

# Calibrations of Conductivity and Temperature for the Aanderaa RCM-5 Current Meter

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March 1982

**Canadian Technical Report of  
Hydrography and Ocean Sciences  
No. 1**

GC  
1  
C37  
no. 1  
1982

Fisheries  
and Oceans

Pêches  
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Canada

## **Canadian Technical Report of Hydrography and Ocean Sciences**

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Ces rapports contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles mais que l'on ne trouve pas normalement dans les revues scientifiques. Le sujet est généralement rattaché aux programmes et intérêts du service des Sciences et Levés océaniques (SLO) du ministère des Pêches et des Océans.

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Les établissements des Sciences et Levés océaniques dans les régions et à l'administration centrale ont cessé de publier leurs diverses séries de rapports depuis décembre 1981. Vous trouverez dans l'index des publications du volume 38 du *Journal canadien des sciences halieutiques et aquatiques*, la liste de ces publications ainsi que le dernier numéro paru dans chaque catégorie. La nouvelle série a commencé avec la publication du Rapport n° 1 en janvier 1982.

Canadian Technical Report of  
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April 1982

Calibrations of Conductivity and Temperature  
for the Aanderaa RCM-5 Current Meter

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### ABSTRACT

Boyce, Richard. 1982. Calibrations of Conductivity and Temperature for the Aanderaa RCM-5 Current Meter. Can. Tech. Rep. Hydrogr. Ocean. Sci. 1: 27 p.

The temperature and conductivity sensors for the Aanderaa RCM-5 current meter have been calibrated in the laboratory and in the field. In 1978 Aanderaa introduced a newer type conductivity cell which did not contain a quartz liner as did its predecessor. Tests performed indicate that better results can be obtained using the newer quartz free cells.

Of 120 laboratory calibrations performed on the narrow-range (22 to 64 mmho/cm) cells, the average error was  $0.01 \pm 0.07$  mmho/cm. Pre- and post-deployment in situ calibrations, four months apart, yield errors in conductivity of  $0.02 \pm 0.08$  mmho/cm. The pressure effect on the newer type cell was much less than was discovered by Smith et al. (1978) using the quartz liner type. The standard range temperature sensor had a stability of  $\pm 0.03^\circ\text{C}$  and past history showed that it was very reliable. Other calibrations on the temperature and conductivity channels, modified to measure a narrower range, were also performed.

### RESUME

Boyce, Richard. 1982. Calibrations of Conductivity and Temperature for the Aanderaa RCM-5 Current Meter. Can. Tech. Rep. Hydrogr. Ocean. Sci. 1: 27 p.

Les capteurs de température et de conductivité de l'ampèremètre RCM-5 d'Aanderaa ont été étalonnés en laboratoire et sur le terrain. En 1978, Aanderaa a mis sur le marché un nouveau type de cellule de mesure de la conductivité sans garniture de quartz. Les essais effectués indiquent qu'elle donne de meilleurs résultats que les cellules à quartz.

Après 120 essais en laboratoire sur des cellules à gamme étroite (22 à 64 mmho/cm), l'erreur moyenne était de  $0,01 \pm 0,07$  mmho/cm. Deux étalonnages, l'un avant et l'autre après une expérience in situ de quatre mois, ont permis d'établir une erreur de  $0,02 \pm 0,08$  mmho/cm sur la conductivité. L'effet de la pression sur ce nouveau type de cellule est beaucoup moins important que celui découvert par Smith et coll. (1978) avec les cellules à quartz. Le capteur thermique à gamme normale a une stabilité de  $\pm 0,03^\circ\text{C}$  et l'expérience a montré qu'il est très fiable. Les deux dispositifs ont aussi été étalonnés après avoir été modifiés pour faire des mesures sur une gamme plus étroite.

## 1. INTRODUCTION

A previous report by Smith, Foote, and Boyce (1978) described procedures and results of calibration tests performed on temperature and conductivity sensors of the Aanderaa RCM-5 current meter during the Shelf Break experiment. In their results they describe a pressure effect on conductivity first reported by Huyer (1975), but, more importantly, note a drift which is typically about  $0.2^{\circ}/\text{‰}$  over a period of 4 to 6 months. At the time of the Shelf Break experiment, Aanderaa conductivity cells were manufactured with a glass liner inserted in the cell. Some of these cells contained an airspace to which Huyer attributed the error. Smith found no correlation between airspace and salinity error. In 1978, Aanderaa released a new cell which eliminated the glass liner, and these were utilized in various mooring experiments. A calibration procedure similar to that outlined by Smith was again carried out on these cells. In addition, extensive in-house laboratory calibrations were performed along with two separate deep-sea calibrations. The purpose of these experiments was to check the performance of the new cells, as well as the temperature channel, for accuracy, repeatability, effect of pressure and drift.

The Aanderaa Recording Current Meter (RCM) has been used extensively at the Bedford Institute of Oceanography (BIO) for about eight years. Since 1978 a concentrated effort has been directed towards the modification and calibration of the temperature and conductivity channels of the instrument. Along with current speed, direction, and depth, the Aanderaa instrument measures temperature, T, by a top end-plate-mounted thermistor, and conductivity, C, by an inductively-coupled torroidal coil. The accuracy and resolution of these two measurements as specified by the manufacturer are given in Table 1a. Because of the demand for higher resolution, the

temperature and conductivity channels were modified to give various narrower ranges and then calibrated to produce calibration curves. These specifications are given in Table 1b.

The results from all these calibrations are discussed in this report.

## 2. CALIBRATION METHODS

The Aanderaa current meters were calibrated for conductivity and temperature in the laboratory and in the field. In the laboratory, the instruments were tested under atmospheric conditions, before and after a cruise, to generate a calibration curve. These tests would serve as a check on the manufacturer's calibration as well as monitor any drifts or offsets occurring with the cell or meter during the mooring period. Two instruments were also subjected to varying pressures up to 1000 psi using the pressure facilities at BIO to investigate the pressure dependence of the new Aanderaa conductivity cells as described by Smith et al. (1978). Two separate 'in situ' tests were performed to calibrate the instruments under actual field conditions at various pressures. Twenty-one Aanderaas were subjected to pressures up to 440 psi (300 m) at the mouth of the St. Lawrence River in June (Dawson Cruise No. 78-017) and September (78-030) of 1978. These tests would (1) show any immediate pressure effects on the cell as experienced by Huyer and Smith, (2) show any drift occurring between June and September as the meters were moored during this time, (3) serve as an intercomparison between meters and with the CTD, and (4) serve as a check on the manufacturer's and laboratory calibrations under actual field conditions. Six Aanderaas were calibrated at pressures up to 3700

