Vernier Optical DO Probe

(Order Code ODO-BTA)

The Vernier Optical DO Probe can be used to measure the concentration of dissolved oxygen in water samples tested in the field or in the laboratory. The Vernier Optical DO Probe is a luminescence-based optical oxygen sensor. This technology reduces the need to calibrate the sensor and no stirring is required since it does not consume oxygen.

Use this probe to perform a variety of tests or experiments to determine changes in dissolved oxygen levels, one of the primary indicators of the quality of an aquatic environment. Use the Vernier Optical DO Probe to:

- Monitor dissolved oxygen concentration in an aquarium containing different combinations of plant and animal species.
- Measure changes in dissolved oxygen concentration resulting from photosynthesis and respiration in aquatic plants.
- Measure dissolved oxygen concentration in a stream or lake, in order to evaluate the capability of the water to support different types of plant and animal life.

What is Included with the Vernier Optical DO Probe

- Vernier Optical DO Probe
- Optical DO Storage Bottle
- Light Shield

Collecting Data with the Vernier Optical DO Probe

This probe can be used with the following interfaces to collect data.

- Vernier LabQuest® 2 or original LabQuest as a standalone device or with a computer
- Vernier LabQuest Mini with a computer
- Vernier LabPro® with a computer or TI graphing calculator
- Vernier SensorDAQ®
- CBL 2™
- TI-Nspire™ Lab Cradle

Data-Collection Software

This probe can be used with an interface and the following data-collection software.

- **Logger *Pro* 3** This computer program is used with LabQuest 2, LabQuest, LabQuest Mini, or LabPro. Version 3.8.6.1 or newer is required.
- **Logger Lite** This computer program is used with LabQuest 2, LabQuest, LabQuest Mini, or LabPro.
- **LabQuest App** This program is used when LabQuest 2 or LabQuest is used as a standalone device. Version 1.7 or newer for LabQuest and version 2.1 or newer for LabQuest 2 is required.
- **DataQuest™ Software for TI-Nspire™** This calculator application for the TI-Nspire™ can be used with the TI-Nspire™ Lab Cradle.
- **EasyData App** This calculator application for the TI-83 Plus and TI-84 Plus can be used with CBL 2 and LabPro. We recommend version 2.4 or newer, which can be downloaded from the Vernier web site, www.vernier.com/easy/easydata.html, and then transferred to the calculator. See the Vernier web site, www.vernier.com/calc/software/index.html for more information on the App and Program Transfer Guidebook.
- **DataMate program** Use DataMate with LabPro or CBL 2 and TI-73, TI-83, TI-84, TI-86, TI-89, and Voyage 200 calculators. See the LabPro and CBL 2 Guidebooks for instructions on transferring DataMate to the calculator.
- **LabVIEW™** National Instruments LabVIEW™ software is a graphical programming language sold by National Instruments. It is used with SensorDAQ and can be used with a number of other Vernier interfaces. See www.vernier.com/labview for more information.

Here is the general procedure to follow when using the Vernier Optical DO Probe.

1. Connect the Optical DO Probe to the interface.
2. Start the data-collection software.
3. The software will identify the Optical DO Probe and load a default data-collection setup. You are now ready to collect data.

Taking Measurements

Rinse the tip of the Optical DO Probe with distilled water and gently blot dry. Place the probe into the sample to be tested. **Important:** Make sure the metal dot near the tip of the Optical DO Probe is immersed for the temperature compensation to work. If you are taking readings at temperatures below 15°C or above 30°C, allow more time for the temperature compensation to adjust and provide a stable reading.

The Optical DO Probe is designed so that the tip of the probe can be submerged in an aquatic environment for extended periods of time. The entire probe can only be submerged up to 1 meter in an aquatic environment and for a maximum of 30 minutes. The body of the probe and cable are waterproof, but the box containing the microSD card is not. If the seal on the probe is damaged, liquid may get into the probe and cause damage. This probe is not designed for long-term immersion applications.

Artificial light sources, such as those used for investigating photosynthesis of aquatic plants, can interfere with the Optical DO Probe as it uses fluorescent technology to measure dissolved oxygen. The Light Shield is designed to block this light from interfering with the sensor cap.

Important: This probe should be used in aqueous solutions only. Do not place the probe in viscous, organic liquids, such as heavy oils, glycerin (glycerol), ethylene glycol, or alcohols. Do not place the probe in acetone or non-polar solvents, such as pentane or hexane.

