The Performance of the New Micro-Salinometer MS-310

A look into the future of ambient temperature salinometry

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I. Introduction

Since the introduction of a new automated laboratory salinometer AUTOSAL [1] in the "Sea Technology" 30 years ago, this great invention of the remarkable Canadian engineer Tomas M. Dauphinee has been accepted by oceanographers as the industry standard. The introduction of the Practical Salinity Scale 1978 (PSS-78) and the wide acceptance of submersible instruments to measure conductivity, temperature and depth (CTD systems), have made laboratory salinometers valuable as reference instruments to calibrate and verify the practical salinity (conductivity) measurements against Standard Seawater [2]. During these years, Guildline Instruments Ltd (Canada) has maintained production of the laboratory salinometer, which in its most recent version, the AutoSal 8400B is able to perform calibration of the conductivity sensors of the high precision World Ocean Circulation Experiment (WOCE) CTD systems. With proper electrical alignment, calibration, special care in sampling and maintaining the laboratory temperature about 1 to 2 ºC below that of the AutoSal bath temperature, it is possible to obtain an overall accuracy of salinity of ±0.002[2]. However, this instrument was designed for measurements in a laboratory and requires a controlled room temperature, high voltage power supply and experienced technical staff.

There are many instances when precise salinity measurements need to be made on board small ships and for field verification of CTD probes. It would be a considerable bonus if this task could be done without the need for a temperature-controlled laboratory and high voltage power supply. The instrument described in this paper meets these requirements.

The idea of elimination of the thermocontrolled bath by using two cells in the salinometer design was reported by Riley J. and Chester R., 1971 [3], and Dauphinee in

1986 patented a two-channel (measuring and reference contact conductivity cells) ratiometric salinometer, which was manufactured as MiniSal™ by AGE Inc (Canada) for a while. The main problem found with this method was the difficulty of measuring reference Standard Seawater conductivity in a closed contact 4-electrode cell. A new approach in development dual-channel salinometery was made in the United Soviet Socialist Republic (Marine Hydrophysical Institute, Sevastopol) in 1990, using inductive conductivity cells. This salinometer "SOKOL" was compared with the Autosal in a WOCE intercalibration cruise on Research Vessel Vernadsky in 1991[4]. The results of intercalibration showed that instrument could perform at the level close to Autosal accuracy, but electronics components of those days made this salinometer as big as the AutoSal and with a similar power consumption. In 2003 work in development of the dual-channel inductive Micro-Salinometer MS-310 was started in the RBR Ltd. (Canada) using a different electronic design and software concept. The main purpose of the Micro-Salinometer development was to permit the users of the CTD manufactured by RBR Ltd to have a reliable and low cost reference instrument for easy field calibration and data quality control.

II. Details of Construction

The heart of the instrument is a dual measuring cell, which has separate chambers for the sample and the reference. The chambers are made of quartz glass, and provide two independent measuring circuits that are linked by a single drive coil. The entire set of measuring chambers is immersed in a well-stirred oil bath to ensure that the two cells are at the same temperature. By using an inductive conductivity measurement there is no need for continuous flow through the cells which was critical in the Dauphinee's dual-cell salinometer. The dual cell system also eliminates any need for a stable bath temperature since both reference and sample are measured simultaneously, and the system gives a direct reading of the conductivity ratio of the sample to standard seawater. The reference cell contains about 15ml of Standard Seawater, or some other reference (potassium chloride solution may be used). The second cell contains about 15ml of sample to be measured. A single master oscillator is used to drive the coil, which transects both rings of fluid, inducing the same proportion of flux in both measuring cells. Each ring has an independent pick-up coil, and the signals from these are amplified and digitised to give the raw outputs. Computation of the value of Rt and salinity is performed in the laptop computer readout. A clear chamber and glass cells allow a visual check of the condition of the contents (usually seawater, but a customer has asked for an instrument to measure the salinity of guacamole). This ensures that there are no air bubbles or sediments and organic matter in the Sample Cell. After refilling the Sample Cell, less than 5 min is required to obtain thermal balance between the Sample and Standard Cells (the time depends on a difference between sample temperature and measurement chamber temperature, and can be much less if the samples have been allowed to equilibrate with the room temperature beforehand, or chamber has temperature close to sample temperature). A software window permits easy monitoring of when the reading becomes stable (standard deviation of the salinity reading for 1 min interval less than 0.0004): the green light "ready-to-read" appears. Usually the standard deviation of salinity readings is close to ±0.0001.

III. Laboratory testing

Laboratory trials of MS-310 indicate that in principle this salinometer can measure salinity with accuracy better than 0.002 which is comparable in accuracy with the Autosal 8400B. A dramatic test was used to measure the stability over a wide range of ambient temperatures. A unit was calibrated at 28°C against a standard seawater, and then left with the standard seawater batch number P141 in both cells. The instrument was then cooled down with 5°C steps to 13°C. All measurements of the practical salinity differences of the standard seawater P141 were within ±0.002. Another test was performed by comparison of the MS-310 with Autosal 8400B in full range of salinities. Comparison showed the difference less than 0.0025, which is within the accepted non-linearity of either salinometer.

