WHP relevant work during METEOR cruise 28, Leg 2
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## 0. Preliminary Remark

This report summarizes and updates hydrographic work that has been conducted during METEOR cruise 28, leg 2 (M28/2), in May/June 1994 within the Deep Basin Experiment (DBE) of the World Circulation Experiment (WOCE). It first has been described in the official cruise report (Zenk and Mueller, 1995). The present summary is designated as accompanying document to the WOCE (repeat) hydrographic data of M28/2. It especially describes in more detail, both, improved CTD data processing and calibration of the CTD sensors.

Note that WHP A8 data were acquired earlier during M28/1; they are not subject of this report.

## 1. Cruise Narrative

### 1.1 Highlights

1.1.1 WOCE Line Designation: AR15
WOCE-Suedatlantik 1994
Deep Basin Experiment (DBE), AR15
METEOR cruise 28/2

1.1.2 Expedition Designation: 06MT28_2
(EXPOCODE)

1.1.3 Chief Scientist: Walter Zenk, IFM Kiel, Germany
1.1.4 Ship: FS METEOR, Hamburg, Germany
1.1.5 Ports of call: Walvis Bay, Namibia - Buenos Aires, Argentina
1.1.6 Cruise dates: May 15 - June 14, 1994

### 1.2 Cruise Summary

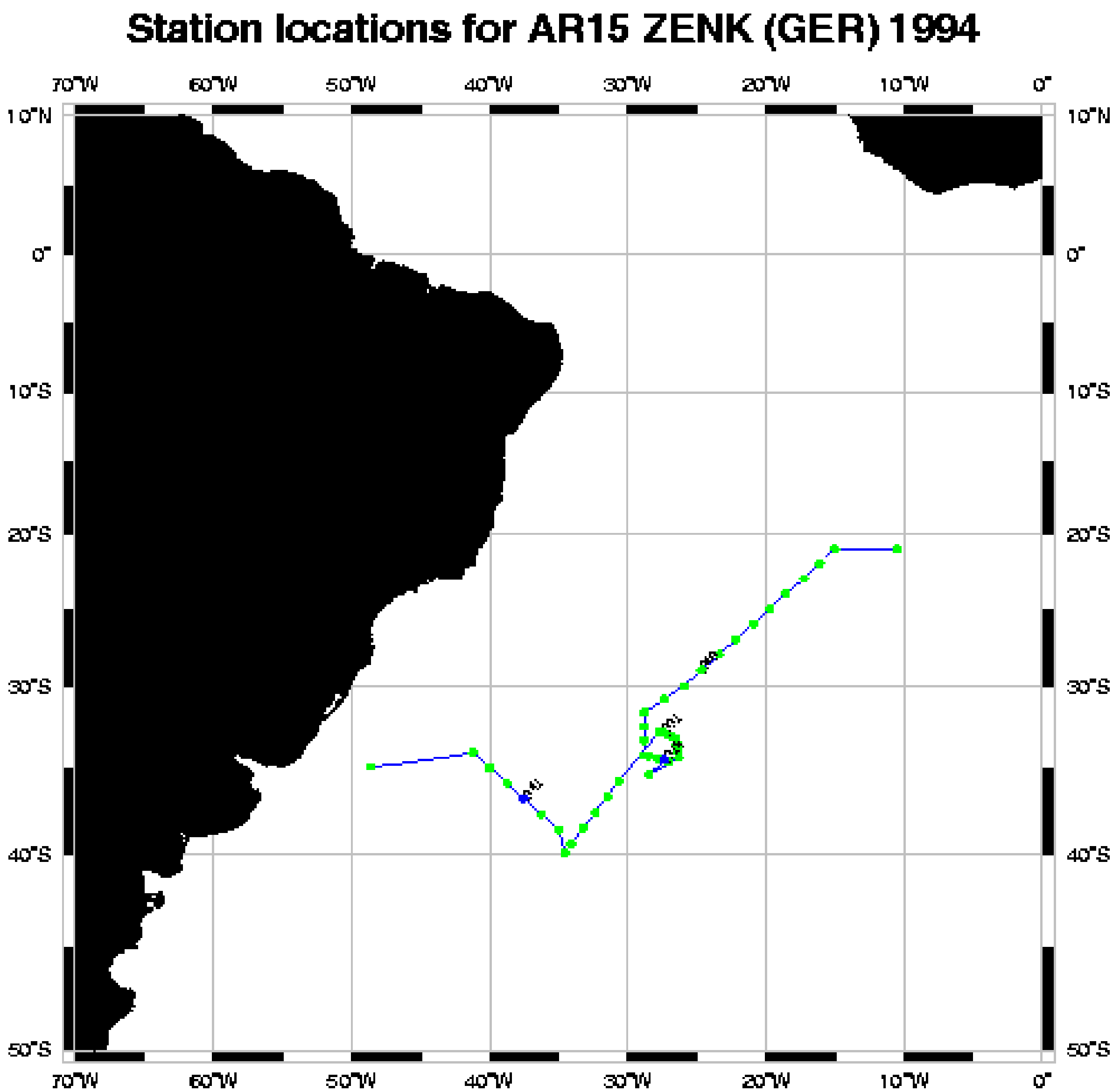
Leg M28/2 was mainly aimed at the Deep Basin Experiment (DBE)of WOCE.

