PSI

Pro-Oceanus Systems Inc.

665 LaHave Street, Bridgewater, N.S., Canada B4V 2V2

Phone: (902) 421-5702; Fax: (902) 530-3551; email: johnson@pro-oceanus.com or mcneil@pro-oceanus.com

PSI CO2-Pro Setup, Deployment and Trouble Shooting Manual

(version 6.2; July 3, 2007)

Pro-Oceanus Systems Inc. CO2-Pro

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CO2-Pro™ Description and Specifications

The PSI CO2-Pro™ is a compact, light-weight, plug-n-play pCO2 sensor that is designed for use on moorings (to 250 m), in under-way mode, and in the laboratory. The PSI CO2-Pro™ is fitted with an IR detector and the new PSI pump-driven fast interface (patent pending). This revolutionary new interface provides an equilibrated gas sample to the detector.

The PSI CO2-Pro™ is factory calibrated from 0 – 600 ppm (other ranges available by special order) with calibration burned into EPROM. To maintain accuracy, the detector module has a power interruption or contact closure initiated automatic zero point calibration (AZPC). When the AZPC is initiated, the gas stream is routed through a CO2 absorbent to provide a zero ppm CO2 measurement. The CO2 AZPC measurement compensates for changes in optical cell performance and significant changes in environmental parameters such as gas stream temperature. The AZPC is used in determinations of ppm CO2 until a new AZPC is performed (recommended a minimum of once per day but more often where possible and especially where conditions such as water temperature change significantly).

Specifications:

accuracy	
CO2 concentration	± - 1 ppm
Gas stream humidity	±1 mb
Gas stream pressure	±2 mb
precision	
CO2 concentration	0.01 ppm
gas stream humidity	1 mb
gas stream pressure	1 mb
calibration range	0 – 600 ppm*
temperature range	0 – 35 °C (above 20EC remove the interior insulation)

Physical Characteristics

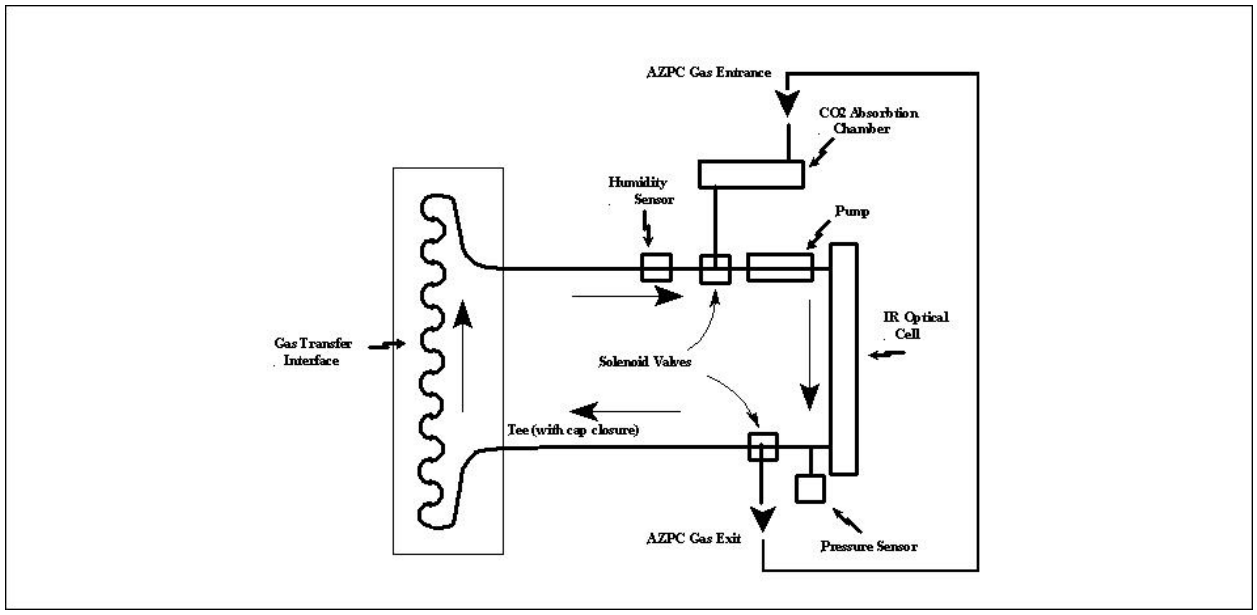
size	length: 33.02 cm (add 10 cm for connectors) diameter: 17.27 cm body (maximum diameter at locking ring 19.05 cm)
weight	total wt in water: 0.40 kg total wt in air: 9.00 kg Seabird pump: 0.3 kg (pump obtained from PSI or Seabird)
housing	hard anodized aluminum proof to 1000 meters

