DISSOLVED OXYGEN SENSOR

Description D0376bt

Figure 1. The Dissolved Oxygen Sensor

1. Short description

The Dissolved Oxygen Sensor can be used to measure the concentration of dissolved oxygen in water samples being tested in the field or laboratory.

The Dissolved Oxygen Sensor is delivered with a BT plug and can be connected to the following interfaces:

- UIA/UIB boards through the Measuring Console (via 0520 adapter)
- CoachLab
- CoachLab II
- Texas Instruments CBL™ data-logger
- Vernier LabPro data-logger

There is an adapter (art. 0520) to connect sensors with BT-plugs to 4-mm inputs.

Since dissolved oxygen is one of the primary indicators of the quality of an aquatic environment, you can use this sensor to perform a wide variety of tests or planned experiments to determine the changes in dissolved oxygen levels:

- Monitor dissolved oxygen 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.
- Use this sensor for an accurate on-site test of dissolved oxygen concentration in a stream or lake survey, in order to evaluate the capability of the water to support different types of plant and animal life.
- Measure Biological Oxygen Demand (B.O.D.) in water samples containing organic matter that consumes oxygen as it decays.
- Determine the relationship between dissolved oxygen concentration and temperature of a water sample.

2. How the Dissolved Oxygen Sensor Works

The Dissolved Oxygen Sensor is a Clark-type polarographic electrode that senses the oxygen concentration in water and aqueous solutions. A platinum cathode and a silver/silver chloride reference anode in KCl electrolyte are separated from the sample by a gas-permeable plastic membrane.

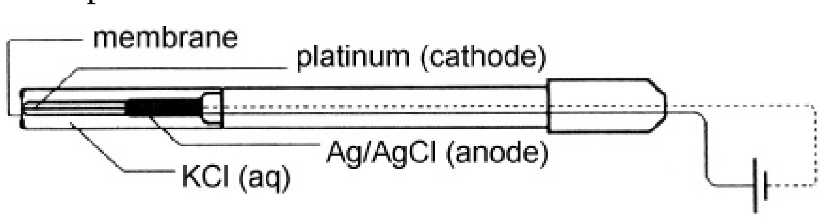


Figure 2

A fixed voltage is applied to the platinum electrode. As oxygen diffuses through the membrane to the cathode, it is reduced:

$$O_2 + H_2O + 2e^- \quad 2\ OH^-$$

The oxidation taking place at the reference electrode (anode) is:

$$Ag + Cl \quad AgCl + e^-$$

Accordingly, a current will flow that is proportional to the rate of diffusion of oxygen, and in turn to the concentration of dissolved oxygen in the sample. This current is converted to a proportional voltage, which is amplified and read by any of the CMA lab interfaces.

3. Inventory of Items Included with the Dissolved Oxygen Sensor

Check to be sure that each of these items is included in your Dissolved Oxygen Sensor container:

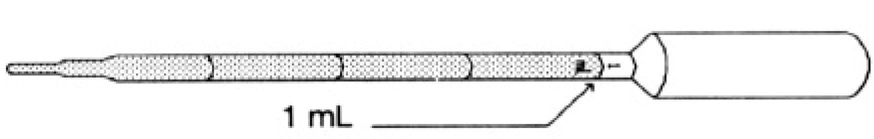
- Dissolved Oxygen Sensor (dissolved oxygen electrode, with membrane cap)
- One replacement membrane cap
- Sodium Sulfite Calibration Standard (2.0 M Na_2SO_3) and MSDS sheet
- D.O. Electrode Filling Solution, MSDS sheet, and filling pipette
- Calibration bottle (empty, lid with hole)
- D.O. Polishing Strips (1 pkg)
- Dissolved Oxygen Sensor manual

4. Preparing the Dissolved Oxygen Sensor for Use

Read this procedure carefully before using your Dissolved Oxygen Sensor. Following the directions outlined in this section will help ensure that you will obtain accurate dissolved oxygen readings with the Sensor.

Important: Do not touch the membrane at the very tip of the Sensor. Contact with the membrane could result in damage to the membrane surface and improper operation of the sensor.

