ISTITUTO NAZIONALE
DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE – OGS
DIPARTIMENTO OGA - CTO

Post-recovery evaluation & calibration of PROVOR Profiling Float CT sensors

Tested unit:
MARTEC PROVOR CTS2, serial no. MT002,
ARGOS ID: (hex) 64DA535; (dec) 50771
mounting the
SEA-BIRD SBE 41CP CTD
serial no. 0770

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Approved for release by:

Dr. A. Crise
Director, OGA

REL. OGS 2008/58 – OGA 21 CTO, Borgo Grotta Gigante (TS), 15.04.2008

The Test & Calibration of the Recovered Float

1. Summary

We recovered the Martec PROVOR CTS2 profiling float bearing the serial number MT004 after 1 year of operation, and tested its temperature and conductivity sensors to identify eventual changes in their performances since deployment. The results demonstrated salinity errors on the order of –0.010 to –0.013, caused by a misbehaving conductivity sensor. Subsequently, the conductivity sensor was cleaned thoroughly and then recalibrated.
The Martec PROVOR CTS2 system of the type that was retrieved is an autonomous oceanographic float that uses the SBE 41CP CTD (Sea-Bird Electronics, Inc.) for measuring temperature and salinity while functioning in the profiling mode. The float data are transmitted to the user using the ARGOS satellite system.

2. Preparing the instrument

In this section, the sequence of operations that we used in the laboratory to ready the SBE 41CP CTD of the PROVOR float prior to any testing and/or calibration is outlined. Firstly, the CTD sensor package was separated from the main body of the float (fig. 1). Then, in order to be able to submerge the sensors safely in the thermostatic testing bath, the CTD's incorporated anti-foulant fittings and devices were removed (fig. 2).

Fig. 1

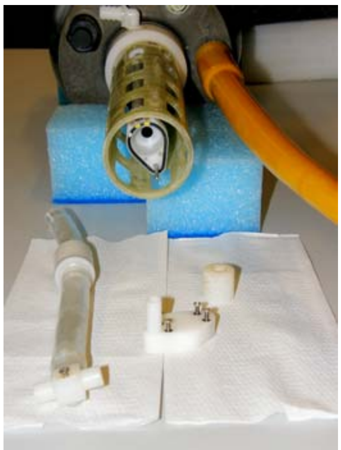

Fig. 2

In the bath, the CTD was immersed with the sensors pointing downwards in such a way that its electronics were well above the waterline and isolated from any spray or accidental physical contact. As much as we would have liked to, it was not possible to operate the CTD with the sensors oriented upwards - its normal operating configuration - due to the particular geometry of our testing bath which, for obvious reasons, we could not change. However, we did take steps to ensure optimal sample flushing in the laboratory setup. The CTD was fitted with a dummy anti-foulant device made of teflon at its inlet so as to recreate as much as possible the original hydraulics of the T-C assembly (fig. 3).

Furthermore, the exhaust port of the CTD assembly was rotated through 90° to facilitate the elimination of potential bubbles in the sample stream (fig. 4).

Fig. 3

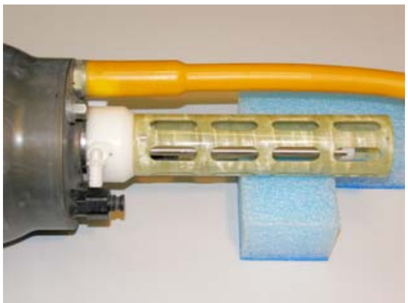

Fig. 4

In order to speak with the CTD and acquire data employing a PC, a specifically constructed interface was used. The interface, connected with a Flat Cable to the connector JP1 on the CTD mother board, can be seen in fig. 5 with its 12 VDC power supply terminals and a cable with a DB9 connector that serves to hook it up to the RS232 serial port of a PC.
The scheme of the interface realized by us to adapt the RTX signals of the SBE unit to the RS232 standard is shown in fig. 6. The PC utilized a common terminal emulation programme, with the following parameters: 9600, N, 8, 1.