The mooring array ACM03/12 consisting of 7 moorings was recovered at 31-34 S, near the Rio Grande Rise and the Hunter Channel. A bathymetric survey of the Hunter Channel hes been taken with METEOR's multibeam echosounder HYDROSWEEP (Paetzold et al. 1996).

44 usable CTD profiles were taken, (Stations No. 292-345) with abundant samples drawn from a rosette for calibration of the CTD's conductivity (salinity) sensor. For positions see the *.SUM file which accompanies this document.

Also 89 XBT's, 20 surface drifters and 29 RAFOS floats were launched.

Two sound sources were moored.




**1.3 List of Principal Investigators:**

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For a complete list of cruise participants see (Zenk and Mueller, 1995)

## 1.4 Preliminary Results

See references

## 1.5 Problems

# 2. Measurement Techniques, Calibration and Processing

## 2.1 CTD/Rosette

Station numbers are not only related to CTD work; thus they are gappy. CTD profiles are counted consecutively, with gaps occuring only if profiles have been omitted.

The only CTD in use was a Neil Brown MKIIIB instrument (IFMK internal identification NB3). This instrument carried a Pt100 Rosemount temperature sensor, a (fast) NTC temperature sensor for analogue time constant compensation, a strain gauge pressure sensor made by Paine Instruments, a standard NBIS 4-electrode conductivity sensor, and a polarographic type Beckman oxygen sensor. The outputs of both temperature sensors are combined in an analogue circuit to a single signal. Pre- and post cruise lab calibration are available for the combined temperature signal and for the pressure sensor. The calibration of conductivity depends on in-situ samples. No oxygen samples are available to calibrate the oxygen sensor.

In-situ samples to measure salinity, were drawn from 10 l Niskin bottles mounted on a 24 x 10 l General Oceanics rosette sampler. Bottles were closed on the way up. Samples were drawn immediately after the profile. Salinity samples solely served for CTD calibration.

No samples were drawn from bottles that failed to close properly or showed other problems like apparent leaking. These bottles therefore are not included in the bottle file. This also means that all bottles in the file were flagged as 'no problem' (QF2).

## 2.2 Bottle Salinity

Samples to be analyzed for salinity usually were drawn from: - The deepest point of the profile or 20 m above the bottom, for the 1500 m and the bottom stations respectively - The Antarctic Intermediate Water level - The mixed layer where vertical gradients are small All samples were filled to German beer bottles 'Flensburger Pils', a cheap and social method that has been recommended in pre-WOCE days by Grasshoff et al. (1983) and that keeps samples stable over the typical length of a cruise (4 weeks) better than 0.001 psu.

Batch No P122 of IAPSO standard seawater was used to standardize the salinometer. No double samples were considered. The overall accuray of bottle salinities for calibration purposes of the CTD is estimated by the precision of the overall calibration (0.005 psu) and the accuracy standard seawater (better 0.001 psu) to 0.002 psu.

Bottle salinities that differ more than 2.8 and 3.5 times the standard deviation in salinity calibration from the calibrated CTD salinity (see below) were flagged as suspicious (QF3) and bad (QF4), respectively. The bottles may have closed at wrong positions here. However, since no other samples were taken, no corrections for wrong bottle depths have been made.

## 2.3 Bottle Oxygen

No samples drawn, therefore the oxygen values in the data files have to be regarded as uncalibrated.