- Remove the blue protective cap from the tip of the sensor. This protective cap can be discarded once the sensor is unpacked.
- Unscrew the membrane cap from the tip of the sensor with a counterclockwise turn.
- Using a pipette, fill the membrane cap with 1 ml of DO Electrode Filling Solution.
- Carefully thread the membrane cap back onto the electrode being careful not to over-tighten the cap. Rinse the electrode with distilled water.



- Place the sensor into a 250-ml beaker filled with about 100-ml of distilled water and connect the sensor with an interface.
- With the sensor still in the water, wait 10 minutes while the sensor warms up. For polarization of the sensor to take place the interface should be powered with the sensor connected to it. If disconnected for a period longer than a few minutes, it will be necessary to warm it up again.
  With the CBL system you need to supply continuos power in order to polarize the sensor. This is the best done by running a program that supports Dissolved Oxygen Sensor such as CHEMBIO program for TI Calculators or Coach program for the computer. Start the measurement for 10 minutes.
  Whenever possible use the CBL adapter so that the batteries do not run down during polarization.
- After polarization has taken place for 10 minutes, the sensor is ready to take readings or to be calibrated.

5. Calibration of the Dissolved Oxygen Sensor

The Dissolved Oxygen Sensor can be easily calibrated at two known levels.
We recommend you to do a two-point calibration whenever you us the sensor.
Important: Prior to calibration the Dissolved Oxygen Sensor must be polarized for about 10 minutes.

Zero-Oxygen Calibration Point

For the first calibration point use the Sodium Sulfite Calibration solution (provided). Sodium sulfite is a good reducing agent that readily removes dissolved oxygen from a solution. If the sulfite solution has been stored brim fully in its storage bottle, you can assume it to be oxygen free.

- Remove the sensor from the water and place the tip of the sensor into the Sodium Sulfite Calibration Solution.
  Important: No air bubbles can be trapped below the tip of the sensor or the sensor will sense an inaccurate dissolved oxygen level. If the voltage does not rapidly decrease, tap the side of the bottle with the sensor to dislodge the bubble.
  The readings should be in the 0.2- to 0.5-V range.
- When the voltage stabilizes (~1 minute) enter “0” as the known value in mg/l.

Saturated DO Calibration Point

- Rinse the sensor with distilled water and gently blot dry.
- Unscrew the lid of the calibration bottle provided with the sensor.
- Slide the lid and the grommet about 1/2 inch onto the sensor body.
- Add water to the bottle to a depth of about 1/4-inch and screw the bottle into the cap, as shown. **Important:** Do not touch the membrane or get it wet during this step.

- Keep the sensor in this position for about a minute. The readings should be above 2.0 V. When the voltage stabilizes enter the correct saturated dissolved-oxygen value (in mg/l) from Table 1 (for example, "8.66") 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.

	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. Dissolved oxygen (in mg/l) in air-saturated distilled water (at various temperature and pressure values).

	690 mm	680 mm	670 mm	660 mm	650 mm
0°C	13.23	13.04	12.84	12.65	12.46
1°C	12.88	12.70	12.51	12.32	12.14
2°C	12.55	12.37	12.19	12.01	11.82
3°C	12.23	12.05	11.88	11.70	11.52
4°C	11.92	11.75	11.58	11.40	11.23
5°C	11.63	11.46	11.29	11.12	10.95
6°C	11.34	11.18	11.01	10.85	10.68
7°C	11.07	10.91	10.75	10.59	10.42
8°C	10.80	10.65	10.49	10.33	10.18
9°C	10.55	10.39	10.24	10.09	9.94
10°C	10.30	10.15	10.00	9.86	9.71
11°C	10.07	9.92	9.78	9.63	9.48
12°C	9.84	9.70	9.56	9.41	9.27
13°C	9.63	9.49	9.35	9.21	9.07
14°C	9.42	9.28	9.14	9.01	8.87
15°C	9.22	9.08	8.95	8.82	8.68
16°C	9.02	8.89	8.76	8.63	8.50
17°C	8.84	8.71	8.58	8.45	8.33
18°C	8.66	8.54	8.41	8.28	8.16
19°C	8.49	8.37	8.24	8.12	8.00
20°C	8.33	8.20	8.08	7.96	7.84
21°C	8.17	8.05	7.93	7.81	7.69
22°C	8.01	7.90	7.78	7.67	7.55
23°C	7.87	7.75	7.64	7.52	7.41
24°C	7.72	7.61	7.50	7.39	7.28
25°C	7.59	7.48	7.37	7.26	7.15
26°C	7.45	7.35	7.24	7.13	7.02
27°C	7.33	7.22	7.11	7.01	6.90
28°C	7.20	7.10	6.99	6.89	6.78
29°C	7.08	6.98	6.87	6.77	6.67
30°C	6.96	6.86	6.76	6.66	6.56
31°C	6.85	6.75	6.65	6.55	6.45
32°C	6.73	6.63	6.54	6.44	6.34
33°C	6.62	6.53	6.43	6.33	6.24
34°C	6.51	6.42	6.32	6.23	6.13
35°C	6.40	6.31	6.22	6.13	6.03

