Long-term stability of a New Conductivity-Temperature Sensor tested on the VENUS Cabled Observatory

Tomohiro Horiuchi, Fabian Wolk
Rockland Oceanographic Services Inc.
520 Dupplin Road
Victoria, BC V8Z 1C1 Canada

and

Paul Macoun
VENUS, University of Victoria

***Abstract*- The stability of the conductivity sensor is a key consideration for the long-term deployments of the instruments on mooring and observatories, because the conductivity measurement is very sensitive to the accumulation of organisms (bio-fouling) inside the sensor. We tested the performance of a conductivity sensor, the ALEC CTW, which features a simple but effective wiper mechanism to keep the sensing cavity of the conductivity cell free of bio-fouling. The sensor was deployed for a period of 12 months on the Victoria Experimental Network Under the Sea (VENUS) observatory, operated by the University of Victoria in British Columbia, Canada. The VENUS observatory provided power and data telemetry to monitor the sensor's performance in real time. A post recovery calibration of the conductivity sensor showed that the wiper mechanism was effective in maintaining the sensors calibration.**

I. Introduction

For the long-term salinity measurements, the conductivity sensor's calibration stability is a key consideration [1, 2], because the sensor is quite sensitive to fouling, i.e., the accumulation of biological organisms on the sensor. In order to prevent the calibration drift over the deployment period, the conductivity cell has to remain free and clear of biological growth. In some cases, the use of toxic chemicals (e.g. Tributyltin) slows down biofouling by poisoning the fluid surrounding sensor. However, the technique is not effective enough in regions of high biological activity and it can't be used in the environment sensitive areas (e.g. near coral reefs, or in enclosed water bodies). As a result, regular maintenance is required to remove biofouling from a sensor. In extreme cases the instrument has to be replaced. The maintenance cost is an important issue to maintain long-term measurements over the years.

The long-term deployable conductivity and temperature sensor, the ALEC CTW, made by JFE Advantech Co. Ltd. (Nishinomiya, Japan) has a mechanical piston wiper that periodically sweeps the internal cavity of the conductivity cell. The wipers effectiveness in keeping the sensor free of biological growth for month-long deployments without chemicals has been reported [3, 4].

Here, we report the year-long stability of the CTW tested on an underwater platform that is part of the Victoria Experimental Network Under the Sea (VENUS) cabled observatory located at the southern end of Vancouver Island, Canada. The CTW remained on VENUS for a 12-month period starting March 2009. The VENUS observatory is an undersea laboratory that delivers oceanographic information from the sea floor via optical fiber optic cables to University of Victoria in real time, allowing the conductivity and temperature data to be continuously recorded over the duration of the deployment.

II. Influence of Biofouling on Conductivity Sensors

Inductive and electrode cell-type sensors are used extensively to measure the electrical conductivity (or more accurately the conductance) of seawater, which is in turn used in the calculation of salinity, but they are susceptible to biofouling inside the sensor. An inductive sensor measures the conductivity by inducing an electrical field with a toroidal transformer. The resulting electrical current, which is measured with another transformer, depends on the water's conductivity and the geometry of the sensor. The highest density of the electrical current is in the center of the toroid, and here the accumulation of marine organisms affects the measured conductance most strongly. Moreover, part of the electric filed is external to the toroid, and so any material build-up on the outside of the sensor will also affect the calibration.

The electrode-cell type sensor, on the other hand, measures conductivity with metallic electrodes in direct contact with the seawater. Typically electrodes are mounted on the inner wall of a glass tube, ideally in a configuration that confines the electric field to the inside of the tube. Biological growth inside the tube changes both the geometry and the electrical contact between the electrodes and seawater. These combine to compromise the original sensor calibration.

978-1-4244-5222-4/10/$26.00 ©2010 IEEE

III. CTW CONDUCTIVITY SENSOR TECHNOLOGY

The conductivity sensor is a seven electrode cell with a mechanical piston wiper that periodically sweeps the measurement cavity to protect from accumulating of debris and biological organisms [Fig.1].