## 2.4 CTD: Data Processing

The CTD used throughout the cruise was a Neil Brown MKIIIB (IFMK identifier NB3). It was mounted below a 24 x 10 l bottle rosette made by General Oceanics and lowered at almost constant speed (about 1 m/s) from 200 m depth on. Data processing is similiar to that described by Millard and Yang (1993). The steps were:

- Visually inspect each profile, especially to identify 'strange' effects in the pressure record.
- Create a time relative to the start of the profile for each record to well resolve the record interval 1/32 s.
- Check that pressure, temperature and conductivity are in reasonable ranges.
- Remove spikes in pressure, temperature and conductivity values.
- Identify the first 'in water' record and associated pressure offset from the first reasonable conductivity measuremnet.
- Remove cycles that were taken at a lowering speed less 0.2 m/s. Monotonize with respect to increasing pressure. For a lowering speed of 1 m/s, the number of remaining cycles then corresponds to the resolution of the pressure sensor.
- Correct for different response times of the (combined) temperature and conductivity measurements. Visual inspections in large gradients suggested a 60 ms time constant for a recursive filter to slow down the conductivity response.
- Apply a moving average over 29 cyles (corresponding to 3 dbar)
- Apply calibrations to pressure, temperature and conductivity (see below).
- Interpolate Lagrangian to 2 dbar.
- Recalculate salinity and potential temperature.
- Identify records as statically unstable if the vertical gradient of potential density (reference level increasing at 500 dbar intervals) over a 2 dbar interval is less
- 0.001 Kg/m^3. Set salinity flag of such cycles to 3.

For a 2 dbar output interval after removing spikes etc, the number of basic measurements is 13 on the average. This was transferred as constant to the output files.

A special problem showed up in two profiles: At constant lowering rate of the CTD, one expects smooth sensor outputs as a function of time at large depths, say from 1400 m on. However, a problem showed up with the conductivity signal on station 543/profile 3 and on station 579/profile 35. When plotted, temperature is smoothly decreasing and pressure is linearly increasing as expected but conductivity jumps at 1750 dbar at station 543. This jump could not be removed, and therefore the deeper part of this profile was cut off. At station 579, bad conductivity values occurred between 1198 dbar and 1226 dbar. These were interpolated using polynomial of 3rd. order and flagged as such.

## 2.5 CTD: Sensor Calibration

### 2.5.1 Temperature

Pre- and post- cruise laboratory calibrations are available from July 1992 and April 1993, respectively. They were performed over the whole range at 2 K intervals between -1 C and 28 C. As a secondary standard served a Rosemount Pt25 resistance in a bridge made by SIS, Kiel. The Pt25 was calibrated according to the ITS90. Prior to the CTD calibrations, bias and linear coefficient of the Pt25 basic calibration were adjusted to meet the triple point of water (2 cells independently) and the melting point of Gallium. The adjustments were small (less 1 mK). The quadratic term is believed not to change.

A polynomial regression for the CTD's correction to T90 in pre- and post-cruise calibrations (Tables A1 and A2) shows standard deviation of less than 1 mK with about 10 degrees of freedom. The drift of the sensor output was small (1.5 mK/a at 0 C). High order polynomials are needed to correct for the MKIIIB typical nonlinearity close to 0 C (see Mueller et al., 1995). From these results, temperature outputs TCTD were corrected for both laboratory calibrations and then interpolated in time to the mean cruise date (Tables A1, A2). Figure 2 shows the corrections applied to the CTD temperatures in the bottle file.

### 2.5.2 Pressure

Two aspects are important with the calibration of the Paine strain gauge pressure sensor: (i) nonlinear and temperature dependent static responses to pressure changes (including a hysteresis during up-profiles) and (ii) dynamic response to fast temperature changes. Corrections from, both, the static (PRC) and the dynamic responses (PDYN) are superposed linearly to the sensor output PCTD. The procedure has been described in more detail by Mueller et al. (1994, 1995).

$$PRES = PCTD + PRC + PDYN$$

Static laboratory calibration is performed on a Budenberg dead- weight tester in loading mode up to 6000 dbar in 500 dbar intervals with the pressure sensor being immersed in a water bath of different temperatures, i.e 13 calibration points at fixed temperatures. At the same temperatures, unloading calibrations are achieved in 500 dbar intervals starting at maximum pressures of 2000 dbar, 4000 dbar and 6000 dbar. All calibration points are arranged in a single table. For the loading mode, for each temperature polynomial correction coefficients are calculated (PRC=POLY(PCTD,TEMP). Typical standard deviations in a 3rd to 5th order polynomial regression are less than 1 dbar.