Table (continuation).

6. Elevation Barometric Pressure Table

If you do not have a barometer available to read barometric pressure, you can estimate the barometric pressure reading at your elevation in feet (1feet= 30.48 cm) from Table 2.

Elevation (feet)	Pressure (mm Hg)	Elevation (feet)	Pressure (mm Hg)	Elevation (feet)	Pressure (mm Hg)
0	760	2000	708	4000	659
250	753	2250	702	4250	653
500	746	2500	695	4500	647
750	739	2750	689	4750	641
1000	733	3000	683	5000	635
1250	727	3250	677	5250	629
1500	720	3500	671	5500	624
1750	714	3750	665	5750	618

Table 2. The values are calculated based on a barometric air pressure reading of 760 mm Hg at sea level.

7. Effect of salt concentration on dissolved oxygen (at salinity levels > 1000 mg/l)

Dissolved Oxygen concentration for air saturated water at various salinity values, DO(s), can be calculated using the formula:

$$DO(s) = DO - (k * s)$$

- DO(s) is the concentration of dissolved oxygen (in mg/l) in salt-water solutions.
- DO is the dissolved oxygen concentration for air-saturated distilled water as determined from Table 1.
- s is the salinity value in ppt (part per thousand). Salinity values can be determined using the Chloride Ion-Selective Electrode or Conductivity Sensor.
- k is a constant. The value of k varies according to the sample temperature, and can be determined from Table 3.

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

Example: Determine the saturated DO calibration value at a temperature of 23°C and a pressure of 750 mm Hg, when the Dissolved Oxygen Sensor is used in seawater with a salinity value of 2.0 ppt[1] (2000 mg/l NaCl).
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(for 2 ppt) = DO - (k * s) = 8.55 - (0.04662 * 2) = 8.55 - 0.09324 = 8.46 mg/l

Use the value 8.46 mg/l when performing the saturated DO calibration point (water-saturated air) as described in the Calibration section. The Dissolved Oxygen Sensor will be then calibrated to give correct DO readings in salt-water samples with a salinity of 2.0 ppt (2000 mg/l NaCl).

Important: For most dissolved oxygen testing, it is *not* necessary to compensate for salinity; for example, if the salinity value is 0.5 ppt (500 mg/l NaCl), using 25°C and 760 mm Hg, the calculation for DO(s) would be:

DO(for 0.5 ppt) = DO – (k * s) = 8.36 - (0.04498 * 0.5) = 8.36 - 0.023 = 8.34 mg/l

At salinity levels less than 1.0 ppt (1000 mg/l), neglecting this correction results in an error of less than 0.2%.

8. Storage and Maintenance of the Dissolved Oxygen Sensor

Following the procedure outlined in this section will enhance the lifetime of your Dissolved Oxygen Sensor and its membrane cap. Follow these steps when storing the electrode:

- **Long-term storage (more than 24 hours):** Remove the membrane cap and rinse the inside and outside of the cap with distilled water. Shake the membrane cap dry. Also rinse and dry the exposed anode and cathode inner elements (blot dry with a lab wipe). Reinstall the membrane cap loosely onto the electrode body for storage. Do not screw it on tightly.
- **Short-term storage (less than 24 hours):** Store the Dissolved Oxygen Sensor with the membrane end submerged in about 1 inch of distilled water.
  Important: Storing the sensor in this manner for longer than 24 ours may result in damage to the membrane.
- **Polishing the metal electrodes:** If the cathode (the small, shiny, metal contact in the center of the glass stem) and anode (the silver, metal foil surrounding the lower portion of the inner body) become discolored or appear corroded, polish them with the polishing strip that is provided with the sensor. Perform this operation only as