Fig. 5

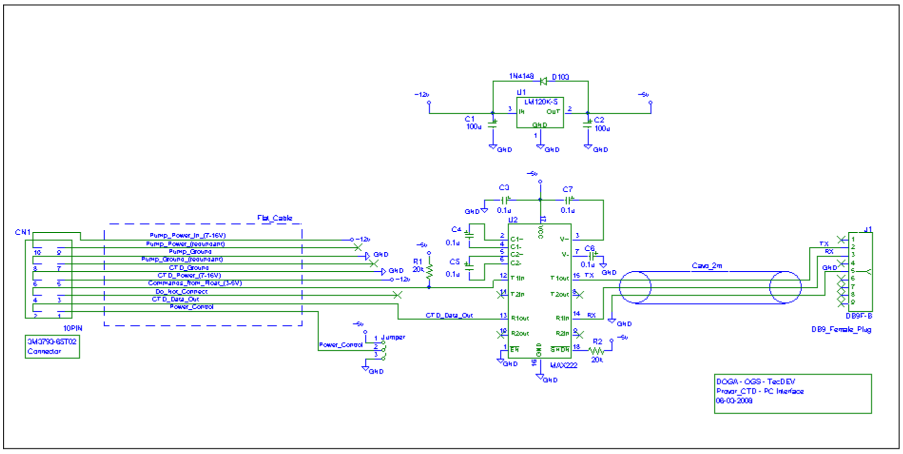

Fig. 6

Before placing the CTD in the testing bath, its exhaust port was fitted with a short tube and syringe arrangement (fig. 7). This arrangement served to aid in priming the pump and eliminating trapped air bubbles once the unit entered the water (fig. 8). Water was aspirated past the sensors a few times by actioning the syringe manually, and the arrangement was disconnected after the CTD pump had begun to function normally.

Fig. 7

Fig. 8

The main elements of the laboratory testing and calibration setup that was used is shown in fig. 9. The Hart 7052 thermostatic bath containing the PROVOR CTD and the OGS laboratory C-T Monitor (Sea-Bird Electronics, Inc.) can be clearly seen. The Hart 1590 Super-thermometer that is used with the Standard Platinum Resistance Thermometer (SPRT) for high-quality temperature readings is also visible on one side.
The 200 ml sampling bottles used for collecting water samples for salinity analyses can be seen in the foreground in fig. 10 whereas the Guildline 8400B Laboratory Salinometer employed for measuring salinity is shown in fig. 11.

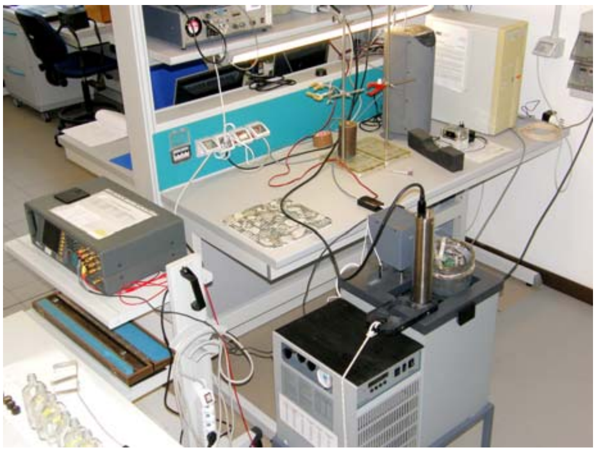

Fig. 9

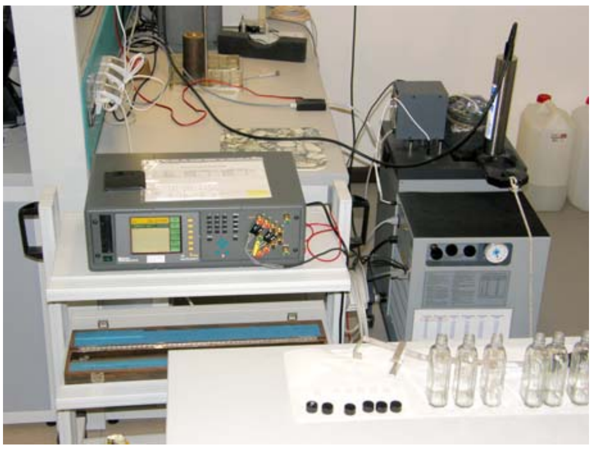

Fig. 10

Fig. 11

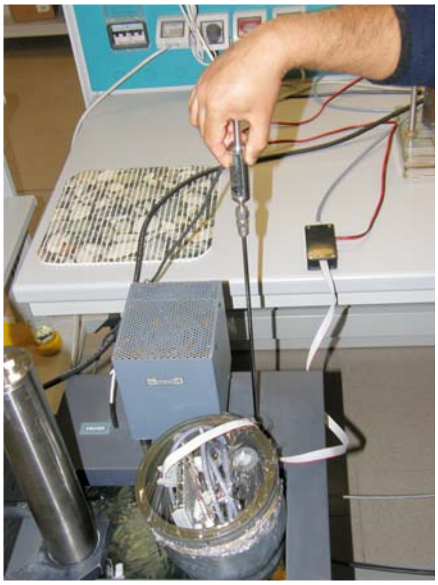

Fig. 12

In fig. 12, the insertion of the “working” SPRT in the Hart bath for accurately monitoring its set-point temperature is shown.