This probe is equipped with circuitry that supports auto-ID. When used with LabQuest 2, LabQuest, LabQuest Mini, LabPro, SensorDAQ, TI-Nspire™ Lab Cradle, or CBL 2™, the data-collection software identifies the probe and uses pre-defined parameters to configure an experiment appropriate to the recognized probe.

NOTE: Vernier products are designed for educational use. Our products are not designed nor are they recommended for any industrial, medical, or commercial process such as life support, patient diagnosis, control of a manufacturing process, or industrial testing of any kind.

Choosing Units (mg/L or %)

Milligrams per Liter (mg/L)

The unit mg/L is an absolute measurement in which the dissolved oxygen concentration is expressed as milligrams of oxygen gas dissolved per liter of water. The solubility of oxygen in water is dependent on pressure, salinity, and temperature. The maximum capacity that water can hold at various temperatures and pressures is presented in Table 1, assuming salinity is negligible.

At standard atmospheric pressure, oxygen-saturated water at 0°C can hold 14.57 mg/L of oxygen whereas at 25°C, water can only hold 8.36 mg/L. Both these conditions represent 100% saturation, but cold water can hold more oxygen than water at higher temperatures.

Percent Saturation (%)

The unit % is a relative measurement in which the dissolved oxygen concentration is expressed as a percentage of the maximum amount of oxygen that water can hold. Percent saturation is described by the following equation.

$$\%\, saturation = \left(\frac{actual\ DO\ reading\ in\ \text{mg/L}}{saturated\ DO\ reading\ in\ \text{mg/L}} \right) \times 100$$

At standard atmospheric pressure and 25°C, 100% saturation indicates 8.36 mg/L of oxygen is dissolved in the water. If the concentration were 4.18 mg/L for the same sample of water, the water has half the amount of oxygen that it could potentially hold at that temperature, thus the water is only 50% saturated.

Optional Calibration Procedure

It is not necessary to perform a new calibration when using the Optical DO Probe. The sensor is set to the stored calibration before shipping. If you do find that you need to calibrate the Optical DO Probe, complete a one-point calibration using the saturated DO value. **Note:** This calibration method is different from the usual two-point calibration performed with other Vernier sensors.

Position the switch to either mg/L or %. See Choosing Units section for more information about these units of measurement. Connect the Optical DO Probe to the interface and start the data-collection software.

Calibrating the Optical DO Probe with a Computer

1. Choose Calibrate from the Experiment menu.
2. Select the box marked One Point Calibration. Click the Calibrate Now button.
3. Add distilled water to the storage bottle to the top of the sponge. Insert the probe into the bottle. The tip of the probe should not be touching the water or the sponge. Keep the probe in this position for minimum of 60 seconds.
4. When the displayed voltage reading stabilizes, enter the correct saturated dissolved oxygen value. If the unit of measurement is mg/L, enter the mg/L value from Table 1 using the current barometric pressure and air temperature values. If you do not have the current air pressure, use Table 2 to estimate the air pressure at your altitude. See Elevation and Barometric Pressure section for more information about these values. If the unit of measurement is %, enter 100.
5. Click Keep, and then click Done.

Calibrating the Optical DO Probe with LabQuest App

1. Choose Calibrate from the Sensors menu.
2. Select the box marked One Point Calibration. Tap the Calibrate Now button.
3. Add distilled water to the storage bottle to the top of the sponge. Insert the probe into the bottle. The tip of the probe should not be touching the water or the sponge. Keep the probe in this position for minimum of 60 seconds.
4. When the displayed voltage reading stabilizes, enter the correct saturated dissolved oxygen value. If the unit of measurement is mg/L, enter the mg/L value from Table 1 using the current barometric pressure and air temperature values. If you do not have the current air pressure, use Table 2 to estimate the air pressure at your altitude. See Elevation and Barometric Pressure section for more information about these values. If the unit of measurement is %, enter 100.
5. Tap Keep, and then tap OK.

Storage and Maintenance

When you have finished using the Optical DO Probe, rinse it off with distilled water and blot it dry using a paper towel or lab wipe. Insert the probe back into the storage bottle containing the damp sponge.

