Cycle phosphate (PO_4) sensor

User manual

01/2014, Edition 3

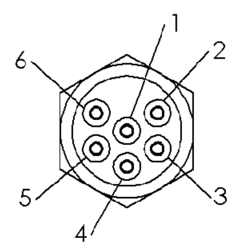
Table of Contents

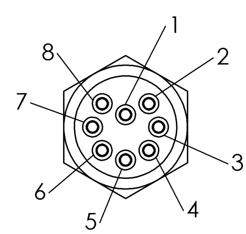
Section 1 Specifications

1.1 Mechanical

Height (w/handle)	56 cm
Diameter	18 cm
Weight in air	6.8 kg (w/reagents)
Weight in water	0.37 kg
Depth rating	200 m

1.1.1 Bulkhead connectors

Pin	Function	MCBH-6-MP connector
1	Ground	
2	RX	
3	External wake	
4	Voltage in	
5	TX	
6	Analog out	

Pin	Function	Diagram of MCBH-8-MP
1	Ground	
2	Bi-directional SDI-12	
3	V in	
4	Reserved—Do not use	
5	Reserved—Do not use	
6	Reserved—Do not use	
7	Reserved—Do not use	
8	Reserved—Do not use	

1.2 Electrical

	Main port (6-pin)	**SDI port (8-pin)**
Input	10.5–18.0 V	
Current draw	115 mA avg, 2 A max	9 mA avg, 11 mA max
Low power current draw	30 µA	
Power dissipation	1.15 W avg, 12 W max	
Communications	RS232 ASCII	SDI protocol
Serial data rate	9600–115,200 baud	1200 baud
Data storage	1 GB compact flash card type II	
External wake high voltage	3.5–20.0 V	
External wake low voltage	0.0–3.3 V	

1.3 Optical

Wavelength	870 nm
Pathlength	5 cm
Linearity	> 95% R^2

1.4 Analytical

Detection limit, three standard deviations of 18 MOhm water	less than or equal to 0.075 µM less than or equal to 0.0023 mg/L PO_4-P
Quantification limit, ten standard deviations of 18 MOhm water	less than or equal to 0.025 µM less than or equal to 0.0077 mg/L PO_4-P
Range, nominal	0–10 µM 0–0.3 mg/L PO_4-P
A higher range of 0–40 µM, 0–1.2 mg/L PO_4-P is possible but outside specifications.	

Section 2 Sensor setup

2.1 Assemble the sensor

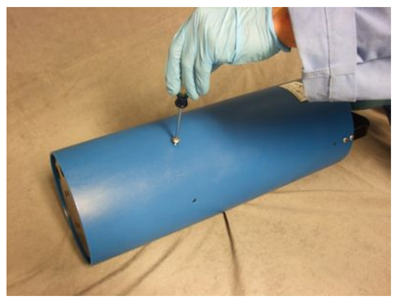
⚠ CAUTION

Wear Personal Protective Equipment (PPE) to remove or replace cartridges. PPE includes a lab coat or smock, gloves, safety glasses.

The Cycle PO_4 sensor comes in two boxes. One is a fiberboard box with the reagent cartridges. The second is a ruggedized plastic case with the sensor and spare parts.

1. Remove the sensor and the spare parts kit from the plastic case.
2. Remove the cartridges from the fiberboard box.
3. Set the sensor on its side to remove the seven screws that attach the protective sleeve to the sensor.
4. Remove the seven Phillips screws on the sleeve. Keep the screws.

Figure 1 Screws removed from protective sleeve



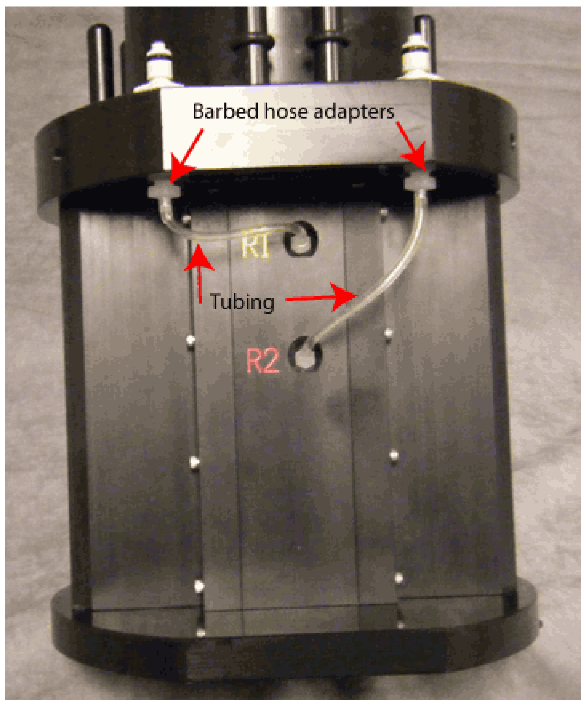
5. Hold the bottom of the sensor and bring it vertical to slide the protective sleeve off.

Figure 2 Sensor with protective sleeve removed

6. Look at the sensor. One side has the intake tubing to the sample port, marked with "S."

Figure 3 Intake tubing

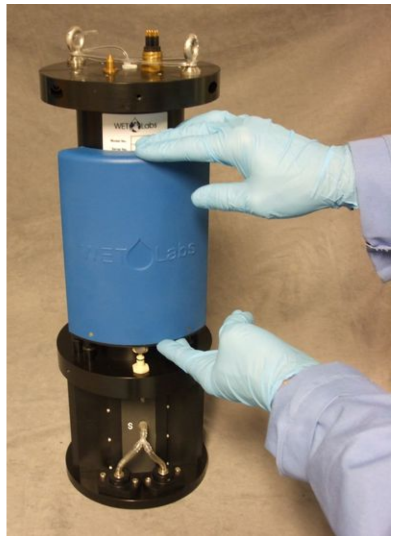
Figure 4 Reagent tubing



Cartridge color	Location on sensor	Contents
Blue	S	phosphate
Yellow	R1	ascorbic acid
Red	R2	sulfuric acid, < 10%

7. Remove the reagent cartridges from the box and unwrap each cartridge. Note that the cartridges are indexed so each one will only fit in one place on the sensor.
8. Install the blue calibration cartridge first. Hold it above the upper housing, above the intake ports.

Figure 5 Blue calibration cartridge installed



9. Set the cartridge on the guide pins and push down until it "clicks" into place.
   If the cartridge does not "click" into place, lift it off of the guide pins and push on the stainless steel tab of the fluid coupler to make sure it is unlocked.

Figure 6 Blue cartridge on guide pins

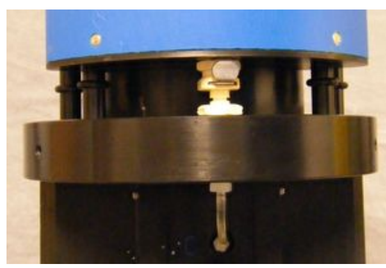


Figure 7 Fluid coupler at the bottom of each cartridge

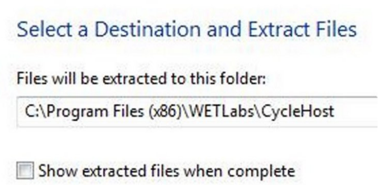
10. Install the yellow and then the red cartridges.
    The cartridges are installed correctly if they cannot be lifted off of their bases.

Figure 8 Cartridges installed

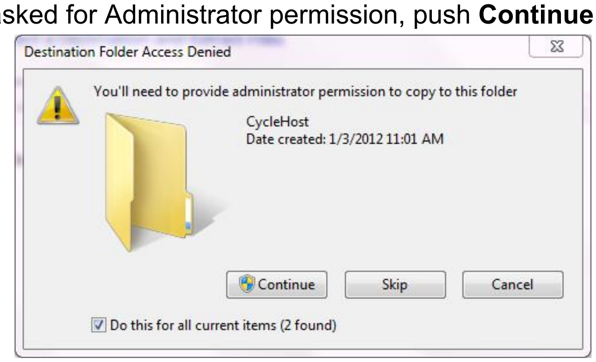
2.2 Install the software

Install the Cycle Host software from the CD that comes with the sensor, or download it from the Software tab of the Cycle Host product page on the manufacturer's web site.

1. Make a Cycle folder in C:\Program Files(x86) on Windows Vista, Windows 7 or Windows 8 or in C:\Program Files for earlier versions of Windows.
2. Make a CycleHost folder in the Cycle folder from the previous step.
3. Put the CD into the PC or go to the downloaded zip file.
4. Right-click on the CycleHost.zip folder and choose **Extract All...**
5. Extract the files to **C:\Program Files (x86)\WETLabs\CycleHost**.

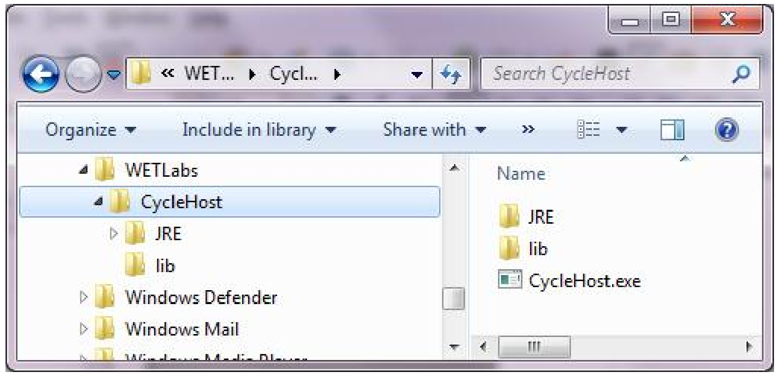


6. If asked for Administrator permission, push **Continue**.

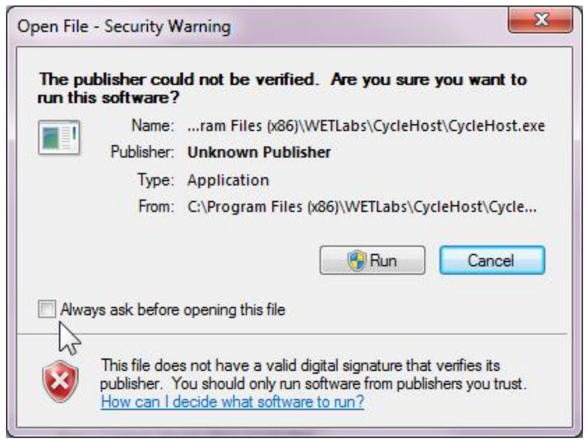


The Cycle software files will "unzip."

7. Go to the main program file.
8. Double-click on the **CycleHost.exe** file.



9. If a Windows security warning shows, push **Run** to continue to install the Cycle Host software.



2.3 Prime the sensor

⚠ CAUTION

Wear Personal Protective Equipment (PPE) to remove or replace cartridges. PPE includes a lab coat or smock, gloves, safety glasses.

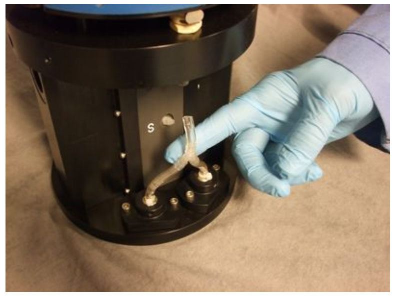
The sensor comes with de-ionized (DI) water in all of the fluid passages. The user must prime the sensor before it is turned on. This will move the reagents and calibration standard into the fluid passages.

Table 1 Equipment needed to prime the Cycle

User-supplied	Manufacturer-supplied
2 receptacles for water	50 mL syringe
Regulated power supply	Test cable
PC	¼" outside diameter (OD) tubing, < 1 m in length

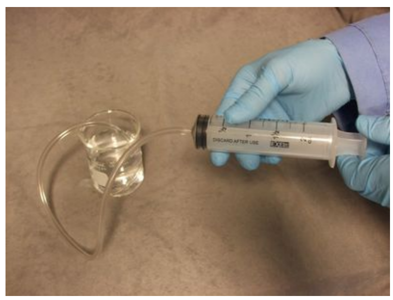
1. Find the ¼-in OD tubing connected to the "S" mark on the meter.
2. Pull the tubing from the hose barb next to the "S" straight off the barb. The barb is angled up.

Figure 9 Y-shaped tubing disconnected from "S"



3. Unwind the exhaust tubing from the top of the sensor.
4. Put one end of the exhaust tubing in an empty receptacle.
5. Fill another receptacle with 150 mL or more of DI water.
6. Connect the 50 mL syringe to a length of ¼" tubing.
7. Put the end of the tube in the de-ionized water and fill it with water using the syringe.

Figure 10 Tube filled with DI water



8. Make a kink in the tube near the syringe so that no water drains from the tube and remove the syringe.

Figure 11 Syringe removed from filled tube

9. Keep the tube with a kink in it and push it onto the hose barb near the "S" mark.

Figure 12 Sensor ready to be primed

10. Make sure to prime the sensor with a vacuum. Refer to Prime sensor with vacuum on page 11 for details.
11. Connect the manufacturer-supplied test cable to the sensor, a power supply that can provide 2 amps, and the host PC. The user will need a serial-to-USB adapter cable.
12. Start the Cycle software.

2.3.1 Prime sensor with vacuum

1. Attach the Luer-lock to the 1/16" ID barb adapter and to the supplied syringe.
2. Attach the syringe with the adapter to the outlet of the 1/16" ID sensor effluent tubing that comes out of the top end flange.
3. Under the *Settings* tab, set the calibration pump to run 100 pump cycles.
4. While the pump is in operation, pull a light vacuum, approximately 1/5 (10 mL) of the full travel of the plunger.
5. After the pump has operated for 100 cycles, make sure that the reagent tubing that connects the cartridges and the inlet barbs does not have any air bubbles.
6. Look at the tubing from the reagent cartridges to the manifold to check for bubbles
    - If bubbles are present, do steps 1–4 again.
    - If bubbles are small, it may not be possible to remove them.
7. Do steps 1–5 with R1 and R2.

2.3.2 Fill sensor filters

1. Fill the filters with DI water:
    1. Disconnect the 1/8" ID tubing that connects the filter to the "S" inlet barb.
    2. Connect the manufacturer-supplied syringe to the 1/8" tubing. Push clean water into the filters.
    3. Pinch the tubing and remove it from the syringe.
    4. Connect it to the "S" barb again to prevent the loss of prime.
    5. The filters will drip some water after this step.

    It is not possible to remove all the air bubbles. Try to remove as many as possible.

2.4 Prepare sensor for deployment

1. Use the host software to make sure that the sensor is in a low power ("sleep") mode.
2. Disconnect the test cable from the sensor, the power supply, and the PC.
3. Disconnect the filling tube from the "S" inlet of the sensor.
4. Connect the "Y" tube to the "S" inlet again.

