Mini CO_2

Digital Model

User's Manual

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1.0 General Information

1.1 Introduction

The Mini CO_2 is a compact in situ submersible pCO_2 sensor designed for broad use in aquatic sciences. The sensor can be deployed in both fresh- and sea-water. The Mini CO_2 instrument can be used for long term monitoring in remote areas, spot-checking specific locations, and in industrial applications.

The Mini CO_2 operates through diffusion of dissolved gases from liquids through a supported semi-permeable membrane to a gas headspace containing a non-dispersive infrared detector (NDIR). The NDIR sensor is factory calibrated using WMO traceable standards (http://www.esrl.noaa.gov/gmd/ccl/).

Use caution when unpacking your sensor. Check all the contents of your package immediately upon arrival and refer to the packing list to ensure all items are included with your sensor. We recommend that you retain original packaging for future use. If you suspect any items are missing or anything is damaged, please contact Pro-Oceanus or authorized distributer immediately.

1.2 Warnings

To prevent damage to your sensor, carefully read all deployment and operating instructions before using the sensor.

* When opening the sensor, ensure the outside is completely dry and open while sensor is horizontal to prevent any water entering housing.
* The membrane is the most important part of the instrument, great care must be taken not to damage it.
* Do not use abrasive materials on membrane.
* Use caution when unscrewing the instrument face plate, a screwdriver can easily puncture membrane.
* When faceplate is removed, do not allow sensor to come in contact with water/spray with water.
* When deploying vertically, ensure the head is facing down and no gas is trapped along the membrane.
* Use caution when deploying in water that significantly colder than the air. Condensation of water vapor can occur inside the detector.
* Caution removing the instrument when dissolved gas pressure is substantially above atmospheric pressure. Slowly bring the instrument to the surface under these conditions.
* Hand-tighten cable connector locking sleeves, do not over tighten.
* When using a pumped head, flow rates should not exceed 3 L/min.

1.3 Start Guide

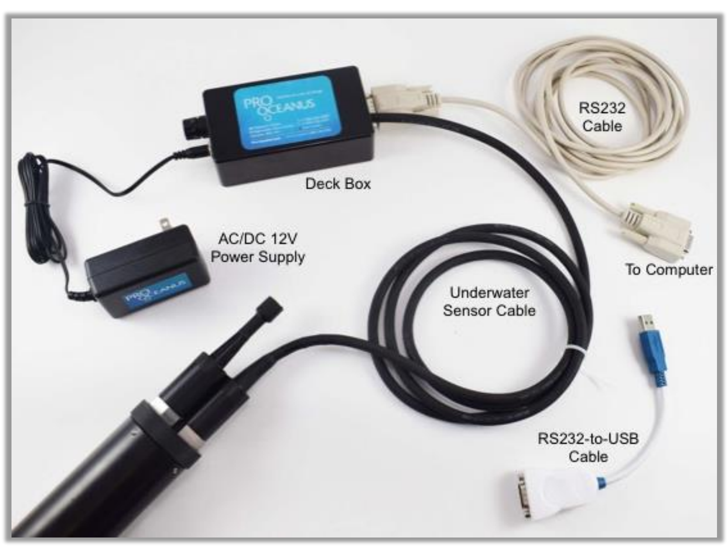
Software Setup:

1) Insert the Pro-Oceanus flash drive provided with your sensor into a computer operating Microsoft Windows 2000 or newer.
2) Open the folder labelled "Software"
3) Right click on Interface and copy and paste application to desired location on computer

*The sensor will also run with *Tera Term* (free to download) as well as other terminal programs.

Instrument Setup:

1) **Caution:** Protect the membrane of the sensor from damage during testing and deployment
2) **Note**: if the sensor has an internal battery, refer to the "Internal Battery Operation" below
3) Connect the sensor to the communications/power deck box using the underwater cable with connector
4) Ensure the correct dummy plug is connected to the battery ON/OFF bulkhead connector (if available)
5) Connect the deck box to a Windows-based computer using an RS-232 serial cable or RS-232 to USB converter cable. **Note:** if using a Serial-to-USB converter, the correct driver must be installed for proper operation
6) Apply 12 VDC power supply to the deck box through the barrel jack. It is recommended to use the AC/DC converter supplied with the deck box



7) Open the terminal program on your computer and refer to "*Sensor Configuration*" below.

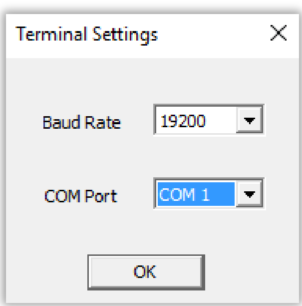
OPTIONAL **Internal Battery Operation**:

1) **Caution:** The Mini CO_2 sensor is designed to be powered using either a 7-24 VDC external input **or** the optional internal battery pack, but **not both** at the same time.
2) To activate the internal battery power, connect the labelled "shorted plug" to the battery ON/OFF bulkhead connector to enable the battery. Ensure no external power supply is connected. If the external battery is not being used, connect the unlabeled dummy plug to the battery ON/OFF bulkhead connector.

3) For internal battery endurance, refer to Section 4.5

Sensor Configuration

1) After powering the sensor and connecting to a Windows-based computer, open the terminal program
2) Configure the serial port settings (*View* > *Terminal*) to baud rate = 19200 and the correct COM port and click *ok*



3) Program will open a terminal with a serial connection to the sensor, click the *Start User Interface* button, status banner and menu will appear.

4) Enter *"t"* and set the sensor's real-time clock. Once set, the sensor will keep time whether powered or not.
5) Enter *"3"* to choose sampling method (*continuous/timed/command*) **Note:** if "*timed mode*" is chosen, the FIRST sample time must be <u>at least 5 minutes</u> after the current clock time that is set. Once configured, press "*ESC*" to return to the main menu.
6) To begin sampling, press *"1".* Data will be logged to the internal SD memory as well as transmitted via RS-232 to computer.

   Continuous Mode: sampling will begin within 10 seconds of selecting *"1"*

   Timed Mode: the sensor will wait until the pre-set first sample time before outputting data

   Command Mode: a sample will be taken when *"s"* is pressed. In *command* mode, the user interface must be active. If there is no activity for 60 seconds, the RS-232 port will go to sleep and can be activated by pressing any key followed by the *"ESC"* key.

7) To stop sampling, select *"2"*. *"2"* must also be selected before switching sampling modes
8) If using Oceanus View, data can be directly logged to the computer by clicking the *Saved Logged Data* button and selecting a location and name of the same file. In Oceanus View, data will only be saved from the moment the *Saved Logged Data* button was pushed.

2.0 Instrument Overview

2.1 Sensor Checklist

<u>2.1.1 Digital Logging Model – P/N: M220</u>

Includes:

- Mini CO_2 Instrument
- USB memory stick with Oceanus Software and User's Manual
- QuickStart Guide

Recommended:

Power and communications deck box (P/N: A10-103), includes:

A. Water-Resistant deck box with Underwater Cable and Connector Sleeve (various underwater cable lengths available)
B. 2-meter RS-232 cable
C. RS-232-to-USB Converter
(FTDI-driver download available at: http://www.ftdichip.com/Drivers/VCP.htm)
D. AC to DC 12 V Power Supply

2.1.2 Digital Logging Model with Internal Rechargeable Battery – P/Ns: M230 or M235

Includes:

- Mini CO_2 Instrument
- USB Memory with Oceanus Software and User's Manual
- QuickStart Guide
- Internal 6 VDC x 5 Ahr NiMH Battery Pack (D) – P/N: M230 (12 VDC for M235)
- Battery Charger with Cable (E)
- Locking sleeves and plugs

2.1.3 Digital Logging Model with Internal Non-Rechargeable Battery – P/N: M240

Includes:

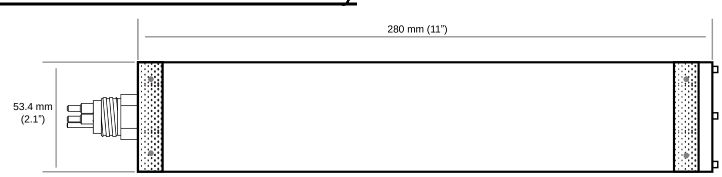
A. Mini CO_2 Instrument
B. USB Memory with Oceanus Software and User's Manual
C. QuickStart Guide
D. Internal 19 Ahr Alkaline Battery Pack
E. Locking sleeves and plugs