The tip of the probe is a replaceable screw-on cap called the Optical DO Probe Cap. This cap is warranted to be free from defects for a period of two years from the date of purchase; it is possible that you may get somewhat longer use than the warranty period. If you start to notice a reduced response, it is probably time to replace the cap (order code ODO-CAP). To extend the lifetime of the cap, do not expose to direct sunlight for an extended period of time.

Automatic Temperature Compensation

The Vernier Optical DO Probe is automatically temperature compensated using a thermistor built into the probe. The temperature output of this thermistor is used to automatically compensate for the change in diffusion rate of oxygen through the cap and oxygen solubility in water eliminating the need to recalibrate at different temperatures.

For example, in an oxygen-saturated sample of water, the dissolved oxygen concentration expressed as % will be 100 regardless of the temperature because it is fully saturated. However, the dissolved oxygen concentration expressed in mg/L will change with temperature because the solubility of oxygen in water changes with temperature. For instance, at 15ºC water can dissolve 10.15 mg/L while at 30ºC water can only dissolve 7.67 mg/L of oxygen even though the % saturation value is 100 in both samples.

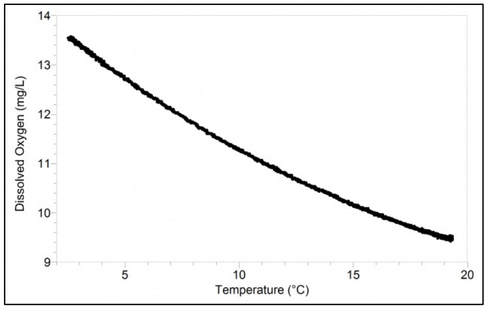

Figure 1 Saturated dissolved oxygen vs. *temperature data*

Barometric Pressure Compensation

The Vernier Optical DO Probe is automatically pressure compensated using a barometer built into the probe The pressure output of this barometer is used to automatically compensate for the change in diffusion rate of oxygen through the cap and oxygen solubility in water eliminating the need to recalibrate at different pressures or elevations.

Elevation and Barometric Pressure

When determining the local barometric pressure use "true" barometric pressure and not a barometer reading that has been corrected to sea level. "Station pressure" is the true pressure at your site, or station. This is the pressure a mercury barometer would read in your classroom. "Sea level pressure" is the pressure after the station pressure has been adjusted to its equivalent at sea level. Airports and television stations usually report the sea level pressure rather than the station pressure. This is commonly done to take altitude out of the equation for weather forecasters.

An approximate formula to calculate local barometric pressure is below where BP is the Barometric Pressure in mmHg:

$$\textit{true BP} = [\textit{corrected BP}] - [2.5 \times (\textit{local altitude in ft. above sea level})/100]$$

If you do not have a barometer available to read barometric pressure, you can estimate the barometric pressure reading at your elevation (in feet) from Table 2. The values are calculated based on a barometric air pressure reading of 760 mmHg at sea level.

Sampling in Ocean Salt Water or Tidal Estuaries

(only required when at salinity levels greater than 1000 mg/L)

Dissolved oxygen concentration for oxygen-saturated water at various salinity values, $DO_{(salt)}$, can be calculated using the formula.

$$DO_{(salt)} = DO - (k \times S)$$

- $DO_{(salt)}$ is the concentration of dissolved oxygen (in mg/L) in salt-water solutions.
- *DO* is the dissolved oxygen concentration for oxygen-saturated distilled water as determined from Table 1.
- *S* is the salinity value (in ppt). Salinity values can be determined using the Vernier Chloride Ion-Selective Electrode, Conductivity Probe, or Salinity Probe as described in the *Water Quality with Vernier* lab manual.
- *k* is a constant. The value of *k* varies according to the sample temperature and can be determined from Table 3.

Example

Determine the saturated DO calibration value at a temperature of 23°C and a pressure of 750 mmHg, when the Optical DO Probe is used in seawater with a salinity value of 35.0 ppt.

First, find the dissolved oxygen value in Table 1 (DO = 8.55 mg/L). Then find *k* in Table 3 at 23°C (*k* = 0.04662). Substitute these values, as well as the salinity value, into the previous equation.

$$DO_{(salt)} = DO - (k \times S) = 8.55 - (0.04662 \times 35.0) = 8.55 - 1.63 = 6.92 \text{ mg/L}$$

Use the value 6.92 mg/L when performing the saturated DO calibration point (water-saturated air). The Optical DO Probe will now be calibrated to give correct DO readings in salt-water samples with a salinity of 35.0 ppt.