[1] parts per thousand

needed to restore electrode performance—it should be necessary only once every year or so. Remove the membrane cap from your Dissolved Oxygen Sensor. Thoroughly rinse the inner elements of the sensor with distilled water to remove all filling solution. Cut a one-inch piece from the D.O. Electrode Polishing Strip provided. Wet the dull (abrasive) side of the polishing strip with distilled water. Using a circular motion, polish the center glass element of the cathode (on the very end of the electrode). Use gentle finger pressure during this polishing operation. Polish only enough to restore a bright, clean surface to the center element. Next, polish the silver anode located around the base of the electrode inner element. Polish only enough to restore a silver appearance.

NOTE: Aggressive polishing will damage the sensor inner elements. *Be sure* to use only gentle pressure when performing the polishing of the anode and cathode. When you have completed the polishing, rinse the cathode and anode elements thoroughly and dry with a lab wipe.

With normal use, the Dissolved Oxygen Sensor will last for years. The membrane cap will, however, require replacement after about 6 months of continuous use. Replacement of the membrane is recommended when your Dissolved Oxygen Sensor will no longer respond rapidly during calibration or when taking D.O. readings. Use of your Dissolved Oxygen Sensor in samples that are non-aqueous or in those that contain oil, grease, or other coating agents will result in shortened membrane life. Replacement membranes can be obtained from the CMA.

9. Maintaining and replenishing the Sodium Sulfite Calibration Solution

Having an oxygen-free solution to perform a zero-oxygen calibration point is essential for accurate readings with your Dissolved Oxygen Sensor. The Sodium Sulfite Calibration Solution that was included with your sensor will last a long time, but not indefinitely. Here are some suggestions for maintaining and replacing this solution:

- After your first use of the solution for calibration, the solution will no longer be brim full (some overflow results when the sensor is inserted into the solution). If you cap the solution with an air space above the sensor, oxygen gas in the space will dissolve in the sodium sulfite solution—as a result, the solution may not be oxygen free. To prevent this from occurring, before putting on the lid, gently squeeze the bottle so the level of the solution is at the very top of the bottleneck; with the solution at this level, screw on the lid. The bottle will remain in this “collapsed” position. Using this procedure, the 2.0 M Na_2SO_3 should remain oxygen free for a long period of time. If the calibration voltage reading displayed during the first calibration point is higher than in previous calibrations, it may be time to replace the solution, as described below.

  The 2.0 M sodium sulfite (Na_2SO_3) solution can be prepared from solid sodium sulfite crystals: add 25.0 g of solid anhydrous sodium sulfite crystals (Na_2SO_3) to enough distilled water to yield a final volume of 100 ml of solution. The sodium sulfite crystals do not need to be reagent grade; laboratory grade will work fine. Prepare the solution 24 hours in advance of doing the calibration to ensure that all oxygen has been depleted[2]. If solid sodium sulfite is not available, you may substitute either 2.0 M sodium hydrogen sulfite solution, (20.8 g of $NaHSO_3$ per 100 ml of solution) or 2.0 M potassium nitrite (17.0 g of KNO_2 per 100 ml of solution).

10. Taking measurements using the Dissolved Oxygen sensor

Once the Dissolved oxygen sensor has polarized and calibrated your are ready to take readings. Place the tip of the probe into the water being tested. Gentle stir the probe in the water sample (swirling motion) and allow the dissolved oxygen reading to stabilize. *Important:* It is important to keep stirring the probe in the water sample. There must always be water flowing past the probe tip when you are taking the measurements. As the sensor measures the concentration of dissolved oxygen, it removes oxygen from water at the junction of the sensor membrane. If the sensor is left still in calm water, reported DO readings will appear to be dropping.

Sampling in streams and lakes

It is best to sample away from shore and below the water surface, if possible. In free-flowing streams, there will usually be good mixing of the water, so that sample taken near the current will be quite representative of the stream as a whole.