Electrical Characteristics

input voltage	9.5 to 18 VDC (all instruments sold after Jan. 2007; for instruments sold prior to that date contact PSI)
power consumption	-0.8 A at 12 Volts for warmup; 0.4A during operation; not including pump power; lower power consumption options available
data storage	available when equipped with PSI data logger/ contoller; otherwise provides data via cable to external computer
data output	RS-232 serial output
sample rate	0.6 hertz; 0.31 hertz with data logger / controller
equilibration time constant	about 3.5 minutes depending on pump flow rate, water temperature and ambient pressure

WARNING: do not immerse the power supply or interface box in water; where safety is a concern, use a ground-fault line for the AC adapter; Also, do not insert a 9V battery into the interface box

Note: a small permeable packet of soda lime (10 g to 20 g) should be taped to the inside of the endcap before closing the PSI CO2-Pro for testing or deployment.



Schematic of the CO2-Pro flow paths

Modes of Operation:
The PSI CO2-Pro is designed to operate in two modes:

1) Measurement - The PSI CO2-Pro normally operates in a closed loop format. Sample gas exchanges through the gas transfer interface and then passes through a humidity sensor. The gas stream then flows through a solenoid valve (AZPC), through the circulation pump and then into the IR optical cell. Gas that passes through the optical cell, flows through the second AZPC solenoid valve and then re-enters the gas transfer interface for further equilibration.

2) Zero Point Calibration – When the AZPC routine is initiated, the two AZPC solenoids are activated, allowing air from the CO2-Pro to be drawn through the CO2 absorption chamber and into the optical cell. The AZPC minimizes the effects of sample cell contamination, optical source aging, changes in detector sensitivity and changes in pre-amplifier gain. The AZPC also provides accommodation for changing environmental conditions such as occur with significant changes in external temperature. The AZPC function is normally initiated by interruption of power (2 seconds) to the detector board or by momentary grounding of pin 10 on the db 15 connector.

Measurement Principle
The PSI CO2-Pro is fitted with a non-dispersive, infrared gas analyzer with an automatic zero function. The analyzer features onboard sensors that allow automatic pressure, temperature and humidity compensation via code in the sensor board EPROM.

Input/Output Connector

Inputs/ outputs on the db-15 connector for the CO2-Pro detector board are as shown in the table below. The data output from the CO2-Pro does not normally include the auxiliary sensor data that is input on pins 1-5 (depending on the EPROM configuration). These outputs have been omitted, but can be restored by changing the EPROM (contact Pro-Oceanus for more information on changes to the EPROM).

When auxiliary sensors are connected to pins 1-5, the inputs require 1 volt (1000 mV), and must not exceed 1.2 volts (1200 mV) or damage may occur.

The CO2-Pro detector data stream is unidirectional. Only transmit (pin 9) and digital ground need to be connected. Note that power to the board is not input through pins 12 and 15, but instead is supplied through a separate connector.

Pin Number	Description	Connection
1	Auxiliary Sensor Input A	May Not Be Supported
2	Auxiliary Sensor Input B	May Not Be Supported
3	Auxiliary Sensor Input C	May Not Be Supported
4	Auxiliary Sensor Input D	May Not Be Supported
5	Auxiliary Sensor Input E	May Not Be Supported
6	+5 V DC Output	Not Normally Used
7	Alarm (Buffered Output . 6.5 V)	Used To Control Data For Logging
8	Digital Ground For RS-232	Connected For RS-232 Output
9	RS-232 Transmit Out To PC/Logger	Connected For RS-232 Output
10	AZPC Line	AZPC Initiated By Momentary Grounding
11	NC	
12	12 V Power Input	Board Powered Alternately
13	NC	
14	Analog Output (5V)	Not Used
15	Analog Ground	Board Powered Alternately

Start-up

Without optional data logger controller: The CO2-Pro sensor board is designed to operate from a 9.5 to 18V power supply (if purchased prior to January 2007, contact PSI). A deck box power supply is included (**note the deck box is not water proof, only splash resistant**). Once the sensor board is connected to a proper power supply there is a short pause and then the IR source lamp begins to flash. If the RS-232 line is connected to a PC running a terminal program, the following information is transmitted:

B, SBA-4, nnnn, x.xx
Where: B = Begin
N = Serial Number
x.xx = EPROM Version Number

There is then a delay of 3 seconds followed by 25 counts of 1.6 seconds to allow for initialization and internal calibration of electronics during which the following is transmitted:

I, nn
Where: I = Initialization
nn = the count up to 25

The optical cell temperature is checked until it exceeds the temperature set point (typically 40E C).

