RBR

Pressure correction of conductivity cell

1 Summary

In 2016 several new models of conductivity cell was released by RBR. Those new conductivity cells are called combined CT cells and are available in three versions: 1000dbar, 2000dbar, and 6000dbar.

The shallow version uses a pressure vessel made from POM and ceramic while the two deeper models use OSP and ceramic. The pressure correction of conductivity is currently done using a parameter derived empirically from an earlier design, and this is being refined. The immediate change is a correction in the magnitude of that coefficient. The more complete change will be a possible change of model and additional coefficients.

2 Conductivity calibration

Although electrode based conductivity cells are simple to characterise in terms of pressure sensitivity, particularly when the electric field is entirely self-contained and the cell shape is a geometric primitive (hollow cylinder) with isotropic material properties, the mechanical behaviour of an inductive cell under pressure can be more complex to understand. The electric field in an inductive cell forms a toroid that passes through the centre of the cell (typically also a hollow cylinder, though one with a much lower aspect-ratio than the electrode-based counterpart) but then out and around the exterior volume of the cell. This may also be a geometric primitive (a larger cylinder) and in cells designed for moored applications, this is the most efficient form factor as hydrodynamic concerns are less significant. However, for cells intended for profiling use, considerable design effort is expended in order to achieve optimal flushing of the cell due to the movement of the host platform. This results in a cell exterior which does not have an easily calculated physical deformation as a function of hydrostatic pressure.

The RBR combined CT cell (where the thermistor housing and the conductivity cell are manufactured as a single combined unit) is of such a shape.

The equation that produces a conductivity value corrected for both temperature and pressure effects is as follows:

$$C_{corrected} = \frac{C_{uncorrected} - x_0 \cdot (T - x_3)}{1 + x_1 \cdot (T - x_3) + x_2 \cdot (P - x_4)}$$

where **P** is the absolute pressure (dbar), **T** is the internal temperature of the conductivity cell (°C). Coefficients **x0** ((mS/cm)/°C) and **x1** (°C^{-1}) are the temperature correction coefficients, **x2** (dbar^{-1}) is the pressure correction coefficient, **x3** is the temperature during calibration (°C), and **x4** is always 10 (dbar), indicating the nominal pressure during calibration.

The pressure sensitivity is modelled as a simple first order dependence, and has no effect to the nominal conductivity calibration performed at 10 dbar (**x4**, atmospheric pressure).

In instruments which have been shipping for the past few years, **x2** has been set to 4e-7 dbar^{-1}. This valued had been determined empirically through sea trials on board the R/V "Thomas G. Thompson" (TN298 cruise) in 2013 using our moored conductivity cell. However, our results with the combined cell have shown a systematic error at depth (too salty) using that value. This can be seen in buddy-float deployments, rosette casts, and WOA comparisons. Comparing data from three RBR*argo* Teledyne Apex floats to such reference data indicates that the salinity bias at 2000 dbar is +0.05 psu (C = 31 mS/cm).

The bias results from applying the conductivity pressure correction developed for the moored cell to the combined RBR*argo* CT cell. The RBR*argo* CT cell pressure correction term is different because its construction differs from that of the moored cell.

3 Correcting the RBRargo CT cell conductivity for pressure

In the summer of 2018, we are undertaking three cruises with JAMSTEC, DFO Canada, and IFREMER, with the intention of assessing whether the pressure correction model itself should be improved, either as an increased order polynomial or a power law. In addition, a large salt water pressure tank (1.4m deep by 0.7m diameter) is being used to provide more controlled evaluation of these terms.

In the interim, we have calculated a new value of **x2** which is better suited to the 2000 dbar rated combined CT cell if the current linear model is used: 1e-6 dbar^{-1}. For the time being, this new value of **x2** can be used. In fact, Argo China applies this new compensation to the SIO RBR*argo* Apex float WMO 2902730. The interim compensation value brings the deep salinity to within 0.001 psu of the WOA mean (see figures in the Appendix). However, we recommend waiting until September 2018 so that we can analyze the summer 2018 cruise and pressure tank tests.

4 Computer simulation

RBR Ltd. is also conducting at the same time a pure model based evaluation of the pressure dependency of the CT cells. The idea is to reproduce results obtained experimentally and ensure in the future that any potential future iteration of cells will be checked for a change of pressure dependency.

5 Changing the pressure dependence coefficient

Changing the effective value of **x2** is easy in Matlab or any other suitable tool. The following example uses the Gibbs Seawater Matlab toolbox.

Matlab implementation for interim pressure correction

```
x2_orig = 4e-7; % old pressure compensation factor for conductivity
x2_new = 1e-6; % new pressure compensation factor for conductivity

% calculate conductivity from salinity, temperature, and pressure
rbr.Conductivity = gsw_C_from_SP(rbr.Salinity,rbr.Temperature,rbr.Pressure);

% remove pressure compensation
rbr.Conductivity = rbr.Conductivity.*(1+x2_orig.*rbr.Pressure);

% apply new pressure compensation coefficient
rbr.Conductivity = rbr.Conductivity./(1+x2_new.*rbr.Pressure);

% re-derive salinity
rbr.Salinity = gsw_SP_from_C(rbr.Conductivity,rbr.Temperature,rbr.Pressure);
```

6 Appendix: SIO Apex float T/S diagrams

Plotting the T/S relationship for the SIO Apex/RBR*argo* float (WMO 2902730) over the bottom 1000 dbar (T<5^{o}C) provides an easy way to quantify the improvement of using the interim pressure correction. When the "old" pressure correction coefficient is used, the salinity error for this float is +0.04 psu at 2000 dbar (θ = 2^{o}C) relative the the WOA mean value and the reference CTD. Applying **x2** = 1e-6 dbar^{-1}, the updated value for a linear model, brings the salinity error at 2000 dbar to within 0.001 psu of the WOA value.