Table 1

(a) Aanderaa RCM4/5 Specification for Temperature and Conductivity Sensors  
(Aanderaa Operating Manual, June 1979)

Temperature

Sensor type: Thermistor (Fenwal GB32JM19)  
 Range: Low range:  $-2.46^{\circ}\text{C}$  to  $21.48^{\circ}\text{C}$  (standard)  
 High range:  $10.08^{\circ}\text{C}$  to  $36.04^{\circ}\text{C}$   
 Wide range:  $-0.34^{\circ}\text{C}$  to  $32.17^{\circ}\text{C}$   
 Accuracy:  $\pm 0.15^{\circ}\text{C}$   
 Resolution: 0.1% of range selected  
 63% Response time: 12 s

Conductivity (optional)

Sensor type: Inductive cell  
 Range: 0 to 70 mmho/cm (wide)  
 22 to 64 mmho/cm (narrow)  
 Resolution: 0.1% of range

(b) Specification for Temperature and Conductivity Sensors with Ranges  
Modified by BIO

Temperature (special ranges)

|             |   | <u>WR2</u>   | <u>WR3</u>   |
|-------------|---|--------------|--------------|
| Range 1:    | $-2^{\circ}\text{C}$ to $6^{\circ}\text{C}$ | 720 $\Omega$ | 500 $\Omega$ |
| Resolution: | 0.008 $^{\circ}\text{C}$                    |              |              |
| Range 2:    | $1^{\circ}\text{C}$ to $4^{\circ}\text{C}$  | 260 $\Omega$ | 195 $\Omega$ |
| Resolution: | 0.003 $^{\circ}\text{C}$                    |              |              |

Conductivity (special ranges)

| Range 1:    | 30 to 36 mmho/cm | 15596 $\Omega$ | 3153 $\Omega$ |
|-------------|------------------|----------------|---------------|
| Resolution: | 0.006 mmho/cm    |                |               |
| Range 2:    | 31 to 42 mmho/cm | 7600 $\Omega$  | 3052 $\Omega$ |
| Resolution: | 0.011 mmho/cm    |                |               |
| Range 3:    | 35 to 46 mmho/cm | 7600 $\Omega$  | 2703 $\Omega$ |
| Resolution: | 0.011 mmho/cm    |                |               |



psi (2500 m) during the Risex experiment in November 1980 (Dawson Cruise No. 80-038) and March 1981 (81-004) near the Gulf Stream. The main objective of these tests was to show any pressure dependencies inherent to the cell.

## 2.1 Laboratory Experiments

The Aanderaa current meters were calibrated, one at a time, for temperature and conductivity using an insulated nylon bath approximately 2 ft. in diameter by 3 ft. high, containing sea water from Bedford Basin. To ensure temperature stability, a stirrer and a Neslab Refrigerated Recirculating Heat Exchanger (HX-75) connected to 42 ft of coiled stainless steel tubing, 0.5 inch diameter, were used. At first, a calibrated Richter and Wiese glass thermometer, graduated in 0.05°C divisions, was used to measure temperature. This was replaced by a Guildline digital platinum resistance thermometer, Model 9535, accurate to better than 10 millidegress. Prior to calibration, the instruments were conditioned in a preliminary bath at approximately the same temperature and salinity as the main bath. Once placed in the stabilized main bath, the instruments, set to cycle at 30-s intervals, were left to equilibrate for at least 15 min., taking care that no air bubbles were trapped inside the cell bore. When six to eight repetitive readings were recorded for temperature and conductivity, along with the temperature measured by the thermometer, a salinity sample was taken.

The instruments were subjected to six different values of conductivity at two salinities, about 30‰ and 34‰. To achieve the higher salinity of 34‰, sea salt was added. Since March 1980, one

salinity of approximately 30‰ (Bedford Basin seawater) was used combined with six temperatures ranging from -1 to 16°C to generate the required conductivity range. For the special ranges, the bath was adjusted using sea salt to approximately 35.5‰. The salinity samples were analyzed using a Guildline Autosol 8400 which was standardized with Copenhagen standard seawater resulting in an accuracy better than 0.003‰ equipment salinity. With this value for salinity and the PRT temperature, conductivity was computed according to Bennett's (1976) formula. A graph of conductivity, C (mmho/cm), versus encoder reading, N, was plotted for each cell using the method of least squares and a linear relationship derived. The graph would show if an individual point did not fit the curve due to some miscalculation.

The narrow range conductivity cells have a calculated average range of 25 to 71 mmho/cm. This is a broader range than is necessary for the type of mooring environments the meters are subjected to by BIO. Therefore, the narrow range conductivity cells were calibrated within the range used mostly at BIO, 25 to 40 mmho/cm. The output pulses generated by the Aanderaa current meter consist of a 10-bit binary word which can be decoded into a decimal number using an Applied Microsystems "Digi Printer." For the full range the decimal number, N, is between 0 and 1023, but for the calibrated range N is between 0 and 330. Wide and special range cells have also been calibrated; however, most work has been concentrated on the narrow range.

To evaluate any pressure dependencies of the new Aanderaa conductivity cells, two instruments were placed in baths of uniform temperature and salinity and subjected to pressures from 0 to 1000 psi (0 to 700 m)

using the pressure facilities at BIO. A discussion of the procedure can be found in Smith et al. (1978). The basic procedure is still the same; however, slight modifications to the technique and equipment have yielded more consistent results than found by Smith.

## 2.2 Field Experiments

Initial 'in situ' calibrations using the new style cells were carried out during Cruises 78-017 in June 1978 and 78-030 in September 1978. Field calibration procedures were similar to those outlined by Smith. Four Aanderaa instruments set to cycle at 30-s intervals were shackled to the underside of the frame which carried the rosette bottles. A Guildline CTD was mounted on the rosette approximately one metre above the instruments. The rosette was lowered to three depths, typically 5, 50, and 190 m, and left at each depth for approximately 5 min. A similar procedure was followed during Cruises 80-038 and 81-004 with the addition of an up cast. These instruments were calibrated at two separate stations on each cruise at typical depths of 30, 500 and 2500 m (down cast) and 500 and 200 m (up cast).

