SBE 41CP CERTIFICATES

CTD Serial Number 41CP-3020

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SBE 41CP Instrument Configuration

Model Number: SBE 41CP

Serial Number: 41CP-3020

Part Number: 90521.015

Description : APEX SBE 41CP-IDO Integrated Oxygen Configuration

Firmware Version: 2.0b

Pressure Type: Kistler

Pressure Range: 2000 Dbar

Pressure Serial Number: 2077379

Oxygen Sensor Type: SBE 43i

Oxygen Serial Number: 0533

Document Date: Tuesday , March 02, 2010

```
SBE 41CP-IDO-UW V 2.0b  SERIAL NO. 3020
temperature:  24-feb-10
    TA0 =  9.695200e-06
    TA1 =  2.877893e-04
    TA2 = -3.487123e-06
    TA3 =  1.804824e-07
conductivity:  24-feb-10
    G = -9.963608e-01
    H =  1.427131e-01
    I = -4.227502e-04
    J =  5.059873e-05
    CPCOR = -9.570001e-08
    CTCOR =  3.250000e-06
    WBOTC =  0.000000e+00
pressure S/N = 2077379, range = 2900 psia:  15-feb-10
    PA0 = -6.193596e-02
    PA1 =  1.360910e-01
    PA2 =  1.481198e-08
    PTCA0 = -1.448906e+02
    PTCA1 = -4.887073e-01
    PTCA2 =  2.264361e-02
    PTCB0 =  1.024204e+02
    PTCB1 = -5.052626e-03
    PTCB2 =  0.000000e+00
    PTHA0 = -9.582295e+01
    PTHA1 =  4.136588e-02
    PTHA2 =  7.155740e-07
    POFFSET =  0.000000e+00
oxygen S/N = 0533:  12-feb-10
    SOC =  1.239800e-04
    FOFFSET = -3.227640e+03
    A = -2.653400e-03
    B =  1.613600e-04
    C = -2.950200e-06
    E =  4.520000e-02
    TAU_20 =  6.080000e+00
```

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SENSOR SERIAL NUMBER: 3020
CALIBRATION DATE: 24-Feb-10

