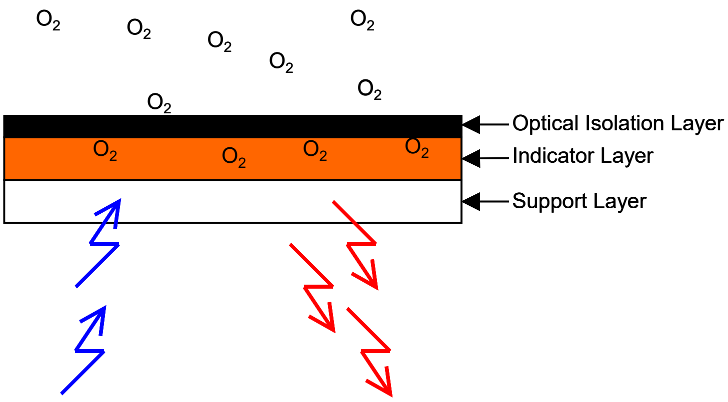


Figure A 2 Foil

Luminescence Decay Time

Due to its fluorescent behaviour the sensing foil will return a red light when it is excited with a blue-green light (505 nm). If there is O_2 present this fluorescent effect will be quenched.

The amount of returned light will therefore depend on the O_2 concentration in the foil.

The intensity of the returned light is however not the optimal property to measure since it depends on many other factors as i.e. optical coupling or bleaching of the foil.

Since the returned light is delayed with respect to the excitation light, the presence of O_2 will also influence the delay.

This property is called luminescence decay time (or lifetime) and it will decrease with increasing O_2concentrations.

The relationship between the O_2 concentration and the luminescence decay time can be described by the Stern-Volmer equation:4

$$[O_2] = \frac{1}{K_{SV}} \left\{ \frac{\tau_0}{\tau} - 1 \right\}$$

where:

τ = decay time

τ_0 = decay time in the absence of O_2

K_{SV} = Stern-Volmer constant (the quenching efficiency)

In order to measure this luminescence decay time, the sensing foil is excited with a blue-green light modulated at 5 kHz.

The decay time is a function of the phase of the received signal.

In the Oxygen Optode the relationship between the phase and the O_2-concentration is used directly, without calculating the decay time.

Figure A 3 shows a typical relationship between the phase measurement and O_2 concentration.

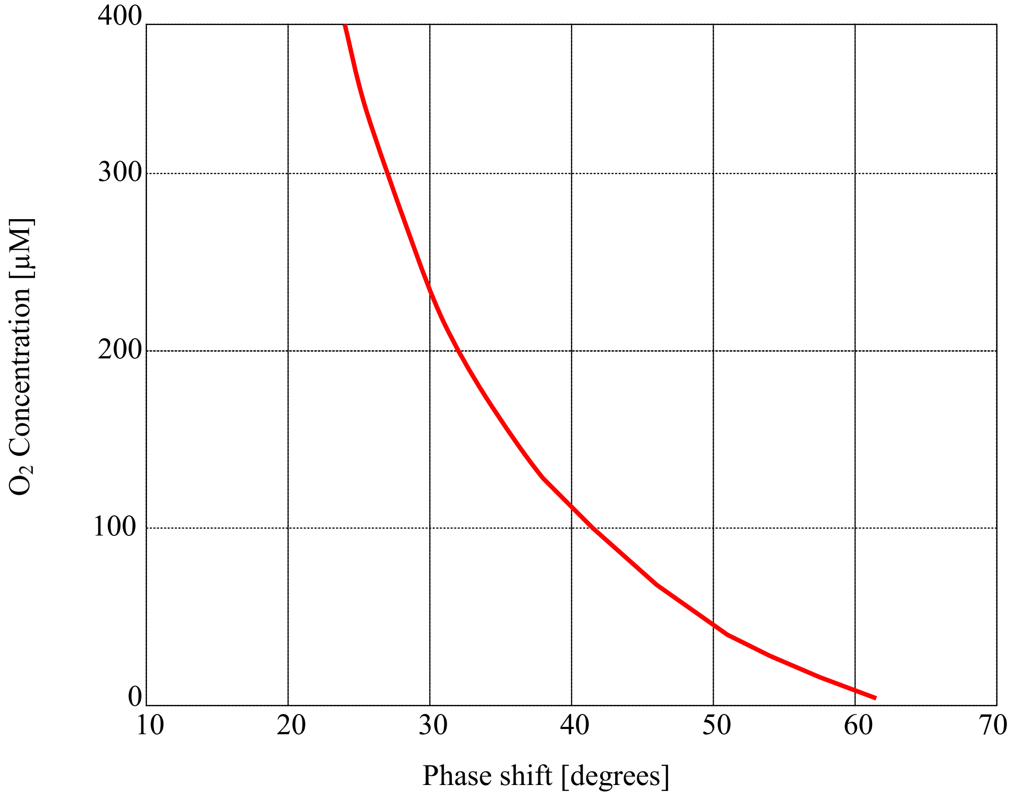


Figure A 3 Typical Phase/O_2 response

Appendix 2 **The Optical Design**

An illustration of the optical design is given in Figure A 4.

The sensing foil is mounted outside the optical window and is exposed to the surrounding water. The foil is held in place by a screw fixed plastic plate.

Two light emitting diodes (LEDs) and one photodiode are placed on the inside of the window. A blue-green LED is used for excitation of the foil. The photodiode is used for sensing the fluorescent light.

Even thought the sensing foil is highly fluorescent parts of the transmitted light will be directly reflected.

The photo diode is equipped with a colour filter that stops light with short wavelengths to minimize the influence of the reflected light. Further, the blue-green LED is equipped with a filter that stops light with long wavelengths.

In addition, a red 'reference' LED is included to compensate for potential drift in the electronics of the transmitter and receiver circuit.

The spectral response of the LEDs and the filter are illustrated in Figure A 5.