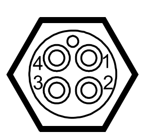
2.2 Sensor Specifications

Parameter	Specification
Accuracy	± 2% (of maximum range) TDGP: ± 1%
Resolution	0.1% of max range
Power Consumption	85 mW (7 mA @ 12 VDC)
External Input Voltage	7 - 24 VDC
Signal Output	Serial RS-232, CSV ASCII String
Water Temperature Range	0 to 40˚C
Detection Method	Non-Dispersive Infrared (NDIR)
Warm up Time	3 minutes
Housing Material	Acetal Plastic (Titanium optional)
Weight	Air: 0.53 kg (1.2 lbs) Water: -0.06 kg (-0.1 lbs)
Depth Rating	600 meters (up to 6000 meters optional - titanium)
Equilibration (t_{63})	3 minutes (pumped head at 20 ˚C)
Sample Rate	2 seconds (variable with logger/controller)

Dimensions and Pinouts:

P/N: M220 – No internal battery

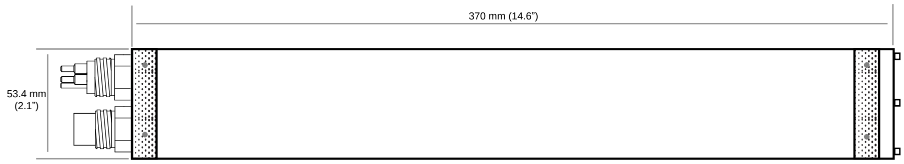


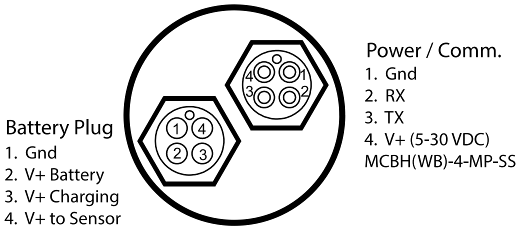


1. Gnd
2. RX
3. TX
4. V+ (5-30VDC)

MCBH(WB)-4-MP-SS

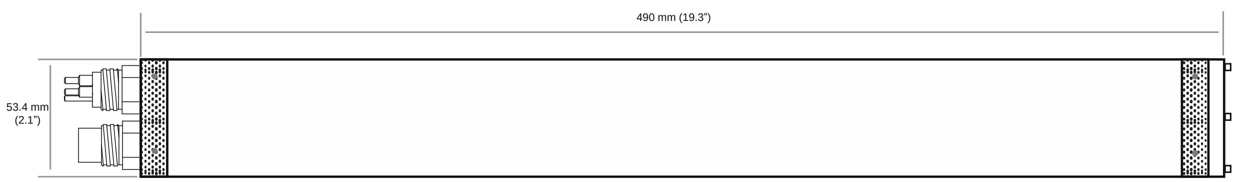
P/N: M230 – Internal rechargeable battery 5 Amp hr at 6 VDC

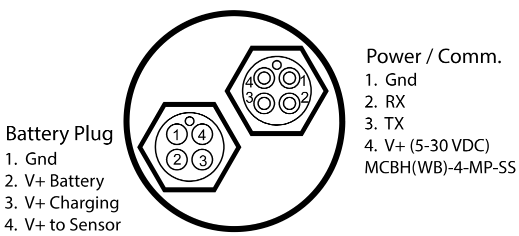




Requires: MCDC(WB)-4-MP-SS
Shorted Dummy Plug, connects pins 2 and 4 (Supplied)

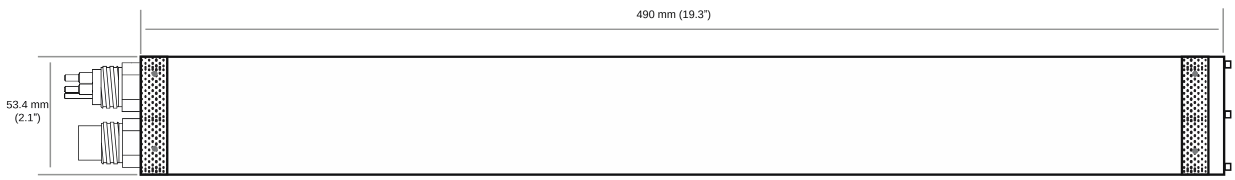
P/N: M235 – Internal rechargeable battery 5 Amp hr at 12 VDC

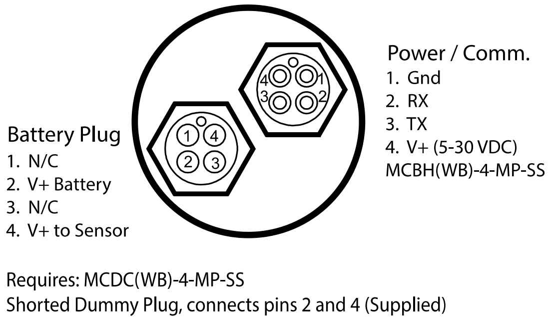




Requires: MCDC(WB)-4-MP-SS
Shorted Dummy Plug, connects pins 2 and 4 (Supplied)

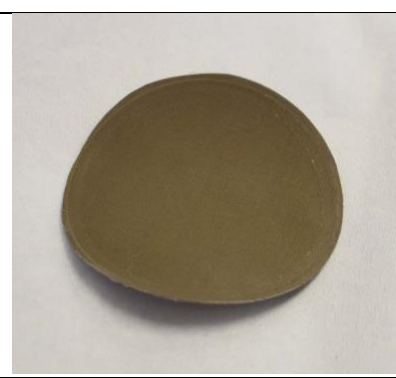
P/N: M240 – Internal D-cell battery 19 Amp hr at 6 VDC





2.3 Optional Accessories

Water-Pumped Head Assembly **P/N: MA-30-01**	
Copper Antifouling Head **P/N: MA-301-01**	

Replacement Copper Antifouling Shield **P/N: MR-361-01**	
Pelican Storm Hard Shell Case range of sizes available	
Internal Battery Packs 5 Amp-hour x 6 VDC rechargeable NiMH **P/N: B500-6V** 5 Amp-hour x 12 VDC rechargeable NiMH **P/N: B500-12V** 19 Amp-hour x 6 VDC non-rechargeable alkaline **P/N: B600-6V**	
Replacement Membrane **P/N MR500-1**	

External Battery Housings, Packs, and Cables	
Mooring Cage with Instrument Brackets	
Pigtail Cables with Locking Sleeves 2-meter pigtail cable with locking sleeve – **P/N: C20-002M** 5-meter pigtail cable with locking sleeve – **P/N: C20-005M** 10-meter pigtail cable with locking sleeve – **P/N: C20-002M** 25-meter pigtail cable with locking sleeve – **P/N: C20-025M** 50-meter pigtail cable with locking sleeve – **P/N: C20-050M** Other lengths available	
Mooring Frame with Instrument Brackets *Titanium* **P/N: MA21-TI** *Aluminium* **P/N: MA21-AL**	

2.3 Gas Concentration Ranges Available

Standard Measurement Ranges	0 – 1000 ppmv (molar gas volume ratio of CO_2)
	0 – 2000 ppmv
	0 – 5000 ppmv
	0 – 1% (0 – 10 000 ppmv)
	0 – 2.5% (0 – 25 000 ppmv)
	0 – 10% (0 – 100 000 ppmv)
	0 – 100% (0 – 1 000 000 ppmv)
	TDGP: 0-2 bar

2.4 Customized Units

Pro-Oceanus can provide customers with uniquely designed and/or modified Mini CO_2 instruments. Customizations can take the form of larger battery pack capacity, variable concentration ranges, and modifications to the logging program, housing material, membrane thickness, and more. If you have a specific need, contact Pro-Oceanus to discuss possible solutions.

3.0 Instrument Setup and User Interface

3.1 Software Overview / Installation

Software can be found on the USB stick included with the sensor or by contacting support@pro-oceanus.com.

Software is compatible with PC-based computers running Microsoft Windows. The computer must be equipped with a serial port, or a USB port with appropriate drivers installed.

Sensors will also run with Tera Term (free to download online) and other terminal programs.