W, nn
Where: W = Warm up delay
nn = optical cell temperature

This is then followed by an AZPC with the following transmitted:

Z, nn
Where: Z = Zero
nn = the count up to 12

At count number 7, a click will be heard as the valve switches to measure mode. The remaining time is allowed for flushing out of the optical cell.

Pin 7 (see connector Table 1) is held low during the setup period, and then goes high once the AZPC is completed and measurement begins. Pin 7 is used in the CO2-Pro to control data logging (when fitted with separate data logger). If pin 7 goes low during measurement, this may indicate a fault such as a low power supply.

With optional data logger controller: Install TFToolsv2 from the supplied CD to your computer (or download from *http://www.onsetcomp.com/Support/TT_Support/manual.html* and click on *Tattletale TFX-11v/ TFX11-v2*) . Setup of the instrument adjustable parameters is accomplished by connecting the CO2-Pro to the serial port on your computer (or USB port given proper adapter) through the CO2-Pro deck box (note the deck box is not waterproof, only splash resistant). Bring up TFToolsv2 and then supply power to the CO2-Pro (do not supply more than 18 V).

When power is supplied, the program will ask if you wish to set time. Type "Y" (no return) and the program will request year. Type the year, then RETURN. Continue until all components of time are entered.

The Program will then request a series of setup parameters:

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1) ENTER TIME DELAY (seconds) =
2) WARMUP TIME(seconds) =
3) CONTINUOUS OR POWER SAVING =

If "Contiunous":
4) MEASUREMENTS BETWEEN AZPC'S (number of 3.22 second intervals) =
5) DATA STORAGE INTERVAL (number of 3.22 second intervals) =
If "Power Saving":
4) TIME INTERVAL BETWEEN DATA BURSTS (seconds) =
5) NUMBER OF INTERVALS BETWEEN AZPC's =
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1) TIME DELAY: This is the time necessary to deploy the instrument, i.e., remove the underwater cable from POWER/COM, connect battery power to the POWER/COM connector and then deploy the instrument. If you are only performing a bench test, you can continue using power from the plug-in supply through the deck box.

When changing over to battery power, the data logger/ controller operates on a 9V battery resident in the CO2-Pro housing. This 9V battery must be connected to the battery clip prior to removing the external underwater connector to the deck box otherwise setup parameters will be lost.

2) WARMUP TIME: The time available for the instrument to reach full power. This is included as an adjustable parameter to allow different warm-up times for different environmental conditions, i.e., instrument warm-up may take longer at low ambient temperature. Typically, a warmup time of about 360 seconds is chosen.

3) CONTINUOUS OR POWER SAVING: "Continuous" is normally chosen where power is abundant, e.g. on shipboard, bench top or when powered from a shore facility; "Power saving" where instrument power is limited, e.g., when powered by a battery pack.

If "continuous" is chosen:

4) MEASUREMENTS BETWEEN AZPC's: because measurements are at 3.22 second intervals, the number entered here should allow time for the instrument to reach equilibrium after the AZPC. **This means no fewer than about 560 intervals should be entered here (0.5 hours between AZPC's)**. The CO2-Pro should be set to perform an AZPC at least once per day and more often (as often as every half hour) in rapidly changing environmental conditions.

5) DATA STORAGE INTERVAL (number of 3.22 second intervals): in "continuous" mode data are transferred through the 2 pin underwater auxillary coms connector at 3.22 second intervals. The same data are also available to be stored onboard the instrument in EPROM. If the data storage capacity of the EPROM is exceeded (approximately 2 mega bytes of storage at about 80 bytes per data line) the instrument will turn off. To conserve EPROM memory choose an appropriate number of 3.22 second intervals for data storage, e.g., 100 intervals, indicates one data point to be stored every 322 seconds.