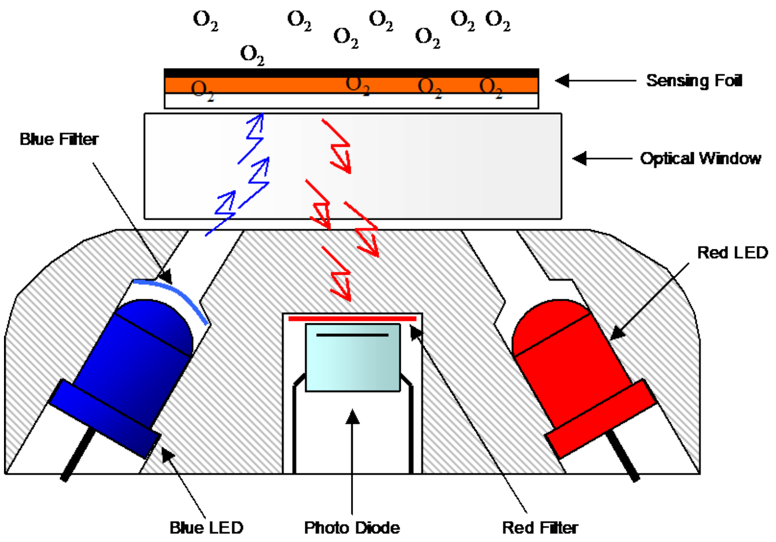


Figure A 4 The Optical Design

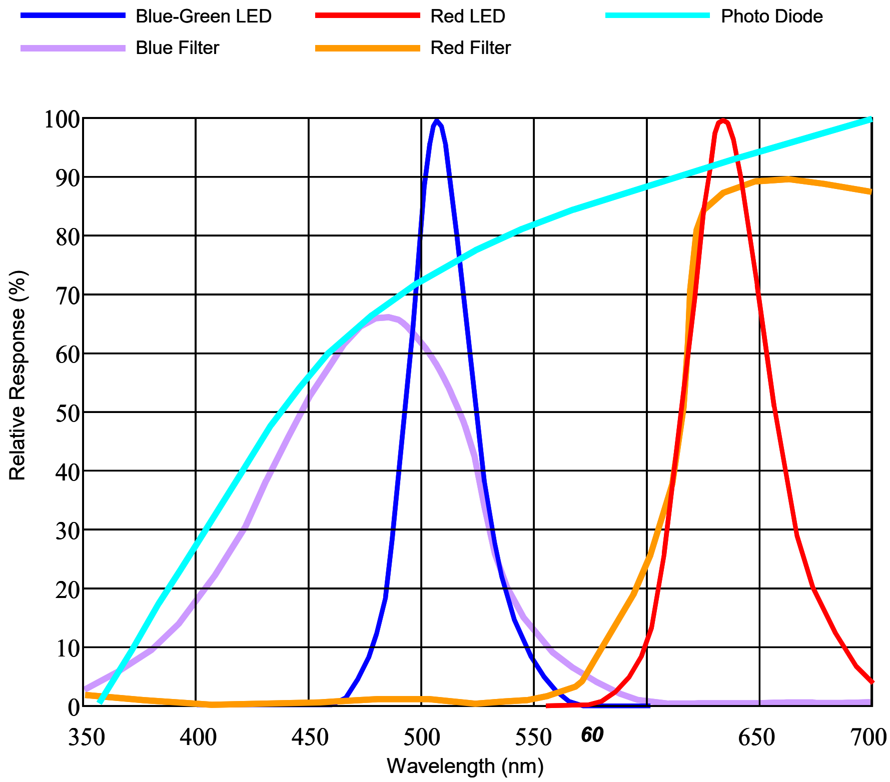


Figure A 5 An example of Spectral Response

Appendix 3 **Electronic Design**

Figure A 6 Functional diagram

Figure A 6 illustrates the main functions of the electronics.

To obtain good oxygen measurements the electronic circuit must be able to measure the phase between the excitation signal and the received signal accurately and with good resolution.

The received signal is sampled with a frequency of four times the excitation frequency. Two signal components with a phase difference of 90 degrees are extracted from these samples and are used for calculations of the phase of the received signal.

The O_2-concentration is calculated after linearizing and temperature compensating the phase measurements.

A thermistor thermally connected to the sensor body, provides temperature measurements.

Appendix 4 **Mechanical Design of Optode 4330, 4831 and 5331**

Figure 1-1 and Figure 1-2 and Figure 1-3 and A8 for illustration of the Oxygen Optode 4330.

A cylindrical titanium housing shields the electronics from the surrounding water and high pressure (pressure resistance for standard sensor is 6000 m. These sensors do also exist in a special 12 000 m rated version 5331).

A 4mm thick sapphire window provides the optical connection between the optics inside the Optode and the sensing foil on the outside.

The foil is fixed to the window by a POM securing plate and is easily replaceable.

For the 4330 a 10-pin receptacle in the sensor foot provides all electrical connection to the sensor.

To prevent potential leakage from the sensor to the rest of the measurement system, the receptacle is moulded inside a receptacle housing.

For the 4831 the receptacle is an 8 pin Subconn **MCBH8M** wet-mate connector.

For the 4831U the receptacle is a 6 pin Subconn **MCBH6M** wet-mate connector.

For the 5331 the receptacle is an 8 pin Subconn **MCBH8M** wet-mate connector.

For the 5331H the receptacle is a 10 pin Subconn **MCBH10M** wet-mate connector.

Note! The sensor should not be opened! Opening the sensor housing can breach the warranty (ref. CHAPTER 6 , page 37 for instructions on how to change the Sensing Foil).

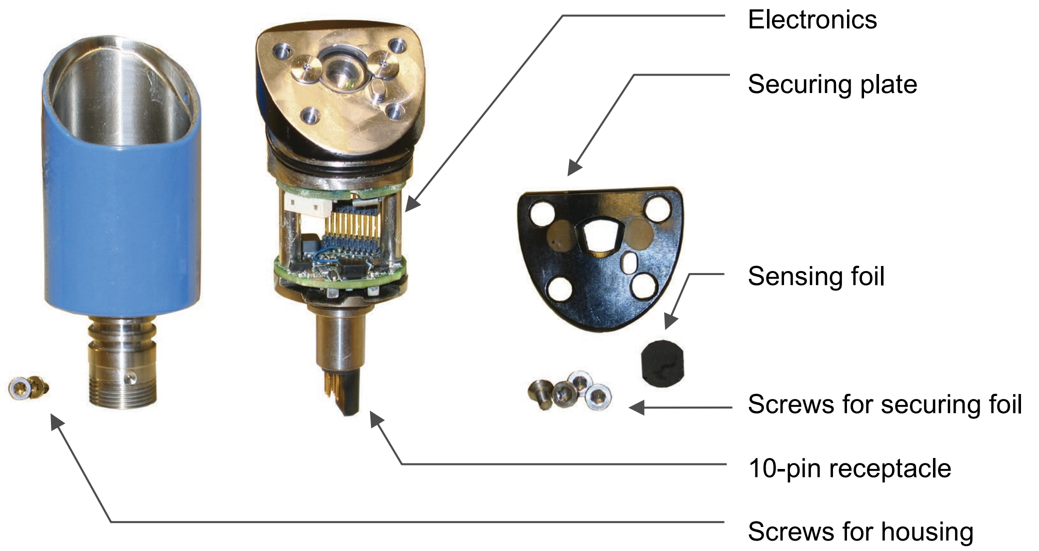


Figure A 7 Oxygen Optode 4330 components.

Appendix 5 **Mechanical Design of Optode 4835**

Refer Figure 1-3 and Figure A 8 for illustration of the Oxygen Optode 4835. A cylindrical polymer housing shields the electronics from the surrounding water (pressure rated to 300 m).

A 4mm thick sapphire window provides the optical connection between the optics inside the Optode and the sensing foil on the outside. The foil is fixed to the window by a POM securing plate and is easily replaceable.

A 10-pin receptacle in the sensor foot provides all electrical connection to the sensor. To prevent potential leakage from the sensor to the rest of the measurement system, the receptacle is moulded inside a receptacle housing.

Refer CHAPTER 6 for instructions concerning changing the Sensing Foil.

Note! The sensor should not be opened! Opening the sensor housing can breach the warranty (ref. CHAPTER 6 , page 39 for instructions on how to change the Sensing Foil).

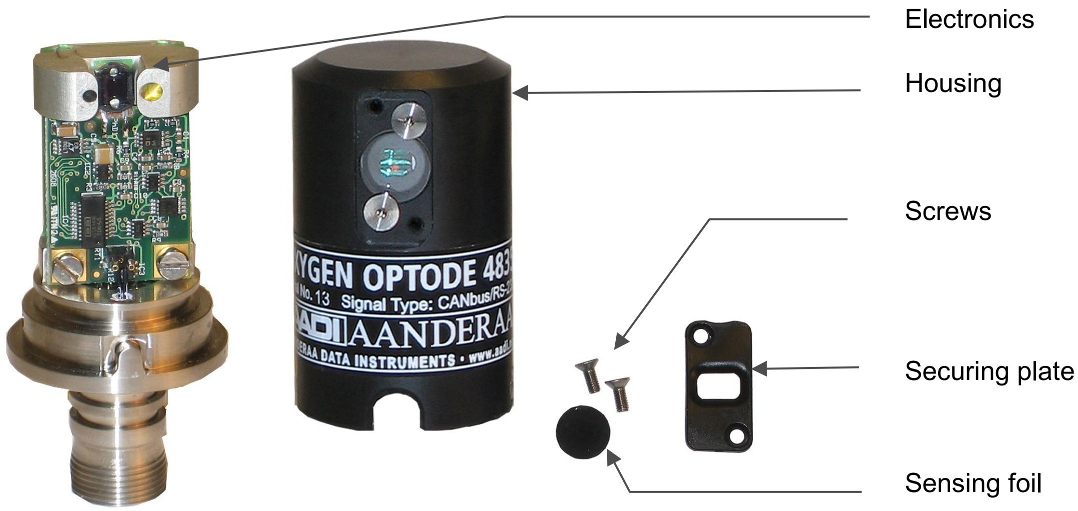


Figure A 8 Oxygen Optode 4835 components.