If you are sampling an impounded stream or a lake, there will be very little mixing, it is important to sample at different places and different depths.

We do not recommend submerging the entire electrode in the water; the electrode is not constructed to withstand higher pressures, so seepage into electronic components might result. As an alternative we recommend that you devise an extended sampling device that allows to reach out into a stream from shore, downward from bridge. Many ecology books suggest various designs of such sampling devices from inexpensive materials. The important characteristic of a sampling device is that it allows for collection of a water sample without affecting the dissolved-oxygen level by creating turbulence during sampling. Finally, perform a measurement as soon after collecting the sample as possible. If immediate measuring is not possible, take samples using bottles that are easily filled brim full, so that no air space is left above the sample; reagent bottles with ground-glass stoppers work well for this task.

A bubble of 1 air contains of circa 0.25 mg O_2. When this amount is dissolved in 100-ml water then the dissolved oxygen changes with 2.5 mg/l. This is en error of about 25%.

The Dissolved oxygen sensor has built-in temperature compensation so you can do your calibration in the lab. If you decide to do your calibration on site, be sure to bring a thermometer or temperature sensor (Table 1). You will also need to know an approximate value for the barometric pressure (Table 2).

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[2] Adding one or two crystals of solid cobalt chloride solid ($CoCl_2$) to 100 ml of the sodium sulfite solution will catalyze the initial removal of oxygen.

Sampling in controlled laboratory experiment
During the controlled experiments in the lab the Dissolved Oxygen Sensor requires a constant flow of liquid past the membrane, magnetic stirrer is often used. However, the stirring action, with its resulting turbulence, can result in more oxygen being dissolved from the atmosphere.
To avoid this the sensor, small stirring bar and test solution can be situated in the Calibration bottle. If the bottle is filled brim full with the test solution, it is nearly impossible for atmospheric oxygen to interfere with the experiment.

Long-term monitoring of an aquarium
During the monitoring of dissolved oxygen in aquarium a primary consideration must again be establishing constant flow of water past the membrane. An inexpensive aquarium pomp can serve this purpose.
During this experiment you can see dissolved oxygen fluctuations taking place in the aquarium due to photosynthesis or respiration. Sample data shows photosynthesis-respiration cycles measured by the Dissolved oxygen sensor on the aquarium using Elodea and tropical fish.

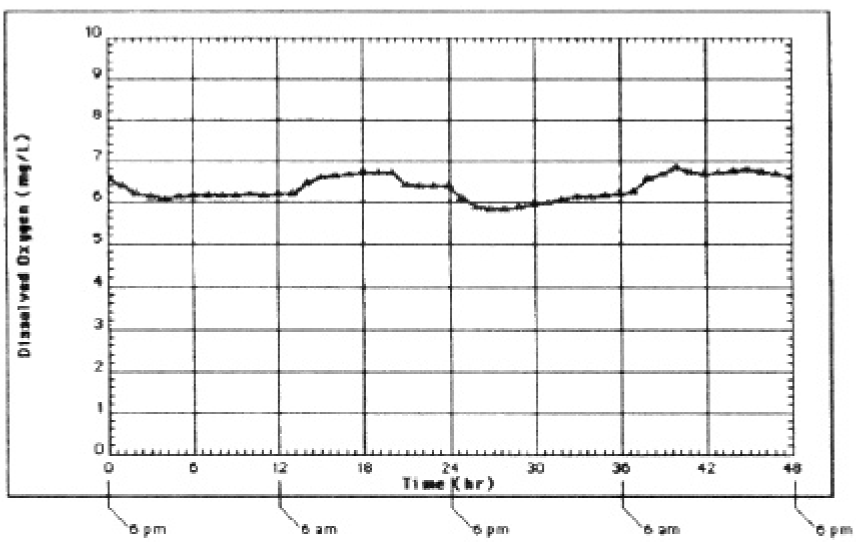


Figure 3. Dissolved oxygen in an aquarium.

Biological oxygen demand (B.O.D.)