Important: For most dissolved oxygen testing, it is not necessary to compensate for salinity

Specifications

Range	
mg/L	0 to 20 mg/L
%	0 to 300%
Accuracy	
mg/L	± 0.2 mg/L below 10 mg/L ± 0.4 mg/L above 10 mg/L
%	± 2% below 100% ± 5% above 100%
Accuracy with calibration reset	
mg/L	± 0.1 mg/L below 10 mg/L ± 0.2 mg/L above 10 mg/L
%	± 1% below 100% ± 5% above 100%
Resolution	
13-bit (SensorDAQ)	0.003 mg/L
12-bit (LabPro, LabQuest, LabQuest 2, TI-Nspire Lab Cradle, LabQuest Mini)	0.006 mg/L
10-bit (CBL 2)	0.025 mg/L
Response time	90% of final reading in 40 seconds
Temperature compensation	automatic from 0 to 50°C
Pressure compensation	automatic from 228 mmHg to 1519 mmHg
Salinity compensation	manual, accounted for during calibration
Minimum sample flow	none required
Stored calibration values (mg/L)	
slope	4.444
intercept	–0.4444
Stored calibration values (%)	
slope	66.666
intercept	–6.6666

Optical DO Probe Replacement Cap

order code ODO-CAP

The Optical DO Replacement Cap is a replacement for the sensing cap on a Vernier Optical DO Probe. The cap is warranted to be free from defects for a period of two years from the date of purchase; it is possible, however, that you may get somewhat longer use than the warranty period. If you start to notice a reduced response, it is probably time to replace the cap.

The caps are factory calibrated and a calibration code specific to each individual cap is determined during the manufacturing process. Replacement caps are supplied with their calibration codes on a microSD card, which is inserted into the box on the probe. **Note:** Each cap and microSD card is a unique set.

Replacement and Calibration Reset Instructions

1. Restore factory default settings:
   a. Connect the Optical DO Probe to the data-collection interface and start the data-collection program.
   b. Choose Calibrate from the Experiment menu (Logger *Pro*) or the Sensors menu (LabQuest App).
   c. Choose Calibration Storage (Logger *Pro*) or Storage (LabQuest App).
   d. Click or tap Sensor Factory Default.
   e. Click Done or tap OK.
2. Replace the cap:
   a. Disconnect the Optical DO Probe from the data-collection interface.
   b. Remove the screw in the microSD card cover and remove the microSD card (see Figure 2).
   c. Insert the new microSD card, replace the cover, and screw.
   d. Unscrew the used cap from the Optical DO Probe and twist on the new cap.

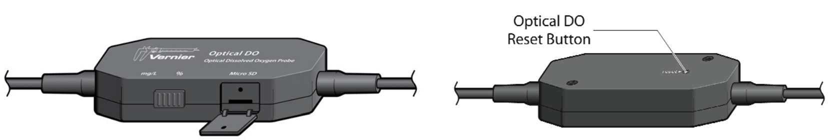

Figure 2 Location of microSD card and reset button

3. Reset the calibration:
   a. Position the switch to %.
   b. Connect the Optical DO Probe to the data-collection interface and start the data-collection program.
   c. Add distilled water to the storage bottle to the top of the sponge.
   d. Insert the probe into the bottle. The tip of the probe should not be touching the water or the sponge. Keep the probe in this position for a minimum of 60 seconds.
   e. Use a small paper clip to press down the reset button for three seconds. The reset button is located on the bottom of the box containing the microSD card (see Figure 2).
   f. Release the button. The reading will drop to almost 0%.
   g. Wait for the reading to change to 100%. This may take up to 60 seconds.

   h. Once the reading reaches 100%, wait another 30 seconds for the reset process to complete. **Note:** This waiting time is important for the probe to internally save the reset information.
   i. The probe is now ready to use.

Optical DO Probe Metal Guard

order code ODO-GRD

Attach this optional accessory to the Vernier Optical DO Probe to protect the cap and to help weigh down the probe when submerged.

The metal guard helps protect the probe from damage when taking measurements in the field. If any of the seals on the probe are compromised, liquid may get into the probe and cause damage.

When using the metal guard with the Optical DO Probe, do not swing the probe by the cable. This may cause injury to the user and will cause severe strain on the cable. Damage under these conditions is not covered by the product warranty.