The setup of the communication port must be set as:

Serial Communications Parameter	**Value**
Baud rate	19200
Data bits	8
Parity	none
Stop bits	1

<u>Installing the Pro-Oceanus software</u>

1) Insert the Pro-Oceanus flash drive provided with your sensor into a Windows-based computer
2) Open the folder labelled "Software"
3) Right click on Interface and copy and paste application to desired location on computer

3.2 Connecting the Sensor

- Connect the instrument to the communication/power deck box (A):

- Connect the AC/DC power supply (D) to the deck box and plug into a wall outlet.
- Connect the instrument to the computer with the supplied RS-232 Cable (B). Use the RS-232-to-USB cable (C) if needed.

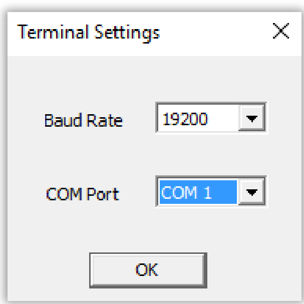
3.3 Serial Terminal

- Open the terminal program.

For Oceanus View:

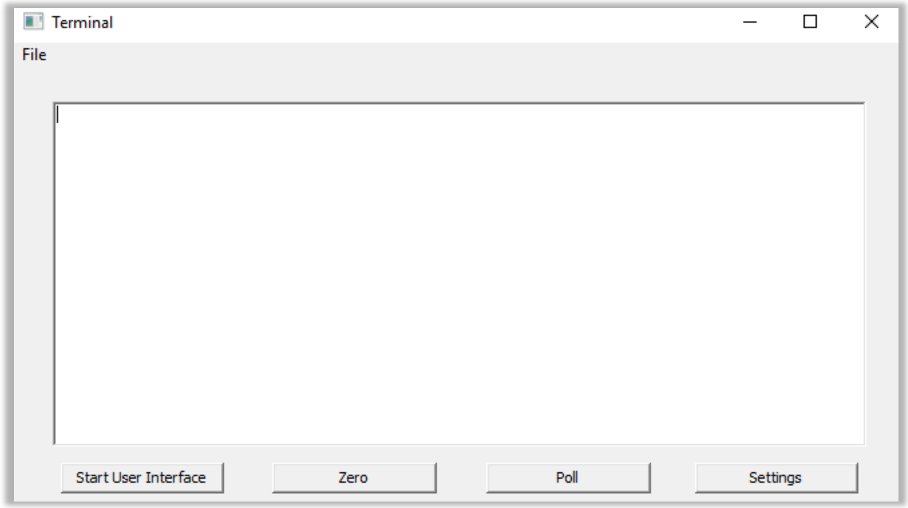
- A home screen will open:

- Select the *Terminal* option under the *View* menu.
- The following communications port settings window will open:



If there is a problem connecting, the program will close connection. If this happens, ensure all settings are correct and try again.

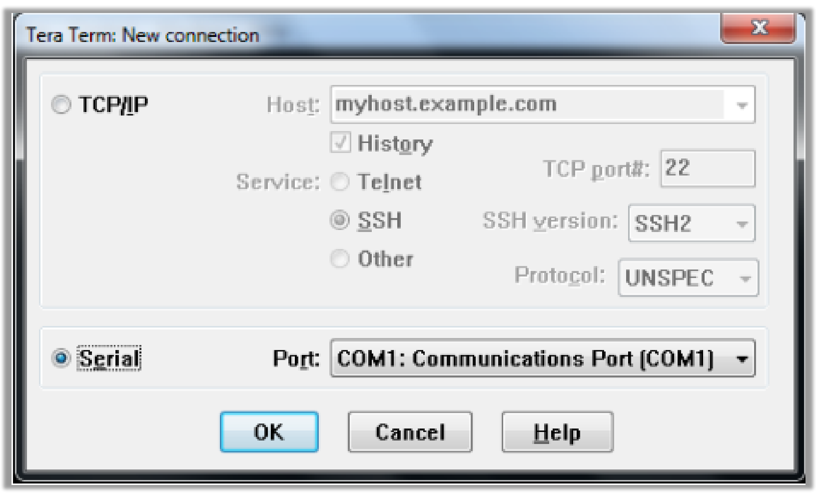
- Enter the correct baud rate (factory configuration is 19200) and COM port and click *ok.*
- The program will open a terminal with a serial connection to the sensor:



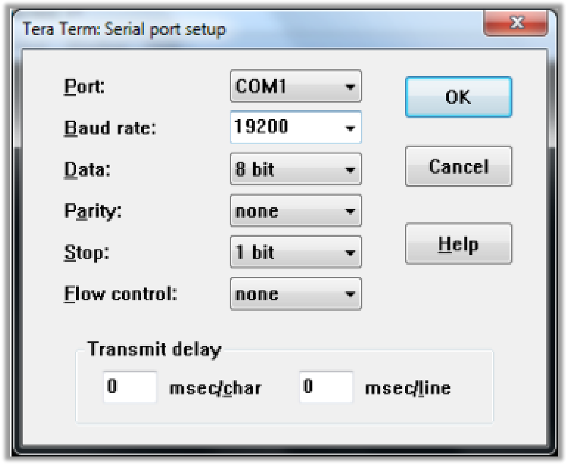
- Click the *Start User Interface* button. The sensor will activate and a status banner and menu will appear. (There may be a delay of several seconds for this to occur).

For Tera Term:

- Open Tera Term and a window will open:



- Select the serial option and ensure the correct port is selected.
- Click *Ok*
- Select the *Serial Port* option under the *Setup* menu and a window will open to configure the serial port:



- Select the correct baud rate (19200) and ensure the port is correct. All other settings should be correct.
- Click *Ok*
- Click "*enter"* to activate the sensor, a status banner and menu will appear.

3.4 Menu Overview

Once connection with the sensor is established in the terminal program, the following status banner and menu will appear:

The status bar shows the:

Firmware version

Currently set date and time

Detector ORT – the amount of time that the CO_2 detector module connected to the logger has been on and operating
Supply Voltage – measure of the main system power input
Mode – This is the current mode of measurement the sensor has been configured for. This is changed in the main menu under *Setup Sampling*

The sensor is equipped with an automatic sleep mode. If no user interaction is detected within 60 seconds of powering the instrument, it will return to low-power sleep. With the Oceanus Software, press the *Start User Interface* button to wake from sleep. If user another terminal program such as Tera Term, from the banner display press the "*escape"* key to enter the user interface. If the 60-second user-interface timeout has occurred, press the any key to wake the sensor and then press "escape" to start the user interface.

Menu options are selected by typing the preceding number or character.
Pressing *"escape"* key at any point will return to the main menu.

1) START sampling mode: Starts sampling in currently set mode
2) STOP sampling mode: Stops the sampling
3) Setup sampling: Start a different sampling mode
   This brings up a choice of sampling modes:

   1) Continuous
   2) Timed
   3) Command

Continuous: Type '1' to select continuous mode
This mode samples as often as the sensor can.
(usually every few seconds)
- After selecting *continuous* option, there is an option to log samples in intervals:
  1) Number of continuous mode samples skipped between log entries (0)
- To set this option, type '1' and this message will appear:
  Enter the number of continuous samples to skip (0-1125)>>
- Enter a number between 0 and 1125 to set the number of samples to be skipped between logged samples
- Then press *Enter*

Timed: Type '2' from the setup sampling menu to activate timed mode.
Timed mode has three settings:

```
Timed sampling setup menu
****************************************************************************************
1) Sample interval in minutes                (30)
2) Number of readings per sample                (1)
3) First sample time                         (11:59:54)
****************************************************************************************
```

Each can be selected by typing the number preceding the option.