SBE 41cp TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

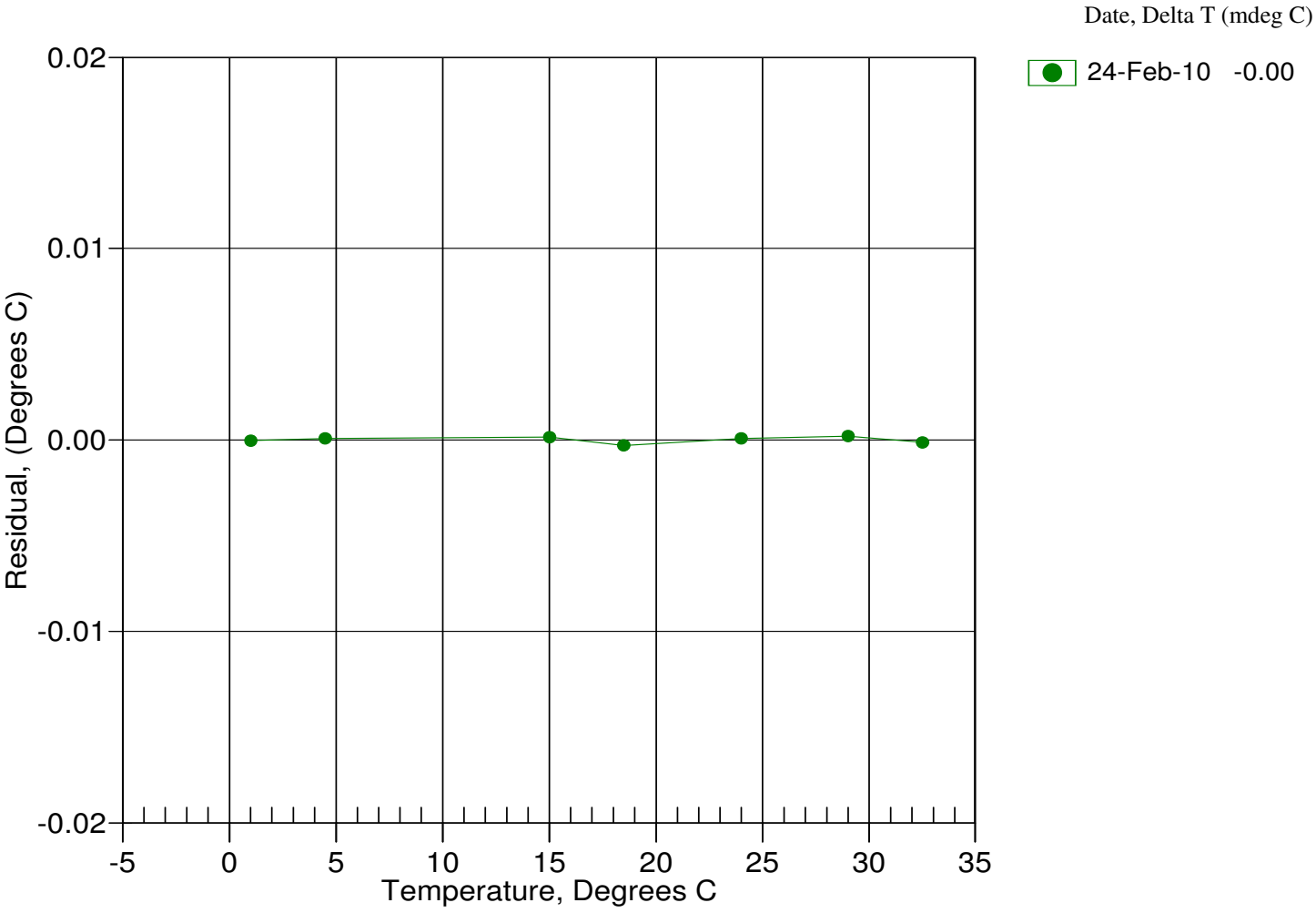
ITS-90 COEFFICIENTS

a0 = 9.695200e-006
a1 = 2.877893e-004
a2 = -3.487123e-006
a3 = 1.804824e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	602503.1	1.0000	-0.0000
4.5000	514239.7	4.5001	0.0001
15.0000	326076.0	15.0001	0.0001
18.5000	281896.5	18.4997	-0.0003
23.9940	225638.8	23.9941	0.0001
29.0000	185348.2	29.0002	0.0002
32.5000	162076.8	32.4999	-0.0001

Temperature ITS-90 = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 3020
CALIBRATION DATE: 24-Feb-10

