Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

**Relazione Interna OGS 2024/67**

# Test Report

## SBE 4 CTMO Conductivity Transfer Standard

### Serial number 6227

**Property of:**

**Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – OGS Trieste**

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## Units Under Test: SBE 4 conductivity sensors s/n 6227

*Conductivity testing Level[1]: 1*

*Test Equipment*

| Instrument | Model | Serial n. |
|---|---|---|
| Seawater Calibration Bath[a] | Fluke Hart Scientific 7052 | C2A012 |
| Deep Ocean Standards Thermometer[b] | SBE 35 | 0084 |
| Multi-Channel Counter | SBE 31 | 3179135-0168 |
| Submersible Pump | SBE 5P | 05-11062 |
| Laboratory Salinometer[c] | Guildline Autosal 8400B | 65744 |

[a] Calibration bath filled with 50 L of natural seawater, filtered (filter size/type: 0.45 μm/Millipore) and UV sterilized seawater;

[b] Deep Ocean Standards Thermometer last calibrated on 30 August 2023 sub-range 11 (0.01°C - 29.7646 °C) of the International Temperature Scale of 1990 (ITS-90) using a Fluke 5901A-Q Triple Point of Water cell and a Fluke 5943 Gallium Melting Point cell;

[c] When in use, the Laboratory Salinometer is standardized every 24 hours, using IAPSO Standard Seawater (Batch: P167).

*Uncertainty:*
*Expanded Measurement Uncertainty (95% level of confidence; k = 2) for conductivity: 0.00033 S/m (Gerin and Savonitto, 2024).*

[1] Testing Level 1: testing performed using recognized standards and/or transfer standards.
Testing Level 2: testing performed using internal laboratory transfer standards and/or reference instrumentation traceable to standards/transfer standards employed under Testing Level 1

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# Sensor Calibration Sheet – 1 (a)

Test date: 05 September 2024 **SBE 4 conductivity sensor s/n 6227**

Ambient conditions:
Temperature: 24°C ± 1 °C
Relative Humidity: 51 % ± 10%
Atmospheric pressure: 980.5 hPa

**"As received" conductivity calibration coefficients[2]:**

g = -1.00736605e+01
h = 1.65890031e+00
i = -1.36088992e-03
j = 1.92261776e-04

CPcor = -9.57e-08
CTcor = 3.25e-06

f = Inst Freq [kHz]
t = ITS-90 Temperature [°C]; p = pressure [decibars] = 0; $\delta$ = CTcor; $\varepsilon$ = CPcor
Conductivity = $(g + hf^2 + if^3 + jf^4) / [10(1 + \delta t + \varepsilon p)]$ [S/m]

| Inst Temp (°C) | Reference (S/m) | Inst Freq[3] (Hz) | Predicted (S/m) | Predicted-Reference[§] (S/m) |
|---|---|---|---|---|
| 24.5910 | 0.00000 | 2465.86 | -0.00001 | -0.00001 |
| 1.9831 | 3.26194 | 5075.96 | 3.26180 | -0.00014 |
| 5.1568 | 3.56198 | 5251.27 | 3.56205 | 0.00007 |
| 10.2422 | 4.06197 | 5530.80 | 4.06201 | 0.00004 |
| 15.1890 | 4.56857 | 5800.17 | 4.56849 | -0.00008 |
| 20.0693 | 5.08599 | 6062.89 | 5.08584 | -0.00016 |
| 24.9546 | 5.61816 | 6321.84 | 5.61840 | 0.00025 |
| 26.9168 | 5.83520 | 6424.37 | 5.83548 | 0.00028 |

[§]Accuracy declared by the Manufacturer = ±0.0003 S/m.

where:

**Inst Temp** = the temperature (°C, ITS-90) of the seawater filling the bath as read by the instrument's temperature sensor at the reference set-point conductivity;
**Reference** = the set-point conductivity (S/m) of the bath seawater, measured using the laboratory salinometer;
**Inst Freq** = the instrument output frequency (Hz) at the reference set-point conductivity;
**Predicted** = the bath set-point conductivity (S/m), as computed by the instrument using the new calibration coefficients;
**Predicted-Reference** = the conductivity residual (S/m), i.e. the difference between the "Predicted" and "Reference" set-point conductivities.

[2] Rel. 2024/5, CTMO test report, 01/2024.
[3] Zero conductivity frequency = 2465.85 (±1) Hz; Sea-Bird Scientific, Calibration sheet, 02 May 2023

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# Sensor Calibration Sheet – 1 (b)

Test date: 05 September 2024 **SBE 4 conductivity sensor s/n 6227**

Ambient conditions:
Temperature: 24°C ± 1 °C
Relative Humidity: 51 % ± 10%
Atmospheric pressure: 980.5 hPa

**New conductivity calibration coefficients:**

g = -1.00569479e+01
h = 1.65208431e+00
i = 7.09556299e-04
j = 2.37463502e-05

CPcor = -9.57e-08
CTcor = 3.25e-06

f = Inst Freq [kHz]
t = ITS-90 Temperature [°C]; p = pressure [decibars] = 0; $\delta$ = CTcor; $\varepsilon$ = CPcor
Conductivity = $(g + hf^2 + if^3 + jf^4) / [10(1 + \delta t + \varepsilon p)]$ [S/m]

| Inst Temp (°C) | Reference (S/m) | Inst Freq (Hz) | Predicted (S/m) | Predicted-Reference§ (S/m) |
|---|---|---|---|---|
| 24.5910 | 0.00000 | 2465.86 | 0.00000 | 0.00000 |
| 1.9831 | 3.26194 | 5075.96 | 3.26180 | -0.00014 |
| 5.1568 | 3.56198 | 5251.27 | 3.56209 | 0.00011 |
| 10.2422 | 4.06197 | 5530.80 | 4.06209 | 0.00012 |
| 15.1890 | 4.56857 | 5800.17 | 4.56855 | -0.00001 |
| 20.0693 | 5.08599 | 6062.89 | 5.08583 | -0.00017 |
| 24.9546 | 5.61816 | 6321.84 | 5.61823 | 0.00007 |
| 26.9168 | 5.83520 | 6424.37 | 5.83522 | 0.00001 |

§Accuracy declared by the Manufacturer = ±0.0003 S/m.

where:

**Inst Temp** = the temperature (°C, ITS-90) of the seawater filling the bath as read by the instrument's temperature sensor at the reference set-point conductivity;
**Reference** = the set-point conductivity (S/m) of the bath seawater, measured using the laboratory salinometer;
**Inst Freq** = the instrument output frequency (Hz) at the reference set-point conductivity;
**Predicted** = the bath set-point conductivity (S/m), as computed by the instrument using the new calibration coefficients;
**Predicted-Reference** = the conductivity residual (S/m), i.e. the difference between the "Predicted" and "Reference" set-point conductivities.

## Conclusions

The conductivity sensor was re-calibrated about 9 months after the previous calibration and adjustment. Although all the residuals were within the accuracy declared by the manufacturer, the computations performed at the higher temperatures exhibited residual values very close to the instrument accuracy; therefore, the coefficients were recomputed.

## References

Gerin R. and Savonitto G. (2024). Uncertainty estimate associated with the measurement of ITS-90 temperature and conductivity at the Oceanographic Calibration and Metrology Center (CTMO) of OGS Rel. OGS 2024, Trieste, Italy, 7 pp.