The dynamic response model used is written:

$$PDYN = k * (T1l - T2l)$$

where T1l and T2l are lagged from the CTD temperature sensor at record time t(j):

$$Tl1(j)=TCTD(j) + (Tl1(j-1)-TCTD(j))*\exp(-(t(j)-t(j-1))/tau1)$$
$$Tl2(j)=Tl1(j) + (Tl2(j-1)-Tl1(j)) *\exp(-(t(j)-t(j-1))/tau2)$$

The three coefficients tau1, tau2 and k are the two time constants representing the temperature response time at the outer (tau1) and the inner (tau2) part of the pressure sensor, respectively, and an amplitude that typically amounts to 0.2 dbar/K. These coefficients are calculated from a laboratory dunck test with the pressure sensor being duncked from a warm (20 C) water pool into a cold (0.5 C) water pool. The sensor is kept there until full response is achieved and duncked back to the warm water pool again. With the dynamic correction applied, the error in the pressure sensor output can be reduced to less than 30% of its amplitude.

To process the pressure record in CTD profiles of M28/2, it was assumed that the CTD was in temperature equilibrium before the profile started. Then, for the lowering part pressure measurements were corrected with the polynomial regressions that are valid for the two temperatures that bracket the in-situ temperature with the bias being replaced by the 'in water' offset. The two resulting corrections are linearly interpolated with respect to temperature. If the in-situ temperature was outside a calibration interval the correction was constantly set forth. Finally, the dynamic correction was added.

On the way up, hysteresis plays a role, and simple regressions are not possible. Therefore, CTD pressure measurements in the rosette file were corrected by linear interpolation within the calibration table with the offset being replaced by the 'in water' offset. Dynamic correction started with the assumption that the CTD was lowered at a mean speed of 1 m/s to its maximum pressure.

For M28/2, laboratory calibrations are available for static effects from July 1992 (pre-cruise, Table A3), for static effects at from April 1993 (post- cruise, Table A4) and for the dynamic response to temperature changes from July 1992 (Table A5). They were applied as described above. The accuracy of corrected pressure values is estimated to be better than 3 dbar at full range (6000 dbar). Figure 3 shows the corrections as applied to the CTD pressure sensor records in the bottle file.

### 2.5.3 Conductivity and Salinity

In the bottle file, bottle salinity and calibrated CTD temperature and pressure are used to calculate in-situ reference conductivity. Then, the CTD cell's output is corrected for a nonlinearity for values CCTD<=32.768 (Mueller et al., 1995)

CN = CCTD -0.002 mS/cm.

Next, the cell's output CCTD is compensated to temperature and pressure effects (Millard and Yang, 1993).

CC = CN*(1+ alpha*(TEMP-T0) + beta*(PRES-P0))

where alpha =-6.5e-06, T0=2.8 beta = 1.5e-08, P0=3000

In-situ calibration coefficients are then estimated for the compensated conductivity measurements applying a linear least square method for a five coefficient correction CRC that includes a drift correction by profile number PROF, i.e. time (Tables A6).

COND = CC+CRC where CRC = a1 + (a2+a3*CC)*CC + (a4+a5*PROF )*PROF

It was found that the calibration could be done over the whole data set (Table A6, fig. 4).

Let a conservative estimate of the number of degrees of freedom in the calibration be either the number of profiles from which samples are used or half of all individual samples (2 samples maximum for each profile), whatever is the minimum. From the statistics below, the precision in CTD salinity then is estimated to 0.001 psu. For stations where bottle salinities were measured, accuracy is the maximum of CTD salinity precision and bottle salinity accuracy, i.e. 0.002 psu.

### 2.5.4 Oxygen

As no oxygen samples were drawn, the CTD oxygen sensor has not been calibrated. The oxygen sensor's current and temperature output are kept as raw data.

## References

Grasshoff, K, M. Ehrhardt and K. Kremling (editors, 1983): Methods of Seawater Analysis. Verlag Chemie, Weinheim.

Millard, R.C. and K. Yang (1993): CTD calibration and processing methods used at Woods Hole Oceanographic Institution. Techn. Rep. WHOI-93-44, 96 pp.

Mueller, T.J., J. Holfort, F. Delahoyde and R. Williams (1994): Improving NBIS MK IIIB Measurements. In: WOCE Operations Manual, Vol. 3, Sect. 3.1, Part 3.13. WHP Operations and Methods (T.M. Joyce, editor), Rev. 1. November 1994. Woods Hole, MA, U.S.A.

Mueller, T.J., J. Holfort, F. Delahoyde and R. Williams (1995): MKIIIB-CTD: Improving ist system output. Deep-Sea Res. 42, 2113- 2126.

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W. Zenk and T.J. Mueller (1995): WOCE Studies in the South Atlantic. Cruise No. 28, 29 March - 14 June 1994. METEOR-Berichte No. 95-1, Institut fuer Meereskunde an der Univ. Kiel, 193 pp.