Appendix 6 **Primer –Oxygen Calculations in the Sensor**

The Optode normally excites the foil with both blue and red light. Since the red light does not produce any fluorescence in the sensing foil the phase obtained in this measurement is used as a reference in the system. After collecting the raw data the difference between the phase obtained with blue (C1Phase) and red light (C2Phase) excitation is calculated as:

$$TPhase = A(t) + (C1Phase - C2Phase) \cdot B(t)$$

The A(t) and B(t) are 3rd order temperature dependent polynomials that provides for a possibility for temperature compensation of the phase measurement. Normally this option is not used and A(t)=0, B(t)=1. Coefficients for A and B are held in the properties called PTC0Coef and PTC1Coef respectively.

Subsequently the CalPhase is calculated as:

$$CalPhase = PhaseCoef_0 + PhaseCoef_1 \cdot TPhase + PhaseCoef_2 \cdot TPhase^2 + PhaseCoef_3 \cdot TPhase^3$$

For older Optodes (serial number less than 1000) the first two coefficients where adjusted during a 2-point calibration. For newer optodes these coefficients are used for factory adjustments of the phase measurement.

The temperature in °C is calculated from raw data (RawTemp) by use of a polynomial similar to the above with coefficients stored in the TempCoef property.

Based on the calibrated phase (CalPhase) and temperature (Temperature) the partial pressure of O_2 is calculated by use of a two dimensional polynomial:

$$\Delta p = C_0 \cdot t^{m_0} \cdot ph^{n_0} + C_1 \cdot t^{m_1} \cdot ph^{n_1} + C_2 \cdot t^{m_2} \cdot ph^{n_2} + ... + C_{27} \cdot t^{m_{27}} \cdot ph^{n_{27}}$$

where the polynomial coefficients C_0 to C_{13} are stored in the property *FoilCoefA* and C_{14} to C_{27} are stored in *FoilCoefB*. The temperature exponents, $m_{0..27}$, are stored as *FoilPolyDegT* and phase exponents, $n_{0..27}$, are stored as *FoilPolyDegO*.

From the partial pressure the air saturation is then calculated as:

$$AirSaturation(\%) = \frac{\Delta p \cdot 100}{[NomAirPress - p_{vapour}(t)] \cdot NomAirMix}$$

where *NomAirPress* is a property for the nominal air pressure, usually 1013.25 hPa, and *NomAirMix* is the nominal O2 content in air, by default 0.20946.

The $p_{vapour}(t)$ is the vapour pressure calculated from temperature by the following equation:

$$p_{vapour}(t) = e^{\left(52.57 - \frac{6690.9}{t+273.15} - 4.681 * \ln(t+273.15)\right)}$$

If the property *Enable HumidityComp* is set 'No' the $p_{vapour}(t)$ will be set to zero.

The oxygen concentration is finally calculated as:

$$O2Concentration(\mu M) = \frac{C^* \cdot 44.659 \cdot AirSaturation}{100}$$

where C^* is the oxygen solubility (cm^3/dm^3) calculated from the Garcia and Gordon equation of 1992:

$$\begin{aligned}&\ln(C^*) = \\ &A_0 + A_1T_S + A_2T_S^2 + A_3T_S^3 + A_4T_S^4 + A_5T_S^5 \\ &+ S(B_0 + B_1T_S + B_2T_S^2 + B_3T_S^3) + C_0S^2\end{aligned}$$

where:

T_s = scaled temperature

$$= \ln\left[\frac{298.15 - t}{273.15 + t}\right]$$

t = Temperature, °*C*

S = *Salinity* (configurable property, default set to zero)

A_0 = 2.00856	B_0 = -6.24097e-3
A_1 = 3.22400	B_1 = -6.93498e-3
A_2 = 3.99063	B_2 = -6.90358e-3
A_3 = 4.80299	B_3 = -4.29155e-3
A_4 = 9.78188e-1	C_0 = -3.11680e-7
A_5 = 1.71069	

By nature the relationship between the phase shift and oxygen concentration should follow Stern-Volmer relationship. The above formula is a general two dimensional polynomial with a flexible degree and was introduced since the basic Stern-Volmer did not provide satisfactory curve fit. In Uchida et al., 2008 a modified Stern-Volmer function was suggested:

$$[\mathbf{O_2}]' = \frac{\left(\frac{\mathbf{P_0}}{\mathbf{P_c}} - \mathbf{1}\right)}{\mathbf{K_{SV}}}$$

and:

$$K_{SV} = c_0 + c_1t + c_1t^2$$

$$P_0 = c_3 + c_4t$$

$$P_c = c_5 + c_6P_r$$

where t is temperature (°C) and P_r is the raw phase shift reading (CalPhase)

Later it has been shown by Craig Neill (CSIRO) that this formula generally performs better with respect to interpolation between calibration points and extrapolation outside the calibration range. Based on this and recommendation from the Argo oxygen meeting in Brest 2011 the above formula has been implemented in the Optode firmware (serial no. 1000 and above).

In order to use the "Stern-Volmer-Uchida" formula the property called *Enable SVUformula* must be set to 'yes'. The coefficients c_0 to c_6 are stored in the *SVUFoilCoef* property.

A possibility for linear correction of the O_2 concentration was also introduced:

$$\mathbf{O2Concentration[uM] = ConcCoef_0 + ConcCoef_1[O_2]'}$$

For new Optodes (serial no. 1000 and above) the two-point calibration procedure (ref Calibration Procedure chapter 6.2.2) will adjust the *ConcCoef* coefficients.

Appendix 7 **Multipoint Calibration**

The standard calibration for the oxygen Optodes is based on a common characterization of a production batch of sensing foils with an additional two-point adjustment for individual Optodes and foils.

For application demanding higher accuracy an individual multipoint calibration is available. The Optodes are then placed in a temperature regulated bath where the oxygen saturation is changed by diffusing different mixtures of O2 and N2 into the water. The gas mixture is controlled by use of high accuracy Mass Flow Controllers. The water is stirred vigorously to provide homogeneity and oxygen concentration is referenced to three reference sensors that are calibrated with respect to high quality Winkler titrations. For a standard multipoint calibration the oxygen is changed from 0 to 120% air saturation in 10 steps, and temperature from 1 to 30 °C in 4 steps, resulting in 40 individual calibration points. Based on these data 7 coefficients (c0 to c6) in the modified Stern-Volmer formula derived by Uchida et al, 2008 [17] is calculated:

$$[\mathbf{O_2}]' = \frac{\left(\frac{\mathbf{P_0}}{\mathbf{P_c}} - \mathbf{1}\right)}{\mathbf{K_{SV}}}$$

and:

$$K_{SV} = c_0 + c_1 t + c_2 t^2$$

$$P_0 = c_3 + c_4 t$$

$$P_c = c_5 + c_6 P_r$$

where *t* is temperature (°C) and P_r is the raw phase shift reading (CalPhase)

After the calibration sequence the performance of all sensors are verified in 20 points covering the complete calibration range.

Note that the multipoint calibration is only available for the 4330 and 4831 Optode and that in order to enable of use of the above formula the property called *Enable SVUformula* must be set to “yes” (requires firmware version 4.4.8 or higher).