If "power saving" is chosen:

4) TIME INTERVAL BETWEEN DATA OUTPUT (seconds): This is the time interval between measurements of data. This interval includes warm-up time and equilibration time and should be a minimum of 5 equilibration time constants (see "example setup procedures" in the "PSI CO2-Pro Controller/ Data Logging" supplement).

5) NUMBER OF INTERVALS BETWEEN AZPC's: This is the number of intervals (see 4 above) between AZPC's. **This number should be greater than 1 but no more than 5**.

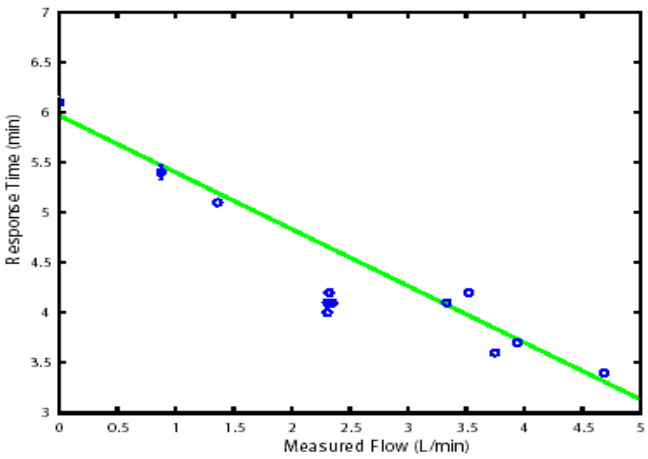
Offloading data: interrupt power to the CO2-Pro (if a 9V battery is connected inside the CO2-Pro for

change-over, this battery must also be disconnected). Connect the CO2-Pro though the deck box to a computer. Bring up TFToolsv2. A blank window should open. Apply power to the CO2-Pro through the deck box. The program resident in EPROM should initiate. You have 5 seconds from appearance of the product version identifier to press "Ctrl C" to interrupt the program. Now click on the menu item "TATTLETALE" and then "XMODEM off-load". A box will then appear usually with the number "0". Type in the number of bytes to offload, click enter, and supply the file name and location where you wish to store the data. Check the stored data file to determine if all data are there (complete if the data are followed by "y" in the data file). It may take a few tries to determine the right number of bytes to offload, but remember, the data still reside in memory until erased. A few tries should be sufficient to offload all of the data.

Once the data are off-loaded and safe, you can erase the data file on the logger by again clicking on "TATTLETALE" in the menu and then on "ERASE DATA"

Power Management: For the CO2-Pro fitted with data logger/ controller, power management strategies have been embedded in the software. These strategies include using detector sleep mode within time intervals, heating the optical cell with the sample pump inactive, and operating the water pump and sample pump on a duty cycle. Contact Pro-Oceanus Systems for more information.

Sample Flow: Flow of sample water through the interface inlet port is necessary for equilibration of sample gas across the interface. The time constant for equilibration as a function of water flow rate appears in figure 2 (room temperature and one meter ambient pressure). Longer times are needed at low temperature and higher hydrostatic pressures.



Time constant for equilibration of CO2 across the supported interface as a function of sample water flow rate.

Housing Information

The CO2-Pro has a unique omni-position ACME thread mason jar closing mechanism. When closing, place the housing interface down on a flat surface, then press firmly downward to seat the O-Ring, and

screw on the mason jar ring. To remove the endcap, place the housing on a flat surface, loosen the mason jar ring, and then gently work the endcap out of the housing opening. Be careful not to damage the wires that run from the sensor tray to the back endcap as you pull out the tray.

The mason jar ring is made of delrin whereas the housing is aluminum. Differences in coefficients of thermal expansion between the two materials means that the ring can become difficult to remove or attach if the temperature of the housing is relatively cold. If this becomes a problem warm the ring, e.g., with warm water, or by heating it gently with a heat gun or in front of a heater vent. Do not heat it excessively as this can cause the ring to deform.

The CO2-Pro electronics are covered with layers of insulation, top and bottom, to protect against excessive heat loss. This insulation reduces warm-up time for the constant temperature cell, and improves performance of the sensor. Replace the insulation before instrument deployment and especially at colder temperatures. However, if the ambient or water temperature exceeds 25 EC, remove the insulation before deployment.

The CO2-Pro housing is protected with zinc anodes to reduce corrosion. However, on recovery always rinse the external surface of the housing several times with fresh water. See "Interface Care" for instructions on maintaining the interface.