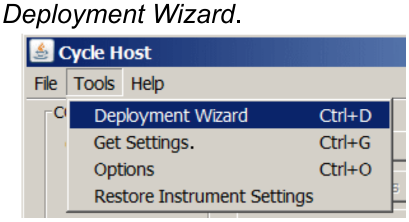
Figure 13 "Y" tube connected to the "S" inlet

5. Wind the exhaust tubing at the top of the sensor.

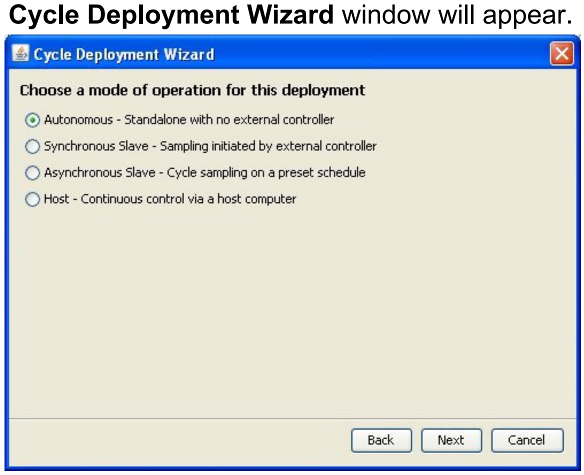
6. Make sure to align the indentations of the protective sleeve with the eye bolts, then slide the protective sleeve over the sensor.

Figure 14 Protective sleeve aligned with eye bolts

7. Put the sensor on its side, hold the eye bolts, and align the screw holes for the sensor and the protective sleeve.
   Note that the protective sleeve is longer than the sensor. The screws cannot be installed when the sensor is vertical.
8. Install the seven Phillips screws again.
9. Make sure that the sensor is connected to the host PC and a power supply, and is in standby mode.
10. Put the sensor in approximately 20 cm of water.
11. If necessary, start the Cycle software.
12. Go to the **Tools** menu.
13. Select the *Deployment Wizard*.



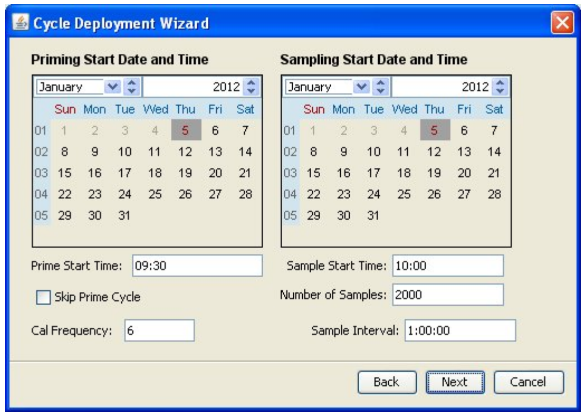
14. The **Cycle Deployment Wizard** window will appear.



15. Select "Autonomous - Standalone with no external controller."
16. Push **Next.**
17. Enter the name of a directory in which to store the collected data.

Note that the name can have only 8 characters.

18. Push **Next.** The **Priming and Sampling Start date and Time** window appears.



19. Set up the sensor to do a prime cycle. Either use the *Settings* tab or the "Deployment Wizard" before the sensor operates.

20. Select the date to deploy on the **Sampling Start Date and Time** calendar.

21. Enter the time to deploy at the Sample Start Time variable box.

22. Select the date to deploy on the **Priming Start Date and Time** calendar.

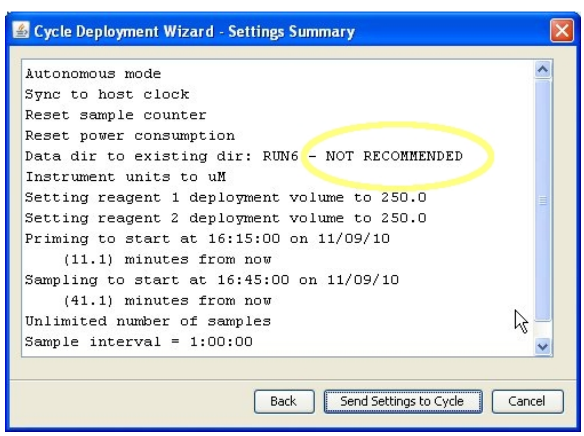
23. Enter the time to deploy minus 30 minutes in the Prime Start Time variable box. The sensor will begin the priming cycle 30 minutes before it is deployed.

24. Enter the total samples for the deployment in the variable box next to Number of Samples.

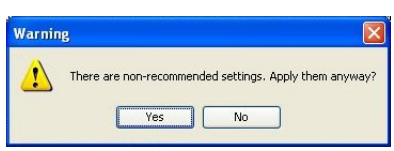
25. Enter the sample interval in the variable box area next to **Sample Interval.**

26. Keep the default of 6 in the Cal Frequency variable box. This is the manufacturer's recommended frequency.

27. Push **Next.**
A summary of the configuration shows.

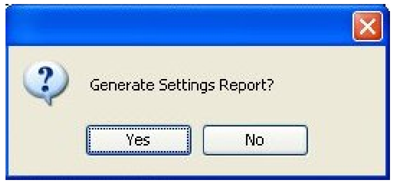


28. Push **Send Settings to Cycle.**
If the user selects a configuration that will have a negative effect on the operation of the sensor, a window shows.



29. Push **Yes.**

30. Push **Yes** at the next window to make a configuration report.



Configuration values will still be sent to the sensor if the user does not want a report and pushes **No.**

31. Enter a name and location to store the report. Use **.txt** or **.log** as the filename extension.
32. Push **Save.**
33. Push **Finish**, then **Yes** to make a results report.
    The results report records the new values and the previous values.

The software will put the sensor into a low power mode.

34. Disconnect the sensor from the power supply.

Section 3 Deployment

3.1 Modes of operation

There are six modes of operation. Both raw and engineering units for each sample are stored in the sensor's memory.

Cycle modes of operation:

- **Host-controlled mode**. The sensor is connected to a host PC and is controlled and monitored by the Cycle software. The user can look at the sensor's data output and other status indicators in this mode.
- **Autonomous mode**. The sensor operates by itself, for example, installed on a mooring with a battery pack to supply power. **Deployment**: the sensor is installed on a mooring that has no controller or data logger. The power is supplied by a battery pack.
- **Asynchronous slave mode**. The sensor is connected to a master controller. At certain intervals, the controller pulls the most recent data from the sensor. The sensor collects data on its pre-determined schedule, independent of the controller. The controller supplies power to the sensor. **Deployment**: the sensor is installed on a mooring with a system controller that is set to collect and send the collected data to a shore-side database at regular intervals. Other sensors on the mooring turn on for 2 minutes of every 15. The Cycle collects data once per hour.
- **Synchronous slave mode**. The sample rate of the sensor is synchronized with the controller. The sensor collects data when signalled by the controller. The controller supplies continuous power to the sensor. **Deployment**: the sensor is installed on a mooring with a system controller that is set to collect and send the collected data to a shore-side database in real-time.
- **SDI-12 mode**. The sensor operates in the synchronous slave mode through the SDI-12 port.
- **Commanded mode**. The sensor is connected to the controller and is under the control of the controller. This mode has the most control over the sensor, and also needs the most work to use.

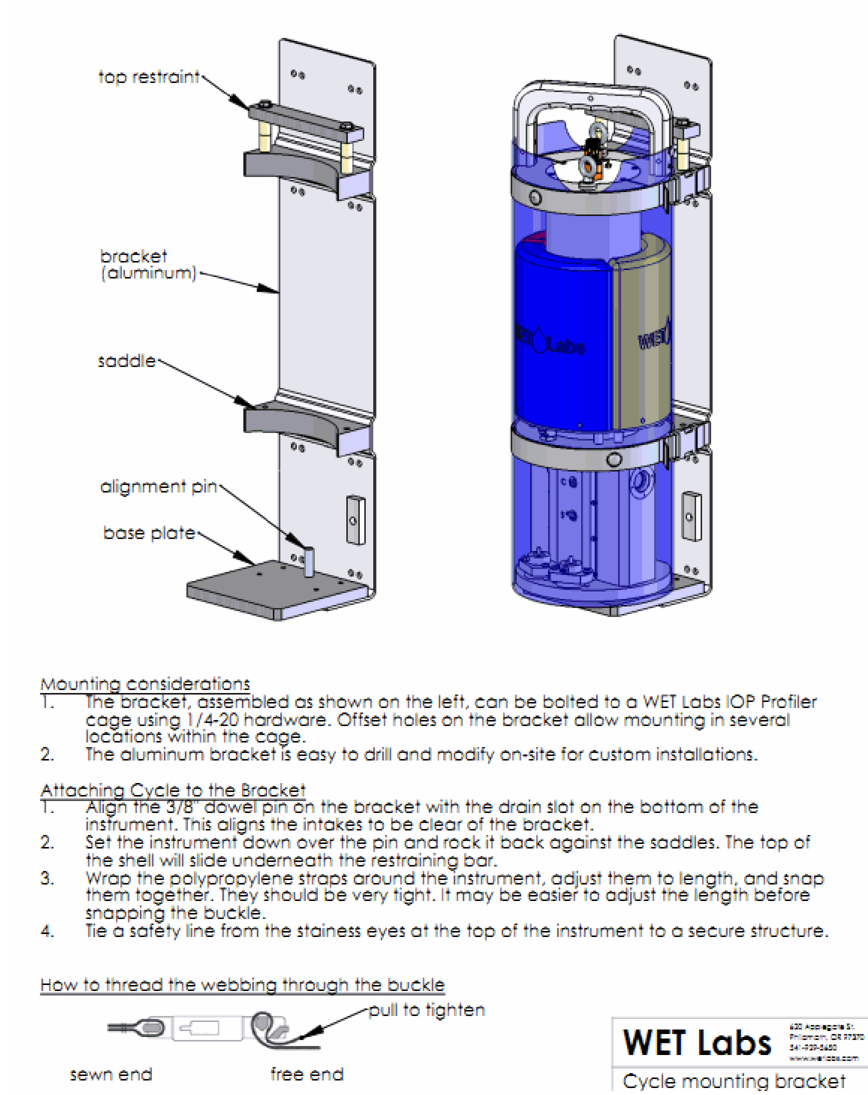
3.2 Set up for deployment

⚠ CAUTION

Wear Personal Protective Equipment (PPE) to remove or replace cartridges. PPE includes a lab coat or smock, gloves, safety glasses.

- The sensor can be hung under a dock with a length of rope or installed as part of a larger system.
- Operate the sensor ± 15° off-vertical.
- The manufacturer recommends full submersion of the sensor. The sensor can operate in less water as long as the intake filters on the bottom of the sensor are submerged. If they are not, the sensor cannot flush air bubbles, which can result in poor data quality.
- Prevent the reagent cartridges from freezing and use a sun shade to keep the cartridge temperatures below 35 °C.
- Make sure that the waste tubing does not have kinks in it when the sensor is deployed.
- Operate the sensor at least 10 cm above the bottom of a body of water. This allows for circulation around the intake filters.
- **Do not** use the handle to deploy the sensor.
- Make sure that the electrical cables have no tension.
- The user may attach the sensor to a structure such as a mounting bracket. Make sure to have a backup attachment for safety.

- Use braided line rope, not twisted nylon, to support the cables.



Replace any questionable hardware that is less expensive than the data from the sensor. Make sure screws, screw eyes, brackets, ropes, straps, zinc anodes, etc. are in good condition. Replacement parts are available from the manufacturer or a marine supply store.

The sensor effluent exits through the outlet tubing. Make sure the effluent flows freely and does not go onto the sensor or its mounting. The effluent contains antimony and molybdenum and has a pH of < 2. Make sure to wear the proper Personal Protective Equipment (PPE) to work near this effluent. Refer to the MSDS that comes with the reagent cartridges for specific information. Obey local, state, and federal laws to dispose of waste. Contact the manufacturer for waste containment solutions.

3.2.1 SDI operation

All sensors that have an 8-pin connector can operate on an SDI-12 network. SDI-12 version 1.3 is supported. Refer to the SDI-12 Version 1.3 specification at http://www.sdi-12.org for details.

Required equipment

1. Cycle sensor with both 6- and 8-pin connectors
2. PC with Cycle host software installed
3. SDI recorder

4. Power supply
5. 6-socket test cable
6. 8-socket SDI cable.

Power requirements and example setups

- The sensor must have a minimum of 10.5 VDC at 2 amps.
- The decrease in voltage over 30 m of 18-gauge cable is approximately 2.2 V.
- Use a standalone power supply if the SDI recorder cannot supply 2 amps.
- Connect the negative terminal of a standalone power supply to the ground terminal of the recorder.
- Do not connect the positive terminal of a standalone power supply to any terminal on the recorder.
- Make sure to add the power requirements of any SDI-capable sensor to the total current requirement.

Sample setup 1

	Equipment	Power requirement
sensor	Cycle PO_4	10.5 VDC, 2 amps
cable length	60 m (200 ft)	4.4 VDC (200 x 2.2)
cable gauge	18	
power supply	SDI recorder that supplies 12 VDC at 0.5 amps	14.9 VDC at 2 amps*
	*this setup requires a power supply that supplies 14.9 VDC at 2 amps	

Sample setup 2

	Equipment	Power requirement
sensor	Cycle PO_4	10.5 VDC, 2 amps
sensor	SUNA	12–18 VDC, 1 amp
cable length	30 m (100 ft)	3.3 VDC
cable gauge	18	
power supply	SDI recorder that supplies 12 VDC at 0.5 amps	15.3 VDC at 3 amps*
	*this setup requires a power supply that supplies 15.3 VDC at 3 amps	

***Note:** Set the Cycle PO_4 and SUNA to different SDI addresses. Change the Cycle from its default of 0 to 1 before deployment.*

3.2.2 SDI deployment

1. Connect the SDI cable to the 8-pin connector on the sensor.
2. Connect the other end of the SDI cable to the SDI recorder and a 12V power source. Note that the power supply must supply a minimum of 2 amps.
3. Configure the SDI recorder to send "aM!" or "aC" commands at the chosen frequency.
   These will start measurements on a preset schedule.
   - The sensor will ignore the "aM!" and "aC" commands if a priming sequence is schedule but not complete. The priming sequence will complete before the sensor starts measurements.
   - The SDI schedules when to start measurements. The sensor controls whether the measurement is spiked or normal.

- Schedule the "aM!" or "aC" commands at an interval longer than 35 minutes: spiked measurements take approximately 35 minutes.

3.3 Deployment procedures

⚠ CAUTION

Wear Personal Protective Equipment (PPE) to remove or replace cartridges. PPE includes a lab coat or smock, gloves, safety glasses.

The user makes the decision about which mode of operation to use, then does the steps below to deploy the sensor.

