Network System Testing and Deployment Plan

Prepared by

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PURPOSE

This plan provides guidance for initial testing and deployment of the Network System.

TEAM

Team Lead	Steve Stanic, Landry Bernard
Deployment Chief	Arne Diercks
Data	Vishwamithra Sunkara

OUTLINE

- **Conduct Integration Test** of Network System sensor package at MRC Connect entire array of sensors to TRBM and Surface buoy to confirm operational status of all sensors.
    - Test found that 2 of the Temperature sensors were not responding properly during sleep and wake cycles. Those sensors were returned to Manufacturer for replacement.
    - Two new sensors were delivered and tested out fully functional.
- **Acquire data** from all temperature sensors under controlled conditions in a single water bath for pre deployment inspection.
- **Final System performance Evaluation** prior to deployment under controlled condition at MRC
- Securely pack and load entire network system onto deployment vessel
- **Deploy Sensor Array** at a location North of Cat Island in the MS Sound.
- **Acquire data** from Network System via remote Data transfer

TEST OBJECTIVES

INITIAL ACCEPTANCE AND INTEGRATION TEST

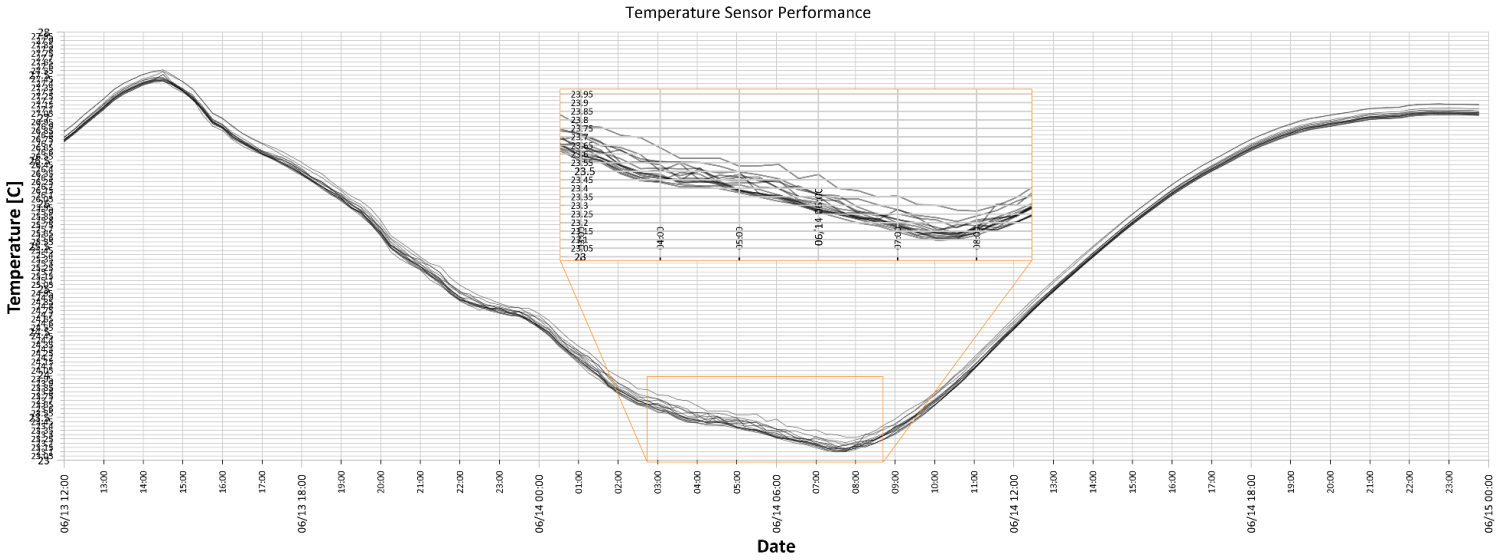
1) Setup entire Network System at Marine Research Center (MRC) in Gulfport.
2) Power on system and monitor output at buoy.
3) Connect via remote access to buoy and observe data acquisition and data transfer to server.
4) Connect via remote access into the server to monitor data arrival.
5) Collect several days' worth of data from system.
6) QC incoming data to verify functionality of sensors and acquired data against standard.
7) Evaluate and mark erroneous sensor returns.
8) Return faulty sensors for repair.