How the Vernier Optical DO Probe Works

The Vernier Optical DO Probe operates on the principle of reversible luminescence quenching of a luminophore by oxygen as it passes through the cap. The cap is coated with a luminescent compound encased in a matrix for protection. Blue light from an LED is transmitted to the cap and excites the luminophore.

A collision of an oxygen molecule with the luminophore in its electronic excited state results in energy transfer from the luminophore to oxygen. As the luminophore relaxes it emits red light. The time from when the blue light is transmitted and the red light is emitted is measured by a photodiode. The more oxygen that is present, the shorter the time it takes for the red light to be emitted.

This time is measured and correlated to the oxygen concentration. Between the flashes of blue light, a red LED is flashed onto the sensor and used as an internal reference to help validate each measurement. This process is described by the Stern-Volmer equation

$$\tau_0 / \tau = 1 + K_{SV}[DO]$$

where τ_0 and τ are the luminescence lifetimes in the absence and presence of oxygen, respectively, [DO] is the dissolved oxygen concentration, and K_{SV} is the Stern-Volmer quenching constant.

The Stern-Volmer constant (K_{SV}) depends directly upon the rate constant for the diffusion of oxygen, the solubility of oxygen, and the natural lifetime of the electronic excited state of the luminophore. Lifetime measurements have an advantage over intensity measurements since they are not usually affected by processes which result in loss of the complex, such as bleaching or photodegradation.

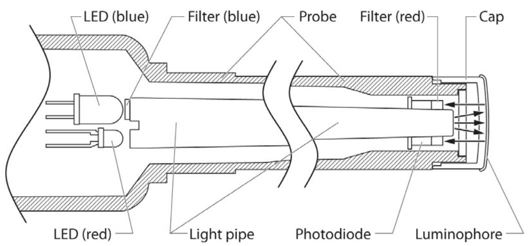

Figure 3 Interior schematic of the Optical DO Probe

Background Information about Dissolved Oxygen

Dissolved oxygen is a vital substance in a healthy body of water. Various aquatic organisms require different levels of dissolved oxygen to survive. Whereas trout require higher levels of dissolved oxygen, fish species like carp and catfish survive in streams with low oxygen concentrations. Water with a high level of dissolved oxygen is generally considered to be a healthy environment that can support many different types of aquatic life.

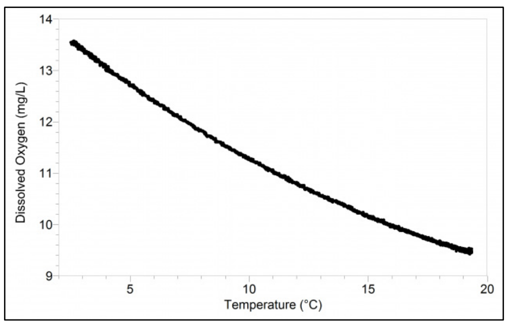

Figure 4 Saturated dissolved oxygen vs. *temperature at 760 mmHg*

There are many factors that can affect the level of dissolved oxygen in a body of water. Turbulence from waves on a lake or from a fast-moving stream can greatly increase the amount of water exposed to the atmosphere, resulting in higher levels of dissolved oxygen. Water temperature is another factor that can affect dissolved oxygen levels; like other gases, the saturated level of dissolved oxygen is less in warm water than in cold water, shown in Figure 4.

Photosynthesis cycles also have a large effect on dissolved oxygen levels of an aquatic environment. Aquatic plants and photosynthetic microorganisms will cause oxygen gas to be produced during daylight hours from photosynthesis:

$$CO_2 + H_2O \rightarrow C_xH_yO_z + O_2$$

As the afternoon progresses, dissolved oxygen levels increase as photosynthesis occurs. After sundown, photosynthesis decreases—however, plant and animal organisms continue to respire. Throughout the night and early morning, respiration results in a decrease in dissolved oxygen levels:

$$C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$$

The amount and variety of plant and animal life in a stream affects the degree to which the photosynthesis-respiration cycle occurs.

Levels of organic wastes from manmade sources such as pulp mills, food-processing plants, and wastewater treatment plants can also result in lower levels of dissolved oxygen in streams and lakes. Oxidation of these wastes depletes the oxygen, sometimes at a faster rate than turbulence or photosynthesis can replace it. Thus, use of a dissolved oxygen probe to determine dissolved oxygen concentration and biological oxygen demand of a stream can be important tests in determining the health and stability of an aquatic ecosystem.