Post–Recovery Test

Post–Recovery Test Report

Unit Under Test: SBE 41CP, s/n 00770 — Testing Level: 1*

Date: 11 March 2008

Notes: *Before the test, the CTD was subjected to a standard superficial cleaning procedure. The cleaning operation was restricted to the external surfaces of the Unit and involved preliminary rinsing with tap water followed by repeated rinsing with fresh, de-ionized water.*

Test equipment

Instrument	Model	Serial no.
Seawater Calibration Bath	Hart 7052	A1A003
Laboratory Salinometer[1]	Guildline Autosal 8400B	65744
Precision Digital Thermometer	Hart – 1590	A1A164
Metal-sheath SPRT[2]	Rosemount 162CE	1844

[1] Laboratory Salinometer standardized on 11 March 2008 using IAPSO Standard Seawater (Batch: P147);
[2] Reference SPRT last calibrated on 04 July 2007 at the following two ITS-90 fixed points: the Triple Point of Water (273.16 K/0.010 °C) and the Melting Point of Gallium (302.9146 K/29.7646 °C).

Expanded Measurement Uncertainty (k = 2) for Temperature: 0.0024 °C (ITS-90).
Expanded Measurement Uncertainty (k = 2) for Conductivity: 0.00040 Siemens/m.

Notes: *Calibration bath filled with natural, filtered seawater (filter size/type: 0.22 μm/Millipore).*

* 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.

Results of Post-Recovery Temperature Test

Test date: 11 March 2008 **SBE 41CP, s/n 0770**

Ambient conditions:
Temperature: 21.0 °C ± 1 °C
Relative Humidity: 45% ± 10%
Atmospheric pressure: 970.1 hPa

"As received" Temperature calibration coefficients (SBE, 29.04.2004)**:**

a0 = -2.07863600e-04
a1 = 3.06803300e-04
a2 = -4.34936300e-06
a3 = 2.02158000e-07

$$T\ (°C) = 1/\ \{[a0 + a1\ [ln\ (n)] + a2\ [ln^{2}\ (n)] + a3\ [ln^{3}\ (n)]\} - 273.15$$

Reference (°C)	Inst Temp (°C)	Inst Temp - Reference♦ (°C)
1.9559	1.9561	0.0002
5.1428	5.1421	-0.0007
10.2454	10.2452	-0.0002
15.2193	15.2187	-0.0006
20.1228	20.1224	-0.0004
26.0166	26.0153	-0.0013

♦Accuracy declared by the Manufacturer = ±0.002 °C

where:

Reference = the bath set-point temperatures (in °C; ITS-90), measured using the reference Standard Platinum Resistance Thermometer;
Inst Temp = the bath set-point temperatures (in °C; ITS-90), measured by the instrument;
Inst Temp-Reference = the temperature residuals (in °C; ITS-90), i.e. the difference between "Inst Temp" and "Reference".

Results of Post-Recovery Conductivity Test

Test date: 11 March 2008 **SBE 41CP, s/n 0770**

Ambient conditions:
Temperature: 21.0 °C ± 1 °C
Relative Humidity: 45% ± 10%
Atmospheric pressure: 970.1 hPa

"As received" conductivity calibration coefficients (SBE, 29.04.2004)**:**

g = -1.04559900e+00 CPcor = -9.570001e-008
h = 1.47938700e-01 CTcor = 3.250000e-006
i = -1.34254000e-04 WBOTC = 3.101494e-006
j = 3.06343200e-05

Conductivity (Siemens/m) = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$

Note: f = Inst Freq * sqrt (1.0 + WBOTC * t) / 1000.0
t = Temperature (°C); p = Pressure (dBar); δ = CTcor; ε = CPcor.

Temp (°C)	Bath Sal (PSU)	Reference (S/m)	Inst Cond (S/m)	Inst Cond-Reference (S/m)	Inst Sal (PSU)	Inst Sal-Bath Sal§ (PSU)
1.9559	38.1118	3.31920	3.31823	-0.00097	38.0993	-0.0125
5.1428	38.1139	3.62591	3.62478	-0.00113	38.1014	-0.0125
10.2454	38.1122	4.13583	4.13474	-0.00109	38.1012	-0.0110
15.2193	38.1149	4.65408	4.65252	-0.00156	38.1012	-0.0137
20.1228	38.1083	5.18183	5.18060	-0.00123	38.0984	-0.0099
26.0166	38.1034	5.83698	5.83544	-0.00154	38.0931	-0.0103