Accuracy of the CTD data was verified by one or more sample bottles, complete with reversing thermometers, at each station for the entire cruise. The salinity samples were analyzed using an Autosol 8400 salinometer calibrated with Standard Sea Water. From these data the accuracy of the CTD was determined for the four cruises as shown in Table 2.

After processing the current meter and CTD data, individual calibration points were determined by plotting the time series and visually averaging the points at the calibration depth. Conductivity errors for the

Table 2

## Guildline 8203A CTD Accuracy

| Cruise No. | Date           | Salinity<br>( $^{\circ}/_{\text{‰}}$ ) | Temperature<br>( $^{\circ}\text{C}$ ) |
|------------|----------------|--|---------------------------------------|
| 78-017     | June 1978      | 0.00 $\pm$ 0.06                        | -0.01 $\pm$ 0.05                      |
| 78-030     | September 1978 | 0.01                                   | 0.00 $\pm$ 0.02                       |
| 80-038     | November 1980  | -0.02                                  | +0.01                                 |

1978 cruises were determined by averaging the errors at the three depths (in some cases, two, if the surface salinity was poor). For the latter two cruises, the conductivity errors are listed for each depth. No attempt was made to compensate for the one-metre difference in depth between the CTD and current-meter conductivity cells. Most of the calibration points on the 78-017 and 78-030 cruises were in areas of significant salinity variability.

### 3. CONDUCTIVITY RESULTS

#### 3.1 Laboratory Calibrations

Over a period of time, each cell was calibrated at least two or three times (which included in most cases the manufacture's calibration) to generate a set of calibration equations for an individual cell. To verify the repeatability of the calibration of a particular cell, the set of calibration equations for that cell were solved with  $N = 1$  and  $N = 300$  and the results subtracted from one another, respectively. Ideally, if the calibration of a cell hadn't changed, the result would fall between zero and the resolution of the conductivity channel of the instrument. For the special ranges,  $N = 300$  and  $N = 750$  were selected since the calibration was done over the entire range of the cell. Table 3 contains the calibration comparisons as well as the length of time (if at all) the meters were moored between calibrations.

Table 4a shows the total number of calibrations performed on the Aanderaa conductivity cells (used at the Bedford Institute) by the manufacturer and BIO. Table 4b shows the total number of individual cells calibrated and the number of cells whose calibration had changed or remained

Table 3

COMPARISONS BETWEEN VARIOUS CALIBRATION EQUATIONS  
FOR THE ANNDERAA CONDUCTIVITY CELL  
(\*classified as a changed calibration)

## Narrow Range

| Instrument No.<br>and (Cell No.) | Date Calibrated                 | Mooring Period<br>(months) | N = 1<br>(mmho/cm) | N = 300<br>(mmho/cm) |
|----------------------------------|---------------------------------|----------------------------|--------------------|----------------------|
| * 217 (2874)                     | Nov. 79<br>Mar. 79              | 6                          | 0.14               | 0.22                 |
| 822 (2867)                       | Nov. 79<br>Mar. 79              | 6                          | -0.01              | -0.03                |
| 1283 (2929)                      | Nov. 79<br>Mar. 79              | 6                          | 0.01               | -0.02                |
| 1288 (2926)                      | Nov. 79<br>Mar. 79              | 6                          | -0.03              | -0.01                |
| *1899 (2919)                     | Nov. 79<br>Mar. 79              | 6                          | 0.18               | 0.31                 |
| 1944 (2928)                      | Jan. 80<br>Nov. 79<br>Mar. 79   | -<br>6                     | 0.03<br>0.03       | -0.03<br>-0.03       |
| 2664 (2842)                      | Mar. 80<br>Apr. 79<br>Aanderaa  | 6<br>-<br>-                | 0<br>0.06          | 0.03<br>0            |
| 3197 (2038)                      | Nov. 79<br>Apr. 79              | 6                          | 0.05               | 0.03                 |
| 3300 (2040)                      | Sept. 79<br>Apr. 79             | 4                          | 0.03               | 0.04                 |
| 3301 (2176)                      | Apr. 79<br>Aanderaa             | 4                          | 0.04               | 0.01                 |
| 3302 (4520)                      | Mar. 80<br>Aanderaa             | -                          | -0.02              | 0.01                 |
| (2171)                           | Mar. 79<br>Aanderaa             | 4                          | 0.01               | 0                    |
| 3303 (2183)                      | Mar. 80<br>Sept. 79<br>Aanderaa | 1<br>10                    | -0.04<br>0.06      | -0.12<br>0.09        |
| 3306 (2179)                      | Oct. 79<br>Aanderaa             | 11                         | 0.07               | 0.08                 |

Table 3 continued:

| Instrument No.<br>and (Cell No.) | Date Calibrated | Mooring Period<br>(months) | N = 1<br>(mmho/cm) | N = 300<br>(mmho/cm) |
|----------------------------------|-----------------|----------------------------|--------------------|----------------------|
| *3307 (2184)<br>(defective cell) | Mar. 80         | -                          | -0.07              | -0.14                |
|                                  | Jan. 80         | -                          | -0.08              | -0.20                |
|                                  | Nov. 79         | 6                          | 0.34               | 0.59                 |
|                                  | Mar. 79         | 4                          | 0.21               | 0.29                 |
|                                  | Aanderaa        |                            |                    |                      |
| 3392 (2196)                      | Oct. 79         | 10                         | 0                  | 0.03                 |
|                                  | Aanderaa        |                            |                    |                      |
| 3394 (2204)                      | Oct. 79         | 15                         | -0.01              | 0.02                 |
|                                  | Aanderaa        |                            |                    |                      |
| 3565 (2529)                      | Oct. 79         | 15                         | 0.05               | 0.03                 |
|                                  | Aanderaa        |                            |                    |                      |
| 3566 (2533)                      | Oct. 79         | 15                         | 0.06               | 0.05                 |
|                                  | Aanderaa        |                            |                    |                      |
| 3567 (2518)                      | Mar. 80         | 4                          | 0.02               | -0.02                |
|                                  | Mar. 79         | 4                          | 0                  | 0                    |
|                                  | Aanderaa        |                            |                    |                      |
| 3568 (2519)                      | Mar. 80         | -                          | -0.03              | -0.01                |
|                                  | Oct. 79         | 15                         | -0.05              | -0.04                |
|                                  | Aanderaa        |                            |                    |                      |
| 3569 (2525)                      | Oct. 79         | 15                         | 0.05               | 0.08                 |
|                                  | Aanderaa        |                            |                    |                      |
| 3579 (2391)                      | Oct. 79         | 15                         | 0                  | 0.01                 |
|                                  | Aanderaa        |                            |                    |                      |
| 3584 (2385)                      | Mar. 80         | 6                          | -0.04              | -0.10                |
|                                  | Apr. 79         | 4                          | 0.04               | 0.03                 |
|                                  | Aanderaa        |                            |                    |                      |
| *3784 (2839)                     | July 79         | 7                          | 0.02               | -0.29                |
|                                  | Aanderaa        |                            |                    |                      |
| *3785 (2375)                     | Oct. 79         | -                          | -0.34              | -0.22                |
|                                  | Aanderaa        |                            |                    |                      |
| 3786 (2841)                      | July 79         | 7                          | 0.05               | -0.02                |
|                                  | Aanderaa        |                            |                    |                      |
| 4154 (3031)                      | Mar. 80         | 6                          | -0.05              | 0.01                 |
|                                  | Apr. 79         | -                          | 0.01               | 0                    |
|                                  | Aanderaa        |                            |                    |                      |
| 4155 (4016)                      | Apr. 79         | -                          | 0.02               | 0.06                 |
|                                  | Aanderaa        |                            |                    |                      |