1. Install new cartridges on the sensor. Refer to sections Assemble the sensor on page 5, Prime sensor with vacuum on page 11, and Prepare sensor for deployment on page 11 for details.
2. Connect the sensor to a 12V, 15-watt power supply and PC with the manufacturer-supplied cable.
   The user needs a serial-to-USB adapter for the supplied cable to connect the sensor to the PC.
3. Start the Cycle software and choose the applicable serial port.
4. Turn on the power supply to the sensor.
5. Push **Get Settings** to make sure that the software and the sensor have communication.
6. Select the **Tools** menu, then *Deployment Wizard*.
7. Choose the desired mode to operate the sensor.
   a. SDI-12 mode: choose the "synchronous slave mode" in the Deployment Wizard.
   b. All other modes: connect the sensor to a battery pack or other power supply.
8. Push **Next**.
9. Complete the steps in the Deployment Wizard.
   a. Choose the prime and sample start times that give sufficient time to deploy the mooring.
   b. Push **Finish**.
   c. Push **Yes** to put the sensor into a low-power mode.
10. Make sure that the sensor is in a low power mode.
11. Disconnect the sensor from the test cable and PC.
12. Fill the filters with DI water.
    Make sure there is no air in the sensor (refer to Prepare sensor for deployment on page 11 for details).
13. If possible, keep the sensor in a bucket in approximately 20 cm of water while the sensor travels to the deployment site.
14. Put the bucket of water with the sensor in it in the water at the deployment site.
    This will keep air from getting into the sensor.
15. Make sure that the waste tubing on the top of the sensor has no blockages or kinks.

3.4 Retrieve the sensor

It is important to make sure that the sensor does not get air bubbles inside it when it is retrieved from a deployment. Stop data collection before the sensor is pulled from the water and before power is supplied again. If data collection is not stopped before power is supplied to the sensor again, it can start operation and pull air in. Also, do not let the reagent cartridges become empty or the pumps can make air bubbles.

The manufacturer recommends that the user retrieve the sensor in a bucket that has approximately 20 cm of water in it so that the sensor stays submerged for travel.

1. For the SDI mode of operation: stop the sample sequence on the SDI recorder.
   This will stop the SDI but not the sensor.
2. Turn the power off to the sensor, and then back on to stop any active samples.
   The sensor will store the last sample even when the power is turned off.
3. For SDI mode of operation: Send an "aR" command.
   The sensor will send the data values from the previous sample.
4. Disconnect the cable from the sensor.
5. Remove the sensor from the mooring.
6. Connect the sensor to the host PC and power supply with the test cable.
7. Turn on the sensor.
8. Push **Refresh Directory Listing** under the *Files* tab and offload the **summary.txt** file and any other desired files from the current data sub-directory.

Section 4 Optional in-laboratory performance analysis

⚠ CAUTION

The waste solution from the sensor cartridges is Hazardous Waste. Follow the applicable regulations to discard the solution.

⚠ CAUTION

Wear Personal Protective Equipment (PPE) to remove or replace cartridges. PPE includes a lab coat or smock, gloves, safety glasses.

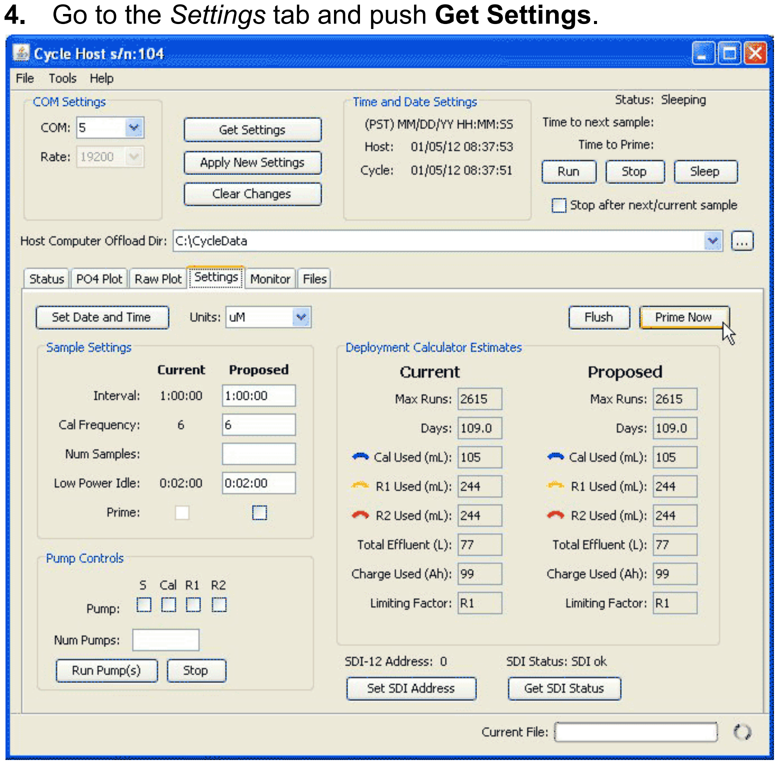
To make an analysis of the sensor's performance, make sure the sensor is primed and that the data is accurate and stable. The sensor can be operated overnight to make sure that the data output is stable.

Make sure the sensor does not run out of solution to sample or it will pull air in. A 500 mL bottle will be enough solution for approximately 10 sample cycles ($csf=1). This will make a little more than 500 mL of waste. Make sure the waste container is large enough for this volume.

Do the steps below to analyze the performance of the sensor in the laboratory before doing the steps to check standards.

4.1 Setup for in-laboratory performance analysis

1. Make sure that the sensor is connected to the host PC and a power supply, and is in standby mode.
2. Make sure to have 1 L of clean water, with no particles over 10µm.
3. If necessary, start the Cycle software.
4. Go to the *Settings* tab and push **Get Settings**.



5. Set the "Interval" to 15 minutes (00:15:00) or as necessary for an overnight test.
6. Set the "Cal Frequency" to 1.
7. Set the "Num Samples" to approximately 20 for an overnight test.
8. Check the *Deployment Calculator* to make sure there is enough reagent in the cartridges for an overnight test.

9. Push **Apply New Settings**.
   The yellow highlights go away.
10. Go to the *Files* tab.
11. Make a folder for stabilization or laboratory sample collection (for example, "Stable" or "Lab1"). Note that the file name is limited to 8 characters.
12. Push **Run**.
13. Push **Set Data and Time** to select when the sensor starts to prime and run.
    It takes approximately 12.5 minutes to prime the sensor.

4.2 Water required for in-laboratory performance analysis

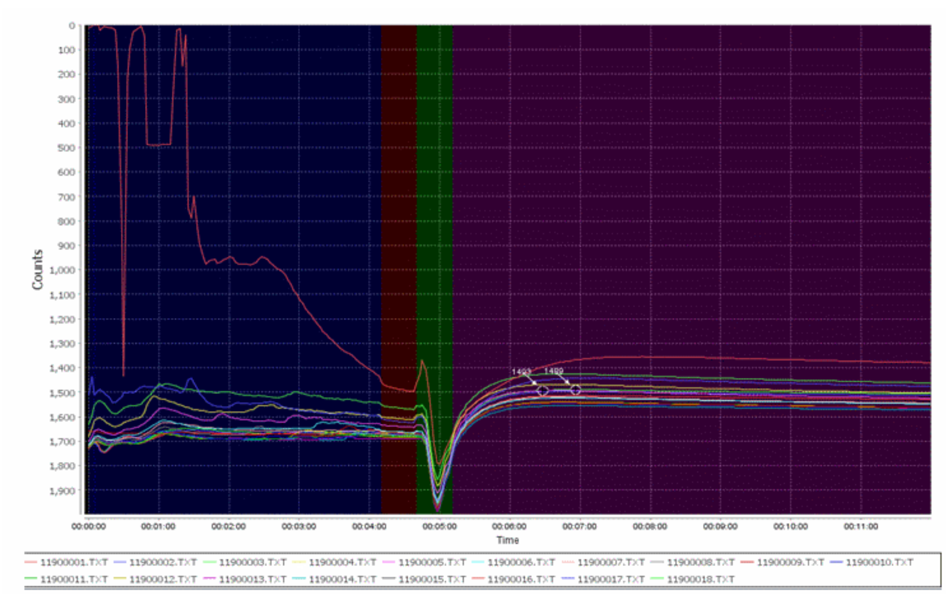
The manufacturer recommends the use of deionized (DI) or tap water until the sensor's data is stable. The sensor can be operated overnight to make sure the data output is stable.

Note: *DI and tap water can contain measurable phosphate. Use ultrapure, millipore, or equivalent (18 MOhm) water to prepare check standards and blanks.*

4.3 In-laboratory sensor stability analysis

1. Select the *Raw Plot* tab to see the data.
2. Look at the data after 19 operation cycles to see if the data is stable.

Figure 15 Example of stabilized data



3. If the data is stable, go to the next section.
4. If the data is not stable, refer to Prime the sensor on page 9 and do the steps again to make sure the sensor is set up correctly and has not pulled in any air, which will give data that is not accurate.

Figure 16 Bubbles the sample line

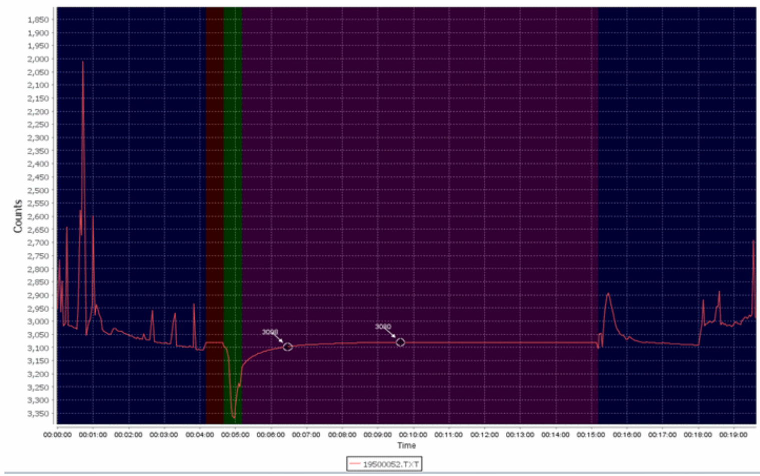
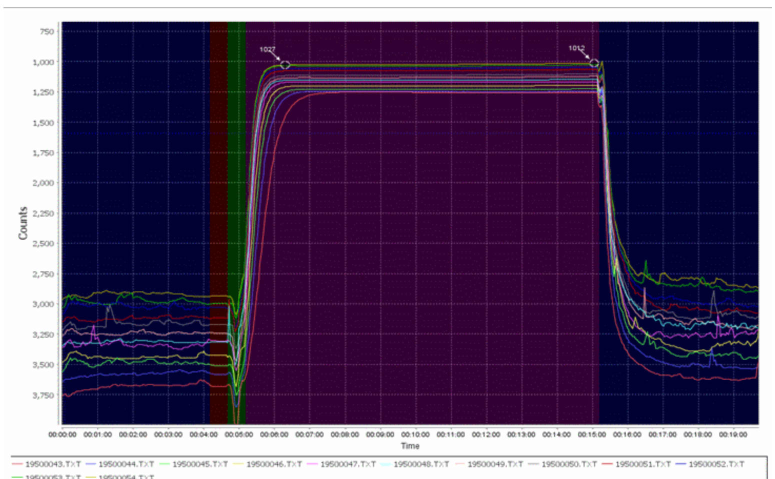


Figure 17 Shifting baseline



4.4 Use of water tanks for in-laboratory performance analysis

When the sensor operates in a laboratory water tank, temperature changes or a decrease in water flow can cause air bubbles to form. The manufacturer recommends that the user operates a pump to circulate the water that crosses the sensor intake areas to prevent the collection of air bubbles.

Data output values may change because of adsorption or primary production of a water tank. The manufacturer recommends that the user do a validation of the water in the tank.

4.5 NIST check standards for in-laboratory performance analysis

The manufacturer uses a 5.3 µM NIST-traceable check standard that is used after calibration and before servicing to check the sensor's calibration. This 5.3 µM check standard is also shipped to the user. The user can check the sensor's calibration and validate any lab-prepared standards. Contact the manufacturer to get more check standard.

To make an analysis of the sensor's performance, make sure the sensor is primed and that the data is accurate and stable. The manufacturer recommends the use of deionized (DI) or tap water until the sensor's data is stable. The sensor can be operated overnight to make sure the data output is stable.

4.6 Solutions for in-laboratory performance analysis

Change to a new solution to analyze with the sensor.
The manufacturer recommends the use of deionized (DI) or tap water until the sensor's data is stable. The sensor can be operated overnight to make sure the data output is stable.

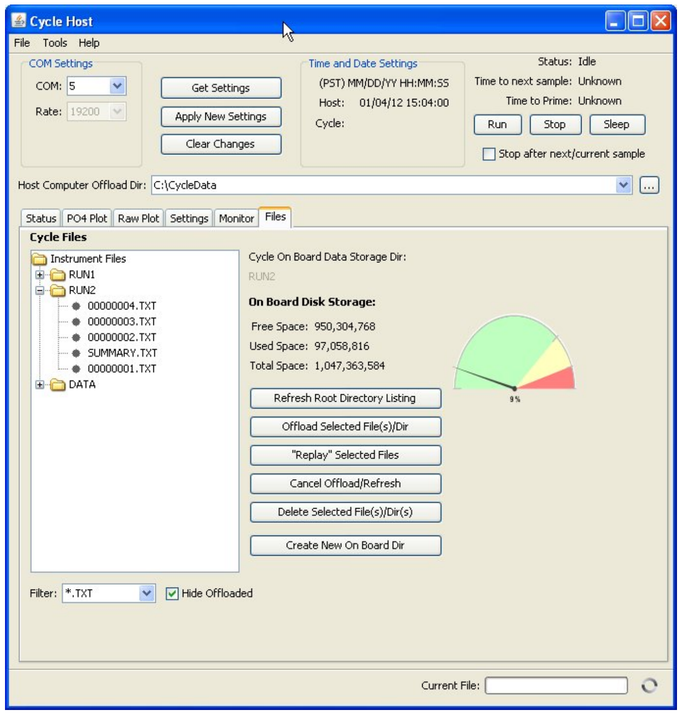
Note: *DI and tap water can contain measurable phosphate. Use ultrapure, millipore, or equivalent (18 MOhm) water to prepare check standards and blanks.*

1. Disconnect the sample inlet tube from the "S" barb.
2. Let the solution drain into the sample reservoir.
3. Flush the inside and the outside of the tube with clean water. The manufacturer recommends 18 MOhm.
4. Shake to dry.
5. Refer to the steps in Prime the sensor on page 9 and be careful to not make more bubbles in the intake tube.
   Degassing sample can minimize the formation of bubbles.

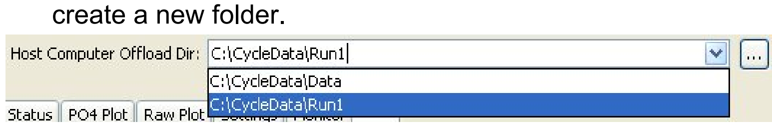
5.1 Get data files

Use the Cycle software to get the data that is stored in the sensor.

1. Start the Cycle software if it is not already on.
2. Select the *Files* tab.



3. Push **Refresh Root Directory Listing**.
   The files stored in the sensor will show in the *Files* tab.
4. Enter the file directory, or folder, on the PC to store the data from the sensor, or create a new folder.