When organic matter in lakes and streams decomposes, it is oxidized by aerobic bacteria. *Biological oxygen demand* is a measure of a quantity of oxygen used by these microorganisms in the aerobic oxidation of organic matter. In streams and lakes with high levels of organic matter, the depletion of oxygen by this process can result in the dissolved oxygen concentration dropping below the level needed to sustain many plant and animal species. Biological oxygen demand is a standard test of water quality.

The test is performed as follows:

- Obtain two sampling bottles (75-100 ml), preferable with a ground-glass stoppers. One of the bottles should be paint black, or wrapped with black electrical tape.
- Fill the two bottles with sample water. Be sure the black bottle is filled brim full. Insert the stopper in the bottle making sure no air is trapped inside. Store the sample in black bottle in the dark and incubate at 20º C for a period of 5 days[3]. If no incubator is available, store the bottle in a light free cabinet at room temperature.
- As soon as possible after collection[4], use your Dissolved oxygen sensor to measure the dissolved oxygen concentration, in mg/l, for the other sample (the clear bottle). Use the general method described earlier in this booklet. This is the original value $DO_{original}$.
- After 5 days, measure the dissolved oxygen concentration, in mg/l, of the water sample in the black bottle.
- The biological oxygen demand level is calculated by subtracting the dissolved oxygen reading for the black bottle sample from the original reading of the clear bottle sample:

$$\text{B.O.D. (in mg/l)} = DO_{original} - DO_{incubation}$$

- The B.O.D value relates the amount of dissolved oxygen consumed by the oxidation of organic matter during the five-day period - larger values indicate higher levels of organic waste present in the water sample.

[3] If your water sample contains large amounts of organic waste, the oxygen demand may be so large that all of the oxygen is consumed before the end of the 5-day period. If this occurs, the sample should be re-saturated with oxygen using a magnetic stirrer, and a incubation continued. The true B.O.D. level would be the sum of the B.O.D measurement for both incubation periods.

[4] The dissolved oxygen measurement of the sample in the clear bottle should be performed on site. If possible. This is because biological or chemical processes can begin to consume the oxygen as soon as it is collected. If you need to bring sample back to the lab to measure its dissolved oxygen level, be sure it is stoppered brim fully.

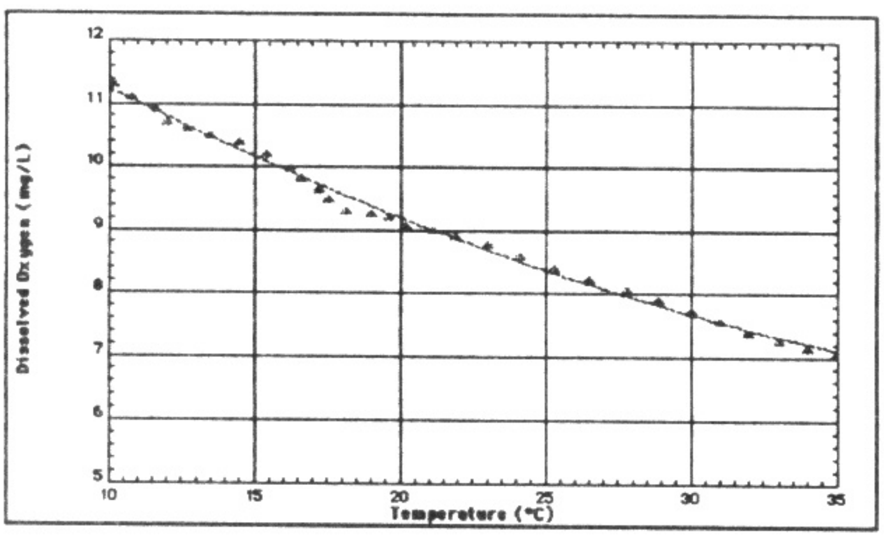
11. Automatic temperature compensation

The Dissolved Oxygen sensor is automatically temperature compensated, using a thermistor built into the sensor. The temperature output of this sensor is used to automatically compensate for changes in permeability of the membrane with changing temperature. If the sensor was not temperature compensated, you would notice a change in the dissolved oxygen reading as temperature changed, even if the actual concentration of dissolved oxygen in the solution did not change.