Table 3 continued:

| Instrument No.<br>and (Cell No.) | Date Calibrated | Mooring Period<br>(months) | N = 1<br>(mmho/cm) | N = 300<br>(mmho/cm) |
|----------------------------------|-----------------|----------------------------|--------------------|----------------------|
| 4195 (3052)                      | Jan. 80         | 8                          | 0.02               | -0.02                |
|                                  | Apr. 79         | -                          | -0.02              | 0.02                 |
|                                  | Aanderaa        |                            |                    |                      |
| 4196 (3065)                      | Sept. 79        | 4                          | -0.01              | 0.04                 |
|                                  | Apr. 79         | -                          | -0.01              | -0.04                |
|                                  | Aanderaa        |                            |                    |                      |
| 4158 (4039)                      | Apr. 79         | -                          | 0                  | -0.01                |
|                                  | Aanderaa        |                            |                    |                      |
| 4197 (4021)                      | Jan. 80         | -                          | 0.02               | -0.03                |
|                                  | Nov. 79         | -                          | 0.01               | 0.04                 |
|                                  | Apr. 79         | 6                          | 0                  | 0.02                 |
|                                  | Aanderaa        | -                          |                    |                      |
| *4199 (3057)                     | Nov. 79         | 6                          | -0.08              | -0.12                |
|                                  | Apr. 79         | -                          | -0.03              | 0                    |
|                                  | Aanderaa        |                            |                    |                      |
| 4200 (2963)                      | Apr. 79         | -                          | 0.01               | -0.03                |
|                                  | Aanderaa        |                            |                    |                      |
| 4201 (2964)                      | Jan. 80         | 6                          | 0.03               | -0.02                |
|                                  | Apr. 79         | -                          | 0.01               | 0                    |
|                                  | Aanderaa        |                            |                    |                      |
| 4202 (3062)                      | Oct. 80         | 6                          | -0.01              | 0                    |
|                                  | Jan. 80         | 6                          | 0.04               | 0.02                 |
|                                  | Apr. 79         | -                          | -0.01              | 0                    |
|                                  | Aanderaa        |                            |                    |                      |
| 4208 (3041)                      | Jan. 80         | 6                          | 0.01               | -0.03                |
|                                  | Apr. 79         | -                          | -0.02              | -0.02                |
|                                  | Aanderaa        |                            |                    |                      |
| 4271 (4042)                      | Oct. 80         | 6                          | 0.01               | 0.03                 |
|                                  | Apr. 79         | -                          | 0.07               | 0.03                 |
|                                  | Aanderaa        |                            |                    |                      |
| 4297 (4060)                      | Apr. 79         | -                          | 0.04               | -0.01                |
|                                  | Aanderaa        |                            |                    |                      |
| 4299 (4112)                      | Apr. 79         | -                          | 0                  | -0.02                |
|                                  | Aanderaa        |                            |                    |                      |
| 4343 (3054)                      | Oct. 79         | -                          | -0.02              | 0.04                 |
|                                  | Aanderaa        |                            |                    |                      |



Table 3 continued:

| Instrument No.<br>and (Cell No.) | Date Calibrated                | Mooring Period<br>(months) | N = 1<br>(mmho/cm) | N = 300<br>(mmho/cm) |
|----------------------------------|--------------------------------|----------------------------|--------------------|----------------------|
| 4346 (2976)                      | Oct. 79<br>Aanderaa            | -                          | 0.01               | 0.04                 |
| 4349 (4265)                      | Oct. 80<br>July 79<br>Aanderaa | 10<br>-                    | 0.03<br>0.06       | 0.01<br>0.07         |
| 4350 (4187)                      | July 79<br>Aanderaa            | -                          | 0.08               | -0.05                |
| 4351 (4249)                      | July 79<br>Aanderaa            | -                          | 0.05               | 0.04                 |
| 4353 (4263)                      | Feb. 80<br>July 79<br>Aanderaa | 4<br>-                     | 0.06<br>-0.03      | 0.02<br>0            |
| 4355 (4314)                      | July 79<br>Aanderaa            | -                          | -0.02              | -0.03                |
| 4356 (2949)                      | July 79<br>Aanderaa            | -                          | 0                  | 0.01                 |
|                                  |                                |                            | <u>Mean</u>        | <u>0.01 ±0.07</u>    |
|                                  |                                | Wide Range                 |                    |                      |
| *1039 (2861)                     | Sept. 79<br>Aanderaa           | -                          | -0.11              | -0.47                |
| *1282 (2855)                     | Sept. 79<br>Aanderaa           | -                          | 0.13               | -0.25                |
| *1287 (4121)                     | Sept. 79<br>Aanderaa           | -                          | 0.06               | -0.23                |
| *1607 (2864)                     | Sept. 79<br>Aanderaa           | 6                          | -0.02              | -0.27                |
| 1950 (2877)                      | Dec. 78<br>Aanderaa            | -                          | 0.05               | 0.04                 |
| *1974 (2930)                     | Dec. 78<br>Aanderaa            | -                          | 0.10               | -0.39                |
| *2387 (2882)                     | Dec. 78<br>Aanderaa            | -                          | -0.13              | -0.33                |
| 2663 (2875)                      | Sept. 79<br>Aanderaa           | 9                          | 0.12               | 0.03                 |
|                                  |                                |                            | <u>Mean</u>        | <u>-0.10 ±0.20</u>   |