1) Sample interval in minutes: sets the amount of time between samples in minutes (from 1 to 10080 minutes)
2) Number of readings per sample: the number of samples that are taken on every sample interval (from 1 to 20 samples)
3) First sample time: sets the time that the sensor will take its first sample (24hr)
   - type hour sampling will start Enter hour (24 hour format)>> Press *Enter*
   - type minute sampling will start Enter minute>> Press *Enter*
   - type second sampling will start Enter second>> Press *Enter*

***ensure internal clock is correct before setting sampling time – option 't' on the main menu**

Command: Type '3' from the setup sampling menu to activate command mode
Takes samples whenever prompted by the user
('s' command in main menu)

```
Commanded mode sampling setup menu
****************************************************************************************
1) Number of readings per sample                (1)
****************************************************************************************
```

- Type '1', prompt will appear: Enter the number of readings per sample (1-20)>>
- Type number between 1 and 20 and press *Enter*

4) View logged data: View data that is logged on the sensor
   When viewing logged data, the first two lines do not contain sensor data. The first line contains the column headings for the data and the second line contains the formatting information. To reduce the data download time, the baud rate can be adjusted to the maximum allowable rate. Viewing data will stop all logging data. *Escape* key can be pressed at any point to abort the download process.
5) Erase logged data: Erases data logged on the sensor
   - Prompt will appear: Are you sure you want to erase all data? (y/n)
   - Type 'y' to erase all data
6) Print status banner: prints the status banner (firmware version, date and time, sensor's run time, supply voltage, current sampling mode)

s) Single sample acquisition in command mode: collects sample or series of samples when in command mode

t) Set clock time: sets the internal clock and should be set to current time (24hr)
b) Set baud rate: set the baud rate of the sensor, factory default is 19200
f) Restore factory defaults

3.5 Data Output and Format

The data is output and stored in the following format:

W M,2015,12,02,11,38,14,1676,2139,500.00,503.28,20.697,1007.02,18.40,11.8,4095,2439,1895

The data is in comma separated variable format (CSV) and the fields have the following meanings:

Field number	Description	Value in example
1	Start of data line (this is fixed and may be used to search for the beginning of the data on any line)	*W M*
2	Year	*2015*
3	Month	*12*
4	Day	*02*
5	Hour	*11*
6	Minute	*38*
7	Second	*14*
8	Reference A/D [counts]	*1676*
9	Current A/D [counts]	*2139*
10	Raw CO_2 [ppm]	*500.00*
11	Corrected CO_2 [ppmv]	*503.28*
12	Sensor temperature [C]	*20.697*
13	Gas pressure [millibar]	1007.02
14	IR detector internal cell temperature [C]	*18.40*
15	Supply voltage [volts]	*11.8*
16	Logger temperature [A/D counts] (0-4095)	*4095*
17	Analog input 1 [A/D counts] (0-4095)	*2439*
18	Analog input 2 [A/D counts] (0-4095)	*1895*
19	Digital input 1 [logic level] (0-1)	
20	Digital input 2 [logic level] (0-1)	

**Note: when the sensor is warming up, several lines of data may display zeros or negative numbers. Once the sensor has warmed up, data will display correctly*.

The "Raw CO_2" column is uncorrected for changes in gas pressure. The "Corrected CO_2" (molar ratio of CO_2) column of data has been corrected for variance in dissolved gas pressure and this data can be used with the "Gas pressure" data column to determine the partial pressure of CO_2, pCO_2. See Appendix B for details on calculating pCO_2.

3.6 Opening, Sorting, and Saving Data Files

The following instructions are for opening, sorting and saving data files in Oceanus View software.

<u>Opening a File:</u>

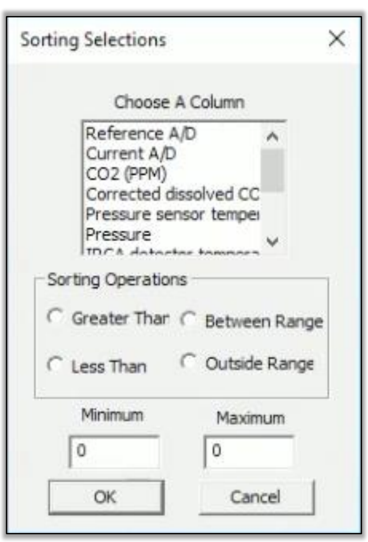
- Click the open option under the *File* menu
- Select the file you want to work with in the window that opens by double clicking it or selecting the file and clicking the open button (large files may take time to open)
- A spreadsheet with the data will open

<u>Sorting the Data:</u>

- Under the *Filter* menu, there are two options:

1) Sort Rows:

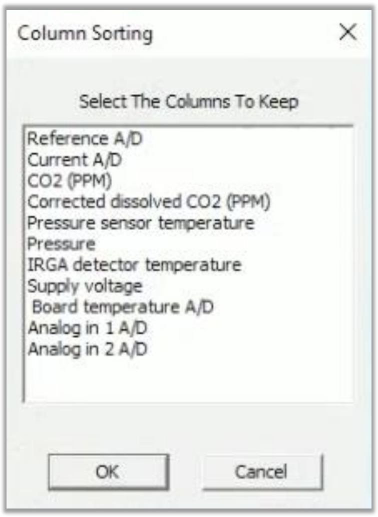
- Select a column to sort in reference to
- Select the desired sorting operation
- Enter the value or range to sort in reference to (min/max)
- Click *ok*
- Save window will open
- File can be existing file or a new file but cannot be the original file
- Click *save*
- New window will open with the sorted data



2) Sort Columns:

- Select columns you want to keep
- Date, time, and measurement columns are locked and cannot be removed

- Click *ok*
- Save window will open
- File can be existing file or new file but cannot be the original file
- Click *save*
- New window will open with the sorted data



3.5 Graphing Saved and Live Data

The following instructions are for graphing data using the Oceanus View software

<u>Graphing saved Data:</u>

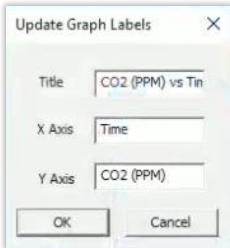
- Open saved data to be graphed
- *Graph Selection* window will open:

- Select x and y axes from the drop-down menus
- Select the number/range of points you want to graph (default is the entire range)
- Click *OK*

- A graph will be generated with auto-scales axis
- To navigate back to the data, click *data* under the *view* menu

Manipulating the Graph:

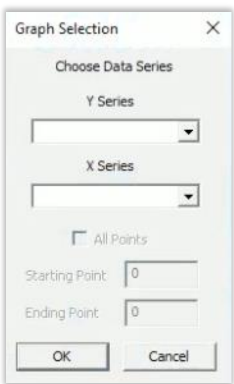
- When the graph is open, there is a format menu at the top with two options:
    - *Labels*: opens window to update the graph labels



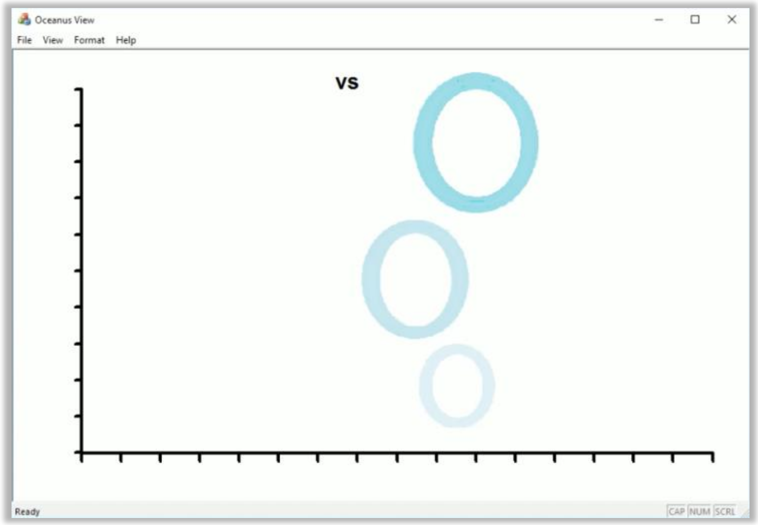
    - *Data Selection*: re-opens the *Graph Selection* window
- Save the graph with the *Save* option under the *File* menu
- Print the graph with the *Print* option under the *File* menu

Graphing Live Data:

- Open terminal
- Under the *View* menu, click the *graph* option
- Graph Selection window will open:



- Select x and y axis to be displayed on the live graph
- Click *OK* and a blank graph will appear:



- In the terminal window, begin sampling
- Points will appear on the graph once sampling begins
- Options under the *Format* menu can be used while the live graph is running to manipulate the graph
- If plotting with time as a variable, a graph line will form. If plotting with two other variables, a point graph will be created

4.0 Instrument Deployment

4.1 Sensor Mounting and Plumbing

The Mini CO_2 sensor should be mounted horizontally when possible. This is to prevent any sediment buildup on the membrane as well as to prevent the trapping of any free gas against the membrane. If the sensor must be mounted vertically, it is recommended to have the membrane facing upwards for quick deployments and profiling, and with the membrane facing downward for prolonged moored deployments. When deploying the sensor with the membrane pointing downward, it is recommended to initially place the sensor horizontally to allow any gas next to the membrane to be removed by buoyancy. Below is an image of the sensor and the preferred location of mounting brackets.