Tables

Table 1 Dissolved oxygen (mg/L) in oxygen-saturated distilled water (at various temperature and pressure values)

	770 mm	760 mm	750 mm	740 mm	730 mm	720 mm	710 mm	700 mm
0°C	14.76	14.57	14.38	14.19	13.99	13.80	13.61	13.42
1°C	14.38	14.19	14.00	13.82	13.63	13.44	13.26	13.07
2°C	14.01	13.82	13.64	13.46	13.28	13.10	12.92	12.73
3°C	13.65	13.47	13.29	13.12	12.94	12.76	12.59	12.41
4°C	13.31	13.13	12.96	12.79	12.61	12.44	12.27	12.10
5°C	12.97	12.81	12.64	12.47	12.30	12.13	11.96	11.80
6°C	12.66	12.49	12.33	12.16	12.00	11.83	11.67	11.51
7°C	12.35	12.19	12.03	11.87	11.71	11.55	11.39	11.23
8°C	12.05	11.90	11.74	11.58	11.43	11.27	11.11	10.96
9°C	11.77	11.62	11.46	11.31	11.16	11.01	10.85	10.70
10°C	11.50	11.35	11.20	11.05	10.90	10.75	10.60	10.45
11°C	11.24	11.09	10.94	10.80	10.65	10.51	10.36	10.21
12°C	10.98	10.84	10.70	10.56	10.41	10.27	10.13	9.99
13°C	10.74	10.60	10.46	10.32	10.18	10.04	9.90	9.77
14°C	10.51	10.37	10.24	10.10	9.96	9.83	9.69	9.55
15°C	10.29	10.15	10.02	9.88	9.75	9.62	9.48	9.35
16°C	10.07	9.94	9.81	9.68	9.55	9.42	9.29	9.15
17°C	9.86	9.74	9.61	9.48	9.35	9.22	9.10	8.97
18°C	9.67	9.54	9.41	9.29	9.16	9.04	8.91	8.79
19°C	9.47	9.35	9.23	9.11	8.98	8.86	8.74	8.61
20°C	9.29	9.17	9.05	8.93	8.81	8.69	8.57	8.45
21°C	9.11	9.00	8.88	8.76	8.64	8.52	8.40	8.28
22°C	8.94	8.83	8.71	8.59	8.48	8.36	8.25	8.13
23°C	8.78	8.66	8.55	8.44	8.32	8.21	8.09	7.98
24°C	8.62	8.51	8.40	8.28	8.17	8.06	7.95	7.84
25°C	8.47	8.36	8.25	8.14	8.03	7.92	7.81	7.70
26°C	8.32	8.21	8.10	7.99	7.89	7.78	7.67	7.56
27°C	8.17	8.07	7.96	7.86	7.75	7.64	7.54	7.43
28°C	8.04	7.93	7.83	7.72	7.62	7.51	7.41	7.30
29°C	7.90	7.80	7.69	7.59	7.49	7.39	7.28	7.18
30°C	7.77	7.67	7.57	7.47	7.36	7.26	7.16	7.06
31°C	7.64	7.54	7.44	7.34	7.24	7.14	7.04	6.94
32°C	7.51	7.42	7.32	7.22	7.12	7.03	6.93	6.83
33°C	7.39	7.29	7.20	7.10	7.01	6.91	6.81	6.72
34°C	7.27	7.17	7.08	6.98	6.89	6.80	6.70	6.61
35°C	7.15	7.05	6.96	6.87	6.78	6.68	6.59	6.50

Table 1, cont. Dissolved oxygen (mg/L) in oxygen-saturated distilled water (at various temperature and pressure values)