Table 3 continued:

| Instrument No.<br>and (Cell No.) | Date Calibrated     | Mooring Period<br>(months) | N = 1<br>(mmho/cm) | N = 300<br>(mmho/cm)     |
|----------------------------------|---------------------|----------------------------|--------------------|--------------------------|
|                                  |                     | Special Ranges             | N=350<br>mmho/cm   | N=750<br>mmho/cm         |
| *3306 (2179)                     | Apr. 80<br>Sept. 79 | 6                          | -0.14              | -0.14                    |
| 3392 (2196)                      | Apr. 80<br>Sept. 79 | 6                          | -0.07              | -0.08                    |
| 4202 (3062)                      | Jan. 81<br>Apr. 80  | 6                          | 0.03               | 0.08                     |
| 4271 (4042)                      | Jan. 81<br>Apr. 80  | 6                          | 0.05               | 0.05                     |
| 4346 (2976)                      | Apr. 80<br>Sept. 79 | 6                          | 0<br>Mean          | 0.01<br>-0.02 $\pm 0.08$ |

Table 4

## (a) TOTAL NUMBER OF CALIBRATIONS PERFORMED

| Calibrated<br>by  | Narrow<br>Range | Wide<br>Range | Special<br>Ranges | Total |
|-------------------|-----------------|---------------|-------------------|-------|
| Bedford Institute | 79              | 8             | 10                | 97    |
| Aanderaa          | 41              | 8             | -                 | 49    |

## (b) TOTAL NUMBER OF CONDUCTIVITY CELLS CALIBRATED

| Range   | Total | Unchanged | Changed |
|---------|-------|-----------|---------|
| Narrow  | 49    | 43        | 6 (5)   |
| Wide    | 8     | 2         | 6       |
| Special | 5     | 4         | 1       |

within acceptable limits. For the narrow range, one cell was found to be defective so the 'changed' column could be decreased by one.

Table 4b indicates that the vast majority of conductivity calibrations performed on the Aanderaa current meters at BIO are repeatable within acceptable limits. Smith et al. (1978) stated the levels of accuracy considered reasonable based on manufacturer's specifications and previous experience in the field are  $\pm 0.03^{\circ}\text{C}$  for temperature and  $\pm 0.10\text{‰}$  for salinity. For the narrow range, the average laboratory calibration error was  $0.01 \pm 0.07$  mmho/cm for conductivity, the resolution being  $0.046$  mmho/cm. It is not exactly known what the calibration error is in the laboratory technique. As stated previously, the temperature and salinity were measured to better than  $0.01$  and the formula used to calculate conductivity was accurate to at least this value, also. The same technique was used on all meters quoted in this report so any errors would at least be cancelled out when comparing the calibrations, except for the manufacturer's. Most of the narrow-range conductivity cells showed no consistent drift during various mooring periods and their calibrations could be duplicated. It is not certain why the five narrow-range and one special-range cells exhibited nonrepeatable calibrations. There is always the possibility of some sort of an electronic drift within the instrument, or the WR5 and WR6 range resistors could have changed their value with age. However, the most probable explanation is that the conductivity cell itself was distorted in some way. Small scars in the epoxy coating of the cell or in parts near the cell may affect the calibration.

The special ranges give greater resolution but result in the same errors during laboratory calibration as the narrow range,  $-0.02 \pm 0.08$ . A

possible explanation for this may be found in the Aanderaa Operating Manual RCM4/5, page 2-08, "Values of WR5 exceeding 3000 ohms may cause electric or magnetic noise to be picked up, that may influence the reading." WR5 is the resistor that determines the range of the conductivity channel. The special ranges for conductivity used at BIO require the WR5 resistor to significantly exceed 3000 ohms as can be seen in Table 1b. However, special ranges of 33-45 mmho/cm (moored at 500 m) and 30-43 mmho/cm (moored at 800 and 1500 m) were used during 1979-80 in a deep-sea environment and showed no apparent drift over periods up to 7 months and no significant noise problem. After correction for a pressure dependent calibration on the basis of a CTD intercomparison, final accuracies of about  $\pm 0.05$  mmho/cm were quoted (Hendry, personal communication).

The wide-range conductivity cells showed poor repeatability when calibrated,  $-0.10 \pm 0.20$  mmho/cm. This range is seldom used at BIO. The only calibrations available for comparison were the manufacturer's, which were old. It is not known what can be expected from a wide-range cell since its resolution is 0.075 mmho/cm. A one- to two-bit variation in the binary number of the conductivity channel leads to an error which is not within the acceptable limit. Since the resolution of the conductivity channel is comparatively low with the wide-range cell, the acceptable limit for error could be raised. If this is done, then the wide-range calibrations could be classed as unchanged. Also, only a small sample (8) of wide range cells have been calibrated so statistical basis for calibration is weak.

BIO conductivity calibrations performed on the Aanderaa current meters have been in good agreement over the years. However, a problem

arose with a batch of 13 current meters delivered in May of 1980. With respect to the conductivity calibrations, 6 agreed with the BIO calibrations, 4 had errors up to 0.09 mmho/cm, and 3 were off in excess of 0.1 mmho/cm. Correspondence with the manufacturer did not reveal any concrete reasons for the disagreement. These calibrations are not included in either Table 4a or b as further investigation is being carried out.

### 3.2 In situ Calibrations

The in situ calibrations are divided into two categories, shallow and deep. The shallow calibrations were performed at the mouth of the St. Lawrence River on Cruises 78-017 and 78-030. The same instruments were used on each cruise as they were moored between calibrations. The deep calibrations were performed south of Cape Sable on the slope of the continental rise on Cruises 80-038 and 81-004. Different instruments were used on each cruise and were not moored between calibrations. The purpose of these calibrations was to test the effect of pressure on the conductivity cell. These results will be discussed under the 'Pressure Tests' section.

Table 5 contains the results of the shallow calibrations on both cruises. The average error, as compared with the CTD, for both the pre- and post-deployment calibrations was  $0.02 \pm 0.08$  mmho/cm. This agrees with the laboratory calibrations which were performed under more controlled conditions. These results appear better than may have been expected as the water column at the calibration sites contained strong salinity and temperature gradients. This resulted in several surface calibration points to be discarded. Over the mooring period, there was no significant drift within the cells as indicated by  $\Delta C_2 - \Delta C_1$ .