Appendix 8 **Illustrations**

Figure no.	Description
Figure A 9	Drawing Cable 4865
Figure A 10	Drawing Cable 3855
Figure A 11	Drawing Cable 5335
Figure A 12	Drawing Cable 4762
Figure A 13	Drawing Cable 4793

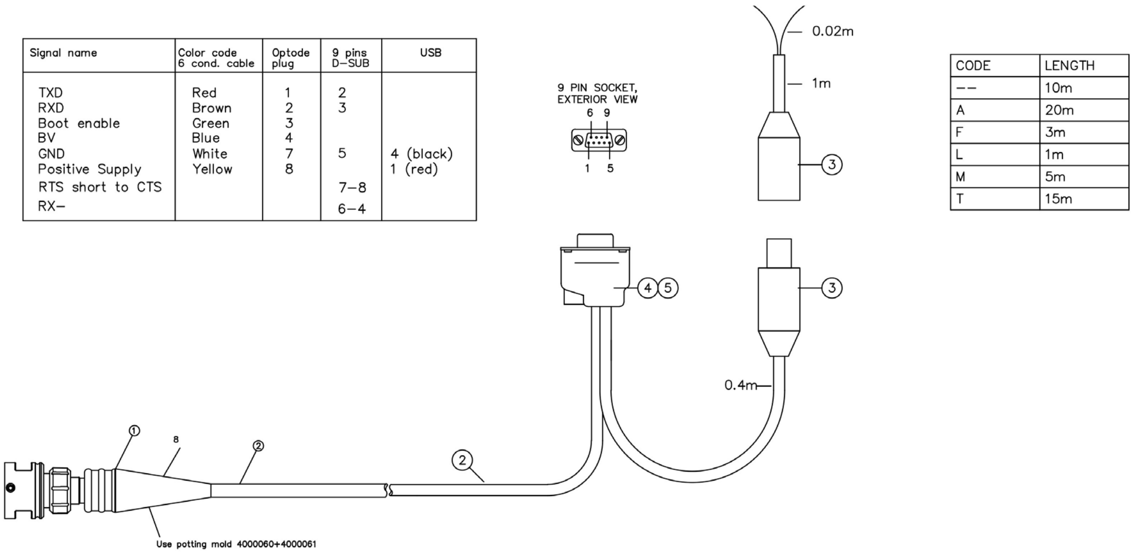
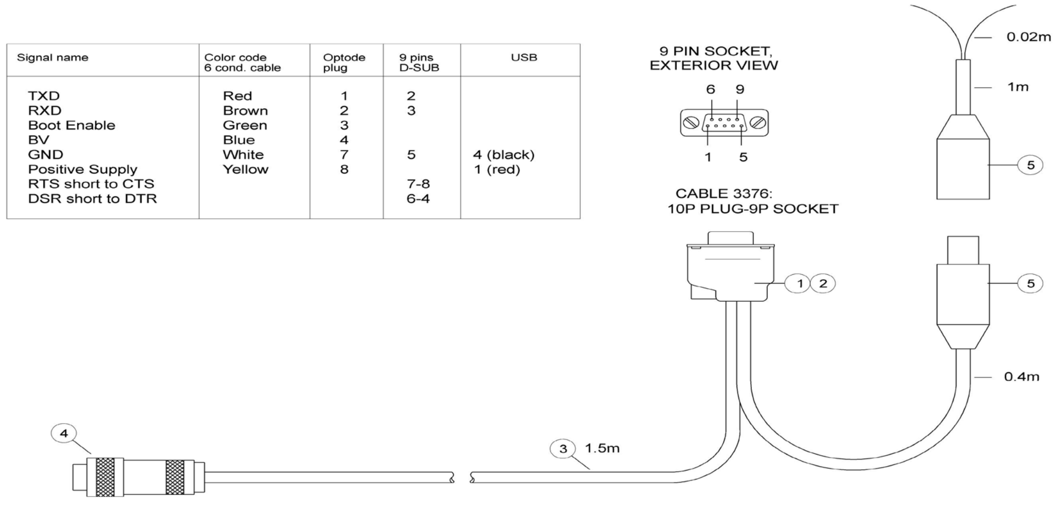
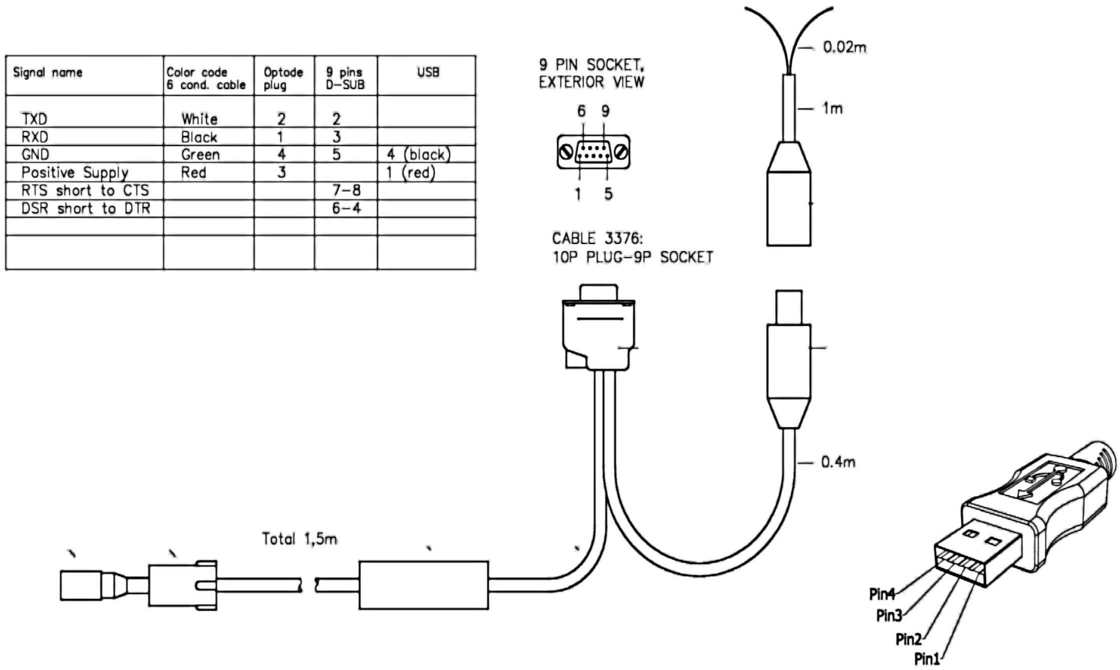


Figure A 9 Drawing Cable 4865.



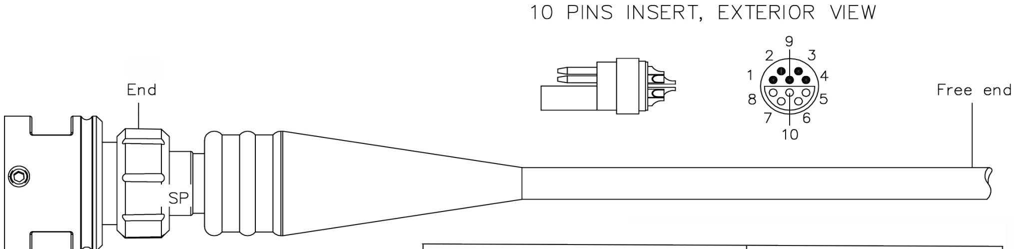
Signal name	Color code 6 cond. cable	Optode plug	9 pins D-SUB	USB
TXD	Red	1	2	
RXD	Brown	2	3	
Boot Enable	Green	3		
BV	Blue	4		
GND	White	7	5	4 (black)
Positive Supply	Yellow	8		1 (red)
RTS short to CTS			7-8	
DSR short to DTR			6-4	

Figure A 10 Drawing Cable 3855.