SBE 41cp CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.963608e-001
h =  1.427131e-001
i = -4.227502e-004
j =  5.059873e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
WBOTC =  0.0000e+000
```

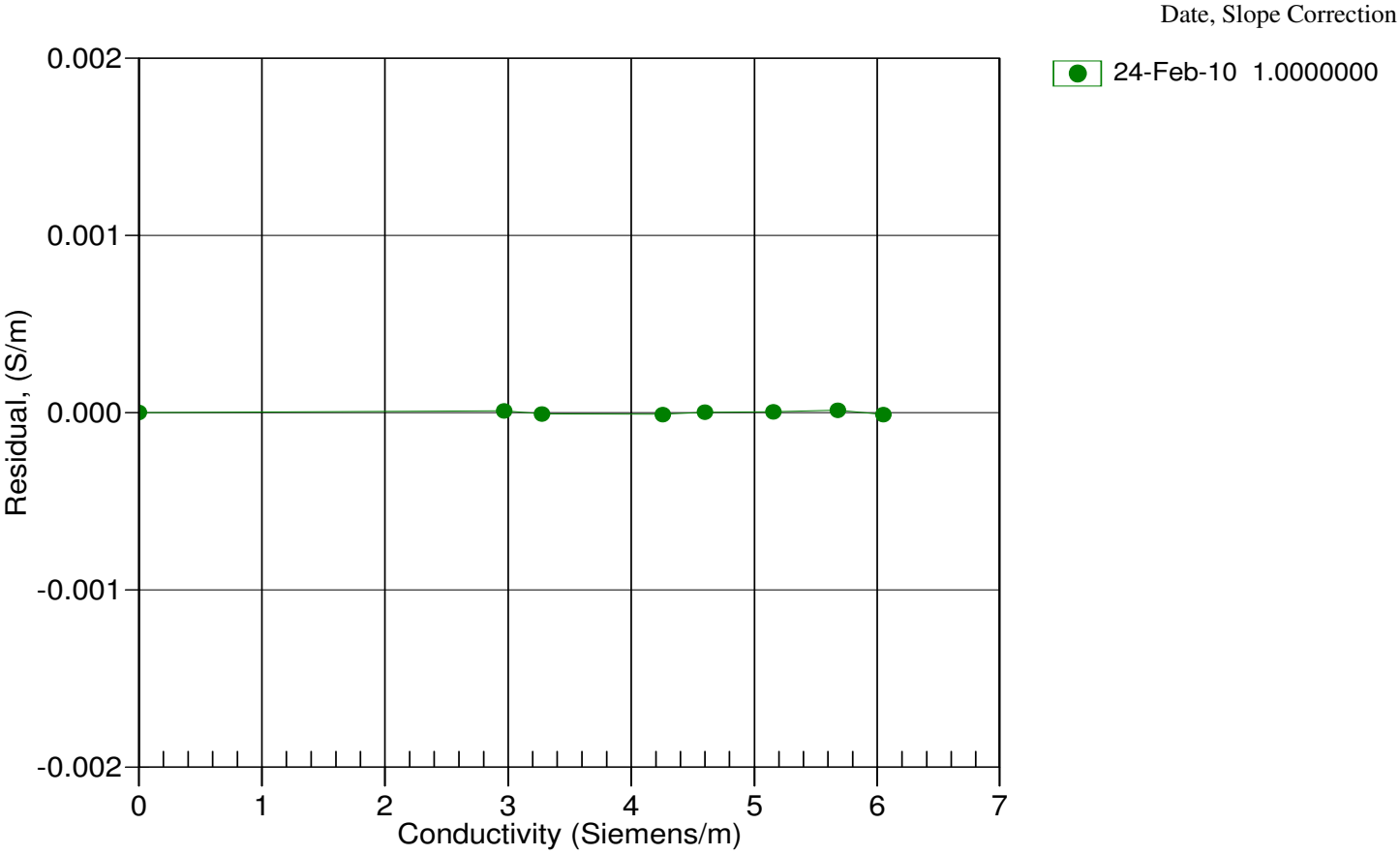
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2649.37	0.00000	0.00000
1.0000	34.7298	2.96927	5286.62	2.96928	0.00001
4.5000	34.7101	3.27569	5486.60	3.27568	-0.00001
15.0000	34.6676	4.25530	6081.23	4.25529	-0.00001
18.5000	34.6588	4.59972	6276.65	4.59973	0.00000
23.9940	34.6498	5.15597	6579.66	5.15597	0.00000
29.0000	34.6452	5.67744	6851.21	5.67745	0.00001
32.5000	34.6434	6.04924	7038.19	6.04923	-0.00001

f = INST FREQ * sqrt(1.0 + WBOTC * t) / 1000.0

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

t = temperature[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 3020
CALIBRATION DATE: 15-Feb-10

SBE 41cp PRESSURE CALIBRATION DATA
2900 psia S/N 2077379

COEFFICIENTS:

PA0 =	-6.193596e-002	PTCA0 =	-1.448906e+002
PA1 =	1.360910e-001	PTCA1 =	-4.887073e-001
PA2 =	1.481198e-008	PTCA2 =	2.264361e-002
PTHA0 =	-9.582295e+001	PTCB0 =	1.024204e+002
