Using a SBE4 in a Laboratory Precision Salinometer

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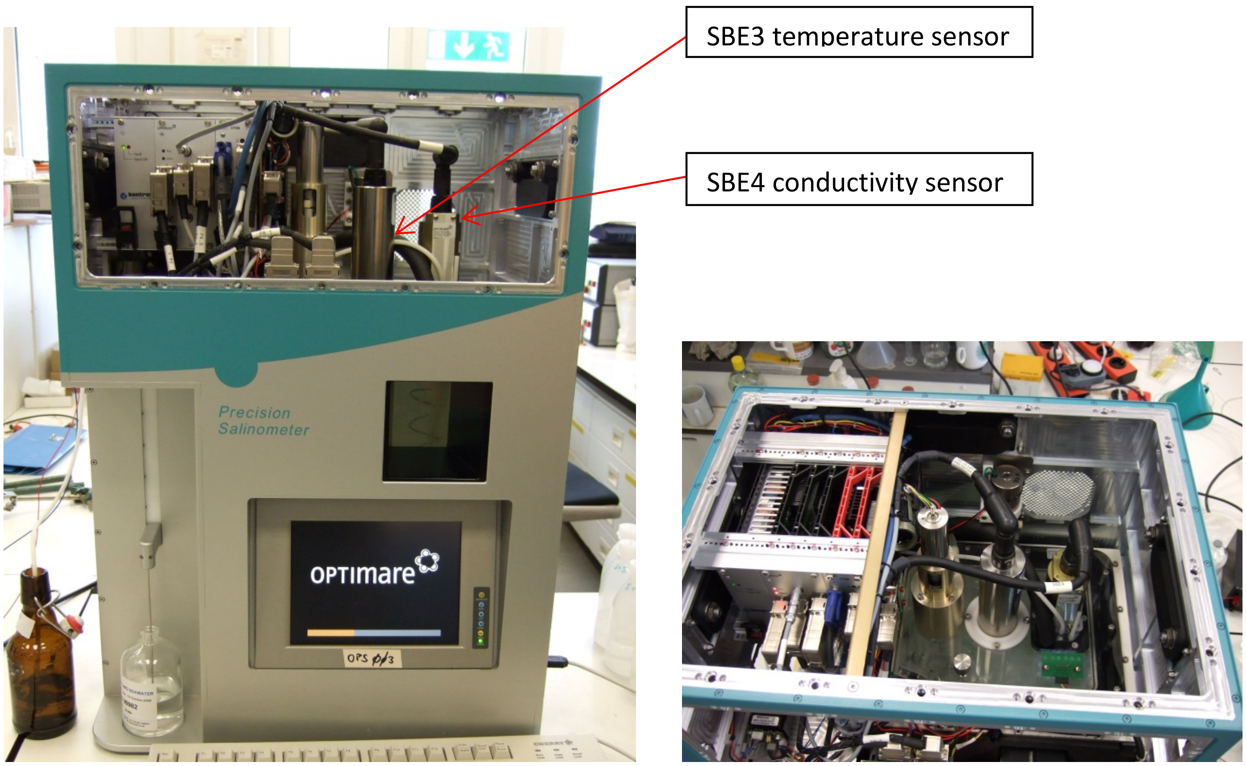
The Optimare Precision Salinometer (OPS) is a modern laboratory salinometer for reference measurements of sea water samples' conductivity. It is designed to be used without accuracy compromises during ship's expeditions, where environmental conditions are mostly not well controlled. During its development, a suitable conductivity cell had to be chosen. Sea-Bird's SBE4 was selected for the reasons outlined below.



In a laboratory salinometer, the sensor's environment is very different from that in the ocean. In the ocean, pressure effects and rough handling are adverse to precision measurements. Temperatures are not constant and mostly far from room temperature. Potentially affected are the sensor's electronics, the time alignment of several sensors, and the sensor's dimensions. In a laboratory salinometer, pressure effects are unimportant and temperature control of the conductivity cell is the most critical single problem. It is common to use a water bath as a stable thermal environment for the conductivity cell. With appropriate measures it is possible today to restrict temperature fluctuations in a water bath of about 10 liters to values below 1 mK. Short term drift can be excellently controlled.

It was important to us that the conductivity sensor should allow for a through flow operation to avoid dead volumes where deposits can accumulate and which are difficult to rinse properly. The SBE4 has the particular advantages that the measurement bridge is incorporated in the sensor ensemble and that its frequency output can be evaluated to a very high precision. (The precision increases with longer time spans of individual measurements.) Furthermore, the sensor has a proven history of stability, operating for many weeks without the need for recalibration during oceanographic research cruises. In contrast to cruises or ocean moorings, biofouling is not an issue during salinometer measurement sessions. A peculiarity of the SBE4 is its nonlinear response to conductivity changes, owing to the use of a Wien Bridge. It is shown below, that the calibration curve of the sensor/bridge combination can be determined with excellent accuracy, so that this response characteristic is not adverse to best precision. A further advantage is the fact that the use of this sensor avoids the need to introduce switches and resistors into the electrical circuit – the entire oceanic salinity range can be covered with outstanding precision by a single measurement range.