	690 mm	680 mm	670 mm	660 mm	650 mm	600 mm	550 mm	500 mm
0°C	13.23	13.04	12.84	12.65	12.46	11.53	10.57	9.62
1°C	12.88	12.70	12.51	12.32	12.14	11.21	10.27	9.34
2°C	12.55	12.37	12.19	12.01	11.82	10.90	9.98	9.08
3°C	12.23	12.05	11.88	11.70	11.52	10.60	9.71	8.84
4°C	11.92	11.75	11.58	11.40	11.23	10.32	9.46	8.60
5°C	11.63	11.46	11.29	11.12	10.95	10.06	9.21	8.38
6°C	11.34	11.18	11.01	10.85	10.68	9.81	8.98	8.17
7°C	11.07	10.91	10.75	10.59	10.42	9.56	8.76	7.97
8°C	10.80	10.65	10.49	10.33	10.18	9.33	8.54	7.78
9°C	10.55	10.39	10.24	10.09	9.94	9.11	8.34	7.59
10°C	10.30	10.15	10.00	9.86	9.71	8.90	8.15	7.41
11°C	10.07	9.92	9.78	9.63	9.48	8.70	7.96	7.24
12°C	9.84	9.70	9.56	9.41	9.27	8.50	7.78	7.08
13°C	9.63	9.49	9.35	9.21	9.07	8.32	7.61	6.92
14°C	9.42	9.28	9.14	9.01	8.87	8.14	7.44	6.77
15°C	9.22	9.08	8.95	8.82	8.68	7.96	7.28	6.62
16°C	9.02	8.89	8.76	8.63	8.50	7.80	7.13	6.48
17°C	8.84	8.71	8.58	8.45	8.33	7.63	6.98	6.34
18°C	8.66	8.54	8.41	8.28	8.16	7.48	6.84	6.21
19°C	8.49	8.37	8.24	8.12	8.00	7.33	6.70	6.08
20°C	8.33	8.20	8.08	7.96	7.84	7.18	6.56	5.96
21°C	8.17	8.05	7.93	7.81	7.69	7.04	6.43	5.84
22°C	8.01	7.90	7.78	7.67	7.55	6.90	6.31	5.72
23°C	7.87	7.75	7.64	7.52	7.41	6.77	6.18	5.61
24°C	7.72	7.61	7.50	7.39	7.28	6.64	6.06	5.50
25°C	7.59	7.48	7.37	7.26	7.15	6.51	5.95	5.39
26°C	7.45	7.35	7.24	7.13	7.02	6.39	5.83	5.29
27°C	7.33	7.22	7.11	7.01	6.90	6.27	5.72	5.19
28°C	7.20	7.10	6.99	6.89	6.78	6.15	5.61	5.09
29°C	7.08	6.98	6.87	6.77	6.67	6.04	5.51	4.99
30°C	6.96	6.86	6.76	6.66	6.56	5.95	5.42	4.91
31°C	6.85	6.75	6.65	6.55	6.45	5.85	5.34	4.83
32°C	6.73	6.63	6.54	6.44	6.34	5.76	5.25	4.75
33°C	6.62	6.53	6.43	6.33	6.24	5.67	5.17	4.67
34°C	6.51	6.42	6.32	6.23	6.13	5.58	5.08	4.59
35°C	6.40	6.31	6.22	6.13	6.03	5.49	5.00	4.52

Table 2 Approximate barometric pressure at different elevations

Elevation (feet)	Pressure (mmHg)	Elevation (feet)	Pressure (mmHg)	Elevation (feet)	Pressure (mmHg)	Elevation (feet)	Pressure (mmHg)
0	760	2000	708	4000	659	6000	609
250	753	2250	702	4250	653	7000	586
500	746	2500	695	4500	647	8000	564
750	739	2750	689	4750	641	9000	543
1000	733	3000	683	5000	635	10000	522
1250	727	3250	677	5250	629	15000	429
1500	720	3500	671	5500	624	20000	349
1750	714	3750	665	5750	618	25000	282

Table 3 Salinity correction constant values

Temp (°C)	Constant, *k*	Temp (°C)	Constant, *k*	Temp (°C)	Constant, *k*	Temp (°C)	Constant, *k*
1	0.08796	8	0.06916	15	0.05602	22	0.04754
2	0.08485	9	0.06697	16	0.05456	23	0.04662
3	0.08184	10	0.06478	17	0.05328	24	0.04580
4	0.07911	11	0.06286	18	0.05201	25	0.04498
5	0.07646	12	0.06104	19	0.05073	26	0.04425
6	0.07391	13	0.05931	20	0.04964	27	0.04361
7	0.07135	14	0.05757	21	0.04854	28	0.04296

Warranty

Vernier warrants this product to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. This warranty does not cover damage to the product caused by abuse or improper use. The sensor cap is under warranty for two years.

Vernier

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