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Technical Note

Verification Methods for Troubleshooting Sea-Bird Dissolved Oxygen Sensors

(July 2018)

Introduction

Sea-Bird Scientific offers two precision dissolved oxygen sensors—the SBE 43 and the SBE 63. The SBE 43 is a membrane-type oxygen sensor designed primarily for profiling applications, while the SBE 63 is an optical dissolved oxygen sensor ideal for moored deployments. Although the two sensors vary in application and underlying measurement technology, users can leverage similar tests to determine the condition of each sensor.

Description of Sensor Technology

SBE 43

The SBE 43 utilizes a polarographic membrane to measure oxygen in marine and freshwater environments. Within the SBE 43's flow path, a Teflon membrane separates the environment from an internal electrode bathed in electrolyte. By counting the number of oxygen molecules that diffuse across the membrane to the internal electrode, the SBE 43 is able to measure dissolved oxygen with a response time appropriate for fast-moving profiling applications.

Three primary issues affect the accuracy of this measurement technology:

- Fouling on the membrane affects the rate of exchange of oxygen molecules, resulting in a measured oxygen concentration that is low of correct.
- Damage to the membrane results in an unpredictable, often unreasonable response.
- The electrolyte is depleted over time, resulting in a gradual loss in sensitivity.

SBE 63

The SBE 63 is an optical dissolved oxygen sensor that utilizes precision optics to determine dissolved oxygen concentration in seawater and freshwater. While slower to respond than the SBE 43, the optical measurement method allows for a longer deployment lifespan, making the SBE 63 ideal for moored deployments.

Most sources of error result from changes to the optical window:

- Fouling on the optical window affects the 63's response to oxygen.
- Photobleaching of the optical window's film causes drift over time.
- Scratches on the optical window can cause a permanent reduction in accuracy.

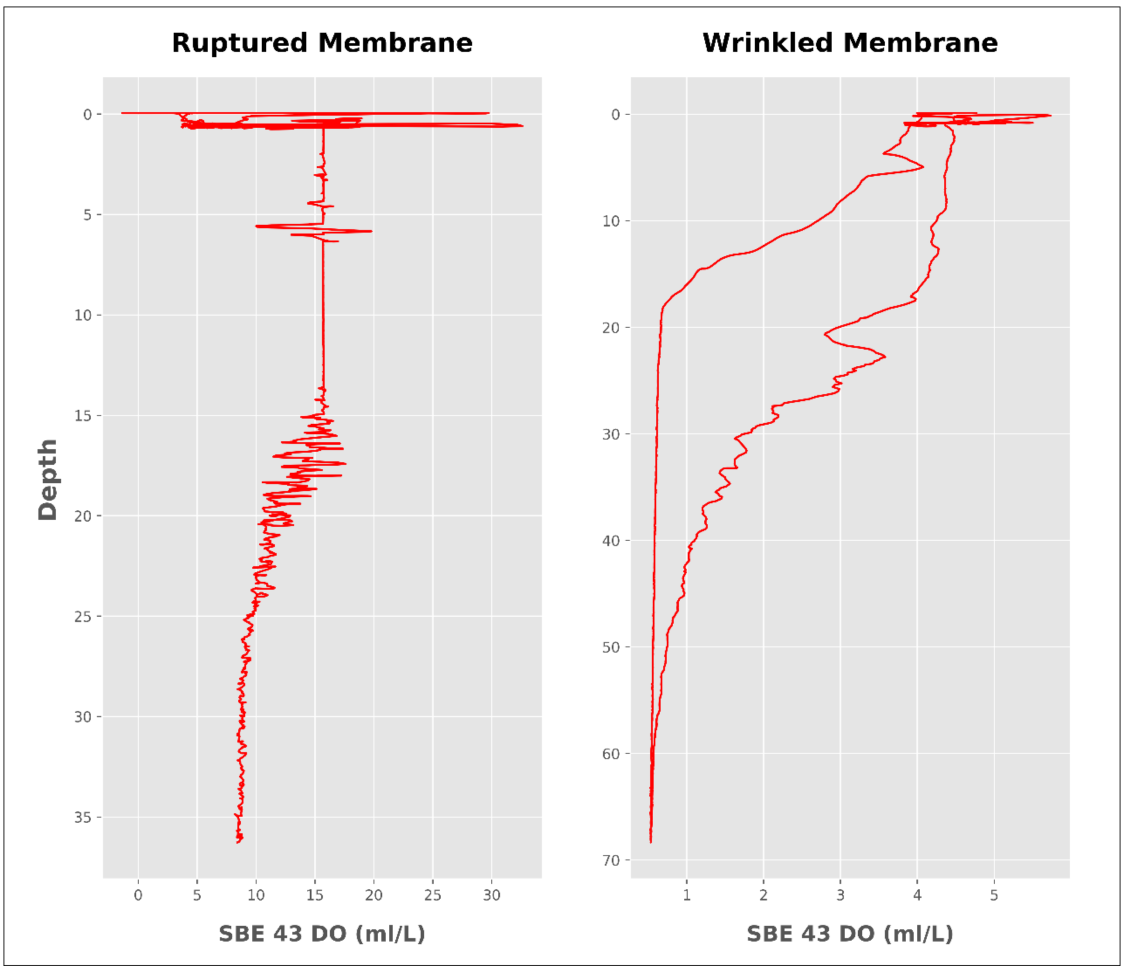
The following tests are useful troubleshooting tools. Done properly, they can help determine if a sensor requires field maintenance, factory repairs, or recalibration. They are listed below in order of increasing precision.