Best possible calibration is, of course, crucial for a reference instrument. The calibration of the conductivity cell should therefore be performed while the cell is mounted in the salinometer, i.e. in exactly the same environment of later sea water sample evaluations. This is easily possible, as Standard Seawater (SSW), which represents the IAPSO approved 'primary standard' in oceanography, can be introduced into the conductivity cell in the same way as sea water samples. The SSW Linearity Set, as available from OSIL, contains salt water with salinities around 10, 30, 35, and 38 and. It is evident that the variation of salt concentration is the method of choice for the calibration of a reference instrument. By this method, the calibration is as close as possible to the oceanographic 'primary standard'.

A typical example for a calibration result is listed below:

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Temp. (degC, IPT90), Cond. (mS/cm), Frequency (Hz), Drift (mikroK/s),
hh:mm:ss

Remarks: SSW 10L13 S=9.989
21.0487, 15.6962, 4440.247,  -0.9, 09:53:27,
21.0487, 15.6962, 4440.242,  -0.8, 09:54:30,
21.0486, 15.6961, 4440.243,  -1.4, 09:55:33,
21.0486, 15.6962, 4440.245,  -1.6, 09:56:36,
21.0487, 15.6962, 4440.245,   0.7, 09:57:40,
21.0486, 15.6961, 4440.240,  -1.1, 09:58:43,

Remarks: SSW 30L15 S=29.969
21.0486, 42.7197, 6511.669,  -0.1, 10:13:36,
21.0486, 42.7197, 6511.670,  -1.0, 10:14:39,
21.0485, 42.7196, 6511.668,  -2.4, 10:15:42,
21.0485, 42.7196, 6511.663,  -0.1, 10:16:45,
21.0485, 42.7195, 6511.662,  -0.5, 10:17:48,
21.0485, 42.7195, 6511.662,  -1.3, 10:18:51,
21.0485, 42.7195, 6511.660,  -3.2, 10:19:54,

Remarks: SSW P157 S=34.994
21.0485, 49.0686, 6907.913,  -0.7, 10:35:12,
21.0485, 49.0686, 6907.918,  -0.2, 10:36:15,
21.0485, 49.0686, 6907.914,  -2.4, 10:37:17,
21.0485, 49.0686, 6907.915,  -0.3, 10:38:19,
21.0485, 49.0686, 6907.913,   1.3, 10:39:21,
21.0485, 49.0686, 6907.911,  -0.8, 10:40:24,
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Remarks: SSW 38H11 S=38.024
21.0484, 52.8277, 7132.014,  -0.2, 10:56:44,
21.0484, 52.8277, 7132.015,  -1.0, 10:57:47,
21.0484, 52.8279, 7132.024,  -1.4, 10:58:50,
21.0484, 52.8277, 7132.016,  -2.4, 10:59:53,
21.0485, 52.8277, 7132.014,  -0.1, 11:00:56,
21.0484, 52.8277, 7132.020,  -0.0, 11:01:59,
21.0484, 52.8278, 7132.017,   0.6, 11:03:02,
21.0485, 52.8279, 7132.019,   0.9, 11:04:05,
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After adding the zero conductivity frequency of the sensor (2.547510 kHz) to the set, a cubic fit determines the calibration parameters. A typical result for the conductivity C as a function of frequency f is

g = -7.699315 e+00

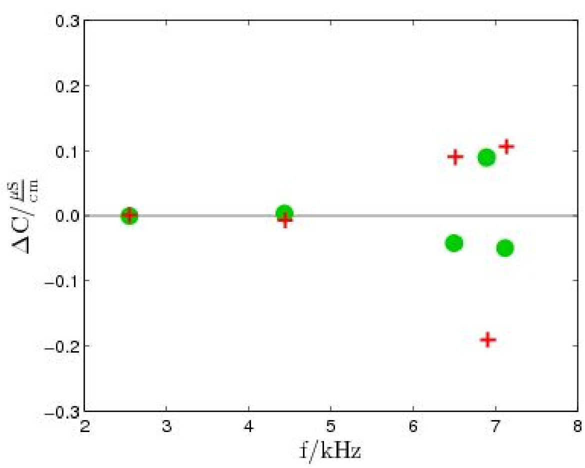
l = 2.628047 e-02

h= 1.171435 e+00

i = 1.812982 e-03

where $C = g + l*f + h*f^2 + i*f^3$

The square term dominates the result as is to be expected for the characteristic of a Wien Bridge. The residual error is of the order of 0.0002 mS/cm. The figure below shows the results of two independent calibrations, performed on 29.4.2015 and 3.5.2015.



Difference between calibration measurements and a cubic fit ('residual error') for two independent calibrations. Green dots for results of 29.4.2015, red crosses for those of 3.4.2015.

With the described calibration procedure and a modern thermal management of a water bath, the SBE4 conductivity sensor provides excellent performance for best accuracy laboratory reference measurements.