5. Push **Offload Selected File(s)/Dir** to move the data from the sensor to the PC.
   The user can save only one directory at a time, but it is possible to select several files at the same time to store to the PC.
6. Monitor the data saved to the PC.
   Look at the *Current File* area at the bottom of the software window.

5.2 Operation sequence

This section describes how the sensor calculates phosphate and how to interpret the quality of the data.

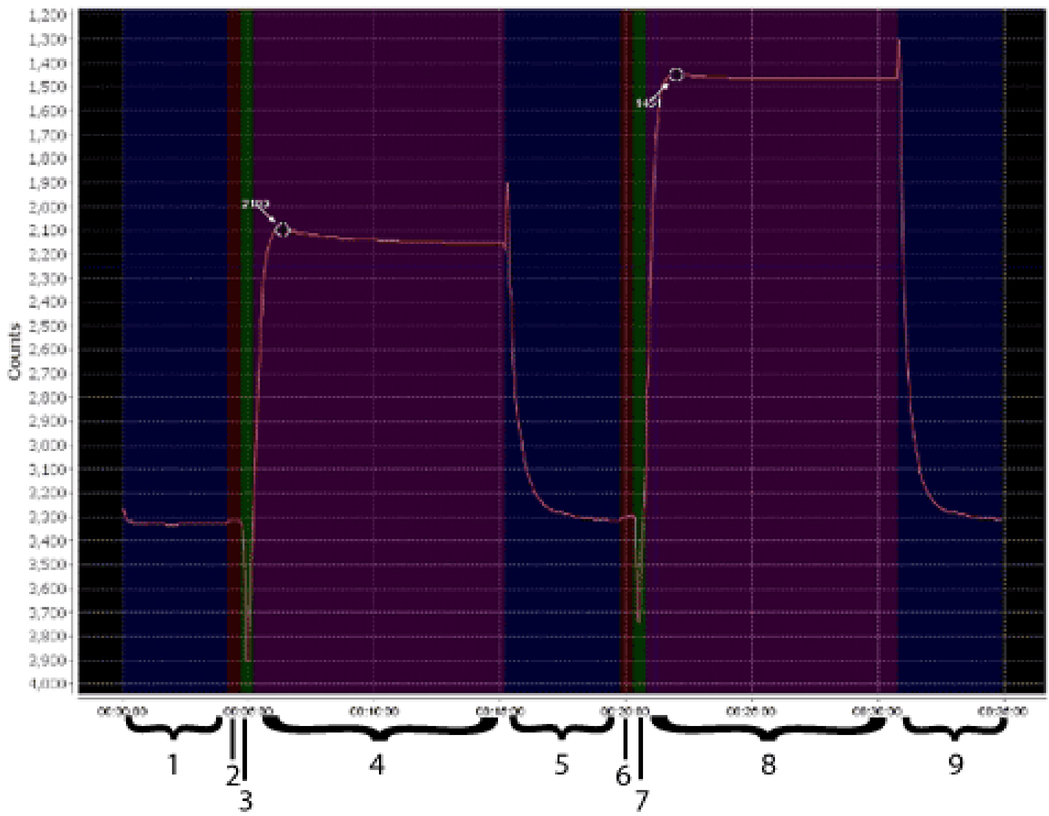
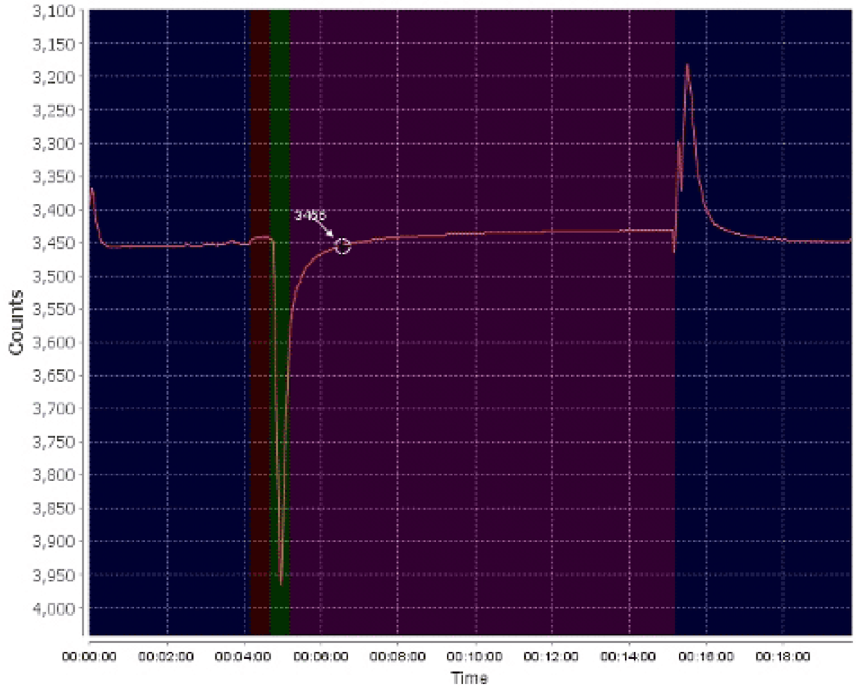


Table 2 Cycle output periods

1	Blue	Pre-analysis flush period. The sample pump operates. Referred to as the "baseline."
2	Red	Ambient read period. Used for 100% transmittance without any absorption from phosphate reaction. No pumps operate.
3	Green	Sample mix period. The sample pump and both reagent pumps operate.
4	Purple	Sample read period. No pumps operate. The reaction curve color develops. Counts decrease until complete. The white circle and number show the signal used as the sample transmission.
5	Blue	Post-analysis flush period. The sample pump operates. Output counts spike then increase to approximately the baseline value.
6	Red	Spike ambient output period. No pumps operate.
7	Green	Spike mix period. The sample pump, both reagent pumps, and the calibration standard pump operate. A known amount of phosphate is added to the sample.
8	Purple	Spiked sample read period. No pumps operate. Signal output counts decrease because there is more phosphate added to the sample. This means more color develops and the transmission is lower.
9	Blue	Final flush period. The sample pump operates. As with the other flush periods, the output returns to a baseline value.

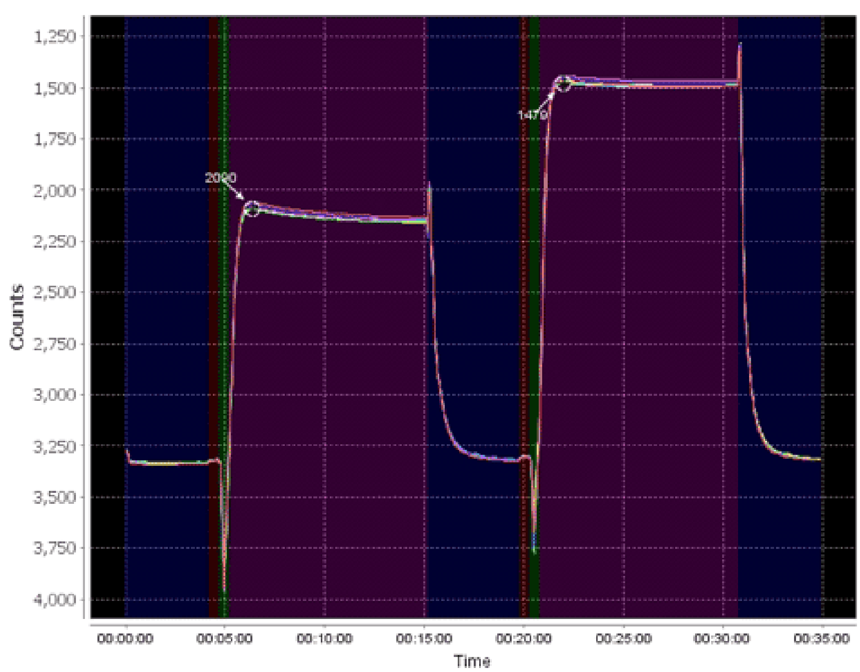
5.3 Blank run example

A clean sensor will usually have a decrease in counts as it is conditioned. When the user calibrates the sensor there is a shift in ambient read counts from run to run, or a slight shift in the pre- and post-analysis rinse baseline of 50–100 counts.



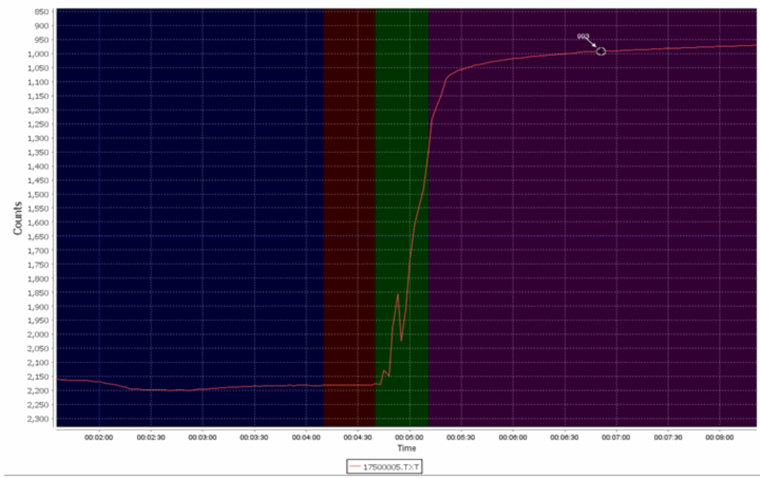
5.4 Good quality calibration data

Data such as the seven overlaid lines below shows good data. The lines show flat, stable flush periods, downward spike during mixing, no signs of bubbles, and all seven lines agree well.



5.5 Bad data

The graph below is an example of bad data caused by bubbles.



Section 6 Maintenance

⚠ CAUTION

Wear Personal Protective Equipment (PPE) to remove or replace cartridges. PPE includes a lab coat or smock, gloves, safety glasses.

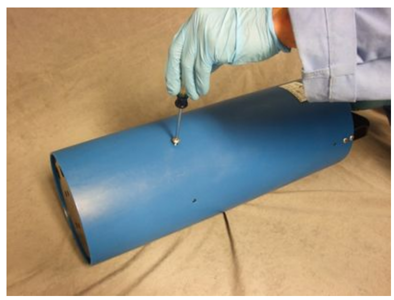
PPE includes a laboratory smock, safety glasses, and gloves.

Replace the Cycle reagent cartridges and intake filters approximately every 1000 samples, and clean the optics flow path. Change the battery core of the battery pack if that is the power source for the Cycle.

The sensor is calibrated to output a reactive phosphate concentration in user-defined units of µM, mg/L, or mgP/L. The sensor will operate for approximately ten 1000-sample deployments between service and re-calibration by the manufacturer.

1. Put the sensor on its side and use a Phillips screwdriver to remove the seven screws that attach the protective cover to the sensor.

Figure 18 Protective cover removed



2. Support the bottom of the sensor and lift into a vertical position.
3. Pull the sleeve up and off the sensor. Keep the sleeve and the screws.

6.1 Clean sensor flow paths

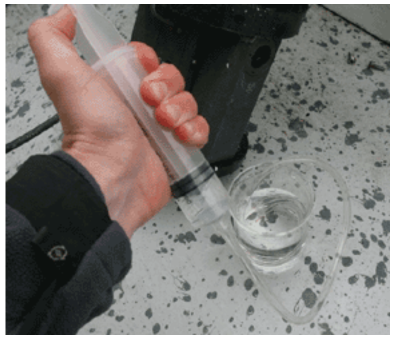
Clean the flow paths between each deployment with a 2% cleaning solution of Micro-90® or Liqui-Nox® to keep the optics clean from the products of chemical reactions, which can cause a decrease in sensitivity. Both solutions are available from various scientific supply companies.

1. Make sure that the sensor is connected to a power supply and a PC with the Cycle software on.
2. Pull the sample tubing straight off the hose barb to disconnect.

Figure 19 Sample tube loosened

3. Unwrap the exhaust tubing from the top of the sensor and put one end into a beaker.
4. Connect a syringe to a 25 cm length of 1/8" inside diameter (ID) Tygon® tubing.
5. Pull a minimum of 10 mL of 2% cleaning solution into the syringe.

Figure 20 Micro-90® pulled into syringe



6. Connect the other end of the tubing to the "S" barb.

Figure 21 Tubing connected to sensor

7. Inject the contents of the syringe into the tubing.

Figure 22 Tubing in cleaning solution

8. Disconnect the syringe and put the tubing it was connected to into the bottle of cleaning solution.
9. Go to the *Settings* tab of the Cycle software and push **Flush.**
   The sensor takes 5 minutes to fill with the cleaning solution.
10. Let the solution soak in the sensor for approximately ½ hour to 1 hour.

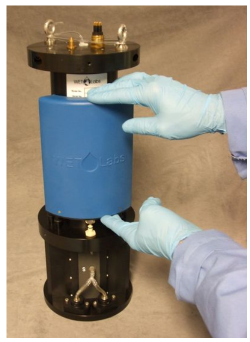
6.2 Replace reagent cartridges

⚠ CAUTION

Wear Personal Protective Equipment (PPE) to remove or replace cartridges. PPE includes a lab coat or smock, gloves, safety glasses.

1. Remove the blue calibration cartridge first. Press the stainless steel coupler on the bottom of the cartridge to release it.
2. Slide the cartridge up and off the guide pins.
3. Pull the cartridge away from the housing and set the cartridge aside.

Figure 23 Blue cartridge removed

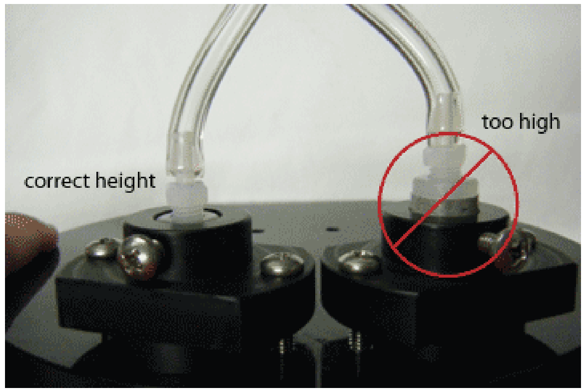


4. Remove the yellow and then the red cartridges.
5. Install new cartridges. Refer to the section on Assemble the sensor on page 5 for details on this procedure.

6.3 Replace intake filter and screen

1. Disconnect the tubing from the top of the two stainless steel filters.
2. Remove the two screws that hold the intake filter holder to the base plate.
3. Remove the filter housing from the base plate.
4. Loosen the set screw that holds the intake filter in the holder.
5. Push (gently) on the tubing fitting of the filter to remove the filter from filter housing.
6. Remove the plastic spacer from the bottom of the filter.
7. Remove the copper screen from the base plate.
8. Replace the copper screen with the new screen that came with the filters.
9. Install the plastic spacer onto the bottom of the new filter.
10. Put the new filter into the filter holder.