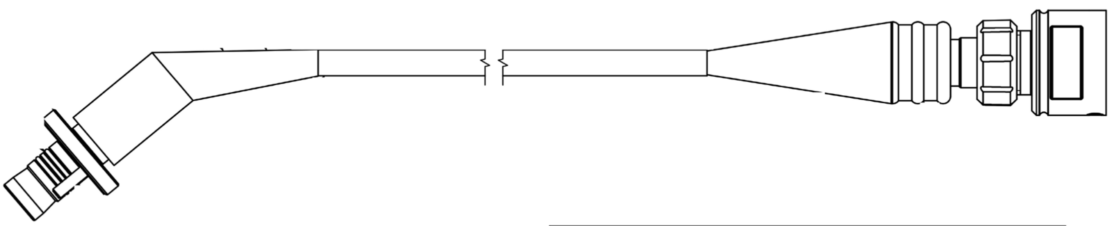
Signal name	Color code 6 cond. cable	Optode plug	9 pins D-SUB	USB
TXD	White	2	2	
RXD	Black	1	3	
GND	Green	4	5	4 (black)
Positive Supply	Red	3		1 (red)
RTS short to CTS			7-8	
DSR short to DTR			6-4	

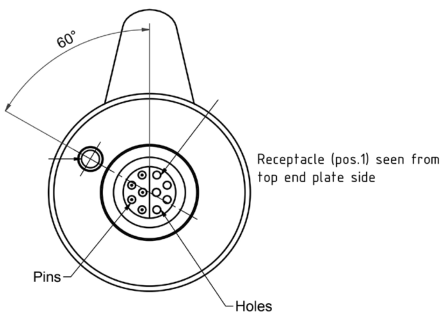
Figure A 11 Drawing Cable 5335



Signal name		SP End	
Analog	**RS-232+ DigOut**	**Lemo pin no.**	**Color**
TXD	TXD	1	Grey
RXD	RXD	2	Brown
Analog 2Gnd	Not used	3	Yellow
Analog 2	Not used	4	Purple
Analog 1Gnd	Not used	5	Blue
Analog 1	DigOut Gnd	6	White
GND	GND	7	Black
Positive Supply	Positive Suppkly	8	Green
Not used	Not used	9	Orange
Not used	DigOut	10	Red

Figure A 12 Drawing Free end Cable 4762





Wiring			
CSP Side (7-14)	Receptacle Side (1)	Function	Colour code
8	1	Positive supply	White 1+2
7	2	Gnd	White 3+4
5	4	CAN_H	(1.pair) White/blue
9	10	CAN_L	(1.pair) Blue
4	5	NCE	(2.pair) White/orange
6	3	NCG_1	(2.pair) Orange
10	9	NCR	(3.pair) White/green
6	3	NCG_2	(3.pair) Green

Figure A 13 Drawing Cable 4793

Appendix 9 **Oxygen Dynamics in Water**

Seawater and Gases

Refer Unisense AS for tabulated physical parameters of interest to those working with micro sensors in marine systems:

http://www.unisense.com/Default.aspx?ID=1109

Tables

Refer Unisense AS for Gas tables with diffusion coefficients, solubility of oxygen in seawater, density of water versus temperature and salinity, and much more:

http://www.unisense.com/files/PDF/Diverse/Seawater%20&%20Gases%20table.pdf

Copies of Unisense AS tables for *solubility of oxygen in seawater* are given in Figure A , Figure A , and Figure A .

NOTE! Refer Unisens AS for more information about the tables.

Oxygen solubility at different temperatures and salinities of seawater
Units: µmol/l