Basic In-Air Test: Checking for Severe Damage

Sensors with severe damage will usually output unreasonable data, where the sensor's raw output and corresponding DO concentrations will shift rapidly. Plotting the sensor's output while in-air can identify these problems right away. Severe issues are often more evident with the SBE 43, as damage to the membrane will result in highly erratic data.

Note: the SBE 43 and SBE 63 were designed to measure dissolved oxygen in water. In-air measurements, while useful for identifying the general condition of the sensor

1. Connect the 43 or 63 to a CTD, such as a 19plusV2, and begin measuring data in-air.
2. Upload and process the data (in SBE Data Processing, SeaSave, or other data processing software). Plot the following parameters:
    a. Y-Axis: Time
    b. X-Axis 1: Oxygen concentration
    c. X-Axis 2: Raw Oxygen (Voltage from the SBE 43, or SBE 63 phase delay in µsec)
3. View the resulting data. In-air data from the SBE 43 and SBE 63 should be a relatively straight line since DO concentrations are not changing significantly. If the sensor is is damaged, then the raw voltage and oxygen concentration will often be erratic and unreasonable.



In-Air Test Continued:

For sensors that do not exhibit erratic data in-air, users can identify if the sensor is properly registering changes in oxygen and reporting the expected raw data. This is especially valuable when an oxygen sensor is reporting static values during the profile.

During calibration, Sea-Bird will measure the output of the sensor in-air, at room temperature. This value is reported on the calibration certificate as the value at 20 °C with the highest bath DO concentration. At the correct temperature, a % change in SBE 43 voltage output or SBE 63 µsec output should correlate with a % change in measured DO concentration.

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SENSOR SERIAL NUMBER: 1337
CALIBRATION DATE: 13-May-17

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.3340
Voffset = -0.7246
Tau20 = 1.28

A = -4.9984e-003
B = 2.6597e-004
C = -3.6953e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.08	2.00	0.00	1.059	1.07	-0.01
1.09	6.00	0.00	1.103	1.08	-0.01
1.10	12.00	0.00	1.173	1.10	-0.00
1.11	20.00	0.00	1.263	1.12	0.00
1.14	26.00	0.00	1.339	1.15	0.01
1.14	30.00	0.00	1.388	1.16	0.02
3.88	6.00	0.00	2.087	3.88	-0.00
3.89	2.00	0.00	1.938	3.89	-0.00
3.93	12.00	0.00	2.333	3.94	0.00
3.94	26.00	0.00	2.839	3.95	0.01
3.97	20.00	0.00	2.638	3.97	0.00
3.98	30.00	0.00	3.001	3.98	0.00
6.68	2.00	0.00	2.811	6.68	0.00
6.77	30.00	0.00	4.591	6.76	-0.01
6.83	6.00	0.00	3.125	6.84	0.00
6.87	26.00	0.00	4.401	6.87	-0.00
6.89	12.00	0.00	3.540	6.89	-0.00
6.96	20.00	0.00	4.073	6.95	-0.00