PTHA1 =	4.136588e-002	PTCB1 =	-5.052626e-003
PTHA2 =	7.155740e-007	PTCB2 =	0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FSR
14.65	-37.5	2689.6	14.63	-0.00
591.72	4198.2	2692.0	591.93	0.01
1168.82	8427.9	2693.4	1168.96	0.00
1745.89	12654.1	2694.5	1746.04	0.01
2322.93	16875.6	2695.5	2323.01	0.00
2899.70	21091.4	2696.3	2899.73	0.00
2322.94	16874.1	2696.2	2322.80	-0.00
1746.16	12654.2	2696.0	1746.05	-0.00
1168.86	8425.9	2695.6	1168.68	-0.01
591.69	4195.2	2695.7	591.52	-0.01
14.65	-37.2	2697.7	14.65	0.00

THERMAL CORRECTION

TEMP ITS90	PRESS TEMP	INST OUTPUT
32.50	2951.50	-25.44
29.00	2874.50	-28.63
23.99	2764.50	-32.21
18.50	2643.10	-34.81
15.00	2564.50	-35.68
4.50	2332.30	-35.23
1.00	2252.20	-33.97

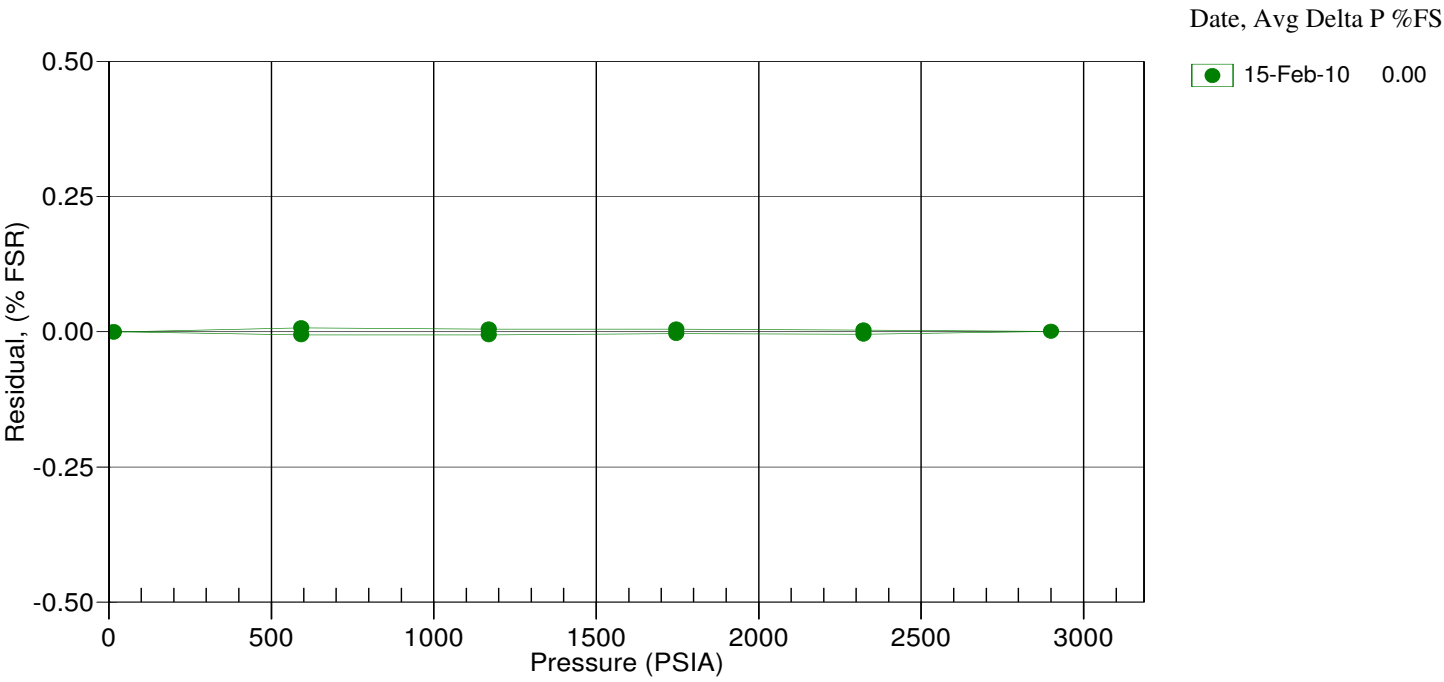
TEMP(ITS90)	SPAN(mV)
-5.71	102.45
33.81	102.25

y = thermistor output; $t = PTHA0 + PTHA1 * y + PTHA2 * y^2$

x = pressure output - $PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

pressure (psia) = $PA0 + PA1 * n + PA2 * n^2$



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SENSOR SERIAL NUMBER: 0533
CALIBRATION DATE: 12-Feb-10p

SBE 43I OXYGEN CALIBRATION DATA

COEFFICIENTS