Salinity	Temperature (°C)																			
(‰)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
0.0	456.6	444.0	431.9	420.4	409.4	398.9	388.8	379.2	369.9	361.1	352.6	344.4	336.6	329.1	321.9	314.9	308.3	301.8	295.6	289.7	283.9
1.0	453.5	441.0	429.0	417.6	406.7	396.3	386.3	376.7	367.6	358.8	350.4	342.3	334.5	327.1	319.9	313.0	306.4	300.0	293.9	287.9	282.2
2.0	450.4	438.0	426.1	414.8	404.0	393.6	383.7	374.3	365.2	356.5	348.1	340.1	332.4	325.0	317.9	311.1	304.5	298.2	292.1	286.2	280.6
3.0	447.3	435.0	423.2	412.0	401.3	391.0	381.2	371.8	362.8	354.2	345.9	338.0	330.4	323.0	316.0	309.2	302.7	296.4	290.4	284.5	278.9
4.0	444.2	432.0	420.4	409.2	398.6	388.5	378.7	369.4	360.5	351.9	343.7	335.9	328.3	321.0	314.0	307.3	300.9	294.6	288.6	282.9	277.3
5.0	441.1	429.1	417.5	406.5	396.0	385.9	376.3	367.0	358.2	349.7	341.6	333.7	326.2	319.0	312.1	305.5	299.0	292.9	286.9	281.2	275.7
6.0	438.1	426.1	414.7	403.8	393.3	383.3	373.8	364.6	355.9	347.5	339.4	331.6	324.2	317.1	310.2	303.6	297.2	291.1	285.2	279.5	274.0
7.0	435.1	423.2	411.9	401.1	390.7	380.8	371.3	362.3	353.6	345.2	337.2	329.6	322.2	315.1	308.3	301.7	295.4	289.4	283.5	277.9	272.4
8.0	432.1	420.3	409.1	398.4	388.1	378.3	368.9	359.9	351.3	343.0	335.1	327.5	320.2	313.1	306.4	299.9	293.6	287.6	281.8	276.2	270.8
9.0	429.1	417.5	406.3	395.7	385.5	375.8	366.5	357.6	349.0	340.8	333.0	325.4	318.2	311.2	304.5	298.1	291.9	285.9	280.1	274.6	269.2
10.0	426.1	414.6	403.6	393.0	383.0	373.3	364.1	355.2	346.8	338.6	330.8	323.4	316.2	309.3	302.6	296.2	290.1	284.2	278.5	273.0	267.6
11.0	423.2	411.8	400.8	390.4	380.4	370.8	361.7	352.9	344.5	336.5	328.7	321.3	314.2	307.3	300.8	294.4	288.3	282.5	276.8	271.3	266.1
12.0	420.3	409.0	398.1	387.8	377.9	368.4	359.3	350.6	342.3	334.3	326.7	319.3	312.2	305.4	298.9	292.6	286.6	280.8	275.1	269.7	264.5
13.0	417.4	406.2	395.4	385.2	375.3	366.0	357.0	348.3	340.1	332.2	324.6	317.3	310.3	303.5	297.1	290.8	284.8	279.1	273.5	268.1	262.9
14.0	414.5	403.4	392.7	382.6	372.8	363.5	354.6	346.1	337.9	330.0	322.5	315.3	308.3	301.7	295.2	289.1	283.1	277.4	271.9	266.5	261.4
15.0	411.7	400.6	390.1	380.0	370.4	361.1	352.3	343.8	335.7	327.9	320.5	313.3	306.4	299.8	293.4	287.3	281.4	275.7	270.2	265.0	259.9
16.0	408.8	397.9	387.4	377.4	367.9	358.7	350.0	341.6	333.5	325.8	318.4	311.3	304.5	297.9	291.6	285.5	279.7	274.0	268.6	263.4	258.3
17.0	406.0	395.2	384.8	374.9	365.4	356.4	347.7	339.4	331.4	323.7	316.4	309.4	302.6	296.1	289.8	283.8	278.0	272.4	267.0	261.8	256.8
18.0	403.2	392.5	382.2	372.4	363.0	354.0	345.4	337.2	329.2	321.7	314.4	307.4	300.7	294.2	288.0	282.1	276.3	270.8	265.4	260.3	255.3
19.0	400.4	389.8	379.6	369.9	360.6	351.7	343.1	335.0	327.1	319.6	312.4	305.5	298.8	292.4	286.3	280.3	274.6	269.1	263.8	258.7	253.8
20.0	397.7	387.1	377.0	367.4	358.2	349.3	340.9	332.8	325.0	317.6	310.4	303.5	296.9	290.6	284.5	278.6	273.0	267.5	262.3	257.2	252.3
21.0	394.9	384.5	374.5	364.9	355.8	347.0	338.6	330.6	322.9	315.5	308.4	301.6	295.1	288.8	282.7	276.9	271.3	265.9	260.7	255.7	250.8
22.0	392.2	381.8	371.9	362.4	353.4	344.7	336.4	328.5	320.8	313.5	306.5	299.7	293.2	287.0	281.0	275.2	269.7	264.3	259.1	254.1	249.3
23.0	389.5	379.2	369.4	360.0	351.0	342.4	334.2	326.3	318.7	311.5	304.5	297.8	291.4	285.2	279.3	273.5	268.0	262.7	257.6	252.6	247.9
24.0	386.8	376.6	366.9	357.6	348.7	340.2	332.0	324.2	316.7	309.5	302.6	295.9	289.6	283.4	277.5	271.9	266.4	261.1	256.0	251.1	246.4
25.0	384.1	374.0	364.4	355.2	346.4	337.9	329.8	322.1	314.6	307.5	300.7	294.1	287.8	281.7	275.8	270.2	264.8	259.5	254.5	249.6	244.9
26.0	381.5	371.5	361.9	352.8	344.0	335.7	327.7	320.0	312.6	305.5	298.7	292.2	285.9	279.9	274.1	268.5	263.2	258.0	253.0	248.2	243.5
27.0	378.8	368.9	359.5	350.4	341.7	333.4	325.5	317.9	310.6	303.6	296.8	290.4	284.2	278.2	272.4	266.9	261.6	256.4	251.5	246.7	242.1
28.0	376.2	366.4	357.0	348.0	339.5	331.2	323.4	315.8	308.6	301.6	294.9	288.5	282.4	276.5	270.7	265.3	260.0	254.9	250.0	245.2	240.6
29.0	373.6	363.9	354.6	345.7	337.2	329.0	321.2	313.8	306.6	299.7	293.1	286.7	280.6	274.7	269.1	263.6	258.4	253.3	248.5	243.8	239.2
30.0	371.0	361.4	352.2	343.4	334.9	326.9	319.1	311.7	304.6	297.8	291.2	284.9	278.8	273.0	267.4	262.0	256.8	251.8	247.0	242.3	237.8
31.0	368.5	358.9	349.8	341.1	332.7	324.7	317.0	309.7	302.6	295.9	289.3	283.1	277.1	271.3	265.8	260.4	255.3	250.3	245.5	240.9	236.4
32.0	365.9	356.5	347.4	338.8	330.5	322.5	314.9	307.7	300.7	294.0	287.5	281.3	275.4	269.6	264.1	258.8	253.7	248.8	244.0	239.4	235.0
33.0	363.4	354.0	345.1	336.5	328.3	320.4	312.9	305.6	298.7	292.1	285.7	279.5	273.6	268.0	262.5	257.2	252.2	247.3	242.6	238.0	233.6
34.0	360.9	351.6	342.7	334.2	326.1	318.3	310.8	303.7	296.8	290.2	283.9	277.8	271.9	266.3	260.9	255.7	250.6	245.8	241.1	236.6	232.2
35.0	358.4	349.2	340.4	332.0	323.9	316.2	308.8	301.7	294.9	288.3	282.0	276.0	270.2	264.6	259.3	254.1	249.1	244.3	239.7	235.2	230.9
36.0	355.9	346.8	338.1	329.7	321.7	314.1	306.7	299.7	293.0	286.5	280.3	274.3	268.5	263.0	257.7	252.5	247.6	242.8	238.2	233.8	229.5
37.0	353.5	344.4	335.8	327.5	319.6	312.0	304.7	297.7	291.1	284.6	278.5	272.5	266.8	261.4	256.1	251.0	246.1	241.4	236.8	232.4	228.2
38.0	351.0	342.0	333.5	325.3	317.4	309.9	302.7	295.8	289.2	282.8	276.7	270.8	265.2	259.7	254.5	249.5	244.6	239.9	235.4	231.0	226.8
39.0	348.6	339.7	331.2	323.1	315.3	307.9	300.7	293.9	287.3	281.0	274.9	269.1	263.5	258.1	252.9	247.9	243.1	238.5	234.0	229.7	225.5
40.0	346.2	337.4	329.0	320.9	313.2	305.8	298.7	292.0	285.4	279.2	273.2	267.4	261.8	256.5	251.4	246.4	241.6	237.0	232.6	228.3	224.1

Figure A 17 Copy of Data Table 6 by Niels Ramsing and Jens Gundersen: 100% Oxygen Solubility @ 1013 mbar pressure