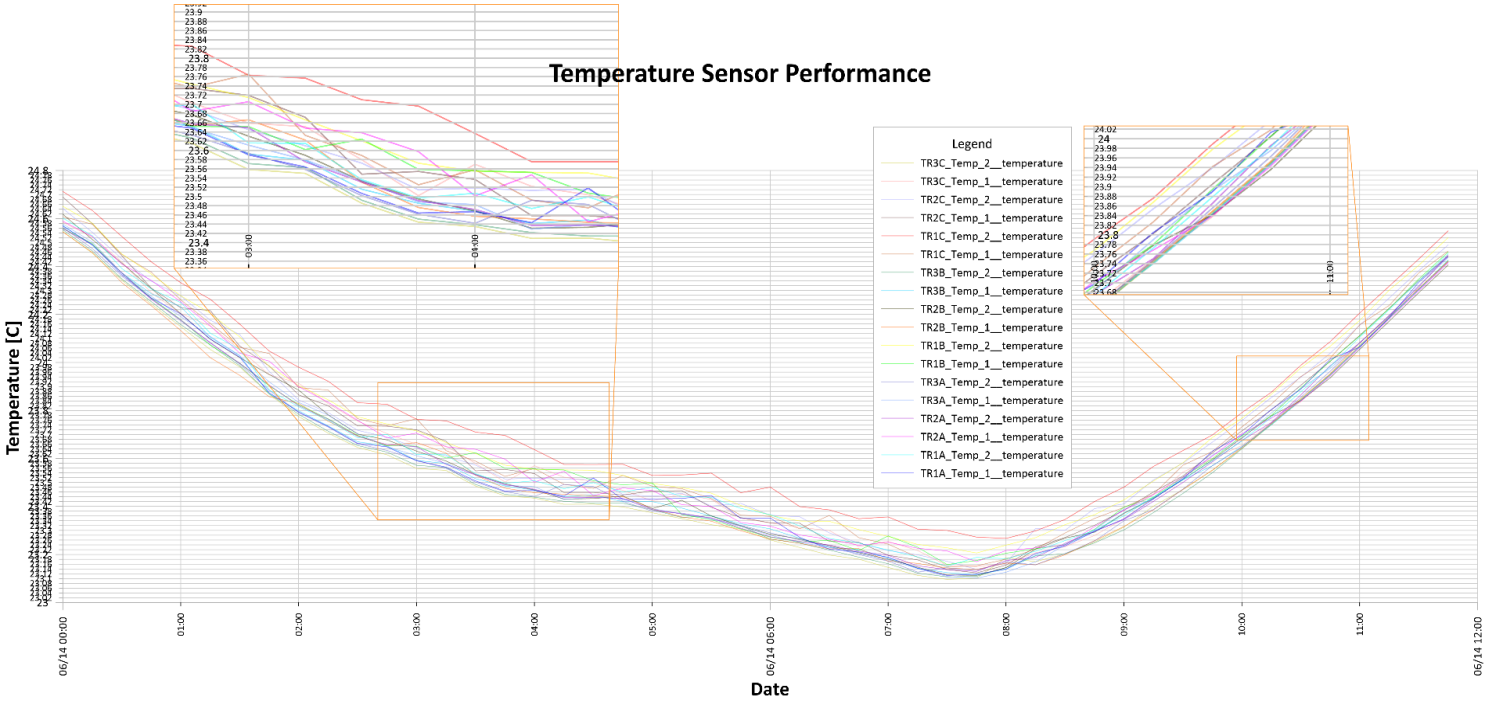
Initial Acceptance and Integration Test Summary

1) The entire Network System is setup at MRC in Gulfport.
2) All the electrical connections are made as per the electrical schematic provided by the vendor. The system was powered on using the building power supply and monitored the outputs of all sensors for any loose connections.
3) Connected a work laptop to the buoy via buoy Wi-Fi and cellular network. Monitored the data acquisition rates of the sensors and the data flow from the sensors to the server.
4) Accessed the sensor data from the database and displayed the data in the html based open-source data visualization platform Grafana.
5) Noticed that two temperature sensors outputs were intermittent. Troubleshooted these two sensors and found that these two sensors were faulty. Sent faulty sensors to the manufacturer for repairs.
6) The Network System was kept powered up collecting several days of data to monitor the health of the system and perform QC of incoming data.