```
Soc = 1.2398e-04 (adj)
Foffset = -3227.64
Tau20 = 6.08

A = -2.6534e-003
B =  1.6136e-004
C = -2.9502e-006
E measured = 0.0452
```

NOMINAL DYNAMIC COEFFICIENTS

```
D1 =  1.92634e-4   H1 = -3.30000e-2
D2 = -4.64803e-2   H2 =  5.00000e+3
                   H3 =  1.45000e+3
```

Note: Soc adjustment from single-point measurement 2/24/10

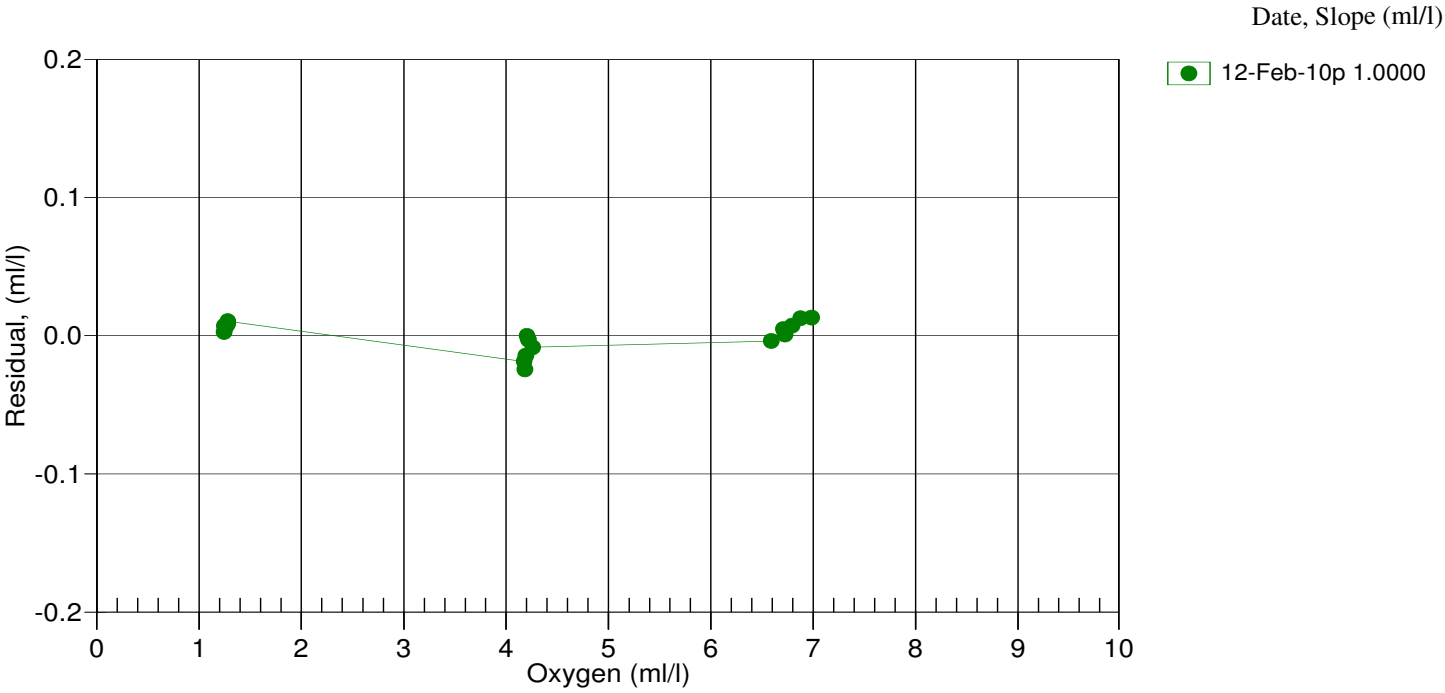
BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(Hz)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.24	2.00	0.00	4287.19	1.24	0.00
1.25	12.00	0.00	4609.61	1.25	0.01
1.26	6.00	0.00	4427.99	1.26	0.01
1.27	20.00	0.00	4898.64	1.28	0.01
1.28	26.00	0.00	5112.42	1.29	0.01
1.28	30.00	0.00	5260.22	1.29	0.01
4.18	6.00	0.00	7183.80	4.16	-0.02
4.18	2.01	0.00	6767.98	4.16	-0.02
4.19	12.00	0.00	7830.05	4.18	-0.01
4.20	30.00	0.00	9837.12	4.20	-0.00
4.22	26.00	0.00	9385.39	4.21	-0.00
4.26	20.00	0.00	8776.35	4.25	-0.01
6.59	30.00	0.00	13581.00	6.59	-0.00
6.71	26.00	0.00	13036.48	6.71	0.00
6.72	20.00	0.00	11997.53	6.72	0.00
6.80	12.00	0.00	10725.08	6.80	0.01
6.88	6.00	0.00	9783.25	6.89	0.01
6.99	2.02	0.00	9187.24	7.00	0.01

Oxygen (ml/l) = Soc * (F + Foffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)

F = frequency output from SBE43I, T = temperature [deg C], S = salinity [PSU], K = temperature [deg K]

OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar]

Residual = instrument oxygen - bath oxygen



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SBE-43I, Dissolved Oxygen Sensor, Serial Number 0533
Part Number: 90586 1.0 mil (24 micron) membrane
Integrated with SBE-41cp Serial Number: 41-3020

Each SBE-43I oxygen sensor, used on ARGO floats, is individually calibrated in three processes:

1) Repeated calibrations are performed in deionized water, each involves three oxygen concentrations at six temperatures (18 points) these define coefficients (**SOC, Foffset, A, B, C**), they are the basic oxygen response and residual temperature sensitivity of the sensor. Repeat calibrations are used to evaluate, document and help qualify stability and quality of each sensors output.
2) Pressure cycle testing, in a constant oxygen environment, defines coefficient (**E**) the pressure sensitivity of the output.
3) Response tests to oxygen steps, define coefficient (**TAU_20**) the time constant at 20 degrees C and atmospheric pressure.