Before reassembly always ensure that the O-ring on the endcap closure is lightly greased and that the O-ring is clean and in good condition.

Biofilm formation

In deploying the CO2-Pro it is essential to reduce biofilm formation. We have configured the interface design to discourage biofilm formation, and we also recommend use of an in-line TBT holder and tablets available from Sea-Bird Electronics (contact information below). When working with TBT remember that it is toxic, and should be handled with great care.

Sea-Bird Electronics, Inc.
1808 136th Place N.E.
Bellevue, Washington
U.S.A. 98005
Phone: (425) 643-9866

Data Output

Once measurement commences, the measurement data string is 1.6 seconds (unless controlled by the data logger/ controller). The data string is as follows:

MT, ZERO, CO2M, CO2AV, ANLT, MB, HT, A, B, C, D, E, ATMP *

*may not be present depending on EPROM configuration

Where:

ITEM	MEASUREMENT	INTERPRETATION
MT	Measurement Time Stamp	Day, Month, Hour, Minute, Second
Zero	16 Bit CO2 Analyzer A/D Reading	Result from most recent AZPC
CO2M	16 Bit CO2 Analyzer A/D Reading	Measurement mode
CO2AV	Linearized CO2 Concentration; Running Average Is Applied	CO2 concentration in Fmol mol^{-1} corrected for temperature (if between set point T and T – 5 CE); Also corrected for pressure and humidity.
ANLT	Optical cell temperature	Thermostated at set point T
MB	Humidity sensor reading in mb	
HT	Humidity sensor temperature	
A - E	Millivolts output if sensor inputs A – E are available and used	Maximum sensor inputs are 1 Volt
ATMP	System pressure in millibars	Gas stream pressure not gas tension

AZPC

The automatic zero point calibration or AZPC automatically corrects the CO2 measurement for changes in detector performance and environmental conditions and facilitates sensor stability. The AZPC operates through stripping CO2 from the gas stream by routing instrument gas through a column filled with soda lime. The AZPC can be initiated in three ways: 1) by temporarily grounding pin 10 (Table 1); 2) by fitting the sensor board with an EPROM programmed at set interval for AZPC; 3) temporarily interrupting power (for instruments equipped with the PSI supplied data logger/ controller, the AZPC interval is stipulated by the user in the setup routine).

Averaging

Averaging has been applied to the CO2AV measurement to improve resolution and reduce fluctuations. It uses an exponential running average algorithm with a time response to a step change of 5.6 seconds to 66% of final value and 26.4 seconds to 99% of final value. If a new CO2 reading differs from the current running average by more than the AVLIMIT value, a new running average is begun. Thus, when the CO2 concentration is changing rapidly, the averaging is eliminated and the instrument can track changes at the basic instrument data rate of 1.6 seconds. The default AVLIMIT is 0.3% of full scale or 1.8 ppm for a 600 ppm instrument. The running average is applied to both analog and digital output signals.

Alarm Line (pin 7 sensor connector)

After initialization and the first AZPC, pin 7 on the sensor connector goes high. This output is used to control the data logging when a data logger is connected to the sensor. When the CO2-Pro is connected to a computer and is logging data, e.g., in underway or bench top-mode, a low on pin 7 may indicate a fault. Such a fault triggers an error message as follows:

- E, zero too low; usually indicates spent CO2 absorbent
- E, analyzer temperature too low
- E, analyzer temperature too high
- E, CO2 reading low
- E, board voltage low

The threshold values that trigger these errors are preset in EPROM. Please contact Pro-Oceanus Systems Inc. if you experience continued problems with any of these error messages.

Maintenance

If a gas stream such as a calibration gas is introduced to the sensor (please contact Pro-Oceanus for instructions before doing this) the gas should be filtered at pore size smaller than 20 microns. One filter that provides superior gas filtration is the Millipore FSLW-14200 PTFE hydrophobic membrane in a Millipore SX00-001300 filter holder. Other filters will also work, but should allow sufficient gas flow and should not be of a type that may fragment such as glass fiber.

The CO2 absorption column should be inspected before each deployment. Soda lime is supplied as self-indicating 1 to 2.5 mm granules. As the absorbent is exhausted the color changes from green to brown. Typically the absorbent should be replaced when 2/3 of the column contents have changed color. Exhausted soda lime cannot be regenerated and should be discarded. The column should be filled while gently tapping the outer wall in order to minimize larger channels in the absorbent bed. The absorbent should last for several months in normal use, and does not need replacing unless the CO2 zero drops significantly below previous levels obtained under the same environmental conditions.