WOCE (1991): WOCE Operation Manual, Vol. 3, Sect. 3.1, Part 3.1.3. WHP Operations and Methods. WHP Office Report WHPO 91-1. Woods Hole, MA, USA, 1991.

Table A1: M28/2 pre-cruise temperature calibration of MKIIIB CTD, IFMK NB3, NOV 1993. TCTD and T90 are the CTD's temperature signal and the reference temperature (secondary standard), respectively. Polynomial correction of TCTD with coefficients c (values below) gives TEMP. TDIF=T90-TLAB is the residuum. TEMP = c(0) + (1 + c(1))*TCTD + c(2)*TCTD^2 + c(3)*TCTD^3 + ...

| Temperature calibration in ITS90 with CALTRC.M. | | | |
|---|---|---|---|
| IFMK NB3 NOV93 | | | |
| **TCTD** | **T90** | **TLAB** | **TDIF** |
| | | | |
| 28.0179 | 28.0011 | 28.0012 | -0.0001 |
| 28.0196 | 28.0030 | 28.0029 | 0.0001 |
| 24.9891 | 24.9738 | 24.9738 | -0.0000 |
| 22.0175 | 22.0037 | 22.0038 | -0.0001 |
| 19.0068 | 18.9951 | 18.9950 | 0.0001 |
| 15.9622 | 15.9529 | 15.9529 | 0.0000 |
| 13.0607 | 13.0545 | 13.0545 | 0.0000 |
| 10.0078 | 10.0049 | 10.0052 | -0.0003 |
| 7.0033 | 7.0050 | 7.0046 | 0.0004 |
| 3.9376 | 3.9425 | 3.9427 | -0.0002 |
| 1.0039 | 1.0122 | 1.0121 | 0.0001 |
| 0.0476 | 0.0565 | 0.0565 | -0.0000 |
| 0.0464 | 0.0553 | 0.0553 | -0.0000 |
| Coefficients for correction, TEMP=TCTD+Pol(TCTD) | | | |

Polynomial degree is M=4
Number of data pairs is N=13
Coefficients, starting at lowest order:
co(0)= 8.952095e-03
co(1)= -6.829018e-04
co(2)= -8.990337e-05
co(3)= 5.035169e-06
co(4)= -7.576727e-08

Statistics:

| | | | |
|---|---|---|---|
| Range: | minimum | is | 5.530000e-02 |
| | Maximum | is | 2.800300e+01 |

| | | |
|---|---|---|
| Number of data points | is | 13 |
| Degree of fit | is | 4 |
| Degree of freedoms | is | 8 |
| Test sigq=rms/(N-M) | is | 1.882761e-05 |
| Mean error | is | -9.140658e-18 |
| 66 perc error, rms | is | 1.694485e-04 |
| 95 perc error, 2*rms | is | 3.388970e-04 |
| 99 perc error, 3*rms | is | 5.083455e-04 |
| Minimum of error | is | -3.302666e-04 |
| Maximum of error | is | 3.826571e-04 |

Table A2: M28/2 post-cruise temperature calibration of MKIIIB CTD, IFMK NB3, AUG 1994. Definitions as in table A1.
TEMP = c(0) + (1 + c(1))*TCTD + c(2)*TCTD^2 + c(3)*TCTD^3 + +

| Temperature calibration in ITS90 with CALTRC.M. | | | |
|---|---|---|---|
| IFMK NB3 AUG94 | | | |
| **TCTD** | **T90** | **TLAB** | **TDIF** |
| | | | |
| 28.0488 | 28.0310 | 28.0316 | -0.0006 |
| 27.9538 | 27.9372 | 27.9366 | 0.0006 |
| 22.8360 | 22.8208 | 22.8207 | 0.0001 |
| 17.8765 | 17.8648 | 17.8650 | -0.0002 |
| 12.9220 | 12.9155 | 12.9155 | -0.0000 |
| 8.2546 | 8.2547 | 8.2542 | 0.0005 |
| 3.0401 | 3.0452 | 3.0464 | -0.0012 |
| 0.0006 | 0.0094 | 0.0086 | 0.0008 |
| 0.0006 | 0.0094 | 0.0086 | 0.0008 |
| 0.0006 | 0.0094 | 0.0086 | 0.0008 |
| -0.8378 | -0.8306 | -0.8299 | -0.0007 |
| -0.8367 | -0.8292 | -0.8288 | -0.0004 |
| -0.8367 | -0.8292 | -0.8288 | -0.0004 |
| Coefficients for correction, TEMP=TCTD+Pol(TCTD) | | | |