Table 5

Conductivity and temperature errors for in situ calibrations on Cruises 78-017 and 78-030 (RCM-CTD). Errors at each of the three depths were averaged together. Surface point was excluded if large salinity and temperature gradients were present.

| Instrument | Predeployment<br>$\Delta C_1$ (78-017)<br>(mmho/cm) | Postdeployment<br>$\Delta C_2$ (78-030)<br>(mmho/cm) | $\Delta C_2 - \Delta C_1$ | Predeployment<br>$\Delta T_1$ (78-017)<br>(°C) | Postdeployment<br>$\Delta T_2$ (78-030)<br>(°C) |
|------------|---|--|---------------------------|--|---|
| 3297       | 0.08  | -0.01  | -0.09                     | -0.01  | 0   |
| 3299       | 0.02  | 0.03   | 0.01                      | 0  | 0   |
| 3300       | -0.24   | -0.25  | -0.01                     | -0.06  | -0.03   |
| 3301       | 0.03  | 0.03   | 0                         | -0.04  | -0.02   |
| 3305       | 0   | 0.03   | 0.03                      | -0.01  | -0.04   |
| *3307      | -0.01   | -0.63  | -0.63                     | 0  | 0   |
| 3391       | 0.12  | -  | -                         | 0.04   | -   |
| 3392       | 0.03  | 0.06   | -0.03                     | 0.01   | 0.01  |
| 3393       | -0.05   | 0.01   | -0.06                     | 0.02   | -0.02   |
| 3394       | 0.08  | -  | -                         | 0.01   | -   |
| 3565       | 0.06  | 0.04   | -0.02                     | -0.01  | 0.02  |
| 3566       | 0.01  | 0.05   | 0.04                      | -0.02  | -0.03   |
| 3567       | 0.03  | -  | -                         | -0.04  | -   |
| 3568       | -0.01   | -  | -                         | 0  | -   |
| 3569       | 0.03  | 0.02   | -0.01                     | 0.01   | 0   |
| 3578       | -0.01   | 0  | 0.01                      | 0  | -0.05   |
| 3579       | 0.09  | 0.08   | -0.01                     | 0.01   | -0.05   |
| 3580       | -0.01   | 0.08   | 0.09                      | -0.03  | -0.01   |
| 3582       | 0.04  | 0.03   | -0.01                     | 0  | 0   |
| 3583       | 0.14  | 0.08   | -0.06                     | -0.04  | -0.03   |
| 3584       | 0.01  | 0.06   | 0.05                      | -0.02  | -0.01   |
| Mean       | 0.02 $\pm$ 0.08                                     | 0.02 $\pm$ 0.08                                      | 0 $\pm$ 0.04              | -0.01 $\pm$ 0.02                               | -0.02 $\pm$ 0.02                                |

Table 5 also contains the in situ temperature errors for the pre- and post-deployment calibrations. The errors were, respectively,  $-0.01 \pm 0.02^{\circ}\text{C}$  and  $-0.02 \pm 0.02^{\circ}\text{C}$ , which agree with the laboratory results.

#### 4. PRESSURE TEST RESULTS

##### 4.1 Laboratory Experiments

Pressure tests in the laboratory consisted of subjecting the Aanderaa conductivity cell to excess pressures from 0 to 1000 psi (700 m). Also, the pressure was increased slowly in 100-psi increments up to 1000 psi. Readings quoted in the results are in terms of salinity.

Figures 1a and 1b show the results of the pressure tests conducted at BIO on the new style conductivity cell. These results are quite different from the findings of Smith et al. (1978). A pressure of 1000 psi applied to the cell increased the salinity reading as measured by the instrument by 0.03 to 0.06‰. There was no appreciable 'set' in the cell as found in those containing a quartz liner. The fibreglass tube into which the RCM was placed decreased the salinity reading by 0.25‰ with both meters. The pressure tests performed on meter 3304 were complete with the salinity samples taken before and after pressurization being equal. Tests performed on meter 3299 were interrupted when the ambient temperature of the pressure vessel surpassed the range of the meter. Tests were continued the following day, but concluded when the temperature again rose exceeding the limit of the meter. A final salinity sample was not taken as about 10 ml of the oil-water mixture in the pressure vessel seeped into the fibreglass tube and floated on the surface.



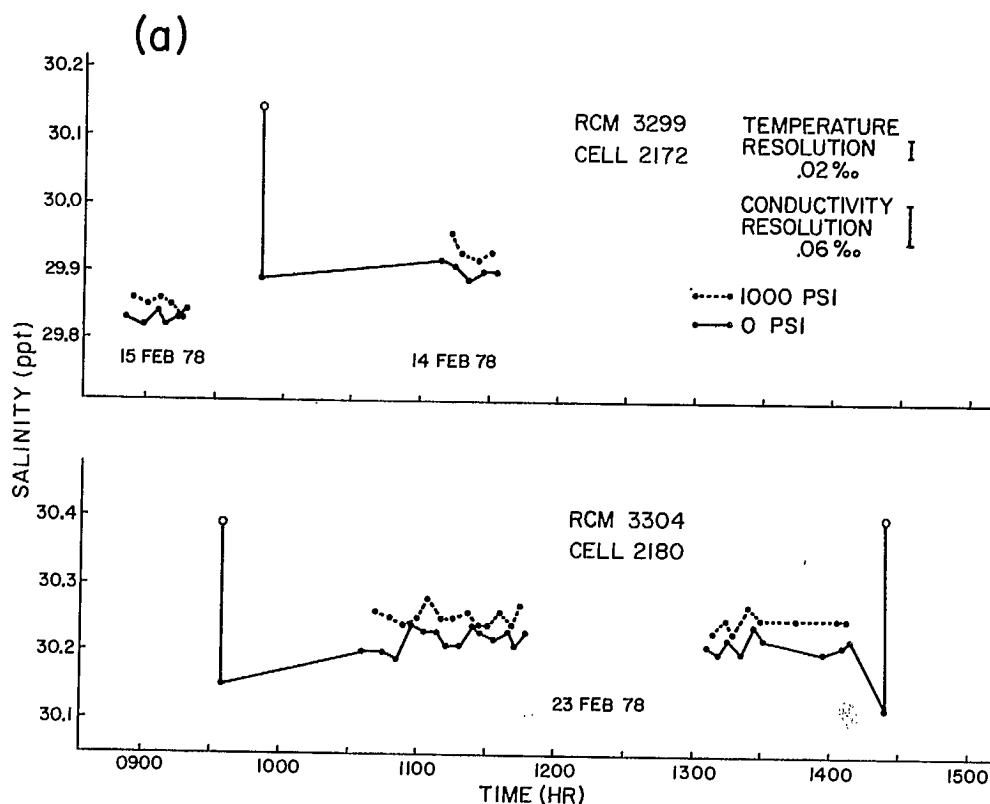


Figure 1a. Salinity measurements at pressure extremes (0, 1000 psi) for RCM 3304 and RCM 3299. The bottle calibrations for salinity are indicated by open circles. Quoted resolutions are the difference in salinity caused by a one bit change in temperature and conductivity at 10°C.