Figure 24 10 µm filter installation



11. Tighten (gently) the set screw that holds the filter in place. Do not over-tighten.
12. Install the filter and the holder onto the base plate.
    a. Start one screw. Hold the other side of the filter holder stable with a thumb or finger.
    b. Start the second screw.
    c. Make sure the screws are tightened evenly.
       Try to keep the filter holder parallel to the base plate.
    d. Tighten to hand-tight. Do not tighten too much.

6.4 Clean macro-fouling

Wash and scrape clean any macro-fouling from the sensor to keep it in good condition. Do not wash with a pressure-washer. Remove any anti-fouling tape before the sensor is returned for servicing.

6.5 Flush sensor flow paths

1. Rinse the inlet tubing or get a new length to connect to the "S" inlet.
2. Fill a clean beaker with approximately 100 mL of clean water and put the other end of the tubing in the beaker.
3. Go to the *Settings* tab of the Cycle software and push **Flush.**
    a. Pull the inlet tubing out of the beaker of water. Let approximately 2 cm of air into the tubing.
    b. Put the inlet tubing back in the beaker. Let approximately 2 cm of water into the tubing.
    c. Do the two steps above until the inlet tubing is filled with 2 cm sections of air and water.
4. Put the end of the inlet tubing in the beaker again.
5. Attach a syringe with a Luer® lock to a 1/16" hose barb and then the outflow tube on the sensor.
6. Pull the plunger to the 15 mL mark to fill the syringe.
   Push **Flush** if necessary.
7. Remove the syringe and put the inlet tubing in the waste beaker.
8. Do the flush two more times to make sure the sensor has been flushed three times.
   The sensor is now clean.
9. Disconnect the syringe and tubing and the inlet tubing from the "S" port.

6.6 Pull a vacuum to prime sensor

Pull a vacuum to remove air bubbles that are in the sensor. Do not pull the syringe too far. This makes too much vacuum and causes more bubbles.

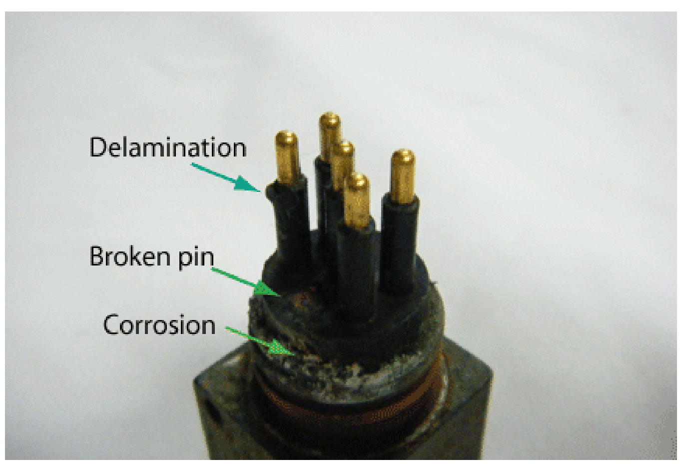
1. Attach the Luer-lock to the 1/16" ID barb adapter and to the supplied syringe.
2. Attach the syringe with the adapter to the outlet of the 1/16" ID sensor effluent tubing that comes out of the top end flange.
3. Under the *Settings* tab, set the calibration pump to run 100 pump cycles.
4. While the pump is in operation, pull a light vacuum, approximately 1/5 (10 mL) of the full travel of the plunger.
5. After the pump has operated for 100 cycles, make sure that the reagent tubing that connects the cartridges and the inlet barbs does not have any air bubbles.
6. Look at the tubing from the reagent cartridges to the manifold to check for bubbles
   - If bubbles are present, do steps 1–4 again.
   - If bubbles are small, it may not be possible to remove them.
7. Do steps 1–5 with R1 and R2.
8. Press **Flush**.

6.7 Bulkhead connector maintenance

Lubricate the mating surfaces of bulkhead connectors at regular intervals with pure silicone spray only. Allow the contacts to dry before they are connected.

Make sure that the pins have no corrosion, which looks green and dull. Make sure that the rubber seals on the pins are not delaminated. Connectors should mate smoothly and not feel "gritty" or too resistant.

Figure 25 Example of damaged connector



The manufacturer recommends 3M™ Silicone Lubricant spray (UPC 021200-85822). Other silicone sprays may contain hydrocarbon solvents that damage rubber.

DO NOT use silicone grease. **DO NOT** use WD-40®. The wrong lubricant will cause the bulkhead connector to fail prematurely and the sensor will flood.

6.8 Send reagent cartridges back to manufacturer

⚠ CAUTION

Wear Personal Protective Equipment (PPE) to remove or replace cartridges. PPE includes a lab coat or smock, gloves, safety glasses.

Return Policy: The user can purchase refurbished cartridges from the manufacturer. Send the used cartridges back within 30 days after the refurbished cartridges are received to get a credit from the manufacturer. Cartridges sent back after this time may not qualify for a credit.

The manufacturer will only accept red reagent cartridges that have been drained and flushed.

Do the steps below to prepare the red cartridge to send back to the manufacturer.

1. Disconnect the red cartridge from the sensor if necessary.
2. Make sure the cartridge is unlocked.

Figure 26 Fluid coupler lock

Push the stainless steel tab in. The coupler is unlocked.

3. Attach an approximately 15 cm long section of 1/8" ID Tygon® tubing to the quick-disconnect inline coupling.
   These two parts are in the manufacturer-supplied spare parts kit.
4. Put the other end of the tubing in an empty beaker.
5. Attach the tubing with the quick-disconnect coupling to the red reagent cartridge. Any fluid in the cartridge will drain into the beaker.
6. Fill a syringe with DI water and fill the cartridge with the water.
7. Disconnect the quick-disconnect coupling body from the cartridge.
8. Shake the cartridge.
9. Connect the quick-disconnect coupling to the tubing and the cartridge again and drain the DI water in the cartridge into a beaker.
10. Do steps 6–9 two more times.
11. Put the empty cartridges into a new box with a minimum of 5 cm of protective material around the cartridges.
12. Send all three of the empty cartridges to the manufacturer for credit on new cartridges.
13. Follow all local laws and regulations to discard the waste water from the cartridges.

6.9 Sensor storage

Always flush out all of the reagents in the sensor. Push **Flush** in the *Settings* tab to do this procedure.

6.9.1 Short-term storage

Make sure that the sensor is clean and has been flushed before it is put into storage for as long as a month.

1. Clean any biofouling from the protective sleeve.
2. Clean and flush the sensor. Refer to the steps in Send reagent cartridges back to manufacturer on page 33 for details on cleaning the red cartridge.
3. Make sure the cartridges are installed on the sensor.
4. Wind the outlet tubing around the eye bolts.

6.9.2 Long-term storage

CAUTION

The waste solution from the sensor cartridges is Hazardous Waste. Follow the applicable regulations to discard the solution.

CAUTION

Wear Personal Protective Equipment (PPE) to remove or replace cartridges. PPE includes a lab coat or smock, gloves, safety glasses.

Make sure that the sensor is clean and has been flushed before it is put into storage for as long as several months.

1. Clean any biofouling from the protective sleeve.
2. Clean and flush the sensor. Refer to the steps in Send reagent cartridges back to manufacturer on page 33 for details on cleaning the red cartridge.
3. Use the syringe to fill the cartridge with DI water.
4. Attach the Tygon® tubing to R2.
5. Turn the sensor on.
6. At the *Settings* tab, type 200 in the *number of pumps* area.
7. Push **Run Pump(s).**
8. Fill and flush each cartridge.
   Keep flow passages filled with DI water.
9. Wrap the outlet tubing around the eye bolts.
10. Keep the reagent cartridges in a refrigerator.
11. Replace any worn parts.
12. Lubricate the bulkhead connectors.
13. Attach the protective dummy plugs and lock collars.
14. Attach the protective sleeve to the sensor.
15. Put the sensor in its case for safe storage.

Section 7 Cycle commands

The user can use commands as an alternative to the host software to communicate with the Cycle sensor. Refer to the discussion below for details about how to use the commands.

Commands are limited to 160 characters, which includes the $.

Command characters are case-insensitive. Characters are converted to uppercase by the sensor, but are echoed as they were input.

- Commands start with an ASCII $ character (0x24) and end with an ASCII carriage return <CR> character (0x0d)
- The command designator follows the $.
- Command designators are usually 3 or 4 characters.
- One or more arguments follow the command designator.
- Arguments can be separated by a space (0x20), a tab, (0x09), or a comma (0x2c).
- If a command does not need an argument, a <CR> line terminator follows the designator.
- Non-printing ASCII characters that occur before the $ that starts a command are ignored and not echoed.
- More than one command can go on a single line if separated by semi-colons (0x3b).
- Commands execute until there are more than 160 characters per line, or there is an error.

Use the backspace character (0x08) to remove characters from the end of the command. The command interpreter will echo the backspace and send a space (0x20) and a backspace (0x08) character to "delete" the removed character from the monitor.

Set up the command interpreter with the SPR command. The default is enabled, which shows the PO4> command prompt when it is ready to accept commands.

Cycle shows the success or failure of user-issued commands and end with <CR><LF> characters.

- Invalid commands will show "Bad command or file name."
- Invalid parameters, or arguments, will show "invalid argument(s)."
- A command that cannot be accepted while the sensor is collecting a sample will show "Not available while sample running."

7.1 Configuration commands

CAS	Constant a-star value (manufacturer's scale factor)
Description	Get the constant a* value
Argument 1	none
Response	The constant a* value to two decimal places

CCS	Calibration Standard Concentration Setting
Description	Get/set the concentration of the calibration standard. Change this value only if the manufacturer gives instruction to do so.
Argument 1	The new calibration standard concentration in μM
Response	The current/new calibration standard concentration in μM to two decimal places.

CLK or DAT	Get/set the sensor's internal clock
Description	Get/set the sensor's internal clock
Argument 1	The new time in hh:mm:ss (24-hour clock) or the new date (mm/dd/yy) if both the date and time are set.

Argument 2	The new time in hh:mm:ss (24-hour clock) if both the date and time are being set.
Response	The current or new date and time in mm/dd/yy hh:mm:ss format. The hours are in a 24-hour format. The date and time are separated by a tab character, (0x09), not by a space.

CNT	Sample counter
Description	Get/set the current or most recent sample number. This is the number used in the raw file naming format. When the sample counter is set, the next sample run is the newly set count plus 1. Set this value to 0 at the start of each deployment.
Argument 1	New count value for the number of data samples completed. Must be followed by a /S switch to change the count. Set to one less than the number of the next sample.
Response	The current or new sample counter.

CSF	Cal spike frequency
Description	Get/set the frequency that a cal spike is done. The default is 6.
Argument 1	The new frequency. The next data sample after this command will do a cal sequence. Allowed values are 1 to 32767. If a data sample is being collected, the new value will not change it.
Response	The current or new cal frequency followed by the number of data samples before the next cal spike. The two values are separated by a space character (0x20). A value of zero for the number of data samples before the next cal spike means that the next sample will run a cal spike.

DCA	Deployment cartridge amounts
Description	Get/set the quantity of chemicals in the sensor at the start of a deployment.
Argument 1	The calibration standard in mL.
Argument 2	The quantity of reagent 1 in mL.
Argument 3	The quantity of reagent 2 in mL.
Argument 4	/S safety flag
Response	The current or new cartridge quantities to three decimals in milliliters at the start of a deployment. The values are separated by a space character (0x20).

DSD	Data subdirectory
Description	Get/set the subdirectory used to store data.
Argument 1	The name of the subdirectory without the root directory (e.g. C:\). Only subdirectories of the root directory are allowed. Subdirectory names can be no longer than 8 characters. Only a–z and 0–9 are permitted.
Response	The message "reset" when the command is completed.

DSI	Device specific information
Description	Get device-specific pump volumes, the optical pathlength, the PO_4 offset, and the scale factor.
Argument 1	The ambient pump volume in µL.
Argument 2	The pump volume of the calibration standard in µL.
Argument 3	The pump volume of reagent 1 in µL.
Argument 4	The pump volume of reagent 2 in µL.
Argument 5	The PO_4 offset volume in µM.
Argument 6	The calibration offset in µL.

Argument 7	The cell pathlength in cm.
Response	The current setting. The arguments in this table show in order from argument 1 to argument 7, separated by space characters (0x20). The pump volumes and pathlength show to two decimal places. The offsets show to four decimal places.

EUF	Engineering units format
Description	Get/set the units to use for engineering units output.
Argument 1	The units to use. 0 = microMolar (µM). 1 = milligrams of phosphate per liter (mg/L). 2 = mg of atoms of phosphorus per liter measured in the form of reactive phosphate (mgP/L).
Response	The new or current values as "µM," "mg/L," or "mgP/L."

IDT	Idle timeout
Description	Get/set the communication idle time in seconds. If no communication is received within this time period while a data sample is not running, the sensor goes back to a low power "sleep" state.
Argument 1	The new communication idle timeout in seconds. The range is 5 to 4924.
Response	The new or current idle timeout in seconds.

INT	Sampling interval
Description	Get/set the time period between data samples, referenced from one start time to the next.
Argument 1	The interval in seconds or minutes:seconds or hours:minutes:seconds. If 0, the sensor will collect one data sample and then stop.
Response	The new or current sample interval as hh:mm:seconds.

NOS	Number of samples
Description	Get/set the number of data samples (includes the current data sample) to collect before the sensor stops.
Argument 1	The number of data samples to collect. The default is -1, which sets no limit to the number of data samples.
Response	The new or current number of data samples to collect.

OPD	Output period
Description	Get/set the data output interval. Use with SDO command that looks like the old sensor data output format to specify how often a data sample is sent from the sensor. The default is 5. This value also specifies how often the raw signal data is written to the raw data files.
Argument 1	The new output interval. Makes the old version data output to show every nth LED cycle.
Response	The new or current period of output.

RAT	Serial port rate
Description	Get/set the baud rate for the serial port.
Argument 1	The new rate. Values are 19200, 38400, and 57600.
Response	If argument 1 is used, the response is "Changing rate to arg1. Hit <Enter> when ready." If no argument is used, or after <Enter> is pushed, the new baud rate shows. Note that data samples collected at a baud rate other than 19200 may result in bad data. The baud rate cannot be changed while data is being collected.

Cycle commands

SDA	SDI address
Description	Get/set the SDI bus address for the sensor.
Argument 1	The new SDI sensor bus address as an integer from 0 to 9.
Response	The current or new address This will also show an address change that was issued via the SDI bus.

SDO	Output mode
Description	Get/set the format of the data that is output. The default mode of 0 is the same as the old data output format with final engineering units added at the end of each sequence. Modes 1 and 2 are for use by the manufacturer. Mode 3 shows only the engineering units of data at the end of a data sequence. Mode 4 shows no engineering units data.
Argument 1	The mode of operation to use.
Response	The current or new mode of operation.