Here are two examples of how automatic temperature compensation works:

- If you calibrate the Dissolved Oxygen Sensor in the lab at 25°C and 760 mm Hg barometric pressure (assume salinity is negligible), the value you entered for the saturated oxygen calibration point would be 8.36 mg/l (see Table 1). If you were to take a reading in distilled water that is saturated with oxygen by rapid stirring, you would get a reading of 8.36 mg/l.
  If the water sample is then cooled to 10°C with no additional stirring, the water would no longer be saturated (cold water can hold more dissolved oxygen than warm water). Therefore, the reading of the temperature-compensated Dissolved Oxygen Sensor would still be 8.36 mg/l.
- If, however, the solution was cooled to 10°C *and* continually stirred so it remained saturated by dissolving additional oxygen, the temperature-compensated sensor would give a reading of 11.35 mg/l—the value shown in Table 1.

  Note: Temperature compensation *does not mean* that the reading for a saturated solution will be the same at two different temperatures—the two solutions have different concentrations of dissolved oxygen, and the sensor reading should reflect this difference.



12. Using the Dissolved oxygen sensor with other sensors

The Dissolved Oxygen Sensor interacts with some other sensors, *if* they are placed in the same solution (in the same aquarium or beaker, for example), *and* they are connected to the same interface. This situation arises because the Dissolved Oxygen Sensor outputs a signal in the solution, and this signal can affect the reading of another sensor. The following sensors *cannot* be connected to the same interface as a Dissolved Oxygen Sensor and placed in the same solution:

- Conductivity Sensor (art. nr. 0382bt)
- pH System (art. nr. 031bt).

13. 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.

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.

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:

$$CO_2 + H_2O \quad C_2H_2O_2 + O_2$$

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:

$$C_xH_yO_z + O_2 \quad CO_2 + H_2O$$

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 Sensor 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.

14. Calibrating and Monitoring Using Units of Percent Saturation

Instead of calibrating using units of mg/l (equal to parts per million or ppm), you may also choose to calibrate dissolved oxygen using units of % saturation. When doing a calibration for units of % saturation, the calibration point done in the sodium sulfite solution (zero oxygen) is assigned a value of 0%, and that for water-saturated air (or air-saturated water) is given a value of 100%. It must be noted, however, that 100% represents an oxygen-saturated solution only at that particular temperature, pressure, and salinity level. If you intend to compare your measured dissolved oxygen values with data collected under a different set of conditions, a preferable method would be to use units of mg/l (described earlier in this manual).

If you have calibrated your Dissolved Oxygen Sensor in units of mg/l, you can easily calculate percent saturation using the formula:

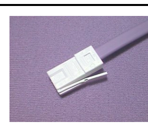
% saturation = (actual DO reading/Saturated DO reading from Table 1)x100

For example, if your Dissolved Oxygen Sensor gives a D.O. reading of 6.1 mg/l at a temperature of 20°C and a pressure of 740 mm Hg, look up the saturated dissolved oxygen reading in Table 1 (8.93 mg/l). The value for % saturation is:

% saturation = (6.1 / 8.93) x 100 = 68%

The name of the position sensor in the sensor library of Coach 5 program is **Dissolved oxygen sensor (0376bt) (CMA) (0..100%)** or **Dissolved oxygen sensor (0376bt) (CMA) (0..14mg/l).**

Technical data

Output voltage	0.3 to 2.8 V
Measurement range	0 to 14 mg/l
Resolution using 10 bit 5V A/D converter Resolution using 12 bit 5V A/D converter	0.007 mg/l 0.028 mg/l
Accuracy	± 0,2 mg/l
Response time	95% of final readings in 30 s. 98% of final readings in 45 s.
Temperature compensation	Automatic from 5 - 35 °C
Pressure compensation	Manual, accounted for during calibration
Salinity compensation	Manual, accounted for during calibration
Minimum sample flow	20 cm/second
Connections	 BT (British Telecom) plug

NOTE: This product is to be used for educational purposes only. It is not appropriate for industrial, medical, research, or commercial applications.

CENTRE FOR MICROCOMPUTER APPLICATIONS
Kruislaan 404, 1098 SM Amsterdam, The Netherlands
Fax: +31 20 5255866, e-mail: cma@science.uva.nl, http://www.cma.science.uva.nl/english