If the water-pumped flow-through head is installed (Section 4.6.1) and connected to a water pump, ensure that water is pushed through the sensor head and not pulled. Pulling water through the sensor head can alter dissolved gas pressure and potentially damage the sensor membrane.

4.2 Moored/Stationary Mode

When the sensor is configured in timed or command mode, it can be used for long periods of time on moorings and stationary platforms. When deploying the Mini CO_2 sensor in moored mode, it is important to ensure gas bubbles do not become trapped against the sensor membrane when first placed into the water. Having the sensor tilted horizontally or vertically with the membrane pointing upwards can facilitate this. The sensor should be mounted in a horizontal position for long-term deployments to prevent buildup of particles on the membrane. Vertical mounting is acceptable as well provided the sensor membrane is facing downward and there is no potential for gas bubbles to rise and become trapped against the membrane surface where it is deployed. While the gas bubbles will dissolve over time, they will create irregular data when present.

4.3 Profiling/Underway Mode

When the sensor is configured in continuous mode, it can be used for short periods of time on profilers and mobile platforms, or longer periods with a dedicated power supply. When deploying the Mini CO_2 sensor in profiling mode, it is essential to ensure gas bubbles do not become trapped against the sensor membrane when first placed into the water. Having the sensor tilted horizontally or vertically with the membrane pointing upwards can facilitate this. The sensor can be mounted in any orientation provided that gas bubbles are not trapped against the membrane during the initial time of deployment. The sensor does have a significant equilibration time when compared to typical CTD instrumentation. This requires the user to stop at pre-determined depths for 15- 20 minutes to allow for full equilibration. The use of a water pump with the water-pumped sensor head will reduce the time to equilibrate and it is highly recommended to minimize the duration of a profile.

4.4 Integration with Existing and Third-Party Systems

Pro-Oceanus works with many third-party companies to integrate our products into their platforms and equipment. If you have a system or platform that you would like to have the Mini CO_2 sensor integrated into, please contact us.

4.5 Power Budgets

The Mini CO_2 can be operated using direct cable power input, an external battery pack, or an optional internal battery pack (Models M230 and M235). The average power consumption for the Mini CO_2 is approximately 4 W (~7 mA @ 12 VDC) when measuring and the internal controller requires ~35 µA of current during sleep.

In order to determine the battery endurance of a pre-set measurement frequency, use the table below to estimate of the duration a battery pack will provide power to the Mini CO_2. **Note**: These are estimates based on a standard Mini CO_2 with an average water temperature of 20ºC.

Mini CO_2 internal battery pack endurance.

Sampling Rate	6V 5 Ahr Battery	12V 5 Ahr Battery	6V 19 Ahr Battery
Continuous	15 days	1 month	2 months
15 minute	4 months	8 months	15 months
30 minute	8 months	15 months	>2 years
1 hr	15 months	>2 years	

Mini CO_2 external battery pack endurance.

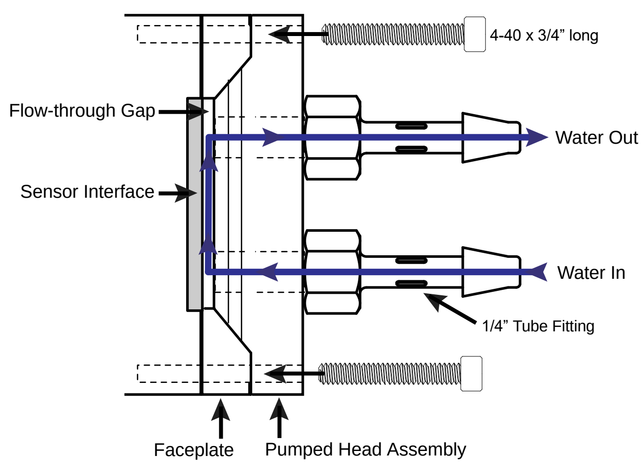
Sampling Rate	12V 19 Ahr Battery	12V 76 Ahr Battery
Continuous	4 months	15 months
15 minute	> 2 years	

4.6 Installing Optional Accessories

4.6.1 Water-pumped flow-through head

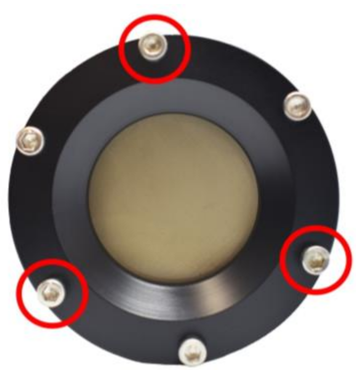
(P/N: MA-30-01)

The water-pumped head provides a reduced time for sensor equilibration with a surrounding water sample and an effective means of preventing biofilms from forming on the membrane.



To install the water-pumped head:

1) Remove three of the socket-head screws (1/2") in an alternating pattern. Do not loosen the three remaining screws as this will compromise the instrument integrity.



2) The pumped-head assembly will fit directly on top of the three remaining socket head screws. (Make sure O-ring on pumped-head is in place – indicated by red arrow below).
3) Ensure the pumped head is flush with the sensor head and insert and hand-tighten the three screws that are supplied with the pumped head (3/4" length).
4) Once the pumped head is gently resting on the O-ring seal, creating a small and even gap between the pumped head and the sensor head, the three screws can be tightened using the supplied 1/32" Hex screwdriver, alternating each screw tightening a quarter turn each time until pumped head is securely connected. *Do not overtighten.

The pumped head is also supplied with a 30 cm piece of silicone tubing for connecting a small, user-supplied water pump to one of the ports of the water pumped head. The recommended water flow rate is 0.5 - 3 liters per minute when using the water-pumped head accessory. Higher flows may abrade the membrane more quickly and should be avoided.

4.6.2 Antifouling copper faceplate

(P/N: MR-361-01)

Installation of the antifouling copper faceplate can discourage the growth of organisms on the sensor's membrane.

To replace the copper face plate:

1) Dry the sensor and place it horizontally on a clean surface.
2) Using a 3/32" Hex screwdriver, remove the screws 1-6, use caution as slipped screw driver can damage the membrane. This will remove the entire faceplate and the membrane will come loose, carefully set the membrane aside.

3) Remove screws 7 & 8 to separate 2 sections of faceplate
4) Replace copper screen
5) Place O-ring on top of copper screen
6) Place top part of faceplate on top of O-ring.

7) Re-install screws 7 & 8 (1/2" length).
8) Ensure O-rings are in place (one on instrument body and one on back of faceplate)

9) Holding the sensor vertically, carefully put membrane on sensor head. Place the faceplate on top and replace screws 1-6. It is recommended to install all six screws and tighten until the O-ring begins to compress. It should not be difficult to tighten the screws. If excess resistance is felt, ensure the membrane and O-rings are in the correct position. Hand-tighten the screws, do not over-tighten. Then alternate sides and tighten each screw with a quarter turn each to install the faceplate evenly.

4.6.3 External battery pack

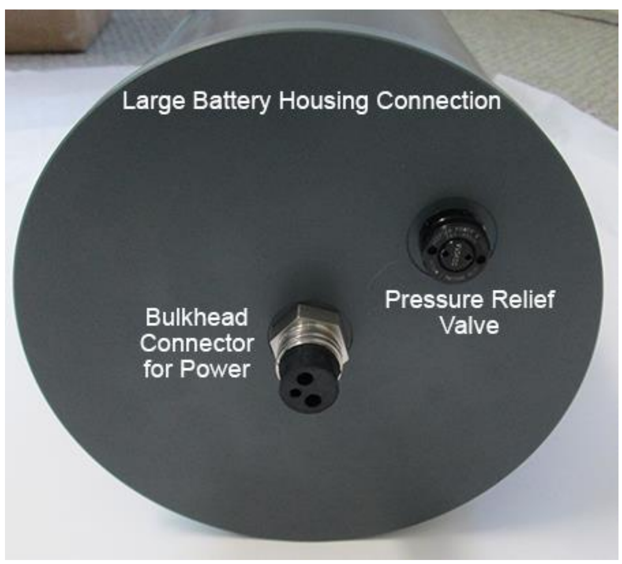
Pro-Oceanus Mini Series sensors can be connected to an external battery power supply where long deployment periods with frequent sampling are required. Pro-Oceanus can provide external battery housings and battery packs along with the appropriate cabling for simple connection and operation.

For external battery power, use the power/comm deck box (A10-103), configure the sensor to the desired sampling setup and press "1" to start the program. Ensure that the clock time is correct and that the first sample time is at least 20 minutes after the current time. If the first sample time is set too close to the current time, the sensor will not start collecting data until the next day. Once the program is set and started, remove the deckbox cable from the Mini sensor.