Pre-Deployment Test

1) Compare and measure the performance of the 18 RBR RBRCoda^3-T sensors to establish measurement baseline.
2) Compare and measure the performance of the 2 RBR RBRCoda^3-C.T.D. sensors to establish measurement baseline.
3) Compare RBRCoda^3-T data to RBR RBRCoda^3-C.T.D. temperatures to establish baseline and offsets of sensors.
4) Immerse all in water temperature sensors in a single container to evaluate performance of entire sensor package.
5) Record data output and note any outliers during test, given the calibration data.
6) Ready entire network system for deployment, making as few as possible disconnects.



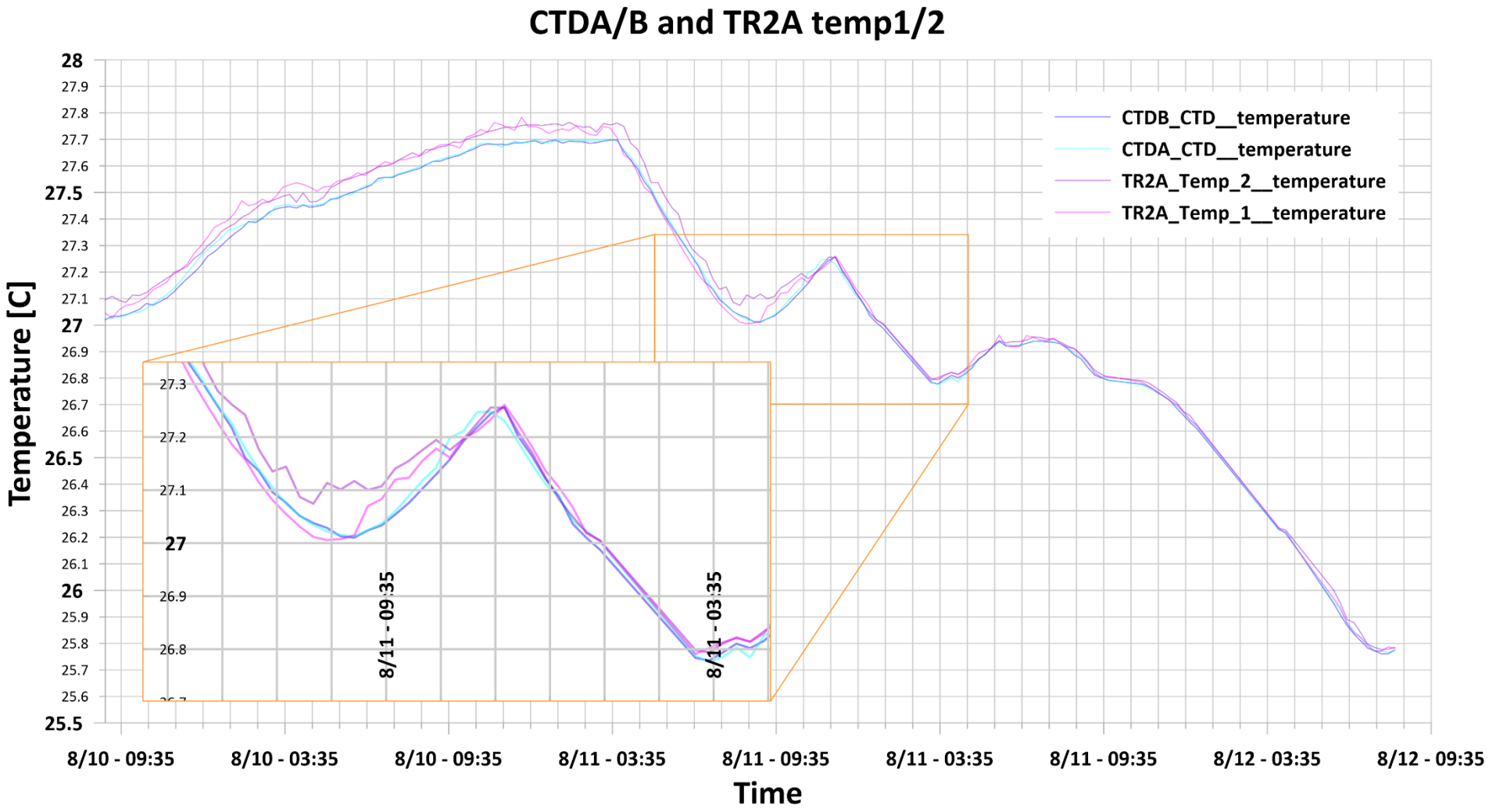


Temperature sensors data over a 20 day sampling period, showed a variation of 0.26 °C during in-water test (see Figures to the left). Sensors were allowed to equilibrate for several days submersed in the same water bucket. Strongest variations in measured temperatures between individual sensors occurred during the shallowest slope in of measurements of temperature over time.

Variations of individual sensors of the mean temperature will be calculated to provide individual offsets for each of the sensors.

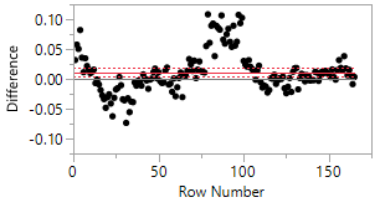
Stats for 18 individual RBR Temp sensors, including deviation of average mean over all sensor average.

	TR1A Temp 1	TR1A Temp 2	TR1B Temp 1	TR1B Temp 2	TR1C Temp 2	TR2A Temp 1	TR2A Temp 2	TR2B Temp 1	TR2C Temp 1	TR2C Temp 2	TR3A Temp 1	TR3A Temp 2	TR3B Temp 1	TR3B Temp 2	TR3C Temp 2	TR2B Temp 2	TR1C Temp 1	TR3C Temp 1	Average Temp over all sensors