SPR	Set prompt
Description	Turn the command prompt of PO4 on or off.
Argument 1	1 = turn on command prompt, 2 = turn off command prompt.
Response	The current or new command prompt shows as either "on" or "off." When the prompt is turned off, there is no prompt after a response. When the prompt is turned on, there is a PO4 prompt after a response.

STO	Store configuration to flash
Description	Stores the current configuration values to a non-volatile flash memory. This command automatically executes when a low input power fault happens, before the sensor enters a low power state, or when the user exits to PicoDOS.
Argument 1	None
Response	The message "written" on a complete command.

SUD	Start time and date
Description	Get/set the time and date for the first or next data collection sample or for a scheduled pump prime cycle. No arguments returns the date and time for the next scheduled data collection sample or none. If NOS is 0, it will automatically be set to -1.
Argument 1	The start date as m/d/y (optional) or /P to show the date and time (or none) of the scheduled pump prime cycle.
Argument 2	The start time (h:m:s) or 0 to stop data collection.
Argument 3	/P to apply the preceding time or date and time to the pump prime cycle start time.
Response	The current or new mode of operation.

UPC	UPS count
Description	Get/set the operation when an external wake signal happens on pin 1. The default = 0 to bring the sensor out of a low power mode. Mode 1: starts a data collection (sample) sequence. Mode 2: sensor to show the most recent data collected.
Argument 1	The wake-up mode.
Response	The new or current wake mode. 0 = off. 1 = start on wake signal. 2 = show GLSO on wake signal.

WKM	External wake mode
Description	Get the number of UPS cycles.

Argument 1	None.
Response	The number of UPS cycles that have happened from low-power faults.

7.2 Operation commands

FLT	Fault Status
Description	Show any fault conditions.
Argument 1	none
Response	A four-character hexidecimal value that shows the fault status. The value 0000 shows that there are no faults.

Table 3 Fault conditions

Bit field	**Fault**
0x0001	Invalid configuration values at startup. The default configuration values are used.
0x0002	The configuration values used at startup were not saved. Some values may not be in effect.
0x0004	Invalid operational values at startup. The default operational values are used.
0x0008	The operational values used at startup were not saved. Some values may not be in effect.
0x0010	The stored data subdirectory did not exist at startup and could not be made.
0x0020	Communications to the gas gauge controller were not made.
0x0040	SYS.QPBCS is not set correctly.

GLSO	Get Recent Sample
Description	Get the data for the most recently completed or ended sample collection sequence.
Argument 1	none
Response	The most recently completed or ended sample collection sequence followed by two pair of <CR><LF> characters. Refer to Error: Reference source not found for the data format.

LSS	Last Shutdown State
Description	Get the status of the last shutdown.
Argument 1	none
Response	The message "ok" if the shutdown was via the "XIT" command or "power failure" if the last shutdown was from a power fault.

ONT	Run Time/Power Consumption
Description	Get/set the total "on" time for the sensor. This number is usually reset when a new battery is connected.
Argument 1	The new "on" time, in seconds.
Argument 2	/S = safety flag.
Response	The current/new "on" time, in h:mm:ss. The hours field is from 1 to 10 characters.

PRI	Prime
Description	Do the priming sequence immediately.

Argument 1	1 = starts the priming sequence. 0 = starts the flush process while the priming sequence occurs.
Response	The status of the priming sequence. The message "on" or "off" will show if no arguments are made. The message "priming" shows if a priming is started.

RUN	Run
Description	Start a new data sample sequence now. If NOS is 0, it will automatically set to -1.
Argument 1	/P = start a priming sequence.
Response	The message "Running" if a data sample sequence is started. The message "Priming" if a priming sequence is started.

SDS	SDI Status
Description	Get the status of the SDI interface board.
Argument 1	none
Response	VER:n n c enabled|disabled. n.n = the interface3 board version number. c = the code that shows the status of operation, and either enabled or disabled to show if the board is on or off. 0–8 = the board is being started, or there is a problem. 9 = the board is OK but does not have power from the SDI bus. 10 = there is no SDI interface board, or it is not in communication. 11 = the board is OK and has power from the SDI bus.

SLP	Sleep
Description	Put the sensor in a low power "sleep" state for a specified time, until a specified time, or indefinitely. Use the serial port or the external wake signal to put the sensor in a "ready" state. There are some characters that are baud rate dependent and cannot be used to "wake" the sensor. The character that is used to "wake" the sensor is not buffered for input. The manufacturer recommends that the user does an RS232 break of at least 500 ms to "wake" the sensor.
Argument 1	The number of seconds to be in a low power state. No argument = stay in low power until the next data sample time occurs.
Response	The message "Sleeping <CR><LF>" shows. When argument 1 is used, or if the sensor is going to collect a sample, the message " for n seconds <CR><LF>" shows, where "n" is the smaller of the value of the commanded interval or the time to the next data sample.

STP	STOP: Stop
Description	Cancel a sample sequence and flush the sensor, or stop immediately. If the flush occurs, NOS goes down, as though a whole sample was completed. If a sample is not being collected, the SUD and SUD /P move to 0 and the NOS value does not change.
Argument 1	no argument = the flush sequence occurs. /I = the sample sequence stops. The NOS does not change, as though the sample sequence did not occur.
Response	"Stopped" shows if there is no sample sequence. "Flushing" shows if the user made the command without the /I argument. "Stopping" shows if the user made the command with the /I argument.

TPC	Total Pump Counts
Description	Get the total number of pump actions by any or all of the pumps in the sensor. Reset the pump counter only when a new pump is installed.

Argument 1	none
Response	Shows the counts for the ambient pump, the calibration pump (blue), the reagent 1 pump, (yellow), and the reagent 2 pump (red) separated by spaces. These are the total counts over the lifetime of the pumps installed by the manufacturer.

TTS	Time To Next Sample Start
Description	Get the time until the start of the next scheduled sample sequence.
Argument 1	none
Response	Shows the time in h:mm:ss until the next sample starts. Shows a 0 if a sample is being collected, or -1 if a sample has been stopped.

VOL	Volumes Pumped/Deployment Pump Counts
Description	Get/set the volumes for all the pumps in the sensor for this deployment. An optional argument is /R /S = resets all four pump volumes to 0.00.
Argument 1	Ambient volume from the pump in mL.
Argument 2	Calibration standard from the pump in mL.
Argument 3	Reagent 1 from the pump in mL.
Argument 4	Reagent 2 from the pump in mL.
Argument 5	/S = safety flag
Response	The current or new volumes in mL to three decimal places in the order above. The values are separated by a space.

XIT | EXIT	Exit
Description	Stop the firmware application and go to PicoDOS. Scheduled samples are stopped. (Same as SUD 0).
Argument 1	none
Response	None from the sensor application. The PicoDOS start message shows at the current baud rate after several seconds.

7.3 File commands

CPY	Copy
Description	Copy a file to a new filename or location on the flash drive. "Wildcards" (* and ?) are permitted. Note that if a destination file already exists, it will be overwritten.
Argument 1	The file or files to be copied.
Argument 2	The destination of the copied file or files.
Argument 3	An optional /V command to verify the new file or files.
Response	The names of the source files, followed by <CR><LF> as they are copied. After the last file is copied, an additional <CR><LF> shows, followed by "n files(s) copied" where "n" is the number of files copied. The message is padded with spaces so that the number field is always eight characters wide and ends with two <CR><LF>.

DEL	Delete
Description	Erase the specified file or files from the flash drive. "Wildcards" (* and ?) are permitted.
Argument 1	The file or files to be erased.
Response	"n" file(s) erased. N = the number of files erased. The response ends with two <CR><LF>.

DIR	Dir
Description	Get a list of the files in the directory. "Wildcards" (* and ?) are permitted. The "*" character = any group of one or more alphanumeric characters. The "?" = any single alphanumeric character.
Argument 1	The directory to list, or /D for the "current" directory.
Argument 2	The optional filename pattern to list. For example, "*.txt"
Response	A list of the directory with the specified filters. If a file is being collected, it will list on the last line, separated by a space from the preceding "Active file".

GET	Get File
Description	Get the specified file or files. "Wildcards" (* and ?) are permitted. The file move is stopped with an RS232 break signal of 500 ms or longer. This is followed by the "checksum" for the characters that were sent before the sensor got the break signal.
Argument 1	The files to be moved.
Response	All of the specified files will be moved. A header line comes before each file. The header line has the filename, the number of the file being moved, from 1 to "n", the total number of files moved, the file size in bytes, and the number of bytes that need to be moved. This information is separated by a space. The whole file is moved and is followed by the CRC-32 "checksum" of eight hexidecimal characters. Data being collected will stop while the file is moved. If GET is used the data output stream will have pauses for the sensor's internal requirements.

REN	Rename
Description	Change the name of a specified file on the flash drive.
Argument 1	The path and the file to change.
Argument 2	The new path and the file name.
Response	<CR><LF>. "Not found error" = the file does not exist. "Rename error" = the file exists or there was another error.

RMD	Remove Directory
Description	Erase the specified sub-directory if it is empty. Note that an open subdirectory cannot be erased even if it is empty. Use the DSD command to change the data sub-directory first.
Argument 1	Path to the empty directory to erase
Response	"Dir Removed"= directory is erased. "error code" = directory does not exist. "Dir not empty error" = directory is not empty.

TYPE	Type
Description	Shows the specified files from the serial port. There is no data verification or way to see the end of a file. "Wildcards" (* and ?) are permitted.
Argument 1	The files to show.
Response	Directory, then filename, separated by a \ character, then <CR><LF>.

7.4 Miscellaneous commands

DAC	Set DAC output
Description	Set the level of output of the Digital-to-Analog converter to a specified level.

Argument 1	The 12-bit value shows in hexidecimal format from 0–fff.
Response	The new DAC level of output.

Table 4 Common DAC output voltages

Value	Approximate output voltage
0	0.00
333	1.00
400	1.25
666	2.0
800	2.5
999	3.0
c00	3.75
ccc	4.00
fff	5.00

DEV	Device Type
Description	Get the device-type and serial number of the sensor
Argument 1	none
Response	The device-type and the serial number of the sensor separated by a space. "PO4" = device-type. "nnn" = three-characters, where "n" is a number fro 0–9.

H | HELP	Help
Description	Show the available commands
Argument 1	none
Response	See table below

$CAS	const a*	$CCS	calibration concentration
$CLK	get/set date and time	$CNT	sample counter
$CPY	source destination	$CSF	calibration frequency
$DAC	set dac output	$DAT	get/set date/time
$DCA	get/set cartridge volumes	$DCS	default config
$DEL	file	$DEV	get device type
$DIR	dir /D for data dir	$DSI	device config
$DSD	data subdir	$EUF	get/set units format
$FLT	get fault status	$GET	get file(s)
$GLSO	get last output	$IDT	idle timeout
$INT	sample interval	$LSS	last shutdown
$NOS	number of samples	$ONT	show on time
$OPD	output period	$PRI	priming state
$PMP	run pumps	$RAT	get/set baud rate
$REN	oldname newname	$RMD	remove empty dir

$RUN	run sample	$SDA	SDI bus address
$SDO	output format	$SDS	SDI status
$SLP	low power sleep	$SPR	prompt on/off
$STO	store config info	$STP	stop sample
$SUD	start time/date	$TPC	get total pump counts
$TTS	time til start	$TYPE	dump file(s)
$UPC	get ups count	$VIN	get input voltage
$VOL	get volumes pumped	$VSN	show version info
$WKM	get/set wake mode	$XIT	exit to PicoDOS

PMP	Run Pump(s)
Description	Operate the specified pumps for a specified number of cycles. Files are not made and data is not collected. Use the STP/I command to stop a PMP command.
Argument 1	None to get the number of pump cycles left, or a decimal code that specifies which pumps to operate. Set a bit position to 1 to start the pump.
Response	The number of pump cycles left. "Pumping Done" = pump operation is complete.

Code	**Amb**	**Cal**	**R1**	**R2**	**Code**	**Amb**	**Cal**	**R1**	**R2**
0	no	no	no	no	**8**	no	no	no	yes
1	yes	no	no	no	**9**	yes	no	no	yes
2	no	yes	no	no	**10**	no	yes	no	yes
3	yes	yes	no	no	**11**	yes	yes	no	yes
4	no	no	yes	no	**12**	no	no	yes	yes
5	no	no	yes	no	**13**	yes	no	yes	yes
6	no	yes	yes	no	**14**	no	yes	yes	yes
7	yes	yes	yes	no	**15**	yes	yes	yes	yes

VIN	Input Voltage
Description	Get the input voltage to the sensor in volts.
Argument 1	none
Response	The input voltage to the sensor to two decimal places. It shows approximately 0.2 V lower than the voltage supplied to the sensor.

VSN	Version
Description	Get the firmware version in the sensor.
Argument 1	none
Response	The firmware version. "n.nn" where "n" is a digit from 0–9.

7.5 SDI commands

The Cycle sensor supports all basic SDI-12 commands. Refer to the SDI-12 specification for details of the command protocol. SDI-12 has been tested with the SDI-12 Verifier from NR Systems Inc. (http://www.sdi-12-verifier.com) with up to 1000 ft. of 24-gauge cable.

For any command not described below, the sensor will respond according to the SDI-12 v1.3 specification.

Definitions

- "a" is the sensor's SDI-12 address
- <CRC> is the 3-character Cyclic Redundancy Check
- <CR> is a Carriage Return character
- <LF> is a Line Feed character

Acknowledge Active (a!)	
Response	a<CR><LF>
Purpose	confirms the SDI-12 address
Example	address = 0
	SDI recorder sends 0!
	sensor sends 0<CR><LF>

Address query (?!)	
Response	a<CR><LF>
Purpose	reports the sensor's SDI-12 address
Example	address = 0
	SDI recorder sends ?!
	sensor sends 0<CR><LF>

Change address (aAb!)	
Response	b<CR><LF>
Purpose	changes the sensor's SDI-12 address to "b". The address defaults to 0.
Example	address = 0
	SDI recorder sends 0A1!
	sensor sends 1<CR><LF>
	address now = 1

Change address (aI!)	
Response	allccccccccmmmmmmvvv_ssssss_fffffff<CR><LF>
	a = sensor address
	ll = 2-character SDI-12 version. For example, "13" for version 1.3
	cccccccc = 8-character vendor identification. For example, "WET LABS"
	mmmmmm = 6-character sensor model. For example, "_CYCLE"
	vvvv = 3-character sensor version. For example, "PO4"
	_ssssss = up to 6-character serial number field. Includes leading space
	_fffffff = up to 7-character firmware version field. Includes leading space
Example	address = 0. serial number = 104. The firmware version is 1.03sd
	SDI recorder sends 0I!
	sensor sends 013WET LABS CYCLEPO4___104_1.03sd<CR><LF>

Cycle commands

Start Measurement (aM!) Start Measurement and Request CRC (aMC!)	
Response	attn<CR><LF>
Purpose	starts a measurement
Notes	a = address = (0–9)
	ttt = measurement time in seconds. The sensor always sends 000.
	n = 7. The number of measurement values the sensor will make and return after subsequent Send Data commands.
	If a scheduled prime sequence is pending or running, the sensor will ignore the Start Measurement and Start Measurement and Request CRC commands.