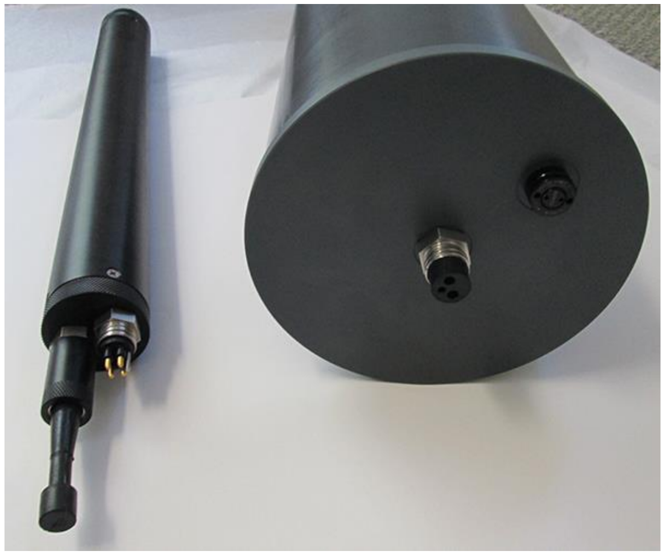
The below images are shown for a Mini sensor with internal battery pack (M230/330 or M240/340 series) being connected to a large external battery housing with pack (BH268-01). The same connections would occur for other Mini Series and smaller external battery housings with packs.

For Mini sensors that have an internal battery pack, ensure that the shorting plug is not installed on the battery bulkhead connector on the rear of the Mini sensor. Please use the supplied dummy plug.

The rear of the external battery housing has a 2-pin female bulkhead connector (V+ and Gnd).



To connect the external battery housing to the Mini sensor, remove the dummy plug from the power/comm 4-pin male bulkhead on the rear of the sensor.



The Mini sensor is connected to the external battery housing using a 4-pin female to 2-pin male cable (CB40-01).

First, connect the 4-pin female end of the cable to the 4-pin male bulkhead on the rear of the Mini sensor.

Next, connect the 2-pin male end of the cable to the 2-pin female bulkhead on the rear of the battery housing.

Once connected, the sensor will be powered via the external battery pack.

4.7 Charging the Internal Battery (if installed)

The internal battery pack for the Mini Series can be charged using the charger and power source included with your sensor.

1) Locate the *Turnigy Accucell 6* charger (A) the charger power supply (B) and the connector cables (C).

2) Remove the instrument from the water and dry completely.
3) Place the instrument on a clean, dry bench and sure in place to prevent rolling.
4) Disconnect the deckbox connection and or/shorting (or dummy) plug(s) from the instrument.

5) Connect the power supply to the charger. Connect the cables together and connect the charging leads to the corresponding outputs that are marked on the charger. [+] is red and [-] is black. (the power supply can be connected to 110 or 220 VAC).

The battery charger screen should read:

6) Choose the correct battery type:
   - push the *TYPE/STOP* button

   - press the *STATUS/+-* button to scroll through the battery types
   - scroll to the NiMH battery and hit the *START/ENTER* button to select
7) The following screen should appear:

   If it does not read 'charge' next to NiMH use the *STATUS/+-* button to scroll through the options until the 'charge' appears. Push the *START/ENTER* button to select.
8) The number in front of the A should be flashing. This is the amount of current the battery will charge at. **This must be set to 0.3 for the Mini sensors**. Use the *STATUS/+-* button to scroll to the correct number. Hit the *START/ENTER* button to select.
9) Push and hold the *START/ENTER* button. This screen will appear:

   and then charging will begin:

   - The timer shows how long (in minutes) the battery has been charging.
10) When charging is complete, the charger will beep and the screen will read:

   *note The charger may time out part way through charging, the END:FINISH screen will appear but the V will be less than the charged battery (i.e. 4.52V for a 6V battery). If this happens, restart the charger from step 6 to continue charging.
11) Disconnect the battery and power down the charger by unplugging it from the power source.

5.0 Care and Maintenance

5.1 Cleaning

5.1.1 Instrument Housing

The standard Mini CO_2 housing is made of acetal plastic. Upon recovery, rinse the external surface of the sensor with clean, fresh water. Mild detergents may be used to help remove biofilms. Diluted Alconox Liquinox is a recommended detergent. A soft cloth can be used on the housing to remove larger and more difficult to remove biological material.

5.1.2 Bulkhead Connectors

Unplug all cables and dummy plugs from the rear of the housing and inspect the connectors for corrosion. Apply a light coat of silicone-based grease to each of the connector pins. Dow Corning Molykote 111 is recommended. Re-connect electrical cables and plugs and ensure the lock-down sleeves are secured. Do not over-tighten the locking sleeves, hand tighten only.

5.1.3 Membrane Interface

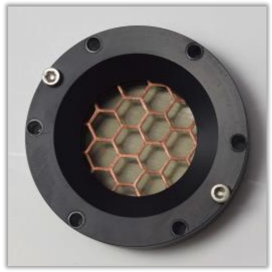
Cleaning of the interface should be completed after any deployment to ensure fast response times of the instrument as well as to prolong the service life of the membrane. Diluted Alconox Liquinox is recommended. Using a small bucket filled with Liquinox diluted in clean fresh water, place the sensor in the bucket with a small water circulation pump. Pumping of the liquid directly onto the membrane surface will help reduce the time of cleaning. At all times, ensure that the membrane is not touched or damaged during cleaning.

5.2 Replacing the Membrane

1) Dry the sensor and place it horizontally on a clean surface.

2) Using a 3/32" Hex screwdriver, remove the six screws from the face of the sensor:

CAUTION: Be careful not to damage the membrane, the hex driver can easily puncture the membrane if it slips. It is recommended to alternate sides when removing the screws to release the faceplate evenly. **Note: If the anti-fouling option is installed, leave the two screws shown* *below in place when replacing membrane. They can be removed if the anti-fouling screen needs to be replaced.*



3) Once all six faceplate screws are removed, gently twist the faceplate while pulling away from the sensor body.

4) Place the faceplate on a clean flat surface with the inside facing upwards to prevent scratching of the O-ring and O-ring groove.

5) Remove the damaged membrane and inspect the membrane support for any indication of water.

> **Note:** If the membrane has been damaged and water intrusion into the sensor has occurred, the sensor potentially needs to be returned to Pro-Oceanus Systems. Refer to the Troubleshooting Section.

6) Inspect the two faceplate O-rings (indicated by the grey arrows in above photo) and replace if necessary. The inner O-ring replacement size is 026 and the outer O-ring size is 029. Very lightly grease each O-ring. Dow Corning Molykote 111 is recommended.

7) Holding the sensor housing vertically, place a new membrane into the sensor head (ensure the shiny side is facing out).

> **Note:** Use an uncoated rubber glove or Kim-Wipe to place the membrane so that no oil residue or dirt ends up on the membrane.

8) Re-install the six screws securing the faceplate of the sensor. It is recommended to install all six screws and tighten until the O-ring begins to compress. It should not be difficult to tighten the screws. If excess resistance is felt, ensure the membrane and O-rings are in the correct position. **Hand-tighten screws only, do not over-tighten**. Then alternate sides and tighten each screw with a quarter turn each to install the faceplate evenly.

9) After installation, test the sensor in freshwater for several hours while monitoring the sensor signal. This is to ensure that the membrane is installed properly and no leakage into the detector is occurring. If the sensor output becomes erratic or begins to output zero or negative values, immediately remove the sensor from water and refer to the Troubleshooting Section.

5.3 Internal Clock Battery Replacement

The Mini CO_2 uses an internal battery to power the logger/controller when not powered externally. This allows for the clock to remain active and accurate when not in use, or between measurements when external power is removed. It is recommended to replace the clock battery once every three years.

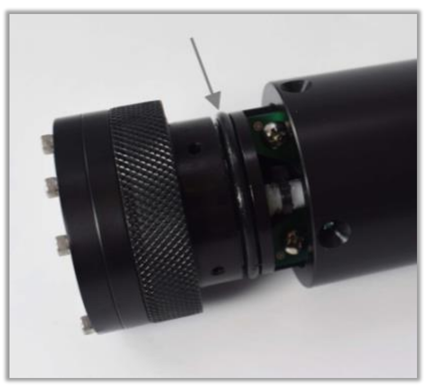
1) Dry the sensor and place it horizontally on a clean surface.