Oxygen solubility at different temperatures and salinities of seawater

Units:µmol/l

Salinity (‰)	Temperature (°C) 20.0	21.0	22.0	23.0	24.0	25.0	26.0	27.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0
0.0	283.9	278.3	273.0	267.8	262.8	257.9	253.2	248.7	244.3	240.0	235.9	231.9	228.0	224.2	220.5	217.0	213.5	210.1	206.7	203.5	200.4
1.0	282.2	276.7	271.4	266.3	261.3	256.5	251.8	247.3	243.0	238.7	234.6	230.6	226.8	223.0	219.4	215.8	212.3	209.0	205.7	202.5	199.3
2.0	280.6	275.1	269.8	264.7	259.8	255.0	250.4	245.9	241.6	237.4	233.3	229.4	225.6	221.8	218.2	214.7	211.2	207.9	204.6	201.4	198.3
3.0	278.9	273.5	268.3	263.2	258.3	253.6	249.0	244.6	240.3	236.1	232.1	228.1	224.3	220.6	217.0	213.5	210.1	206.8	203.6	200.4	197.3
4.0	277.3	271.9	266.7	261.7	256.8	252.1	247.6	243.2	238.9	234.8	230.8	226.9	223.1	219.5	215.9	212.4	209.0	205.7	202.5	199.4	196.3
5.0	275.7	270.3	265.2	260.2	255.4	250.7	246.2	241.8	237.6	233.5	229.5	225.7	221.9	218.3	214.7	211.3	207.9	204.6	201.4	198.3	195.3
6.0	274.0	268.7	263.6	258.7	253.9	249.3	244.8	240.5	236.3	232.2	228.3	224.4	220.7	217.1	213.6	210.2	206.8	203.6	200.4	197.3	194.3
7.0	272.4	267.2	262.1	257.2	252.5	247.9	243.4	239.1	235.0	230.9	227.0	223.2	219.5	215.9	212.4	209.0	205.7	202.5	199.4	196.3	193.3
8.0	270.8	265.6	260.6	255.7	251.0	246.5	242.1	237.8	233.7	229.7	225.8	222.0	218.3	214.8	211.3	207.9	204.7	201.5	198.3	195.3	192.3
9.0	269.2	264.1	259.1	254.2	249.6	245.1	240.7	236.5	232.4	228.4	224.5	220.8	217.2	213.6	210.2	206.8	203.6	200.4	197.3	194.3	191.3
10.0	267.6	262.5	257.6	252.8	248.2	243.7	239.4	235.2	231.1	227.1	223.3	219.6	216.0	212.5	209.1	205.7	202.5	199.4	196.3	193.3	190.3
11.0	266.1	261.0	256.1	251.3	246.7	242.3	238.0	233.8	229.8	225.9	222.1	218.4	214.8	211.3	208.0	204.7	201.4	198.3	195.3	192.3	189.4
12.0	264.5	259.5	254.6	249.9	245.3	240.9	236.7	232.5	228.5	224.6	220.9	217.2	213.7	210.2	206.8	203.6	200.4	197.3	194.2	191.3	188.4
13.0	262.9	257.9	253.1	248.4	243.9	239.6	235.3	231.2	227.3	223.4	219.7	216.0	212.5	209.1	205.7	202.5	199.3	196.2	193.2	190.3	187.4
14.0	261.4	256.4	251.6	247.0	242.5	238.2	234.0	229.9	226.0	222.2	218.5	214.9	211.4	208.0	204.6	201.4	198.3	195.2	192.2	189.3	186.5
15.0	259.9	254.9	250.2	245.6	241.1	236.8	232.7	228.6	224.7	220.9	217.3	213.7	210.2	206.8	203.6	200.4	197.2	194.2	191.2	188.3	185.5
16.0	258.3	253.4	248.7	244.2	239.8	235.5	231.4	227.4	223.5	219.7	216.1	212.5	209.1	205.7	202.5	199.3	196.2	193.2	190.2	187.4	184.6
17.0	256.8	252.0	247.3	242.8	238.4	234.2	230.1	226.1	222.2	218.5	214.9	211.4	208.0	204.6	201.4	198.2	195.2	192.2	189.3	186.4	183.6
18.0	255.3	250.5	245.9	241.4	237.0	232.8	228.8	224.8	221.0	217.3	213.7	210.2	206.8	203.5	200.3	197.2	194.1	191.2	188.3	185.4	182.7
19.0	253.8	249.0	244.4	240.0	235.7	231.5	227.5	223.6	219.8	216.1	212.5	209.1	205.7	202.4	199.2	196.1	193.1	190.2	187.3	184.5	181.7
20.0	252.3	247.6	243.0	238.6	234.3	230.2	226.2	222.3	218.6	214.9	211.4	207.9	204.6	201.3	198.2	195.1	192.1	189.2	186.3	183.5	180.8
21.0	250.8	246.1	241.6	237.2	233.0	228.9	224.9	221.1	217.3	213.7	210.2	206.8	203.5	200.3	197.1	194.1	191.1	188.2	185.4	182.6	179.9
22.0	249.3	244.7	240.2	235.8	231.7	227.6	223.6	219.8	216.1	212.5	209.1	205.7	202.4	199.2	196.1	193.0	190.1	187.2	184.4	181.6	179.0
23.0	247.9	243.2	238.8	234.5	230.3	226.3	222.4	218.6	214.9	211.4	207.9	204.6	201.3	198.1	195.0	192.0	189.1	186.2	183.4	180.7	178.0
24.0	246.4	241.8	237.4	233.1	229.0	225.0	221.1	217.4	213.7	210.2	206.8	203.4	200.2	197.1	194.0	191.0	188.1	185.2	182.5	179.8	177.1
25.0	244.9	240.4	236.0	231.8	227.7	223.7	219.9	216.2	212.5	209.0	205.6	202.3	199.1	196.0	193.0	190.0	187.1	184.3	181.5	178.8	176.2
26.0	243.5	239.0	234.7	230.5	226.4	222.5	218.6	214.9	211.4	207.9	204.5	201.2	198.0	194.9	191.9	189.0	186.1	183.3	180.6	177.9	175.3
27.0	242.1	237.6	233.3	229.1	225.1	221.2	217.4	213.7	210.2	206.7	203.4	200.1	197.0	193.9	190.9	188.0	185.1	182.4	179.6	177.0	174.4
28.0	240.6	236.2	231.9	227.8	223.8	219.9	216.2	212.5	209.0	205.6	202.3	199.0	195.9	192.9	189.9	187.0	184.2	181.4	178.7	176.1	173.5
29.0	239.2	234.8	230.6	226.5	222.5	218.7	215.0	211.4	207.9	204.5	201.2	198.0	194.8	191.8	188.9	186.0	183.2	180.5	177.8	175.2	172.6
30.0	237.8	233.5	229.3	225.2	221.3	217.4	213.7	210.2	206.7	203.3	200.1	196.9	193.8	190.8	187.9	185.0	182.2	179.5	176.9	174.3	171.7
31.0	236.4	232.1	227.9	223.9	220.0	216.2	212.5	209.0	205.5	202.2	199.0	195.8	192.7	189.8	186.9	184.0	181.3	178.6	175.9	173.4	170.9
32.0	235.0	230.7	226.6	222.6	218.7	215.0	211.3	207.8	204.4	201.1	197.9	194.7	191.7	188.7	185.9	183.0	180.3	177.6	175.0	172.5	170.0
33.0	233.6	229.4	225.3	221.3	217.5	213.8	210.1	206.7	203.3	200.0	196.8	193.7	190.7	187.7	184.9	182.1	179.4	176.7	174.1	171.6	169.1
34.0	232.2	228.0	224.0	220.0	216.2	212.5	209.0	205.5	202.1	198.9	195.7	192.6	189.6	186.7	183.9	181.1	178.4	175.8	173.2	170.7	168.2
35.0	230.9	226.7	222.7	218.8	215.0	211.3	207.8	204.3	201.0	197.8	194.6	191.6	188.6	185.7	182.9	180.1	177.5	174.9	172.3	169.8	167.4
36.0	229.5	225.4	221.4	217.5	213.8	210.1	206.6	203.2	199.9	196.7	193.6	190.5	187.6	184.7	181.9	179.2	176.5	173.9	171.4	168.9	166.5
37.0	228.2	224.1	220.1	216.2	212.5	208.9	205.4	202.1	198.8	195.6	192.5	189.5	186.6	183.7	180.9	178.2	175.6	173.0	170.5	168.1	165.7
38.0	226.8	222.7	218.8	215.0	211.3	207.7	204.3	200.9	197.7	194.5	191.4	188.5	185.6	182.7	180.0	177.3	174.7	172.1	169.6	167.2	164.8
39.0	225.5	221.4	217.5	213.8	210.1	206.6	203.1	199.8	196.6	193.4	190.4	187.4	184.5	181.7	179.0	176.3	173.8	171.2	168.7	166.3	164.0
40.0	224.1	220.1	216.3	212.5	208.9	205.4	202.0	198.7	195.5	192.4	189.3	186.4	183.5	180.8	178.1	175.4	172.8	170.3	167.9	165.5	163.1

Figure A 18 Copy of Data Table 7 by Niels Ramsing and Jens Gundersen: 100% Oxygen Solubility @1013 mbar pressure

Unisense

Oxygen solubility at different temperatures and salinities of seawater
Units:µmol/l