Polynomial degree is M=5
Number of data pairs is N=13
Coefficients, starting at lowest order:
co(0)= 8.073036e-03
co(1)= -1.781593e-05
co(2)= -2.260227e-04
co(3)= 1.646537e-05
co(4)= -5.129529e-07
co(5)= 6.174792e-09

Statistics:
Range: minimum is -8.306000e-01
Maximum is 2.803100e+01

| | | |
|---|---|---|
| Number of data points | is | 13 |
| Degree of fit | is | 5 |
| Degree of freedoms | is | 7 |
| Test sigq=rms/(N-M) | is | 7.990552e-05 |
| Mean error | is | -2.328533e-17 |
| 66 perc error, rms | is | 6.392442e-04 |
| 95 perc error, 2*rms | is | 1.278488e-03 |
| 99 perc error, 3*rms | is | 1.917733e-03 |
| Minimum of error | is | -1.200394e-03 |
| Maximum of error | is | 7.569741e-04 |

Table A3: M28/2 pre-cruise laboratory pressure sensor calibration of MKIIIB CTD, IFMK NB3, NOV 1993. Calibration with the sensor immersed into a bath at two temperatures (1 C and 10 C). Unloading modes starting at different maximum pressures.

Pressure calibration with CALPRC.M.
IFMK NB3 NOV93
Input data with PCTD at reference pressure and temperatures:

N O T E : If spikes were removed do not use the last table in the output
Repeat calculation then with spikes removed from start on

| **TEMP PRES** | **0.6** | **0.7** | **0.6** | **0.6** | **9.8** | **10.4** | **10.2** | **10.0** | **25.1** | **24.9** | **24.9** | **25.0** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 1.6 | 1.8 | 1.8 | 1.6 | 0.9 | 1.3 | 1.3 | 1.2 | -0.3 | 0.5 | 0.5 | 0.5 |
| 500.0 | 501.5 | 505.2 | 505.7 | 505.5 | 500.6 | 503.7 | 505.0 | 505.1 | 499.5 | 504.3 | 504.6 | 504.3 |
| 1000.0 | 1002.5 | 1005.8 | 1006.4 | 1006.4 | 1001.5 | 1005.6 | 1006.0 | 1006.0 | 1000.6 | 1004.1 | 1005.5 | 1005.1 |
| 1500.0 | 1502.6 | 1504.2 | 1506.0 | 1505.2 | 1501.9 | 1504.0 | 1505.4 | 1504.7 | 1500.7 | 1502.9 | 1504.5 | 1504.1 |
| 2000.0 | 2001.6 | 2001.8 | 2003.9 | 2003.3 | 2000.9 | 2001.3 | 2003.2 | 2003.0 | 2000.0 | 2000.5 | 2002.5 | 2002.0 |
| 2500.0 | 2500.2 | -9999.0 | 2501.7 | 2501.3 | 2499.6 | -9999.0 | 2500.9 | 2500.6 | 2498.5 | -9999.0 | 2500.1 | 2499.9 |
| 3000.0 | 2998.3 | -9999.0 | 2999.4 | 2999.0 | 2997.7 | -9999.0 | 2998.8 | 2998.3 | 2996.7 | -9999.0 | 2998.0 | 2997.4 |
| 3500.0 | 3496.8 | -9999.0 | 3497.3 | 3497.1 | 3495.6 | -9999.0 | 3496.8 | 3496.7 | 3495.3 | -9999.0 | 3496.0 | 3495.7 |
| 4000.0 | 3995.9 | -9999.0 | 3995.2 | 3995.6 | 3994.9 | -9999.0 | 3995.1 | 3995.3 | 3994.3 | -9999.0 | 3994.3 | 3994.1 |
| 4500.0 | 4494.6 | -9999.0 | -9999.0 | 4494.2 | 4494.2 | -9999.0 | -9999.0 | 4493.5 | 4492.7 | -9999.0 | -9999.0 | 4493.2 |
| 5000.0 | 4993.4 | -9999.0 | -9999.0 | 4993.7 | 4993.4 | -9999.0 | -9999.0 | 4993.1 | 4992.3 | -9999.0 | -9999.0 | 4992.0 |
| 5500.0 | 5493.8 | -9999.0 | -9999.0 | 5493.6 | 5493.2 | -9999.0 | -9999.0 | 5492.9 | 5492.3 | -9999.0 | -9999.0 | 5491.8 |
| 6000.0 | 5993.7 | -9999.0 | -9999.0 | 5993.7 | 5993.3 | -9999.0 | -9999.0 | 5993.0 | 5992.4 | -9999.0 | -9999.0 | 5992.3 |