Before refilling the absorption column it should be inspected as follows: 1) ensure that the black foam disks (one on each end) are not worn or broken. These foam pads stop absorbent from spilling out of the column ends and replacement pieces can be obtained from PSI or can be made using open cell type packing foam; 2) check that the endcaps contain the white filter disks. These disks ensure that absorbent particles do not enter the sensor. They rarely need replacement; 3) the gas connectors on each endcap are o-ring sealed. Check the o-rings for integrity and ensure that they are lightly greased with silicone grease before re-assemly; 4) check that the components of the absorption column are not cracked or otherwise damaged. Integrity of the column is essential for a reliable AZPC.

Interface Care

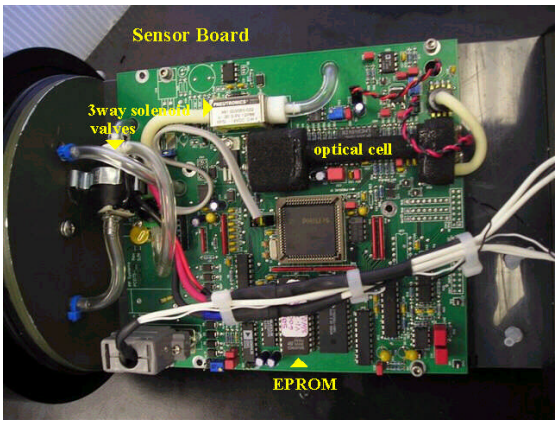
The interface is a tubular silicone membrane that is internally supported to resist hydrostatic pressure (patent pending). The membrane assembly should never be disassembled. If a problem occurs, the instrument should be returned to Pro-Oceanus Systems Inc. for assessment and repair.

When the CO2-Pro is recovered the membrane should be rinsed by pumping dilute detergent solution (e.g. Ivory dish detergent or Sparklean) through the water line in the interface housing. This should be followed by rinsing with distilled water and then distilled water that contains 1 ml of Chlorine bleach (Chlorox or Javex, etc.) per 20 liters of distilled water. Drain the interface as well as possible or preferably, pass dry, filtered, oil-free compressed gas through the water line before storing the instrument for periods longer than a few days. Never deploy the CO2-Pro interface in water containing oil, as this may damage the interface.

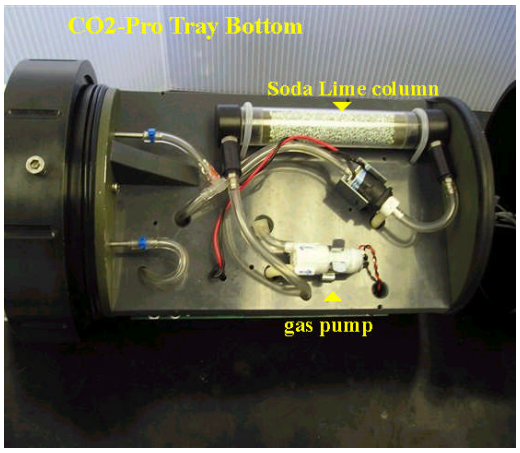
If the time constant of the CO2-Pro equilibration is seen to increase then try pumping a dilute acid (pH about 3) through the interface housing. Dilute phosphoric acid should be sufficient for this purpose. Then rinse with clean fresh water and then again test equilibration time.

Data Logging (without optional data logger/ controller)

In underway mode or on the benchtop, data logging can be accomplished with many different software packages. Connect the CO2-Pro via the underwater cable, through the fused deck box and then through the db-9 connector and cable to the computer (note that the same data stream is available from the 2 pin auxillary coms connector).



CO2-Pro layout



Underside of tray showing solenoid valve, air pump and soda lime column. Note version shown is without data logger/controller. Layout may be changed without prior notice

CO2-Pro bench top/ underway setup (note that the second 2-pin connector is used for data output when the controller/ data logger is installed).