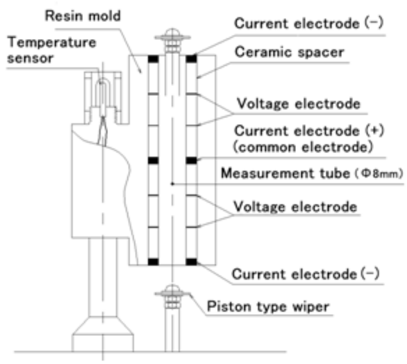

Figure 1. Schematic diagram of the CTW conductivity sensor.

A pair of electrodes of equal polarity (-) are located at the end of the cavity and share a common electrode (+) in the center of the cell. The opposing electrodes drive a current that is completely contained in the inner cavity of the cell. In this arrangement, the measurements are not affected by any biofouling on the outside walls of the sensor. A pair of pick-up electrodes measures the potentials (voltage) created by the drive electrodes (which are in contact with the fluid contained in the cavity) and this potential is a function of the fluid's conductivity. Pressure effects cause no significant geometrical variation of the distance between the electrodes or cross section area, so the sensor only measures conductivity change in the water.

The CTW has a mechanical piston that periodically moves into the sensing cavity. The top of the piston shaft has a circular silicone blade that gently wipes the surface of the electrode before each measurement. The wiper also helps exchange the water inside the cavity with new (surrounding) water. This process helps to maintain an accurate measuring of conductivity. The endurance of the silicone blade depends on the biological activities in the deployment site, but is approximately one year.

IV. INTEGRATION OF THE CTW ON VENUS

The CTW was deployed on the VENUS platform between March, 2009 and February, 2010 in Saanich Inlet, northwest of Victoria [Fig.2]. The deployment depth was 102.5m. The platform also supported an optical DO sensor (Optode 4175, Aanderaa Data Instruments), acoustic current meter (Aquadopp, Nortek), optical nitrate sensor (ISUS-X, Satlantic) and a digital pan-and-tilt camera system.

The power (360 or 24 volts direct current) and real-time communications (100/10 Base T or RS232/422/485) to the connected instruments were provided by the VENUS Science Instrument Interface Module (SIIM) on the platform. The SIIM is linked to the VENUS node via a 70-meter, oil-filled horse cable and a wet-plugged connector (Ocean Design Inc). The CTW worked with 24 volts direct current for power and a link to a serial Ethernet server for two-way communications between the shore station and the instrument.

With a custom software "diver" developed by the VENUS data managing group, the instrument is initialized and then routinely polled for conductivity and temperature data. The mechanical piston wiper was actuated with a separate command. Measurements were taken once per minute, 24 hours per day, and the mechanical wiper was actuated every 10 minutes.

The temperature and conductivity were calculated by the firmware and the data were output digitally in physical units. These data are combined with the time stamps and briefly buffered at the VENUS observatory shore station before being sent via fiber optic backhaul to the data management and archive system (DMAS) at University of Victoria. DMAS stores the data and allow scientists free access via the VENUS web site.

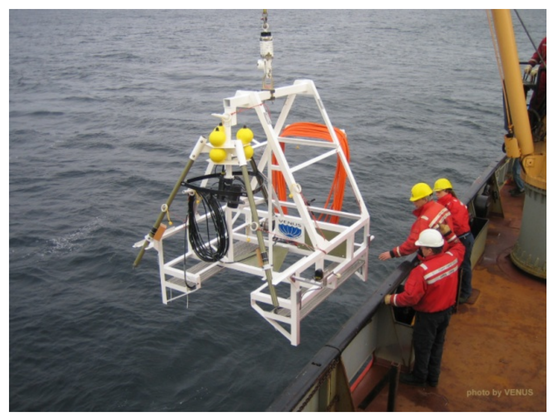

Figure 2. Deployment platform, VENUS digital pan and tilt camera system with cradled platform.

V. FIELD RESULT

Fig. 3 shows the time series of the conductivity and temperature from the CTW sensor and the salinity calculated from IAPSO PSS-78. The conductivity variability of the CTW is coincident with temperature during the deployment period. For the first 2-month, there were significant fluctuations in both conductivity and temperature. The fluctuations were also observed by other CTD sensors at the 95.5 m depth level at a nearby station, so they were thought to be real environmental variations. A jump in the C and T time-series in August was also an environmental change.