N	1346	1344	1344	1344	1344	1344	1344	1344	1344	1344	1341	1344	1344	1344	1344	1344	1341	1259	
N Missing	2	4	4	4	4	4	4	4	4	4	7	4	4	4	4	4	7	89	
Mean	26.10	26.13	26.14	26.20	26.20	26.11	26.11	26.10	26.10	26.12	26.10	26.13	26.10	26.11	26.10	26.10	26.11	26.07	**26.12**
Deviation from Average Mean	0.02	-0.02	-0.02	-0.08	-0.08	0.01	0.01	0.02	0.02	0.00	0.02	-0.01	0.02	0.01	0.02	0.02	0.00	0.04	
Min	23.11	23.15	23.16	23.21	23.27	23.17	23.13	23.14	23.12	23.14	23.10	23.13	23.12	23.11	23.10	23.11	23.15	23.15	**23.14**
Deviation from Average Min	0.03	-0.01	-0.02	-0.06	-0.13	-0.03	0.01	0.00	0.02	0.00	0.04	0.02	0.03	0.04	0.05	0.03	-0.01	-0.01	
Max	28.36	28.40	28.45	28.49	28.47	28.37	28.38	28.37	28.34	28.38	28.42	28.46	28.36	28.39	28.37	28.37	28.36	28.34	**28.39**
Deviation from Average MAX	0.03	-0.01	-0.05	-0.10	-0.07	0.02	0.01	0.02	0.06	0.02	-0.03	-0.07	0.03	0.01	0.02	0.03	0.03	0.05	
Range	5.25	5.25	5.29	5.28	5.20	5.20	5.25	5.23	5.21	5.24	5.32	5.34	5.25	5.28	5.27	5.25	5.21	5.19	
CV	4.73	4.74	4.74	4.74	4.69	4.72	4.74	4.74	4.69	4.70	4.74	4.79	4.74	4.76	4.76	4.73	4.69	4.71	
Median	26.41	26.45	26.46	26.52	26.50	26.42	26.42	26.41	26.40	26.42	26.41	26.45	26.42	26.42	26.41	26.42	26.42	26.39	
Geometric Mean	26.07	26.11	26.11	26.17	26.17	26.08	26.08	26.07	26.07	26.09	26.07	26.10	26.07	26.08	26.07	26.07	26.09	26.05	
Interquartile Range	1.86	1.86	1.87	1.87	1.86	1.86	1.86	1.86	1.85	1.87	1.86	1.87	1.85	1.86	1.86	1.87	1.86	1.87	
Quantiles90	27.52	27.57	27.57	27.63	27.62	27.53	27.53	27.53	27.52	27.54	27.52	27.55	27.52	27.54	27.53	27.52	27.53	27.48	