The sensor needs approximately 1800 seconds to complete a measurement. The SDI-12 specification allows measurement times from 000 to 999. The sensor uses a "store and forward" technique to work around this limitation. The sensor always sends the measurement time as 000 seconds. Measurements are saved in first-in-first-out (FIFO) memory. If the SDI recorder sends a Start Measurement command and subsequent Send Data command, the sensor sends the next set of data in the FIFO. If there is no stored data, the sensor sends a null response (a <CR><LF>). The data recorder or data processing program needs to handle these values appropriately.

The sensor has the same response to Start Measurement and Request CRC except that it appends a 3-byte CRC to the data when it responds to the Send Data command.	
Example	address = 0
	SDI recorder sends 0M!
	sensor sends 00007<CR><LF>
	SDI recorder sends 0MC!
	sensor sends 00007<CR><LF>

Refer to the Send Data command for examples of the commands that come after either the aM! or aMC!

Start Concurrent Measurement (aC!) Start Concurrent Measurement and Request CRC (aCC!)	
Response	atttnn<CR><LF>
Purpose	starts a measurement in the sensor
Notes	a = address = (0–9)
	ttt = measurement time in seconds. The sensor always sends 000.
	nn = 07. The number of measurement values the sensor will make and return after subsequent Send Data commands.
	If a scheduled prime sequence is pending or running, the sensor will ignore the Start Measurement and Start Measurement and Request CRC commands.

Start Concurrent Measurement (aC!). Has 70 characters. Start Measurement (aM!). Has 35 characters.	
Example	address = 0
	SDI recorder sends 0C!
	sensor sends 000007<CR><LF>

	SDI recorder sends 0CC!
	sensor sends 000007<CR><LF>

Send Data commands that come after either the aM! or aMC! commands:

Send Data (aD0!–aD1!)	
Response	a<values><CR><LF> or a<values><CRC><CR><LF>
Purpose	sends data to the SDI recorder
Notes	aD0! after aM!
	35 characters are allowed. For the sensor the response is 6, the first 6 values in the SDI data format table. There is not space in the 35-character field for 7 values. If a subsequent aD1! command is sent the sensor will send the seventh value, battery voltage.
	aD0! after aC!
	70 characters are allowed. For the sensor the response is 7 values. There is space in the 70-character field for 7 values. The recorder does not need to send an aD1! command because all 7 values are sent after the aD0! command.

aD0! and aD1! after an aM! command (Assume the sensor is set to address 0.)	
Example 1	address = 0
values from the previous measurement:	
sample date	11.0705
sample time	06.0708
run number	0500
PO_4 concentration	12.345
units of PO_4 concentration	0
last sample state	9
battery voltage	12.1

	SDI recorder sends 0M!
	sensor sends 00007<CR><LF>
	SDI recorder sends 0D0!
	sensor sends 0+11.0705+06.0708+0500+12.345+0+9<CR><LF>
	recorder sends 0D1!
	sensor sends 0+12.1<CR><LF>

aD0! and aD1! after an aMC! command	
Example 2	address = 0
values from the previous measurement:	
sample date	11.0706
sample time	06.0809
run number	0501
PO_4 concentration	12.678
units of PO_4 concentration	0

last sample state	9
battery voltage	12.0

	SDI recorder sends 0MC!
	sensor sends 00007<CR><LF>
	SDI recorder sends 0D0!
	sensor sends 0+11.0706+06.0809+0501+12.678+0+9<CR><LF>
	recorder sends 0D1!
	sensor sends 0+12.0GFS<CR><LF>

aD0! after an aC! command	
Example	address = 0
values from the previous measurement:	
sample date	11.0707
sample time	06.0910
run number	0502
PO_4 concentration	12.901
units of PO_4 concentration	0
last sample state	9
battery voltage	11.9

	SDI recorder sends 0C!
	sensor sends 00007<CR><LF>
	SDI recorder sends 0D0!
	sensor sends 0+11.0707+06.0910+0502+12.901+0+9+11.9<CR><LF>

aD0! after an aCC! command	
Example	address = 0
values from the previous measurement:	
sample date	11.0708
sample time	06.1011
run number	0503
PO_4 concentration	12.234
units of PO_4 concentration	0
last sample state	9
battery voltage	11.8

	SDI recorder sends 0CC!
	sensor sends 00007<CR><LF>
	SDI recorder sends 0D0!
	sensor sends 0+11.0708+06.1011+0503+12.234+0+9+11.8FZH<CR><LF>

Continuous Measurement (aR01!) Continuous Measurement and Request CRC (aRC0!)	
Response	a<values><CR><LF> or a<values><CRC><CR><LF>
Notes	sensor sends the last measurement data stored in the FIFO. The format is the same as aD0! after an aC! or aCC! command. If there is no data in the FIFO, the sensor sends the last data record sent.
	the Continuous Measurement command does not start a measurement. It sends data from a previous measurement.

aR0!	
Example 1	address = 0
values from the previous measurement:	
sample date	11.0710
sample time	06.1213
run number	0505
PO_4 concentration	12.890
units of PO_4 concentration	0
last sample state	9
battery voltage	11.6

	SDI recorder sends 0R0!
	sensor sends 0+11.0710+06.1213+0505+12.890+0+9+11.6<CR><LF>

aRC0!	
Example 2	address = 0
values from the previous measurement:	
sample date	11.0712
sample time	06.1415
run number	0507
PO_4 concentration	12.456
units of PO_4 concentration	0
last sample state	9
battery voltage	11.4

	SDI recorder sends 0R0!
	sensor sends 0+11.0712+06.1415+0507+12.456+0+9+11.4<CR><LF>

Stop Measurement (aX_STOP!)	
Response	aSTOPPED<CR><LF>
Notes	stops the current measurement, then turns the pumps on to flush the sensor. The sensor flush takes approximately 5 minutes. If aX_STOP is sent when a measurement is not underway, the sensor does nothing and no flush sequence is started.

Cycle commands

aX_STOP!	
Example	address = 0
a measurement is currently under way	

	SDI recorder sends 0X_STOP!
	sensor sends 0STOPPED<CR><LF>
	the measurement stops and a flush sequence starts

Stop Measurement (aX_CLEAR!)	
Response	aCLEARED<CR><LF>
Notes	starts the SDI system. All data in the FIFO buffers are cleared. Any scheduled prime sequences are cleared. If aX_CLEAR is sent while the sensor is running a measurement, the measurement stops and a flush sequence is started.

aX_CLEAR!	
Example	address = 0
a measurement is currently under way. There is already one set of measurement data in the FIFO buffer.	

	SDI recorder sends 0X_CLEAR!
	sensor sends 0CLEARED<CR><LF>
	the FIFO buffer is cleared. The measurement stops and a flush sequence starts

Prime (aX_PRIME!)	
Response	PRIME<CR><LF>
Notes	sends PRIME=Y<CR><LF> and starts a prime sequence. If a measurement is currently under way, the prime sequence will not start correctly. Use the Get Prime Status command to verify that a prime sequence started correctly.

aX_PRIME!	
Example	address = 0
a measurement is not currently under way.	

	SDI recorder sends aPRIME!
	sensor sends PRIME=Y<CR><LF>
	the prime sequence starts

Prime (aX_PRIME?!)	
Response	aPRIME=Y<CR><LF> or aPRIME=N<CR><LF> depends on prime status.
Notes	this command sends the status of the prime sequence ("Y" or "N")

aX_PRIME!	
Example	address = 0
a prime sequence is currently under way.	

	SDI recorder sends 0X_PRIME?!
	sensor sends 0PRIME=Y<CR><LF>
	the prime sequence starts

Section 8 Software reference

8.1 Engineering units output

Table 5 Data output format

Field	Description
mm/dd/yy	Date
hh:mm:ss	Time
Run	Run counter. It increments by one for each sample sequence.
CAP04	The phosphate value calculated by the sensor, then by a space, then the unit designator (default: µM). Collected data shows to 3 decimal places for µM and 4 for mg/L and mgP/L. The data value may also be **nan**, **-inf**, or **+inf**, then the designator.
VAP04	The variable a*-based phosphate calculated by the sensor, then a space and the unit designator. The data format is the same as CAP04.
VAS	The variable a* value to 3 decimal places. Used to calculate VAP04.
State	The last step in the sample sequence. Refer to Table 7.
Flush1	The mean of the last 10 transmittance signal counts in the ambient flush (State = 1) part of a sample sequence.
Amb Min	The mean of the 6 transmittance signal counts that triggered the knee slope threshold reaction (State = 3) part of a sample sequence.
Flush2	The mean of the last 10 transmittance signal counts in the ambient flush (State = 6) part of a sample sequence.
Cal Min	The mean of the 6 transmittance signal counts that triggered the knee slope threshold reaction (State = 8) part of a sample sequence.
Remaining	The number of samples left, as set by the NOS command.
Dia1–2	Reserved. Diagnostic fields.

Table 6 Phosphate units designators

Command	Designator	Description
$EUF0	µM	Micro-molar phosphate concentration
$EUF1	mg/L	Milligrams per liter of reactive phosphate
$EUF2	mgP/L	Milligrams of atoms phosphorus per liter measured in the form of reactive phosphate

Table 7 Step descriptions

Index	Step	Index	Step
0	Initial flush	5	Mid flush 2
1	Ambient read 1	6	Ambient read 2
2	Mix ambient	7	Mix spiked
3	Ambient PO_4 read	8	Spiked PO_4 read
4	Mid flush 1	9	End flush

8.2 Raw transmittance format

Table 8 Raw transmittance measurement fields

Field	Description
mm/dd/yy	The sample date
hh:mm:ss	The sample time

Table 8 Raw transmittance measurement fields (continued)

Field	Description
signal	The transmittance signal counts (0–4095)
run	The run counter. It increments by one for each sample sequence.
step	An index counter that shows the current step in the sample sequence. Refer to the Step descriptions on page 53.
code	A legacy code number that shows which pumps are in operation.
counts	An increment counter that shows the number of transmittance measurements left in the current step of the sample sequence.
vin	The voltage of the sensor's power supply line to two decimal places.

8.3 Summary file format

The summary files have information for all the samples in each of the sensor's sub-directories.

```
Date     Time  Run  CAP04     VAP04     VAS  State     Flush1    Amb Min
   Flush2     Cal Min   Remaining Diag1      Diag2
```

After the header line there are one or more lines of data collected. This ends with a <LF>(0x0a) character. Refer to the Engineering units output on page 53 for details.

8.4 Raw file format

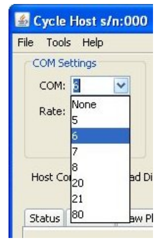
The raw sample text files have two header lines that come before the raw transmittance measurements, then one or more lines after the raw transmittance measurements. The format is shown below.

```
ver:v.vv av=a.aa cv=cc.cc r1v=yy.yy r2v=rr.rr zo=z.zzzz co=o.oooo cas=ss.ss
st=t.ttt cc=10.53 ups=u flt=ffff<lf>
```

Table 9 Raw file first header line

Field	Description
ver.v.vv	The firmware revision number that the file was collected under.
av=a.aa	The pump volume stored by the sensor for the ambient pump volume in µL.
cv=cc.cc	The pump volume stored by the sensor for the calibration pump volume in µL.
r1v=yy.yy	The pump volume stored by the sensor for the R1 reagent pump volume in µL.
r2v=rr.rr	The pump volume stored by the sensor for the R2 reagent pump volume in µL.
zo=z.zzzz	The zero offset stored by the sensor in µM.
co=o.oooo	The calibration pump volume offset stored by the sensor in µL.
cas=ss.ss	The constant a* value stored by the sensor.
st=t.ttt	The slope threshold, which is usually negative, stored by the sensor.
cc=10.53	The calibration standard concentration stored by the sensor
ups=u	The UPS counter stored by the sensor. It increments each time the power is removed from the sensor when the sensor is not in a low power mode.
flt=ffff	A four-character hexadecimal code that shows fault conditions within the sensor. A value of 0000 shows that no faults are detected.

8.5 Communication setup



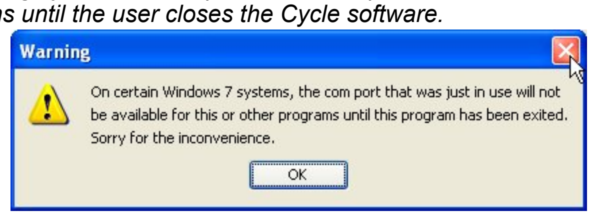
Set the COM port from the host software:

- Select the appropriate communication port from the drop-down menu, or
- Enter the port number in the variable box.
- Go to the **Tools** menu, then select *Options* to turn off the auto-connect option.

The manufacturer recommends that the user keep the default baud rate of 19200.

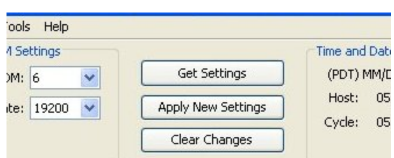
The Cycle software looks for available communication ports on the host PC and makes those available to the user. The port defaults to "None" the first time the software is used. Thereafter, the software will try to connect to the last port used.

***Note:** There is a known issue with the serial port drivers on some PCs using the Windows® 7 operating system. Once opened, a COM port will not be available to the Cycle software or other programs until the user closes the Cycle software.*



8.6 Configuration changes

Change the configuration values in the sensor.

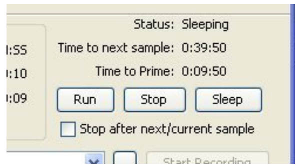


1. Push **Get Settings** to get the configuration values stored in the sensor, unless the Deployment Wizard will be used right away.
   The host will get the configuration values from the sensor.
2. Push **Apply New Settings** to send new configuration values to the sensor.
   The area around the buttons is yellow until the new values are sent to the sensor.
3. Push **Clear Settings** to remove any pending changes.

8.7 Set date and time

Use the *Deployment Wizard* to set the date and the time in the sensor. The user can also use the Control Panel of the host PC to do this.

8.8 Modes of operation



The sensor operates one of five modes.

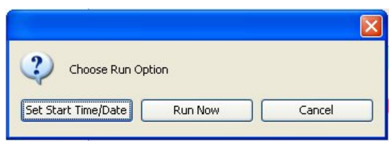
Table 10 Sensor operating modes

Mode	Description
Unknown	The host PC has not yet received any information from the sensor.
Sleeping	The sensor is in a low power mode.
Idle	The sensor is not in operation and has not yet automatically gone to a low power mode. If the sensor does not receive a command within 2 minutes, the default idle time, it will go to low power.
Running	The sensor is in data collection mode or in a flush mode.
Pumping	The pumps are in operation.

The manufacturer recommends the user use the **Run**, **Stop**, and **Sleep** buttons in the laboratory. Use the *Deployment Wizard* for field deployments.