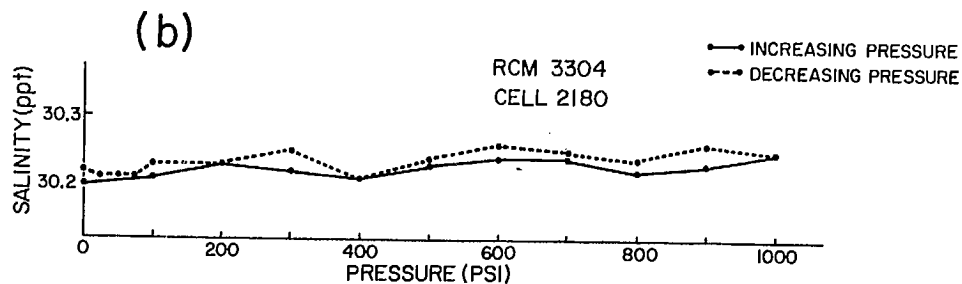


Figure 1b. Pressure versus salinity for RCM 3304.

#### 4.2 In situ Experiments

Three Aanderaa current meters were used for in situ pressure calibrations on Cruise 80-038 at Station #5. Prior to Station #9, one of these meters was required for mooring purposes leaving only two available for calibration. On Cruise 81-004 four current meters were calibrated at Station #7. During the cast, RCM 3300 developed a slow leak through the conductivity cell, rendering the data useless and the meter inoperative for future calibrations. A total of four calibrations, two on each cruise, was performed up to a depth of 2500 m (3550 psi).

Tables 6a and b contain the results of the deep 'in situ' water column at Station #9 was not stable enough to allow accurate readings from the current meters. The data indicate that increased water pressure on the cell results in higher conductivity readings. The magnitude of this increase varies from 0 to 0.08 mmho/cm, with a mean of 0.04 mmho/cm. Also, the data indicate that there is no apparent 'set' in the cell once it is pressurized.

The increase in conductivity due to pressure appears to be the same whether the cell is subjected to 1000 or 3550 psi. This would indicate that most of the effect of pressure on the cell occurs at or before 1000 psi. The laboratory pressure tests showed a steady increase or decrease in conductivity as the pressure was cycled from 0 to 1000 psi (Figure 1b). The error was of the same magnitude in both the 'in situ' and laboratory calibrations. This contrasts with the effect of pressure on the quartz-liner styled conductivity cell. With these, there was a 'set' and most of

22  
Table 6

Comparison of Aanderaa Current Meter (C,S,T) with Guildline CTD

(a) November 1980, Cruise #80-038, RCM #4202, 4272, 4349  
CELL #3062, 4042, 4265

| Station No. | Depth (m) | $\Delta$ Conductivity (mmho/cm) |                     |       | $\Delta$ Salinity (‰) |                    |       | $\Delta$ Temperature (°C) |                     |       |
|-------------|-----------|---------------------------------|---------------------|-------|-----------------------|--------------------|-------|---------------------------|---------------------|-------|
|             |           | Cond <sub>RCM</sub>             | Cond <sub>CTD</sub> |       | Sal <sub>RCM</sub>    | Sal <sub>CTD</sub> |       | Temp <sub>RCM</sub>       | Temp <sub>CTD</sub> |       |
|             |           | 4202                            | 4271                | 4349  | 4202                  | 4271               | 4349  | 4202                      | 4271                | 4349  |
| 5           | 23        | 0.15                            | 0.02                | -0.01 | 0.08                  | 0                  | -0.10 | 0.05                      | 0.02                | 0.11  |
|             | 103       | 0.03                            | 0.03                | -0.02 | 0.03                  | 0.03               | -0.09 | 0                         | 0                   | 0.08  |
|             | 2503      | 0.18                            | 0.08                | 0.06  | 0.25                  | 0.10               | 0.06  | -0.04                     | 0                   | 0.01  |
|             | 520       | 0.14                            | 0.06                | -0.01 | 0.20                  | 0.07               | 0.01  | -0.05                     | -0.01               | -0.02 |
|             | 297       | 0.17                            | 0.08                | 0.03  | 0.17                  | 0.08               | 0.01  | -0.01                     | 0                   | 0.01  |
|             | 212       | 0.14                            | 0.05                | -0.05 | 0.17                  | 0.06               | -0.05 | -0.04                     | -0.02               | 0.01  |
| 9           | 52.5      | 0.08                            | 0.07                |       | 0.09                  | 0.06               |       | -                         | -                   |       |
|             | 102       | -                               | -                   |       | 0.10                  | 0.03               |       | -                         | -                   |       |
|             | 2470      | 0.08                            | 0.08                |       | 0.16                  | 0.11               |       | -0.05                     | -0.01               |       |
|             | 495       | 0.06                            | 0.06                |       | 0.21                  | 0.17               |       | -0.05                     | -0.01               |       |
|             | 313       | -                               | 0.07                |       | -                     | 0.12               |       | -                         | -                   |       |
|             | 203       | -                               | -                   |       | -                     | -                  |       | -                         | -                   |       |

Table 6 continued:

(b) March 1981, Cruise #81-004, RCM #1283, 3394, 4604  
Cell #2929, 2204, 4764

| Station No. | Depth (m) | $\Delta$ Conductivity (mmho/cm)           |       |       | $\Delta$ Salinity (‰)                   |       |      | $\Delta$ Temperature (°C)                 |       |       |
|-------------|-----------|---|-------|-------|---|-------|------|---|-------|-------|
|             |           | Cond <sub>RCM</sub> - Cond <sub>CTD</sub> |       |       | Sal <sub>RCM</sub> - Sal <sub>CTD</sub> |       |      | Temp <sub>RCM</sub> - Temp <sub>CTD</sub> |       |       |
|             |           | 1283                                      | 3394  | 4604  | 1283                                    | 3394  | 4604 | 1283                                      | 3394  | 4604  |
| 7           | 566       | 0   | -0.01 | 0.04  | 0.02                                    | -0.02 | 0.07 | -0.02                                     | 0     | -0.02 |
|             | 2500      | 0.06                                      | 0     | 0.10  | 0.09                                    | 0     | 0.15 | -0.03                                     | -0.01 | -0.03 |
|             | 493       | 0.03                                      | 0.02  | 0.05  | 0.05                                    | 0.03  | 0.07 | -0.02                                     | -0.02 | -0.02 |
|             | 215       | 0.03                                      | -0.02 | -0.03 | 0.06                                    | 0     | 0.01 | -0.03                                     | -0.02 | -0.04 |
|             | 57        | -0.01                                     | -0.02 | 0.02  | 0.02                                    | 0.01  | 0.02 | -0.04                                     | -0.02 | 0     |
| 11          | 30        | 0.06                                      | 0.05  | 0.06  | 0.07                                    | 0.01  | 0.07 | 0.01                                      | 0.05  | 0.01  |
|             | 281       | -0.01                                     | 0     | 0.03  | 0.03                                    | 0.01  | 0.06 | -0.04                                     | -0.01 | -0.03 |
|             | 2296      | 0.08                                      | 0.02  | 0.08  | 0.12                                    | 0.05  | 0.14 | -0.03                                     | -0.03 | -0.05 |
|             | 206       | 0.01                                      | 0.03  | 0.05  | 0.01                                    | 0.02  | 0.07 | 0   | 0.01  | -0.01 |
|             | 24        | 0   | -0.02 | 0     | 0.03                                    | -0.01 | 0.03 | -0.03                                     | -0.01 | -0.03 |

the pressure effect occurred within 100 psi. Also, the magnitude of the error was considerably greater.

#### 5. TEMPERATURE CALIBRATIONS

Temperature monitoring performed on the Aanderaa current meters was done in conjunction with the conductivity cell calibrations. For the standard range,  $-2^{\circ}$  to  $21.5^{\circ}\text{C}$ , past history has shown that the Aanderaa temperature channel was well within the manufacturer's specification of  $0.15^{\circ}\text{C}$ . The average error for the 90 or so current meters used at BIO was found to be  $0 \pm 0.03^{\circ}\text{C}$ . Very few temperature calibrations were required since there was no apparent drift with the thermistor and the repeatability was excellent. One meter had a consistent error of  $0.10^{\circ}\text{C}$  using the manufacturer's calibration so a complete recalibration was performed which has since been repeatable. Four other meters had errors between  $0.01^{\circ}\text{C}$  and  $0.08^{\circ}\text{C}$ ; however, recalibration did not significantly change the error.

Thirty-eight temperature calibrations for both special ranges have been performed at BIO between February 1980 and July 1981. These resulted in a first order equation compared to a third order for the standard range. Of these 38 calibrations, only one was repeated, RCM 2544, which gave a constant error of  $0.03^{\circ}\text{C}$  over the entire range. One set of calibrations is

RCM 2544: Calibrated July 1980  $T(^{\circ}\text{C}) = 0.008074N - 2.6934$

Calibrated July 1981  $T(^{\circ}\text{C}) = 0.008074N - 2.6595$

certainly not enough to base any conclusions; however, an error of this magnitude can probably be expected from other meters. As with the special range conductivity channel, the special range temperature channel appears to have the same error as the standard range. However, the resolution is

much better (Table 1b), which is more significant when measuring differences rather than absolutes.

'In situ' temperature results are recorded in Table 5 for both the pre- and post-deployment calibrations on Cruises 78-017 and 78-030. Respectively, the errors were  $-0.01^{\circ} \pm 0.02^{\circ}\text{C}$  and  $-0.02^{\circ} \pm 0.02^{\circ}\text{C}$ , which are consistent with the laboratory results.

In general, the standard range temperature channel of the Aanderaa current meter is very reliable using the manufacturer's calibration. However, periodic checks should be performed to verify this accuracy.

## 6. DISCUSSION

The new style Aanderaa conductivity cells without the quartz liner appear to be better sensors than the older style cells containing a quartz liner. The cells are more accurate, are affected less by pressure, have better repeatability, and exhibit no apparent drift. Laboratory calibrations produce repetitive conductivity curves to within reasonable levels of accuracy. For the various ranges the results were  $0.01 \pm 0.07$  mmho/cm narrow,  $-0.10 \pm 0.10$  mmho/cm wide, and  $-0.02 \pm 0.08$  mmho/cm special. Comparing the narrow and special range results, it may appear that increasing the resolution for the conductivity channel is not a worthwhile exercise. However, as pointed out in a report by Lake and Cooke (1980), much useful information is contained in a time-series plot of conductivity if differences in measured values are of more importance than accuracy. The 'in situ' calibrations gave errors of  $0.02 \pm 0.08$  mmho/cm for both the pre- and post-deployment calibrations when compared to the CTD. The cells exhibited no apparent drift over the four-month mooring period. Laboratory pressure

tests revealed that a pressure of 1000 psi applied to the cell increased the salinity reading as measured by the meter by 0.03 to 0.06‰. The 'in situ' pressure tests resulted in increased conductivity readings of 0.04 mmho/cm when the cell was subjected to pressures up to 3550 psi. A 'set,' inherent to the quartz liner cells described by Smith et al. (1978), was not exhibited with the new cells. It appears that the pressure error increases consistently until it reaches a maximum near 1000 psi. The standard range temperature channel of the Aanderaa current meter was accurate to  $0 \pm 0.04^{\circ}\text{C}$  during laboratory calibrations. 'In situ' temperature calibrations resulted in errors of  $-0.01^{\circ} \pm 0.02^{\circ}\text{C}$  and  $-0.02^{\circ} \pm 0.02^{\circ}\text{C}$  when compared with the CTD. In general, the temperature channel is very reliable.

A full calibration of the temperature and conductivity channels of the Aanderaa current meter may not be required on a regular basis; however, it is suggested that a one- or two-point check be carried out prior to each deployment. This will not only verify the accuracy of these channels but will also serve as a performance test on the instrument. A one- or two-point calibration at a low temperature, keeping the instrument running overnight, can pick up problems that may not be discovered during a bench test.

#### Acknowledgments

The author wishes to thank Mr. A.J. Hartling for his technical assistance in setting up the calibration equipment and procedures.

We wish to thank Dr. P. Smith, Dr. R. Hendry, A.J. Hartling, and D. Gregory for their advice in preparing this report.

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