Salinity	Temperature (°C)																				
(‰)	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
0.0	456.6	398.9	352.6	314.9	283.9	257.9	235.9	217.0	200.4	185.6	172.2	159.9	148.3	137.2	126.5	115.9	105.5	95.1	84.7	74.5	64.3
5.0	441.1	385.9	341.6	305.5	275.7	250.7	229.5	211.3	195.3	181.0	168.1	156.2	145.0	134.2	123.8	113.6	103.4	93.3	83.2	73.2	63.3
10.0	426.1	373.3	330.8	296.2	267.6	243.7	223.3	205.7	190.3	176.6	164.1	152.6	141.7	131.3	121.2	111.3	101.4	91.6	81.7	71.9	62.2
15.0	411.7	361.1	320.5	287.3	259.9	236.8	217.3	200.4	185.5	172.3	160.2	149.1	138.6	128.5	118.7	109.0	99.4	89.8	80.2	70.7	61.2
20.0	397.7	349.3	310.4	278.6	252.3	230.2	211.4	195.1	180.8	168.0	156.4	145.6	135.5	125.7	116.2	106.8	97.5	88.1	78.8	69.4	60.2
25.0	384.1	337.9	300.7	270.2	244.9	223.7	205.6	190.0	176.2	163.9	152.7	142.3	132.4	123.0	113.7	104.6	95.5	86.4	77.3	68.2	59.2
30.0	371.0	326.9	291.2	262.0	237.8	217.4	200.1	185.0	171.7	159.9	149.0	139.0	129.4	120.3	111.3	102.5	93.6	84.8	75.9	67.0	58.2
35.0	358.4	316.2	282.0	254.1	230.9	211.3	194.6	180.1	167.4	155.9	145.5	135.7	126.5	117.7	109.0	100.4	91.8	83.2	74.5	65.8	57.2
40.0	346.2	305.8	273.2	246.4	224.1	205.4	189.3	175.4	163.1	152.1	142.0	132.6	123.7	115.1	106.7	98.3	90.0	81.6	73.1	64.7	56.3
45.0	334.4	295.8	264.6	238.9	217.6	199.6	184.2	170.8	159.0	148.3	138.6	129.5	120.9	112.6	104.4	96.3	88.2	80.0	71.8	63.5	55.3
50.0	323.0	286.1	256.3	231.7	211.3	194.0	179.2	166.3	154.9	144.7	135.3	126.5	118.2	110.1	102.2	94.3	86.4	78.5	70.5	62.4	54.4
55.0	311.9	276.7	248.2	224.7	205.1	188.5	174.3	161.9	151.0	141.1	132.1	123.6	115.5	107.7	100.0	92.4	84.7	77.0	69.2	61.3	53.5
60.0	301.3	267.7	240.4	217.9	199.1	183.2	169.6	157.7	147.1	137.6	128.9	120.7	112.9	105.4	97.9	90.5	83.0	75.5	67.9	60.2	52.6
65.0	291.0	258.9	232.8	211.3	193.3	178.1	165.0	153.5	143.4	134.2	125.8	117.9	110.4	103.1	95.8	88.6	81.4	74.1	66.6	59.2	51.7
70.0	281.0	250.4	225.5	204.9	187.7	173.0	160.5	149.5	139.8	130.9	122.8	115.2	107.9	100.8	93.8	86.8	79.8	72.6	65.4	58.1	50.8
75.0	271.4	242.2	218.4	198.7	182.2	168.2	156.1	145.6	136.2	127.7	119.9	112.5	105.5	98.6	91.8	85.0	78.2	71.2	64.2	57.1	50.0
80.0	262.2	234.2	211.5	192.6	176.8	163.4	151.9	141.7	132.7	124.6	117.0	109.9	103.1	96.4	89.9	83.3	76.6	69.9	63.0	56.1	49.1
85.0	253.2	226.6	204.8	186.8	171.7	158.8	147.7	138.0	129.3	121.5	114.2	107.3	100.8	94.3	88.0	81.6	75.1	68.5	61.8	55.1	48.3
90.0	244.5	219.1	198.3	181.1	166.7	154.3	143.7	134.4	126.0	118.5	111.5	104.9	98.5	92.3	86.1	79.9	73.6	67.2	60.7	54.1	47.5
95.0	236.2	211.9	192.1	175.6	161.8	150.0	139.8	130.8	122.8	115.6	108.8	102.4	96.3	90.2	84.3	78.2	72.1	65.9	59.6	53.1	46.6
100.0	228.1	205.0	186.0	170.3	157.1	145.8	136.0	127.4	119.7	112.7	106.2	100.0	94.1	88.3	82.5	76.6	70.7	64.6	58.4	52.2	45.8
105.0	220.3	198.2	180.2	165.1	152.5	141.7	132.3	124.0	116.7	109.9	103.6	97.7	92.0	86.3	80.7	75.0	69.3	63.4	57.4	51.2	45.1
110.0	212.7	191.7	174.5	160.1	148.0	137.7	128.7	120.8	113.7	107.2	101.2	95.4	89.9	84.4	79.0	73.5	67.9	62.1	56.3	50.3	44.3
115.0	205.4	185.4	169.0	155.2	143.7	133.8	125.2	117.6	110.8	104.5	98.7	93.2	87.9	82.6	77.3	72.0	66.5	60.9	55.2	49.4	43.5
120.0	198.4	179.3	163.6	150.5	139.5	130.0	121.8	114.5	108.0	102.0	96.4	91.0	85.9	80.8	75.7	70.5	65.2	59.8	54.2	48.5	42.8
125.0	191.6	173.4	158.5	146.0	135.4	126.3	118.4	111.5	105.2	99.4	94.1	88.9	83.9	79.0	74.0	69.0	63.9	58.6	53.2	47.7	42.1
130.0	185.0	167.7	153.4	141.5	131.4	122.8	115.2	108.5	102.5	97.0	91.8	86.9	82.0	77.3	72.5	67.6	62.6	57.5	52.2	46.8	41.3
135.0	178.7	162.2	148.6	137.2	127.6	119.3	112.1	105.7	99.9	94.6	89.6	84.8	80.2	75.6	70.9	66.2	61.3	56.4	51.2	46.0	40.6
140.0	172.6	156.9	143.9	133.1	123.8	115.9	109.0	102.9	97.3	92.2	87.4	82.9	78.4	73.9	69.4	64.8	60.1	55.3	50.3	45.1	39.9
145.0	166.6	151.7	139.4	129.0	120.2	112.7	106.0	100.2	94.9	90.0	85.4	80.9	76.6	72.3	67.9	63.5	58.9	54.2	49.3	44.3	39.2
150.0	160.9	146.7	134.9	125.1	116.7	109.5	103.2	97.5	92.4	87.7	83.3	79.0	74.9	70.7	66.5	62.2	57.7	53.1	48.4	43.5	38.6
155.0	155.4	141.9	130.7	121.3	113.3	106.4	100.3	95.0	90.1	85.6	81.3	77.2	73.2	69.1	65.1	60.9	56.6	52.1	47.5	42.7	37.9
160.0	150.1	137.2	126.5	117.6	110.0	103.4	97.6	92.5	87.8	83.4	79.3	75.4	71.5	67.6	63.7	59.6	55.4	51.1	46.6	42.0	37.2
165.0	144.9	132.7	122.5	114.0	106.7	100.5	94.9	90.0	85.5	81.4	77.4	73.6	69.9	66.1	62.3	58.4	54.3	50.1	45.7	41.2	36.6
170.0	139.9	128.3	118.7	110.5	103.6	97.6	92.3	87.6	83.4	79.4	75.6	71.9	68.3	64.7	61.0	57.2	53.2	49.1	44.9	40.5	36.0
175.0	135.1	124.1	114.9	107.2	100.6	94.9	89.8	85.3	81.2	77.4	73.8	70.2	66.8	63.3	59.7	56.0	52.1	48.2	44.0	39.7	35.3
180.0	130.5	120.0	111.3	103.9	97.6	92.2	87.4	83.1	79.1	75.5	72.0	68.6	65.2	61.9	58.4	54.8	51.1	47.2	43.2	39.0	34.7
185.0	126.0	116.0	107.8	100.8	94.8	89.6	85.0	80.9	77.1	73.6	70.3	67.0	63.8	60.5	57.1	53.7	50.1	46.3	42.4	38.3	34.1
190.0	121.7	112.2	104.3	97.7	92.0	87.0	82.7	78.7	75.2	71.8	68.6	65.4	62.3	59.2	55.9	52.6	49.1	45.4	41.6	37.6	33.5
195.0	117.5	108.5	101.0	94.7	89.3	84.6	80.4	76.7	73.2	70.0	66.9	63.9	60.9	57.9	54.7	51.5	48.1	44.5	40.8	36.9	32.9
200.0	113.5	104.9	97.8	91.8	86.7	82.2	78.2	74.6	71.4	68.3	65.3	62.4	59.5	56.6	53.6	50.4	47.1	43.6	40.0	36.3	32.4

Figure A 19 Copy of Data Table 8 by Niels Ramsing and Jens Gundersen: 100% Oxygen Solubility @1013 mbar pressure

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1) The tissue in plants that brings water upward from the roots;
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