8.8.1 Operation options

Operate the sensor or set a time for the sensor to operate with the **Choose Run Option** window.



Option	Action
Set Start Time/Date	Select the start times and dates to set up and operate the sensor.
Run Now	The sensor starts to operate.
Cancel	The window closes.

8.8.2 Stop options

The user has two options to stop the sensor.

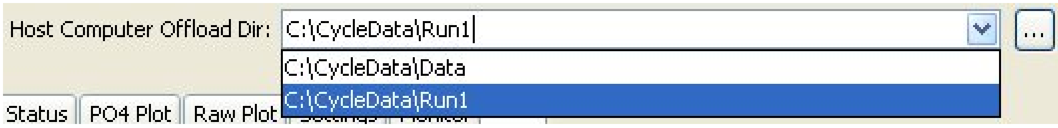
Options	Action
Stop and Flush	Stops the sensor and starts a flush sequence of approximately 5 minutes. Do this at the end of a sample sequence.
Stop Now	Stops the sensor. The manufacturer recommends this only if the user starts a new sample sequence soon after the sensor is stopped.
Continue	Closes the window. The sample sequence will not stop.

8.8.3 Low power option

Put the sensor into a low power mode from a standby mode before power is removed.

8.9 Data file storage

Choose the folder on the host PC in which to store the data collected by the sensor.



Store the data from the sensor on the host PC. There are two options.

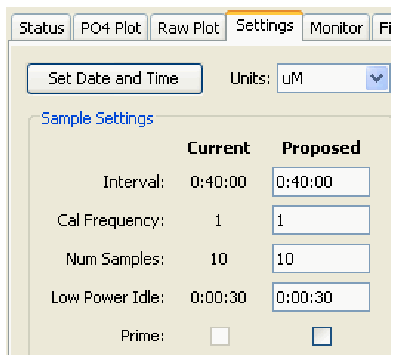
- Enter the file path.
- Find the folder.

If this is a new folder, another window lets the user make sure of the selection and makes the folder. The software stores this file path to use when the next software session starts.

8.10 Settings tab

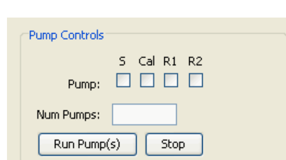
8.10.1 Sample collection schedule

The user makes a decision about the values for the sensor to use in the Sample Settings area of the *Settings* tab. The user can also use the *Deployment Wizard* to automatically set these values.



1. Select how frequently the sensor does a sample. The format for this is hours:minutes:seconds. The sensor takes some time to complete a sample sequence so if the interval is very small, the sensor will apparently collect data continuously. To take a sample once every other day, for example, set the interval to 48:00:00.
2. Select the number of sample sequences or the start date and time. The number of samples can be set from 1 to 32767. A value of -1 or a blank will set the sensor to do sample sequences as long as it has power.
3. Select how frequently the sensor will do a calibration spike after an ambient sample. Change this value to -1 so that the rest of the sequences to not do the "cal spike."
4. Select how long the sensor will stay at full power draw. The default is 2 minutes, then the sensor goes to a low power mode until the next sample sequence starts. Note that if this is set to a value of less than 3 seconds, the sensor may not be responsive.
5. Use the prime checkbox to show the effects of a prime cycle on the deployment calculator.
6. Push **Apply New Settings** when the selected values have been entered into the *Proposed* variable boxes.

8.10.2 Pump controls

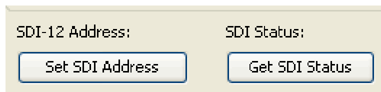


Use the pump control boxes to select a pump to operate. Enter the number of times to operate each of the pumps that are selected in the variable boxes, and push **Run Pump(s)** to start the pump sequence.

To see how many pump operations are left in the current sequence, go to the bottom of the *Monitor* tab and type **$PMP**.

8.10.3 SDI controls

Sensors that have an SDI-12 interface have an additional 8-contact bulkhead connector. The default address is 0. The user can change this address in the host software, or at the "set address" command through the SDI port.

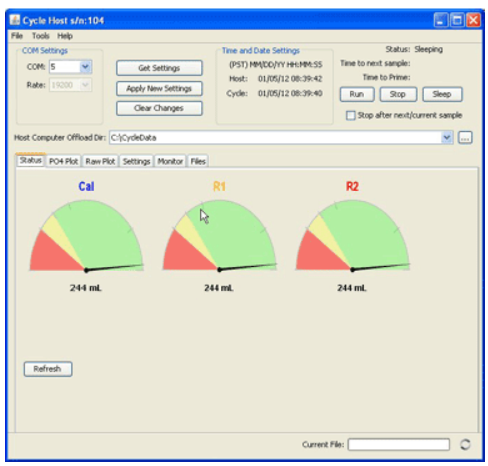


The sensor does not need to be connected to an SDI-12 bus to change the address.

8.11 Status tab

The *Status* tab shows the estimated volumes of chemicals in each of the sensor's cartridges.

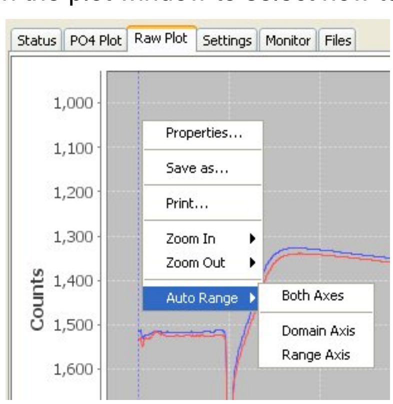
Push **Get Settings** or **Refresh** to get information on the cartridge volumes.



8.12 Plot tabs

Monitor the collected data in counts from the sensor in the *Raw Plot* tab, and collected data in µM, mg/L, or mgP/L in the *PO_4 Plot* tab.

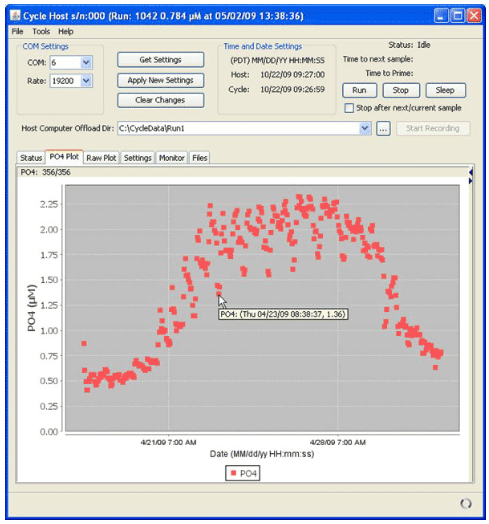
Do a right-click in the plot window to select how to look at the data.



- Select *Domain Axis* to see the time.
- Select *Range Axis* to see the phosphate concentration.

8.12.1 PO_4 plot tab

Look at the data as the concentration of phosphate in selected units. Refer to Table 6 on page 53 in the Output formats section for more information.



The user can also look at stored data in this window. Refer to "Replay Select Files" in the *Files* tab.

8.12.1.1 PO_4 plot controls

Open the plot controls part of the *PO_4 Plot* tab to look at PO_4 data and whether it is in the range selected. Go the to the **Tools** menu then select ***Options*****,** then ***Max PO4 Plot Threshold (µM)*** to enter this value.

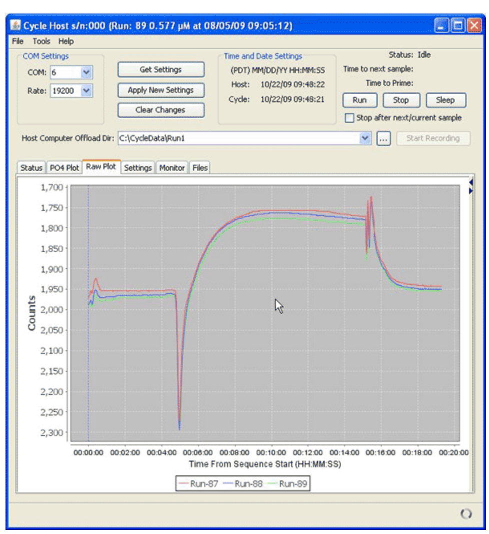
Other controls the user can select:

- Look at and clear data points in the plot area.
- Look at out-of-range data.
- Look at the number of data points plotted compared to the total data points received. This is the counter on the upper left corner of the *Plot* tab.

Note: *If the sensor cannot calculate a phosphate concentration, the output will be NAN (not a number). All NANs are counted the total number of data points. No NANs are counted as valid data.*

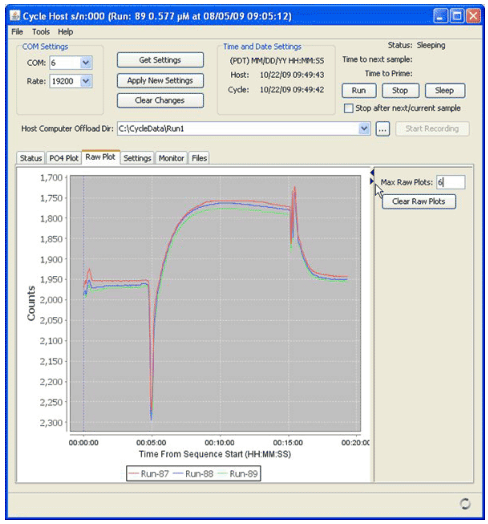
8.12.2 Raw plot tab

Look at the data in this tab as a quality assurance tool. The raw data (in counts) is proportional to transmittance.



8.12.2.1 Raw plot controls

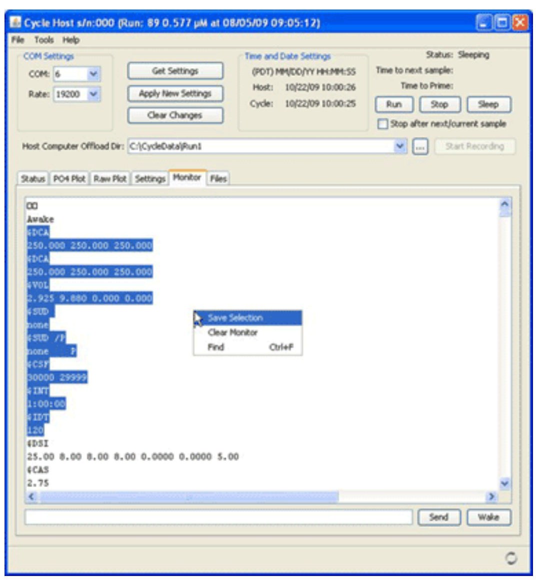
Control the number of plots to show in the Raw Plot tab, and erase all plots from this tab. Note that the default maximum number of raw plots is 6. The manufacturer recommends a limit of 10 plots.



8.13 Monitor tab

This tab is generally used for troubleshooting.

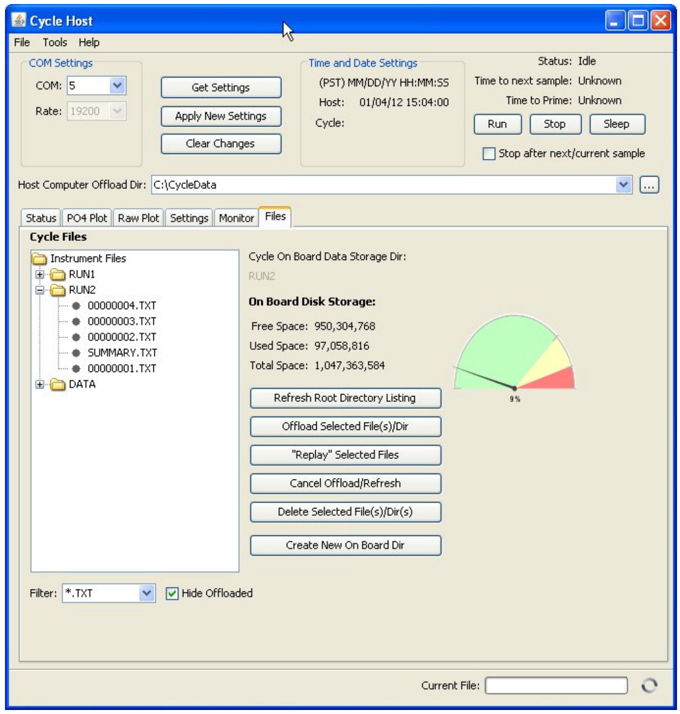
Use the *Monitor* tab to look at the serial data that goes between the host PC and the sensor. Copy and save the serial data in the window to another program for evaluation.



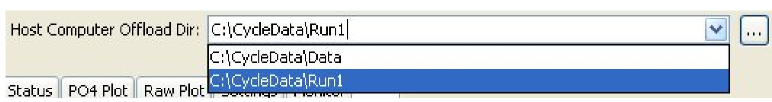
8.14 Get data files

Use the Cycle software to get the data that is stored in the sensor.

1. Start the Cycle software if it is not already on.
2. Select the *Files* tab.



3. Push **Refresh Root Directory Listing**.
   The files stored in the sensor will show in the *Files* tab.
4. Enter the file directory, or folder, on the PC to store the data from the sensor, or create a new folder.



5. Push **Offload Selected File(s)/Dir** to move the data from the sensor to the PC.
   The user can save only one directory at a time, but it is possible to select several files at the same time to store to the PC.
6. Monitor the data saved to the PC.
   Look at the *Current File* area at the bottom of the software window.

Section 9 General information

Revised editions of this user manual are on the manufacturer's website.

9.1 Warranty

This sensor is warranted against defects in materials and workmanship for one year from the date of purchase. The warranty is void if the manufacturer finds the sensor was abused or neglected beyond the normal wear and tear of deployment.

9.2 Service and repair

The manufacturer recommends that sensors be sent back to the factory annually to be cleaned, calibrated, and for standard maintenance. Do the steps below to send a sensor back to the manufacturer.

1. Contact the manufacturer for a Return Merchandise Authorization (RMA).
   Note: *The manufacturer is not responsible for damage to the sensor during return shipment.*
2. Remove all anti-fouling treatment from the sensor before sending it back to the manufacturer.
   Note: *The manufacturer will not accept sensors that have been treated with anti-fouling compounds for service or repair. This includes tri-butyl tin, marine anti-fouling paint, ablative coatings, etc.*
3. Use the sensor's original ruggedized shipping case to send it back to the manufacturer.
4. Write the RMA number on the outside of the shipping case and on the packing list.
5. Use 3rd-day air to ship the sensor back to the manufacturer. Do not use ground shipping.
6. The manufacturer will supply all replacement parts and labor and pay to send the sensor back to the user via 3rd-day air shipping.

9.3 Waste electrical and electronic equipment

Electrical equipment that is marked with this symbol may not be disposed of in European public disposal systems. In conformity with EU Directive 2002/96/EC, European electrical equipment users must return old or end-of-life equipment to the manufacturer for disposal at no charge to the user. To recycle, please contact the manufacturer for instructions on how to return end-of-life equipment, manufacturer-supplied electrical accessories, and auxiliary items for proper disposal.

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