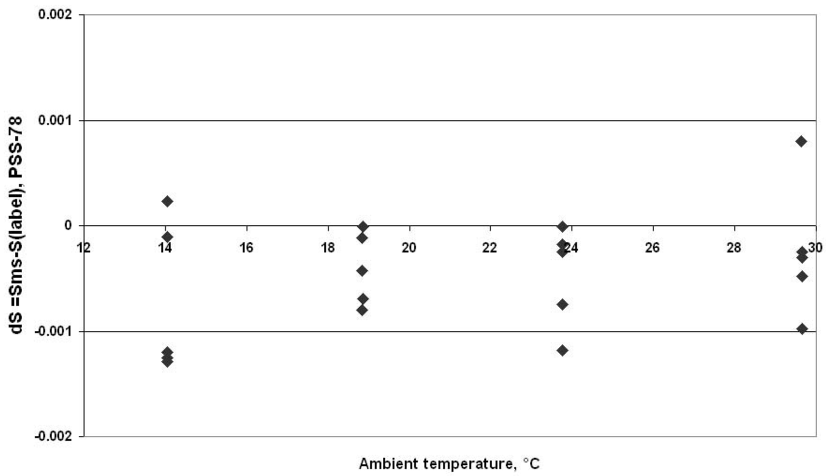

Fig.1 Variation of the measurement of Standard Seawater Salinity with Ambient Temperature. The MS-310 can operate with specification over a wide range of ambient temperatures.

In May 2005 an independent laboratory test was performed of MS-310 in the calibration laboratory of the National Oceanographic Centre (Southampton, United Kingdom). The results of test were very good. For practical salinity measurements stability of calibration over 24 hours was within 0.001 (usually the source of slow drift is in evaporation of the reference sample and can be eliminated with proper sealing of the tubing to valves hoses), repeatability of the measurements (for 15 independent samples the same salinity) was within ±0.001 standard deviation. A linearity check was performed using OSIL salinity linearity pack batch numbers P145, 38H7, 30L12, 10L9 which showed that salinity non-linearity lies within ±0.002.

The temperature influence on the standard seawater salinity in the range 15-30°C lies within ±0.0015. Only one disadvantage was reported, which is the possible long settling time if the samples are not at the chamber temperature. This is because there is no active temperature control. The simple solution to this is to equilibrate the samples before hand. On the other hand, the *ready-to-use* time for MS-310 is significantly less than for an AutoSal – it could measure in 5 min after switch ON (Autosal required at least 12 hours for bath temperature stabilization). Add to this high sensitivity of Autosal reading to environmental temperature (it must be stabilized to within 1°C of the ambient) and the benefit of the Micro-Salinometer technique is clear.

IV. Seagoing trial

Good laboratory results suggested that an extended sea trial would be interesting. In August-September 2005 an MS-310 was taken along on Cruise 298 Royal Research Ship RRS ”Discovery” on the Cape Farewell (Greenland). Measurement of salinity was a key element of the cruise due impact of the loss of the Greenland ice cap interjecting fresh, cold, water onto the North Atlantic waters. One of the authors took part in the cruise and was responsible for salinity measurements of all samples. Standard procedure of the salinity samples measurement included Autosal 8400B technique and in parallel a quarter of all samples were measured with Micro-Salinometer MS-310. A comparison was made of the salinity measurements of 170 samples (20 of them are duplicated) performed by the Micro-Salinometer MS-310 and the Autosal 8400B during the cruise. The mean value of salinity differences is -0.0004 with standard deviation 0.0011. Highest differences (up to 0.004) between salinometers occurred with low salinity samples (less than 30) on the shelf of Greenland. This difference could be due to the non-linearity of both salinometers and this difference lies within an acceptable level of the salinometers non-linearity.

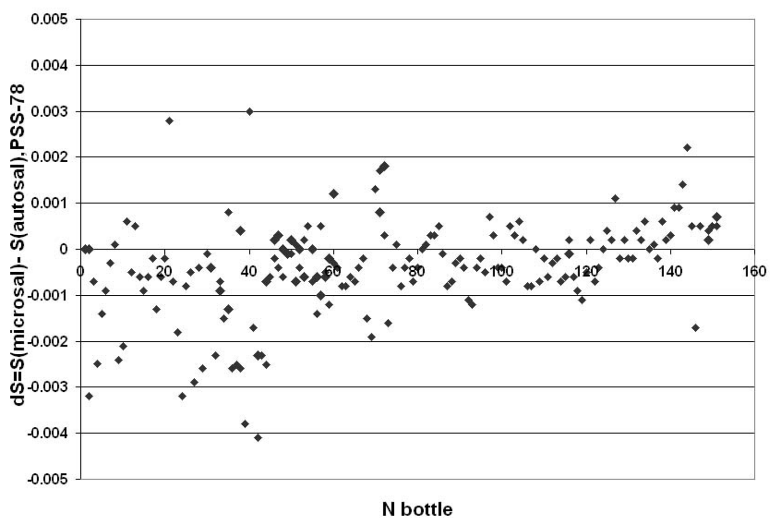

Fig.2. Observed differences between the Micro-Salinometer MS-310 and Autosal 8400B on a set of samples taken during the RRS “Discovery” Cruise 298.