A regular, bi-yearly maintenance service for the observatory and the integrated instruments was carried out at the end of September, which is shown as the period of no-data. At the maintenance recovery, the biofouling in the cavity of the sensor was found in a pristine condition. Without any cleaning and replacements of the sensor, the CTW was redeployed and continued the operations [Fig.4].

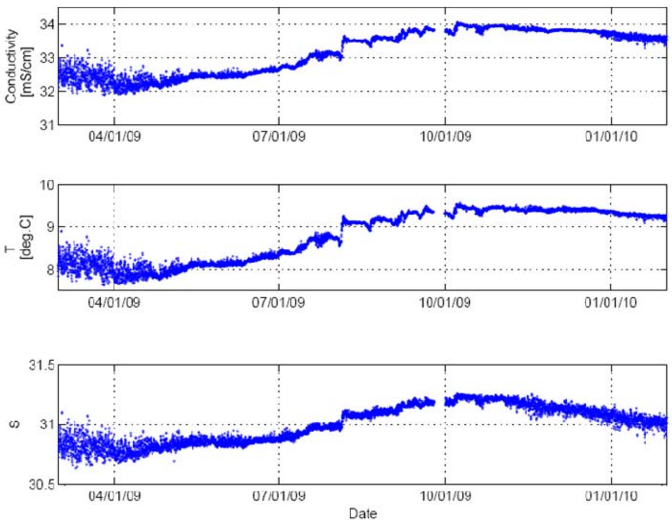

Figure 3. Time series plot of conductivity (upper), temperature (middle) and salinity (lower). The conductivity and temperature were measured by the CTW. Salinity is calculated using the IAPSO PSS-78 algorithm.

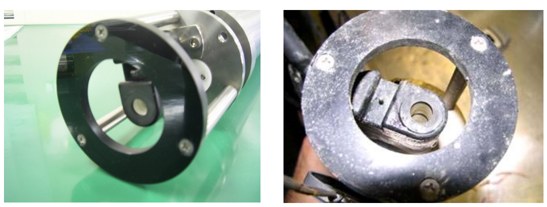

Figure 4. Conductivity sensor before the deployment (left) and after six months (right).

VI. STABILITY EVALUATION

After recovering the CTW from the VENUS cabled observatory in the middle of February 2010 to evaluate the stability of the conductivity and temperature, offsets compared the reference samples were assessed at the factory's calibration laboratory on 11 March, 2010.

Without any cleaning of the sensors before the evaluation, the instrument was tested at eight different conductivity and temperature levels in a controlled bath. Temperature and conductivity were calculated using calibration coefficients that had been established at the pre-deployment calibration on 29 January, 2009. Reference temperatures and conductivities were measured by a thermometer (1575A, HART Scientific) with a NIST-traceable platinum resistance temperature probe (NSR-160, Netsushin). All reference conductivities for the verification were estimated derived from Guildline Autosal salinometer 8400B and reference temperature measurement by inversion of the seawater equations of state (IAPSO PSS-78).

The CTW's conductivity and temperature had strong linear responses (conductivity: R^2 = 0.999, slope = 1.0002, intercept = 0.0043; temperature: R^2 = 0.999, slope = 1.0001, intercept = 0.0029) against eight different levels [Fig. 5]. The averaged offset between the CTW values calculated with pre-calibration formulas and references were 0.012 ± 0.002 mS/cm and -0.001 ± 0.002 °C, respectively [Fig. 6]. The CTW's initial stated accuracies are ± 0.01 mS/cm and ± 0.01 °C, so the observed calibration drift in conductivity was slightly outside the initial accuracy. There was no significant offset in the temperature sensor, which means that the observed drift in the conductivity is not caused by the electronics. Since the conductivity measurement cavity was free of biofouling (as confirmed by visual inspection after recovery), we presume that the drift is related to corrosion or other chemical