§Accuracy declared by the Manufacturer = ±0.005 PSU

where:

Bath Sal = Bath salinities as measured by the Guildline 8400B Salinometer;
Reference = the reference set-point conductivities (in Siemens/m), obtained from inverted salinity measurements (on the Practical Salinity Scale) of the seawater occupying the thermostatic bath;
Inst Cond = the instrument conductivity readings in Siemens/m, at the reference set-point conductivities;
Inst Cond-Reference = the conductivity residuals (in Siemens/m), i.e. the difference between "Inst Cond" and "Reference";
Inst Sal = the instrument salinity readings;
Inst Sal-Bath Sal = the salinity residuals, i.e. the difference between "Inst Sal" and "Bath Sal".

Syntesis of Post-Recovery Test results

SBE 41 CP s/n 0770

The results demonstrate that the float does not exhibit any significant drift in temperature, but it does show a drift in salinity (~ –0.010), probably caused by normal conductivity sensor drift and the effects of bio-fouling.

Calibration

Conductivity Sensor Cleaning

Unit Under Test: SBE 41CP, s/n 00770

Before its calibration, the Conductivity sensor was treated following the Manufacturer's recommendations for this operation following a long period of instrument use (fig. 13 e 14).

Performed operations:

Rinse with de-ionized water. [x]

Scour with dilute bleach solution,
drain & flush with de-ionized water. [x]

Scour with dilute Triton X-100 solution,
drain & flush with de-ionized water. [x]

Fig. 13

Notes: *The cleaning procedure that was utilized is described in Sea-Bird Electronics, Inc. Application Note no. 2D entitled "Instructions for Care and Cleaning of Conductivity Cells" (last revision: October 2006).*

Fig. 14

Post Cleaning Report

SBE 41 CP s/n 0770

During the cleaning operation, the o-ring and the outermost thrust-washer fixing the impeller of the pump to its shaft came free. The o-ring, extracted from the exhaust port, was found to be completely chapped and worn from prolonged use. It is probable that, during cleaning, the two elements had occasion to move within the conductivity cell.
The o-ring and the washer were immediately replaced, and the pump repaired. As we will see, the pre-calibration test with the "As Received" instrument settings shows errors that have increased considerably with respect to those that were found during the Post-Recovery Conductivity Test despite the thorough cleaning operation that was performed. This is contrary to what one would expect, and we attribute this fact to possible modification of the sensor characteristics during cleaning. This was another valid motive for carrying out a full calibration of the conductivity sensor.

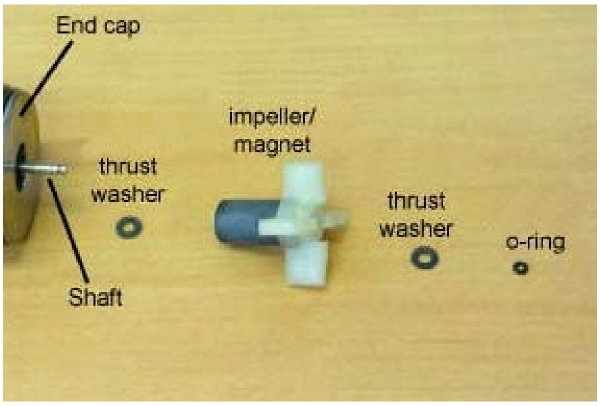

Fig. 15

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Calibration Test Report

Unit Under Test: SBE 41CP, s/n 00770 Testing Level: 1*

Date: 31 March 2008

Test equipment

Instrument	Model	Serial no.
Seawater Calibration Bath	Hart 7052	A1A003
Laboratory Salinometer[1]	Guildline Autosal 8400B	65744
Precision Digital Thermometer	Hart – 1590	A1A164
Metal-sheath SPRT[2]	Rosemount 162CE	1844

[1] Laboratory Salinometer standardized on 31 March 2008 using IAPSO Standard Seawater (Batch: P147);
[2] Reference SPRT last calibrated on 04 July 2007 at the following two ITS-90 fixed points: the Triple Point of Water (273.16 K/0.010 °C) and the Melting Point of Gallium (302.9146 K/29.7646 °C).

Expanded Measurement Uncertainty (k = 2) for Temperature: 0.0024 °C (ITS-90).
Expanded Measurement Uncertainty (k = 2) for Conductivity: 0.00040 Siemens/m.

Notes: *Calibration bath filled with natural, filtered seawater (filter size/type: 0.22 μm/Millipore).*

* 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.