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SENSOR SERIAL NUMBER:
CALIBRATION DATE:

SBE 63 OXYGEN CALIBRATION DATA

COEFFICIENTS:
A0 = 1.0513e+000 B0 = -2.3159e-001 C0 = 1.0171e-001 E = 1.1000e-002
A1 = -1.5000e-003 B1 = 1.6169e+000 C1 = 4.3129e-003
A2 = 3.9427e-001 C2 = 5.8452e-005

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (µsec)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
0.755	30.00	0.00	30.57	0.766	0.011
0.776	26.00	0.00	31.30	0.786	0.010
0.829	20.00	0.00	32.33	0.835	0.006
0.915	12.00	0.00	33.74	0.916	0.000
1.020	6.00	0.00	34.72	1.012	-0.008
1.146	2.00	0.00	35.18	1.135	-0.011
2.225	30.00	0.00	22.64	2.226	0.001
2.351	26.00	0.00	23.20	2.359	0.008
2.505	20.00	0.00	24.32	2.510	0.006
3.007	12.00	0.00	25.25	3.012	0.005
3.420	6.00	0.00	26.20	3.426	0.005
3.689	30.00	0.00	18.73	3.678	-0.011
3.775	2.00	0.00	26.84	3.778	0.003
3.922	26.00	0.00	19.18	3.923	0.000
4.340	20.00	0.00	19.94	4.333	-0.007
5.080	12.00	0.00	20.99	5.077	-0.004
5.184	30.00	0.00	16.26	5.177	-0.008
5.672	26.00	0.00	16.46	5.685	0.013
5.817	6.00	0.00	21.83	5.814	-0.003
6.232	20.00	0.00	17.20	6.231	-0.001
6.440	2.00	0.00	22.40	6.441	0.001
7.279	12.00	0.00	18.17	7.276	-0.003
8.367	6.00	0.00	18.91	8.369	0.002
8.820	2.00	0.00	19.83	8.820	0.000

1. Connect the sensor to a CTD.

2. Remove any tubing from the sensor, exposing the inlet and outlet.

3. Begin outputting raw voltages of each sensor in SeaSave or SeaTerm. For the 19plusV2 or 16plusV2, send "**TV**" for the SBE 43 and "**T63**" for the SBE 63.

4. Blow air into the sensor. Do so lightly from afar. **Do not apply pressure to the 43 inlet and do not use compressed air, which can have impurities that may coat the sensor.**

5. Watch the raw output. This output should be roughly similar to the 20 °C voltage on the calibration sheet for the highest bath DO concentration; check the calibration certificate for the specific sensor you are using.

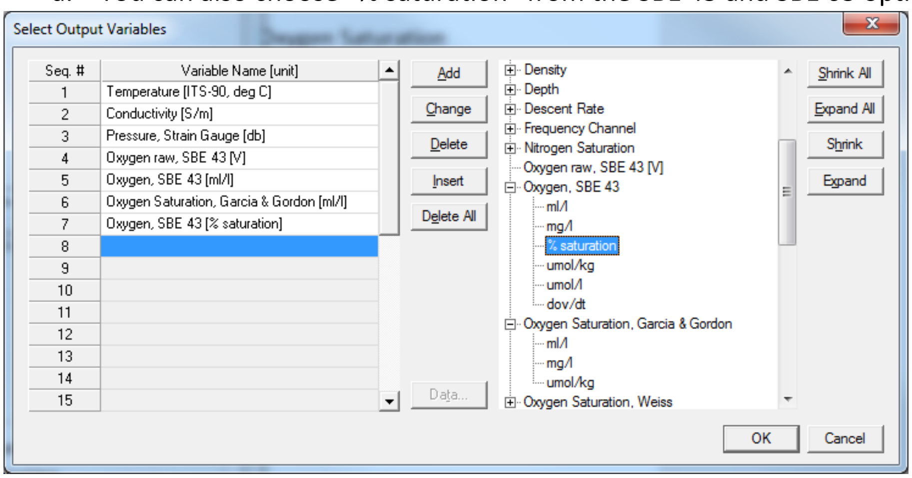
6. As new air enters the sensing volume, check if the voltage is increasing slightly (ie, check if the sensor is responding to changes in oxygen).