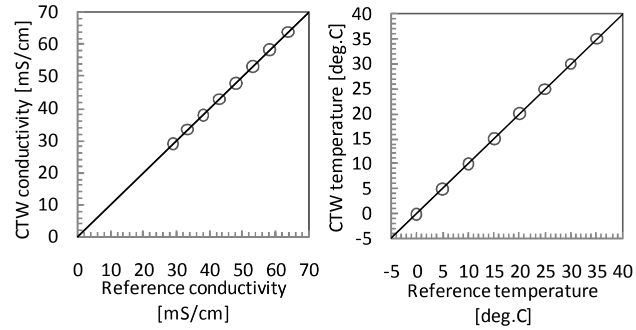

Figure 5. Evaluation of the linearity response for the deployed CTW over 12 months against controlled reference conductivity and temperature.

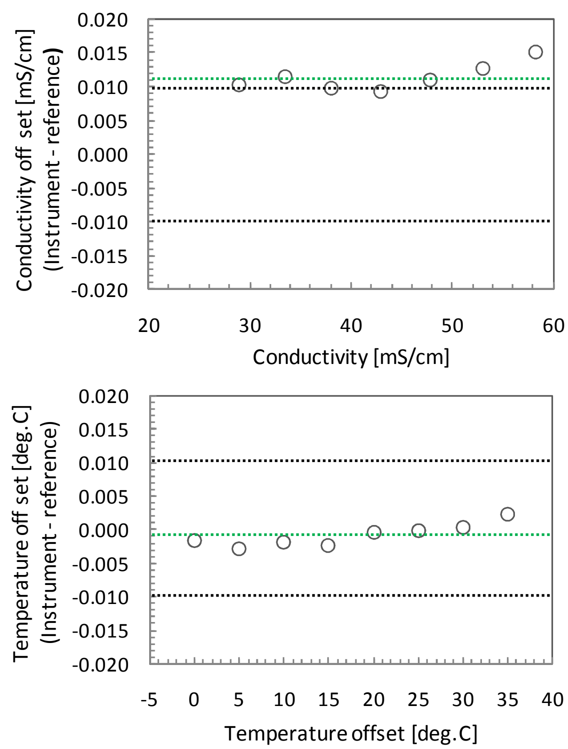

Figure 6. Offsets from reference conductivities (upper) and temperatures (lower), computed using pre-deployment calibration coefficients. Black dotted line and green dotted line show the initial accuracies of the CTW and the averaged offsets,

deterioration of the electrodes. This hypothesis will be the subject of a subsequent study.

VII. SUMMARY & CONCLUSION

The CTW was deployed for a period of one year on the VENUS cabled observatory. Without the use of chemical biofouling retard, and without regular maintenance, the CTW was free of biofouling for 12 months in a highly biologically active environment. The post-calibration against controlled references, the conductivity and temperature sensor maintained strongly linear responses. A small calibration drift was observed for the conductivity sensor, but the magnitude of the drift was close to the initial accuracy. Woody et al. (2000) mentioned, as a goal, in-situ salinity measurements in the coastal ocean with 1-year stability [2]. With a mechanical wiper for anti-biofouling, the CTW had shown to meet this goal and provided year-long accurate and stable salinity measurement. The test further indicates the CTW is a useful tool to monitor salinity on fixed autonomous platforms such as VENUS.

ACKNOWLEDGMENT

We thank the engineers of the JFE Advantech Co. Ltd for engineering support and the sensor calibrations.

REFERENCES

[1] Alliance for coastal technologies, “State of technology for in situ measures using conductivity-temperature sensors “, Workshop Proceedings, ACT-07-05, p.16, 2007.

[2] C. Woody, B. Smith, J. Miller, T. Royer, L. P. Atkinson, R. S. Moody, “Measurements of salinity in the coastal ocean: A review of requirements and technologies”, Marine Technology Society Journal, 32, 26-33, 2000.

[3] F. Wolk, and L. Hua, “Self cleaning sensors for long-term moorings,” Sea Technology, 46, 2005.

[4] Alliance for coastal technologies, “Performance verification statement for the JFE ALEC CTW and CTW-FS Salinity sensors”, ACT technology evaluations report, ACT VS06-09, p.61, 2009.