Loading curve at temperature T0= 0.6

| PCTD | PREF | PPOL | PDIF |
|---|---|---|---|
| | | | |
| 1.6 | 0.0 | 0.4 | -0.4 |
| 501.5 | 500.0 | 499.2 | 0.8 |
| 1002.5 | 1000.0 | 999.9 | 0.1 |
| 1502.6 | 1500.0 | 1500.4 | -0.4 |
| 2001.6 | 2000.0 | 2000.3 | -0.3 |
| 2500.2 | 2500.0 | 2500.1 | -0.1 |
| 2998.3 | 3000.0 | 2999.7 | 0.3 |
| 3496.8 | 3500.0 | 3499.7 | 0.3 |
| 3995.9 | 4000.0 | 4000.2 | -0.2 |
| 4494.6 | 4500.0 | 4500.1 | -0.1 |
| 4993.4 | 5000.0 | 4999.7 | 0.3 |
| 5493.8 | 5500.0 | 5500.4 | -0.4 |
| 5993.7 | 6000.0 | 5999.9 | 0.1 |

Coefficients for static correction at temperature T0
PRES(T0)=PCTD(T0)+Pol(PCTD(T0))
Polynomial degree is M=3
Number of data pairs is N=13
Coefficients, starting at lowest order:
co(0)= -1.182046e+00
co(1)= -3.105522e-03
co(2)= 1.919172e-06
co(3)= -1.996728e-10

Statistics:

| | | | |
|---|---|---|---|
| Range: | minimum | is | 0.000000e+00 |
| | maximum | is | 6.000000e+03 |

| | | |
|---|---|---|
| Number of data points | is | 13 |
| Degree of fit | is | 3 |
| Degree of freedoms | is | 9 |
| Test sigq=rms/(N-M) | is | 3.602675e-02 |
| Mean error | is | 3.484392e-15 |
| 66 perc error, rms | is | 3.602675e-01 |
| 95 perc error, 2*rms | is | 7.205351e-01 |
| 99 perc error, 3*rms | is | 1.080803e+00 |
| Minimum of error | is | -4.129902e-01 |
| Maximum of error | is | 7.819733e-01 |

Table A4: M28/2 post-cruise laboratory pressure sensor calibration of MKIIIB CTD, IFMK NB3, AUG 1994. Notation as in Table A3.

Pressure calibration with CALPRC.M.
'IFMK NB3 AUG94'
Input data with PCTD at reference pressure and temperatures:

N O T E : If spikes were removed do not use the last table in the output
Repeat calculation then with spikes removed from start on

| **TEMP PRES** | **1.8** | **1.8** | **1.8** | **1.8** | **10.0** | **10.0** | **9.9** | **10.0** | **25.1** | **25.0** | **25.0** | **25.0** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.9 | 1.2 | 1.1 | 1.3 | 1.4 | 1.4 | 1.5 | 1.4 | 0.8 | 1.1 | 1.2 | 1.1 |
| 500.0 | 500.7 | 504.8 | 505.2 | 505.1 | 501.0 | 505.0 | 505.4 | 505.2 | 500.6 | 504.7 | 505.0 | 504.4 |
| 1000.0 | 1002.0 | 1005.3 | 1006.4 | 1006.0 | 1002.1 | 1005.7 | 1006.3 | 1006.1 | 1001.7 | 1005.2 | 1006.2 | 1005.6 |
| 1500.0 | 1502.0 | 1503.7 | 1505.2 | 1504.8 | 1501.9 | 1503.9 | 1505.4 | 1504.8 | 1501.9 | 1503.7 | 1505.0 | 1504.4 |
| 2000.0 | 2001.1 | 2001.1 | 2003.2 | 2002.7 | 2000.6 | 2001.1 | 2003.6 | 2002.9 | 2000.8 | 2000.7 | 2002.8 | 2002.4 |
| 2500.0 | 2499.5 | -9999.0 | 2501.2 | 2500.5 | 2499.5 | -9999.0 | 2501.1 | 2500.6 | 2499.3 | -9999.0 | 2500.4 | 2500.2 |
| 3000.0 | 2998.0 | -9999.0 | 2998.6 | 2998.4 | 2997.9 | -9999.0 | 2999.3 | 2998.4 | 2997.7 | -9999.0 | 2998.3 | 2998.0 |
| 3500.0 | 3496.2 | -9999.0 | 3497.0 | 3496.6 | 3496.1 | -9999.0 | 3497.1 | 3496.3 | 3496.2 | -9999.0 | 3495.9 | 3496.0 |
| 4000.0 | 3994.6 | -9999.0 | 3994.7 | 3994.7 | 3994.8 | -9999.0 | 3994.8 | 3994.7 | 3994.4 | -9999.0 | 3994.4 | 3994.4 |
| 4500.0 | 4494.2 | -9999.0 | -9999.0 | 4493.3 | 4493.6 | -9999.0 | -9999.0 | 4493.7 | 4493.5 | -9999.0 | -9999.0 | 4493.6 |
| 5000.0 | 4993.4 | -9999.0 | -9999.0 | 4992.3 | 4991.9 | -9999.0 | -9999.0 | 4992.0 | 4992.9 | -9999.0 | -9999.0 | 4992.6 |
| 5500.0 | 5492.9 | -9999.0 | -9999.0 | 5492.4 | 5490.9 | -9999.0 | -9999.0 | 5492.6 | 5492.4 | -9999.0 | -9999.0 | 5492.2 |
| 6000.0 | 5992.1 | -9999.0 | -9999.0 | 5993.0 | 5992.2 | -9999.0 | -9999.0 | 5991.6 | 5991.9 | -9999.0 | -9999.0 | 5992.8 |