Trouble-Shooting

If a malfunction is experienced:

the mason jar ring is difficult to attach or remove: gently warm the ring with hot water, or heat with a heat gun or hair dryer, or place the instrument in front of a heating vent. Do not over heat, as this may distort the ring.

no power: check the power supply (should be 9.5 to 18 V); if no power is reaching the instrument, check the fuse in the deckbox and replace if necessary.

erratic CO2 measurement: re-zero; if still a problem, check that all tubing is in place and connected at both ends.

standard gas measurements are not accurate: typically this means that the instrument has experienced a significant temperature or other environmental change; the solution typically is to re-zero.

sensor does not zero properly: usually indicated by out of range ZERO or CO2Z; should typically be from 32,000 to 50,000 counts, but depends on environmental factors and the particular instrument. The most probable solution to the problem is to re-zero. If repeated re-zeroing does not work, then the CO2 absorbent (soda lime) may be spent and should be replaced.

on startup very high CO2 levels are experienced: This may mean that the interface was not prepared properly for storage, and the damp interface has a substantial bio-film layer. The best solution is to avoid this problem entirely by rinsing the interface properly before storage. If experienced, the procedure described in “interface care” should be followed.

Revisions to the manual

Please contact Pro-Oceanus Systems if you have questions not answered in this manual. We also appreciate any comments about our products or product information so that we can make improvements.

Notes on instrument deployment and maintenance

- **a small permeable packet of soda lime (10 g to 20 g) should be taped to the inside of the endcap before closing the PSI CO2-Pro for testing or deployment.**

- if degradation of performance occurs, e.g., a lengthening of equilibration time, a weak acid solution (pH 3 to 3.5) should be pumped through the interface housing. We recommend dilute phosphoric acid. The acid rinse should then be followed by a rinse with distilled water.

- periodically and especially before storing the CO2-Pro the interface should be rinsed with a dilute soap solution; followed by 1 ml of household bleach per 10 to 20 liters of distilled water; followed by rinsing with distilled water. If the instrument is to be stored, the interface should then be dried as well as possible by passing clean, dry air or nitrogen through the interface housing.

PSI Warranty Statement:

The PSI Pro™ series instruments are covered by a 3-Year Limited Warranty

1. For a period of three years after the date of original shipment from our factory, products manufactured by Pro-Oceanus Systems Inc. are warranted to function properly and be free of defects in materials and workmanship. Should a Pro-Oceanus Systems Inc. instrument fail during the warranty period, return it freight pre-paid to our factory. Pro-Oceanus Systems Inc. will repair it (or at our option, replace it) at no charge, and pay the cost of shipping it back to you. Certain products and components have modified coverage under this warranty as described below:

Modifications / Exceptions / Exclusions

2. The Paroscientific, Inc. pressure sensors and optional Intelligent Transmitter Board supplied with the instrument are not covered under this warranty. The pressure sensor is covered separately under Paroscientific Inc.'s 5 Year Extended Limited Warranty (see Paroscientific, Inc. for details).
3. Gas permeable membranes, rigid permeable membrane supports, support screens, absorbents, batteries, zinc anodes, and other consumable/expendable items are not covered under this warranty.
4. Damage to the pressure sensor or other internal electronics as a result of flooding from either a punctured membrane or an improperly applied o-ring seal is not covered under this warranty. Care must be taken to deploy instruments according to procedures described in the Operating Manual to minimize the possibility of damage due to flooding.
5. Corrosion damage is not covered under this warranty, as described in the Operating Manual Application of a clean zinc anode to the housing and heavy grease to the closure ring threads is expected to help limit corrosion of the Pro-Oceanus Systems Inc. hard anodized aluminum housings. Enhanced corrosion activity and damage may result from improper electrical isolation between the Pro-Oceanus Systems Inc. instrument and any supporting platforms attached to the instrument.
6. Welded mounting tabs and other mechanisms used to mount Pro-Oceanus Systems Inc. instruments to ships, buoys, mooring lines etc., are not covered under this warranty. Pro-Oceanus Systems Inc. expects the best and safest engineering practices to be applied by knowledgeable and experienced persons during the deployment and recovery of their instruments and can not be held liable for any injuries or damages incurred during use of their instruments.
7. This warranty is void if, in our opinion, the instrument has been damaged by accident, mishandled, altered, or repaired by the customer where such treatment has affected its performance or reliability. In the event of such abuse by the customer, repair costs plus two-way freight costs will be borne by the customer. Instruments found defective should be returned to the factory, clearly marked as fragile goods, and carefully packaged in the transport/ shipping box in which the instrument was sent from PSI.