The Micro-Salinometer showed a drift over the period of the measurements (4-12 hours) of less than 0.001 in practical salinity and all data were accepted without correction. In the Micro-Salinometer technique a sample salinity was recorded when the temperature in both cells was well balanced. Standard deviation of salinity reading is the optimal criterion in determining this condition. To get salinity readings with 0.001 level of precision the standard deviation must be less than 0.0002. All data from MS-310 were recorded with this criterion. Settling time was again seen to be long if the samples were not equilibrated beforehand, but the results of this cruise showed that the fast setup and short ready-to-use time in any environmental conditions make the MS-310 capable for the on-field precision salinity of samples measurements, especially on small ships and in camp base expeditions. As an extreme example of this, the MS-310 was taken out of the air-conditioned room and used in a cold room adjacent to the deck where the samples were brought on board. In this way a measurement of salinity was obtained without having to warm the sample up, with consequent risk of change of ionic and dissolved gases concentration.

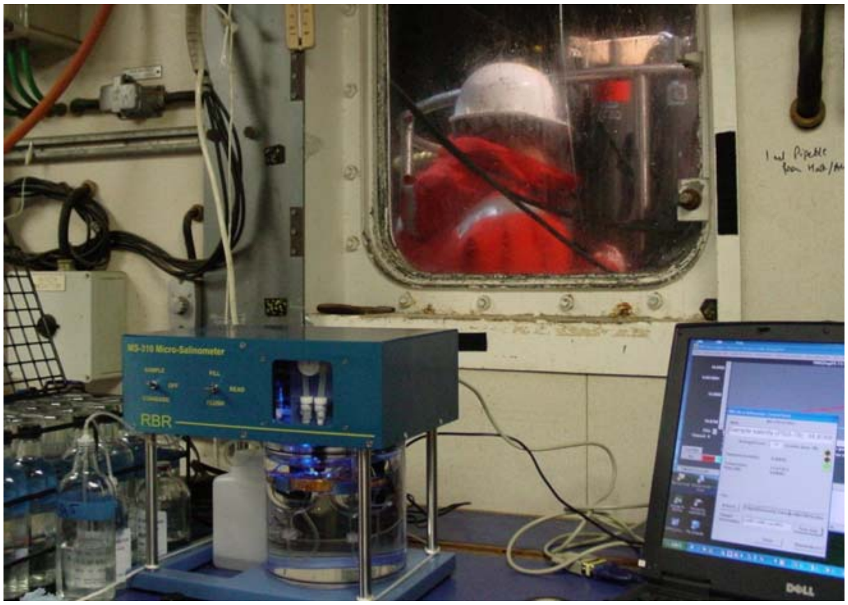

Fig.3. Micro-Salinometer MS-310 in the cold wetlab onboard RRS "Discovery".
This places the instrument where it should be – right next to the deck with the sample bottles.

V. Future of the salinometry

All discussions about the future of the salinometry technology and requests to have more accurate measurements of the seawater salinity, will always be connected with the improvement of on-board techniques for measurement. Requiring that measurements are made in an air conditioned room introduces the serious risk of uncontrolled variations in seawater sample composition, especially of the concentration of dissolved gases. Heating deepwater samples and as result reducing the concentration of dissolved gases can noticeably change the apparent salinity of seawater of the samples, which can be significant especially in deepwater dynamic and climatology studies. The Micro-Salinometer gives researchers a new technology for the future determination of and improvements to salinity measurements in cruises. The most promising feature is to be able to provide measurements of the salinity samples directly after getting CTD-system on the deck and therefore keeping the temperature of the measuring cell close to the temperature *in situ*. This is not only a good technical solution for simplifying on-board salinometry (oceanographers, who "do salts" at sea know, how sweaty it gets), but it also offers a new perspective for understanding the nature of the conductivity measurements of seawater and opens a route for improvement to the PSS-78. Samples should not be adjusted to a salinometer's comfort conditions, but a salinometer should come close to the CTD-measurements conditions – this is the future of salinity technology. The Micro-Salinometer is moving in this direction. Welcome aboard!

Reference:

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Biographies

Igor Shkvorets is Oceanographer at RBR Ltd. He was trained at Odessa Hydrometeorological Institute (Ukraine). He has worked for 20 years in the Marine Hydrophysical Institute of Academy of Science of Ukraine in the Department of Metrology. He maintains www.salinometry.com dedicated to the methods of measurement of seawater salinity.

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