2) Remove the four screws on the side of the sensor head with a Philips screwdriver.

3) Gently slide the head out from the body of the sensor. There will be some resistance from the O-rings, but do not pull hard or electronics could be damaged.

4) Carefully pop out clock battery and replace.

5) Inspect the O-ring (indicated by the grey arrow in the photo below) and replace if necessary. O-ring replacement size is 220. Very lightly grease each O-ring. Dow Corning Molykote 111 is recommended.



6) Slide head back into body, line up screw holes and replace screws.

5.4 Calibration

Calibration of the Mini CO_2 must be completed by Pro-Oceanus staff. The calibration procedure requires 4-6 WMO traceable standards and a linear curve fit function. Sensors are calibrated individually to ensure the best possible accuracy.

It is recommended that each Mini CO_2 to be returned to Pro-Oceanus once every 12-18 months for re-calibration and functional testing. Normal sensor drift over one year is typically less than 3% of the maximum measuring range.

To return an instrument for re-calibration, please contact Pro-Oceanus for an RMA number prior to shipping it freight pre-paid to Pro-Oceanus:

Pro-Oceanus Systems

80 Pleasant Street

Bridgewater, NS, CANADA

B4V 1N1

Carefully package the instrument in its original protective case, and clearly mark as "fragile goods" and "return for repair" on the outside of the case.

6.0 Troubleshooting

There is no power going to the sensor.
Check the power supply, it should be 7-24 VDC.
Check the fuse in the deckbox and replace if necessary.

Fuse is a 1.5Amp Slo-Blo 326 Series.

Standard gas measurements are not accurate.
Typically, this means that the instrument has experienced drift due to length of time since calibration, or damage to the infrared detector. Return to Pro-Oceanus for re-calibration. See section 5.4.

At start-up, the instrument is reading very high CO_2 values.
The interface may have a substantial layer of biofilm. Clean the interface according to the Cleaning the Interface instructions in section 5.1.3.

The sensor is outputting zero or negative values after the warmup period.

- The water the sensor is in may be undergoing very rapid changes in environmental conditions.
- The membrane may be damaged and water has entered the infrared detector or electronics.
- The sensor may be experiencing pressure waves due to turbulent waters when the membrane is not compressed flat against its support.

The sensor's membrane is damaged and water has entered the detector.
If a liquid other than fresh water has entered the sensor:

- Contact Pro-Oceanus for an RMA to return the instrument for repair.

If it is fresh water that has entered the sensor:

- Dry the sensor completely and remove the sensor membrane as outlined in section 5.2 of the user manual. Then, place the sensor in a sealed container or bag with a drying agent such as Drierite. Ensure the drying agent is placed inside of a filter bag to avoid dust and particles from the drying agent to enter into the detector. Leave the sensor to dry for a minimum of 24 hours before attempting to power the sensor. After powered, check the sensor in air to see if it is behaving normally. If so, install a new membrane and continue to use. If the sensor does not operate normally, contact Pro-Oceanus for an RMA to return the instrument for repair.

Symbols or dots are appearing in the terminal program, or sensor does not seem to be communicating with the terminal program.
Check to make sure all cords are connected. Ensure that the baud rate of the sensor matches the baud rate set in the terminal program.

7.0 Warranty

Pro-Oceanus Mini Series instruments are covered by a 1-Year Limited Warranty

For a period of one year after the date of original shipment, products manufactured by Pro-Oceanus Systems Inc. are warranted to function properly and be free of defects in materials and workmanship. Should an instrument fail during the warranty period, please contact Pro-Oceanus for an RMA number prior to shipping it freight pre-paid to Pro-Oceanus:

Pro-Oceanus Systems

80 Pleasant Street

Bridgewater, NS, CANADA

B4V 1N1

Carefully package in the instrument's original protective case, and clearly mark as fragile goods and return for repair on the outside of the case.

Pro-Oceanus Systems Inc. will repair it (or at the company's discretion, replace it) at no charge, and pay the cost of shipping it back to the customer.

Modifications / Exceptions / Exclusions

1. Gas permeable membranes, rigid permeable membrane supports, support screens, absorbents, batteries, and other consumable/expendable items are not covered under this warranty.
2. Damage to the sensor or other internal electronics as a result of flooding from either a punctured membrane or an improperly customer installed O-ring seal is not covered under this warranty. Care must be taken to deploy instruments according to procedures described in this manual to minimize the possibility of instrument flooding.
3. Corrosion damage is not covered under this warranty
4. 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 instruments and cannot be held liable for any injuries or damages incurred during use of Pro-Oceanus instruments.

This warranty is void if 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.

APPENDIX A: Equilibrium Dynamics and Instrument Response Time

The equilibrium of dissolved gas sensors with surrounding water requires diffusion of molecules from a liquid across a semi-permeable membrane to a gaseous headspace. Once in the gas phase, detectors are used to measure a concentration in gaseous form. Several factors affect the time it takes to equilibrate a gas headspace with a surrounding water parcel through a semi-permeable membrane. The main factors are described below.

There is a finite time that is required for the shift between the dissolved and gas phases of a substance due to the kinetics of solubility. The rate is dependent on temperature and salinity, and to a much lesser degree, pressure.

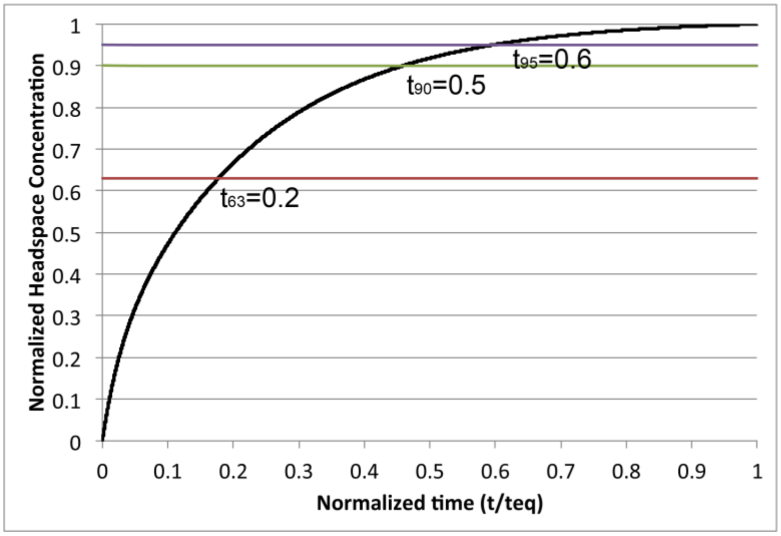
The membrane effect can be described using the Laws of Diffusion, whereby the diffusion coefficient of the semi-permeable membrane is a function of the gas solubility coefficient in the membrane, and the permeability of that gas through the membrane.

The thickness of the membrane also plays a crucial role in the time for equilibration.

Temperature and salinity can dramatically affect the diffusion through a membrane.

The equilibration rate of diffusion processes is often measured in terms of a time constant, t_{63}. This represents the time it takes reach 63% of equilibrium. The flux of gases across a membrane is a function of the gradient of difference between the concentrations on either side of the membrane. For example, the flux of a gas across a membrane will be rapid when the difference in concentration in surrounding water and the gas headspace is large. As a gas moves across the membrane either into or out of the gas headspace, the concentration gradient decreases, and as a result, the rate of gas flux across the membranes slows.

The concentration gradient across the membrane continually changes, and the resulting change in concentration of a particular gas in a headspace can be described mathematically as a logarithmic function. Below is a graph that illustrates the change in concentration in the headspace of an instrument using a semi-permeable membrane to equilibrate. The graph also shows commonly used time constants used in industry, t_{63}, t_{90}, t_{95}.



t_{63} is taken as one fifth of the total time to equilibrate,
t_{90} is approximately half the time to equilibrate, and
t_{95} is roughly 60% of the time to equilibrate.
t_{99} is taken as teq.

The time constant, t_{63} is commonly used and is the number referred to by Pro-Oceanus. There is also the effect of the water-side boundary layer. Advection transfers the dissolved gas to near the membrane surface is a rapid process, but diffusion of gas through the water boundary layer is the rate limiting factor in the transfer from the water to the outer surface of the semi-permeable membrane. Temperature once again has a major effect on the diffusion rate. In all cases, warmer temperatures improve the response time of the instruments, while cooler waters will slow the process.