Conductivity calibration sheet - 1

Test date: 31 March 2008 **SBE 41CP, s/n 0770**

Ambient conditions:
Temperature: 21.0 °C ± 1 °C
Relative Humidity: 35% ± 10%
Atmospheric pressure: 983.5 hPa

Measured zero conductivity frequency = 2659.76 Hz

Old[4] conductivity calibration coefficients:

g = -1.04559900e+00
h = 1.47938700e-01
i = -1.34254000e-04
j = 3.06343200e-05

CPcor = -9.570001e-008
CTcor = 3.250000e-006
WBOTC = 3.101494e-006

Conductivity (Siemens/m) = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$

Note: f = Inst Freq * sqrt (1.0 + WBOTC * t) / 1000.0
t = Temperature (°C); p = Pressure (dBar); δ = CTcor; ε = CPcor.

Temperature (°C)	Reference (S/m)	Inst Freq (Hz)	Predicted (S/m)	Predicted-Reference§ (S/m)
23.4369	0	2659.76	0.00005	0.00005
2.4929	3.35806	5450.99	3.35546	-0.00260
5.1437	3.61578	5607.51	3.61285	-0.00293
10.2466	4.12438	5904.15	4.12102	-0.00336
15.2199	4.64073	6190.43	4.63680	-0.00393
20.1240	5.16735	6469.06	5.16281	-0.00454
26.0179	5.81959	6798.08	5.81454	-0.00505

§Accuracy declared by the Manufacturer = ±0.0005 Siemens/m.

where:

Reference = the reference set-point conductivities (in Siemens/m), obtained from inverted salinity measurements (on the Practical Salinity Scale) of the seawater occupying the thermostatic bath;

Inst Freq = the instrument output frequencies in Hz at the reference set-point conductivities;

Predicted = the bath set-point conductivities (in Siemens/m), as computed by the instrument using the old calibration coefficients;

Predicted-Reference = the conductivity residuals (in Siemens/m), i.e. the difference between "Predicted" and "Reference".

[4] "As received" sensor calibration settings.

Conductivity calibration sheet - 2

Test date: 31 March 2008 **SBE 41CP, s/n 0770**

Ambient conditions:
Temperature: 21.0 °C ± 1 °C
Relative Humidity: 35% ± 10%
Atmospheric pressure: 983.5 hPa

New conductivity calibration coefficients:

g = -1.04502696e+00
h = 1.47579690e-01
i = -9.97504834e-06
j = 2.22302993e-05

CPcor = -9.570001e-008
CTcor = 3.250000e-006
WBOTC = 3.101494e-006

Conductivity (Siemens/m) = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$

Note: f = Inst Freq * sqrt (1.0 + WBOTC * t) / 1000.0
t = Temperature (°C); p = Pressure (dBar); δ = CTcor; ε = CPcor.

Temperature (°C)	Reference (S/m)	Inst Freq (Hz)	Predicted (S/m)	Predicted-Reference§ (S/m)
23.4369	0	2659.76	0	0
2.4929	3.35806	5450.99	3.35807	0.00001
5.1437	3.61578	5607.51	3.61573	-0.00005
10.2466	4.12438	5904.15	4.12444	0.00006
15.2199	4.64073	6190.43	4.64076	0.00003
20.1240	5.16735	6469.06	5.16728	-0.00007
26.0179	5.81959	6798.08	5.81961	0.00002

§Accuracy declared by the Manufacturer = ±0.0005 Siemens/m.

where:

Reference = the reference set-point conductivities (in Siemens/m), obtained from inverted salinity measurements (on the Practical Salinity Scale) of the seawater occupying the thermostatic bath;

Inst Freq = the instrument output frequencies in Hz at the reference set-point conductivities;

Predicted = the bath set-point conductivities (in Siemens/m), as computed by the instrument using the new calibration coefficients;

Predicted-Reference = the conductivity residuals (in Siemens/m), i.e. the difference between "Predicted" and "Reference".

Summary of actions taken during Calibration

SBE 41 CP s/n 0770

1. **The Conductivity sensor was cleaned rigorously following the "As Received" Instrument Check. The condition of the CTD pump had deteriorated due to prolonged use and was repaired.**

2. **After the maintenance of the Conductivity sensor and the CTD pump, the performance of the Conductivity sensor was tested with the "As Received" calibration settings over the full testing range, and found to be unacceptable.**

3. **New calibration coefficients have been computed, reported and introduced via the instrument software for the tested Conductivity sensor.**

4. **The Conductivity sensor was newly tested applying the new calibration settings to verify its proper functioning.**

Measurements performed by: Nevio Medeot, Rajesh Nair

Approved by:
N. Medeot, CTO Group