Summary of coefficient values and calibration dates

Soc =1.2398E-04	24 Feb 2010
Foffset = -3227.64	
A = -2.6534E-03	
B = 1.6136E-04	
C = -2.9502E-06	
E =0.0452	08 Dec 2009
Tau_20 = 6.08 sec	07 Dec 2009

SBE 43I calibration equation

Oxygen (ml/l) = $Soc * (F + Foffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * \exp(E * P / K)$

F = frequency output from 43I sensor in Hz
T = water temperature deg C, K = absolute temperature = T + 273.15
S = water salinity in PSU
P =water pressure dbar
OxSol(T,S) = oxygen saturation [ml/l],

OxSol (T, S) = oxygen saturation function in (ml/L)

Source: Garcia and Gordon (1992) limnology & Oceanography, vol 37 (6), p1307-1312

$\ln[OxSol(T,S)] = A_0 + A_1T_s + A_2T_s^2 + A_3T_s^3 + A_4T_s^4 + A_5T_s^5 + S(B_0 + B_1T_s + B_2T_s^2 + B_3T_s^3) + C_0S^2$
$T_s = \ln[(298.15 - t)(273.15 + t)^{-1}]$

$t_F \geq t \geq 40°C$ $0 \geq S \geq 42\ ^{o}/_{oo}$

A0 = 2.00907	B0 = -6.24523E-03	C0 = -4.88682E-07
A1 = 3.22014	B1 = -7.37614E-03	
A2 = 4.05010	B2 = -1.03410E-02	
A3 = 4.94457	B3 = -8.17083E-03	
A4 = -2.56847E-01		
A5 = 3.88767		

Conti.

Oxygen (response) time-constant as a function of temperature and pressure:

Tau (T, P) = Tau_20 * D0 exp (D1*P+D2*T)
D0 = 2.3060
D1 = 1.9640E-4
D2 = -4.1776E-2

Adaptive pumping time for equilibration of the SBE-43I oxygen sensors on ARGO floats

When the CTD begins pumping at the start of a profile or during a spot-sample while profiling, the SBE-43I must adjust to a step change in oxygen. Pumping for 5.5 time constants allows equilibration to 0.5%of the step magnitude. In cold, deep water the response time, (T,P), increases. Energy is conserved on ARGO floats when pumping at slow speed for the first two time constants before throttling to full speed for the final three and a half .

Pump time before a spot-sample = 5.5*Tau (T,P)= (Ns + Nf)*Tau (T,P)
Ns = number of time constants to pump at slow speed
Nf = number of time constant to pimp at fast speed

Data conversions

[mg/L]= [ml/L]*1.42903
[micromole/Kg]= [ml/L]*44660/(sigma_theta (P,T,S) +1000)

There are two conversion factors currently in use for [ml/L] to [micromole/Kg]. 44660 is the exact value for oxygen gas, 44615is the average conversion factor for several constituents in atmospheric gases (N2, O2, Ar, H2O, CO2,....), and is the historic coefficient used by oceanographers. Seabird used 44660 in all calculations with Seabird software.