The thickness of the boundary layer can vary (and as a result, so too does the time to diffuse through the boundary layer) and the thickness is determined by the hydrodynamics next to the membrane surface. Stagnant water will produce the thickest boundary layer, resulting in the slowest response time. Maximizing the water shear across the membrane surface will reduce the boundary layer thickness to a minimum and is recommended using a Pro-Oceanus pumped head assembly. The effect of high shear also reduces the potential for biofouling of the instrument.

APPENDIX B: Partial Pressure of CO_2, pCO_2

CO_2 (g) is commonly measured in units of ppm (parts per million). This is the molar ratio of **x** number of **CO_2** molecules per million molecules of total gas. The ppm of CO_2 in air does not change with pressure. Ppm CO_2 is also referred to as the mixing ratio, xCO_2 (ppmv).

In natural waters, CO_2 (g) is often reported as a partial pressure, pCO_2, with units of microatmospheres (µatm). Unlike xCO_2, pCO_2 is dependent on the total gas pressure.

The two terms are related through pressure by:

$$\mathrm{p}CO_2 = \mathrm{x}CO_2 \times P \qquad \text{(B.1)}$$

where P is pressure measured in atmospheres and xCO_2 is in ppmv.

A third unit of measure for CO_2 is the fugacity, fCO_2. The fugacity corrects for non-ideal gas behavior of gases and can be estimated from approximate expressions along with temperature and pCO_2. In most cases fCO_2 is within a few µatm of pCO_2.

The Mini CO_2 measures the "wet" (i.e. partial pressure of water vapour included) xCO_2 of a gas stream that has equilibrated with surrounding water. In addition, the sensor measures the total pressure, P, of the gas stream, in millibars (mbar). The measured ppm output from the sensor is corrected for pressure variation, as is needed for NDIR measurement. By converting the measured gas pressure to units of atmospheres:

$$P\ (\mathrm{mbar})\ /\ 1013.25 = P\ (\mathrm{atm}) \qquad \text{(B.2)}$$

pCO_2 (µatm) can then be calculated using eqn. B.1.
Typically, headspace equilibrators remove water vapor prior to measurement of CO_2, and must be corrected for this. The Mini CO_2 sensor measures the "wet" CO_2 concentration and do not need to be corrected for water vapor.

APPENDIX C: CO_2 Solubility and Dissolved Phase Concentration

The measurement of CO_2 in water is facilitated by the Mini CO_2 through equilibration of a gas headspace with surrounding water. This results in a measurement that is in the "gas" phase as a partial pressure of the total gas pressure equilibrated with the water. The same equilibration dynamics occur at the surface of a body of water in contact with the atmosphere, such that the concentration of CO_2 in the water is in equilibrium with the partial pressure of CO_2 in the atmosphere.

$$CO_2(g) \leftrightarrow CO_2(aq) \tag{C.1}$$

The equilibrated ratio of partial pressure to dissolved concentration is governed by:

$$pCO_2 = K_o[CO_2(aq)] \tag{C.2}$$

where pCO_2 is the partial pressure of CO_2 in the gas phase, K_o is a solubility coefficient, and CO_2 (aq) is the concentration of CO_2 dissolved in the water.

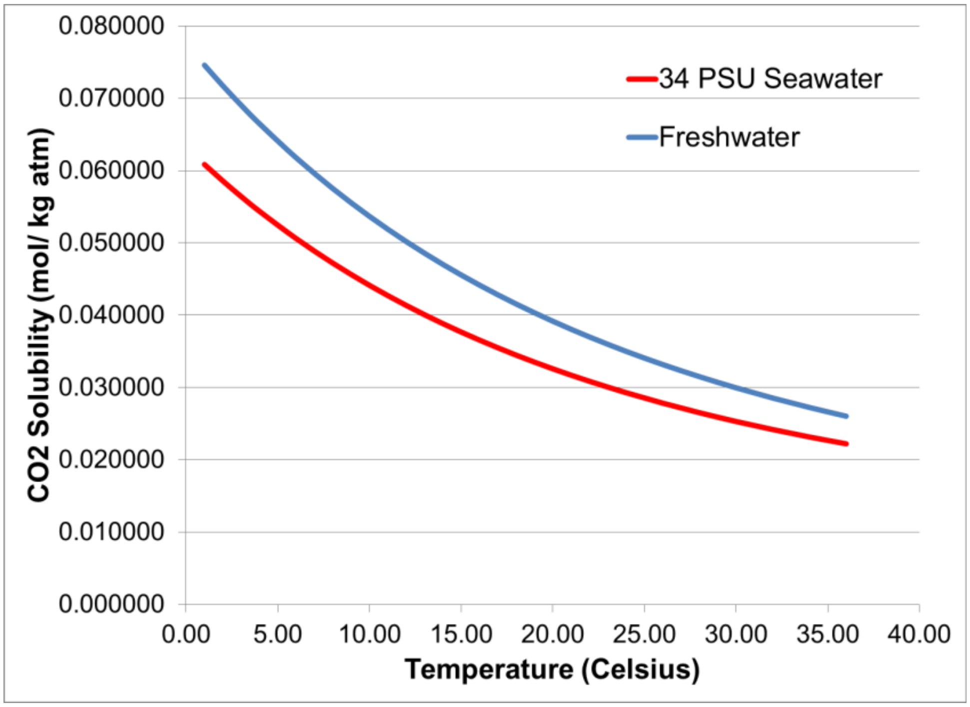
The units of pCO_2 used in the equations that follows are µatm.
The solubility of CO_2 in water is a function of both the temperature and the salinity of the water, from Weiss (1974):

$$\ln(K_o) = -60.2409 + 93.4517\left(\frac{100}{T}\right) + 23.3585\ln\left(\frac{T}{100}\right) + S(0.023517 - 0.023656\left(\frac{T}{100}\right) + 0.0047036\left(\frac{T}{100}\right)^2) \tag{C.3}$$

Where the solubility coefficient, K_o has the units of mol kg^{-1} atm^{-1}, temperature is Kelvin, and salinity is in parts per thousand (approximately equal to PSU).
For non-saline waters, the second term of the equation becomes zero, leading to:

$$\ln(K_o) = -60.2409 + 93.4517\left(\frac{100}{T}\right) + 23.3585\ln\left(\frac{T}{100}\right) \tag{C.4}$$

The figure below depicts the solubility of CO_2 in both freshwater and seawater (S=34) as a function of temperature. CO_2 is more soluble in freshwater than seawater, and solubility decreases with increasing temperature, see figure below.



An excel spreadsheet for conversion calculations can be obtained by contacting Pro-Oceanus Systems.

Reference: Weiss, RF. 1974. Carbon dioxide in water and seawater: the solubility of a non-ideal gas. Marine Chemistry. 2:203-215. 10.1016/0304-4203(74)90015-2.

APPENDIX D: Conversion of CO_2 Units

For applications such as aquaculture, it is common to see units of dissolved CO_2, including mg/L (also referred to as ppmm, parts per million by mass).

The use of "ppm" for both gas phase and dissolved phase concentrations of CO_2 in water can lead to confusion and so it must be made clear what units of measure are being used. For example, 1000 ppmv of CO_2 (g) is only be equivalent to 1-3 ppmm of CO_2 (aq).

Conversion of these units depends on temperature and salinity of the water. To the left is a table converting several partial pressures of CO_2 to aqueous phase concentration of mg/L in freshwater at 20^{o}C.

pCO_2 (µatm)	**$CO_{2(aq)}$ (mg/L)**
500	0.9
1000	1.7
1500	2.6
2000	3.4
2500	4.3
3000	5.2
4000	6.9
5000	8.6
7500	12.9
10000	17.2

Equation for converting from pCO_2 to mg/L:

$$CO_2(mg/L) = \left(\left[\frac{pCO^2}{10^6} * Ko\right] / \left[1 + \frac{S}{10^3}\right]\right) * 44010 \qquad \text{(D.1)}$$

pCO_2 is the measured pCO_2, K_o is a solubility coefficient (eqn. C.3 in Appendix C), and S is Salinity in PSU. (Temperature is accounted for in K_o)

If working with fresh water, the equation can be simplified to:

$$CO_2(mg/L) = \left(\left[\frac{pCO^2}{10^6} * Ko\right]\right) * 44010 \qquad \text{(D.2)}$$

and K_o can be obtained from eqn. C.4 in Appendix C.