Loading curve at temperature T0= 1.8

| PCTD | PREF | PPOL | PDIF |
|---|---|---|---|
| | | | |
| 0.9 | 0.0 | 0.3 | -0.3 |
| 500.7 | 500.0 | 499.1 | 0.9 |
| 1002.0 | 1000.0 | 1000.1 | -0.1 |
| 1502.0 | 1500.0 | 1500.5 | -0.5 |
| 2001.1 | 2000.0 | 2000.4 | -0.4 |
| 2499.5 | 2500.0 | 2500.0 | 0.0 |
| 2998.0 | 3000.0 | 2999.9 | 0.1 |
| 3496.2 | 3500.0 | 3499.6 | 0.4 |
| 3994.6 | 4000.0 | 3999.4 | 0.6 |
| 4494.2 | 4500.0 | 4500.3 | -0.3 |
| 4993.4 | 5000.0 | 5000.4 | -0.4 |
| 5492.9 | 5500.0 | 5500.4 | -0.4 |
| 5992.1 | 6000.0 | 5999.6 | 0.4 |

Coefficients for static correction at temperature T0
PRES(T0)=PCTD(T0)+Pol(PCTD(T0))

Polynomial degree is M=3
Number of data pairs is N=13
Coefficients, starting at lowest order:
co(0)= -5.485625e-01
co(1)= -2.914603e-03
co(2)= 1.775858e-06
co(3)= -1.779409e-10

Statistics:

| | | | |
|---|---|---|---|
| Range: | minimum | is | 0.000000e+00 |
| | Maximum | is | 6.000000e+03 |

| | | |
|---|---|---|
| Number of data points | is | 13 |
| Degree of fit | is | 3 |
| Degree of freedoms | is | 9 |
| Test sigq=rms/(N-M) | is | 4.565122e-02 |
| Mean error | is | 9.052588e-16 |
| 66 perc error, rms | is | 4.565122e-01 |
| 95 perc error, 2*rms | is | 9.130244e-01 |
| 99 perc error, 3*rms | is | 1.369537e+00 |
| Minimum of error | is | -4.770903e-01 |
| Maximum of error | is | 8.850320e-01 |

Table A5: M28/2, MKIIIB CTD, IFMK NB3, APR 1993, pressure senor's dynamic response to temperature changes. Coefficients are outer and inner sensor time constants tau1 and tau2 and the amplitude k (Mueller et al., 1995; see text).

| **Coefficients for dynamic pressure correction** | | | |
|---|---|---|---|
| tau1/s | tau2/s | ishift/s | k/(dbar/K) |
| 83.5033 | 5178.8681 | 499.2000 | 0.1787 |

Table A6: M28/2, MKIIIB CTD, IFMK NB3: Calibration of conductivity cell.

CRC=a1 + (a2+a3*CC)*CC + (a4+a5*PROF )*PROF

Coefficients:

| | |
|---|---|
| 1 | -6.5160e-04 |
| 2 | 3.4858e-04 |
| 3 | 0 |
| 4 | -4.5671e-04 |
| 5 | 9.9464e-06 |

Final statistics ofresiduals:

Number of cycles N=93

| | Cond. mS/cm | Salinity psu |
|---|---|---|
| Min | -2.6278e-03 | -3.1749e-03 |
| Max | 2.8445e-03 | 3.4172e-03 |
| Mean | 7.9014e-05 | 9.3414e-05 |
| Median | 7.6402e-17 | -9.1954e-06 |
| Std. | 1.3942e-03 | 1.5415e-03 |