Measuring Percent Saturation: Comparing Sensor Output Without a Reference

Sea-Bird CTDs are able to calculate the theoretical saturation limit of a parcel of water based on in-situ temperature and salinity. This value represents the amount of oxygen that a given parcel of water can hold. For example, a parcel of water at 20 °C and 32 psu will be 100% saturated at 5.26 ml/L.

A shallow, well-mixed test bath should be very close to 100% saturated, so the calculated oxygen saturation value should be very close to the true DO concentration. This provides an estimated "reference" value to which you can compare your SBE 43/63's output.

1. Establish a shallow well-mixed test bath that can house the CTD and sensors. Allow the bath to sit overnight to equilibrate with the atmosphere- try to get as close to 100% saturation as possible.
2. Place the CTD and SBE 43 sensor in the test bath, ensuring that all of the sensors are submerged and water is pumping through the conductivity cell and DO sensor. Allow all bubbles to purge
3. Record data for a few minutes.
4. Wait until the data is stable (ie, bubbles are purged and the thermal mass of the CTD/sensors is no longer affecting the bath).
5. Upload the data file and process the data via SBE Data Processing. Select Oxygen Saturation in ml/l (Garcia & Gordon is preferred) and the oxygen concentration from the sensor in ml/l.
    a. You can also choose "% saturation" from the SBE 43 and SBE 63 options



6. Compare Oxygen Saturation to the sensor's Oxygen concentration. If your test bath is well-mixed and has properly equilibrated to the atmosphere, check that your SBE 43's output is within 5-10% of the saturation value.

The SBE 43 and 63 accuracy spec is ±2% of saturation. A well-mixed bath should be around 95% saturated or higher; if the sensor is still within calibration, the output should be around 90-95% of saturation.

Fouling of the membrane or optical window generally causes the sensor to report oxygen that is low of correct. If the sensor's output is below 90%, clean the DO sensor and re-run the test.

Comparison to accurate Winkler DO samples (a.k.a. SOC correction)

Comparing the output from the SBE 43 or SBE 63 to accurate Winkler dissolved oxygen samples is the most accurate method of validating the sensor's performance in the field. This test is ideally for sensors that have drifted a small amount but are otherwise performing well. If done correctly, coordinating the sensor's output to a physical water sample allows the user to field-calibrate the sensor. The basic steps are below, but users must have the ability to perform accurate Winkler titrations.

1. Establish a shallow well-mixed test bath that can house the CTD and sensors. If this test is following the comparison to 100% saturation comparison test, you can use the same bath. Allow the bath to sit overnight to equilibrate with the atmosphere for best stability. If possible, let the CTD and sensor soak in the test bath.
2. Begin recording data with the CTD and oxygen sensor.
3. When the data is stable (ie, bubbles are purged and the thermal mass of the CTD/sensors has equilibrated to the bath temperature), collect and analyze a water sample.
4. Compare the data from the sensor to the Winkler-derived oxygen concentration.
5. If the sensor output is significantly different from the Winkler sample, clean the sensor and recollect data and a water sample.
6. If the sensor/sample data are still offset after cleaning, conduct an SOC correction if desired.

For the SBE 43, refer to Application Note 64-2 for SOC correction instructions.

For the SBE 63, the user must manually calculate the SOC correction factor, and apply the ratio to the SBE 63 data.

1. Calculate a correction factor: (water sample DO)/(sensor DO).
2. Multiply that correction factor by each sample from the SBE 63.

Example:

- Water Sample = 5.40 ml/L
- Sensor = 5.31 ml/L

The correction factor = 5.40/5.31 = 1.017

Time	Sensor DO (mL/L)	Corrected Sensor DO (mL/L)
1/29/2014 11:15	5.31	5.40
1/29/2014 11:30	5.35	5.44
1/29/2014 11:145	5.54	5.63

Keep in mind that correcting the sensor's output with a Winkler sample is not a perfect substitute for factory recalibration and repair. Coordinating the sensor's output to the water sample is difficult without a highly stable test bath. Furthermore, a sensor may be out of calibration due to deterioration of components or depleted electrolyte, which must be addressed at Sea-Bird. However, regular SOC corrections can help extend the lifespan of the sensor's accuracy if done properly.