CTDA/B and TR2A temp1/2
CTDB_CTD__temperature
CTDA_CTD__temperature
TR2A_Temp_2__temperature
TR2A_Temp_1__temperature
Temperature [C]
Time
8/10 - 09:35
8/10 - 03:35
8/10 - 09:35
8/11 - 03:35
8/11 - 09:35
8/11 - 03:35
8/11 - 09:35
8/12 - 03:35
8/12 - 09:35
8/11 - 09:35
8/11 - 03:35

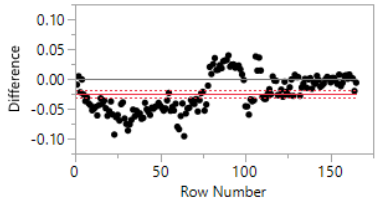
Matched Pairs

Difference: TR2A Temp 2: temperature-TR2A Temp 1: temperature



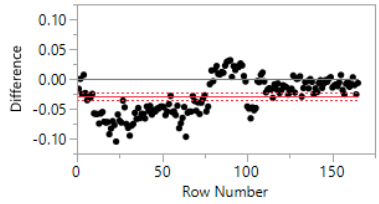
TR2A Temp 2: temperature	27.1865	t-Ratio	4.308852
TR2A Temp 1: temperature	27.175	DF	164
Mean Difference	0.01144	Prob > |t|	<.0001*
Std Error	0.00265	Prob > t	<.0001*
Upper 99%	0.01835	Prob < t	1.0000
Lower 99%	0.00452		
N	165		
Correlation	0.99751		

Difference: CTDA CTD: temperature-TR2A Temp 1: temperature



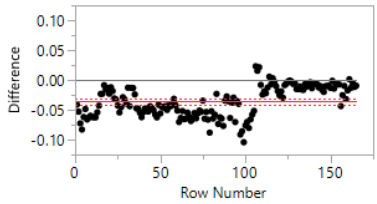
CTDA CTD: temperature	27.1508	t-Ratio	-10.1957
TR2A Temp 1: temperature	27.175	DF	164
Mean Difference	-0.0242	Prob > |t|	<.0001*
Std Error	0.00237	Prob > t	1.0000
Upper 99%	-0.018	Prob < t	<.0001*
Lower 99%	-0.0304		
N	165		
Correlation	0.9984		

Difference: CTDB CTD: temperature-TR2A Temp 1: temperature



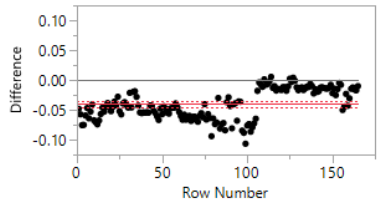
CTDB CTD: temperature	27.1459	t-Ratio	-12.1214
TR2A Temp 1: temperature	27.175	DF	164
Mean Difference	-0.0292	Prob > |t|	<.0001*
Std Error	0.00241	Prob > t	1.0000
Upper 99%	-0.0229	Prob < t	<.0001*
Lower 99%	-0.0354		
N	165		
Correlation	0.99833		

Difference: CTDA CTD: temperature-TR2A Temp 2: temperature



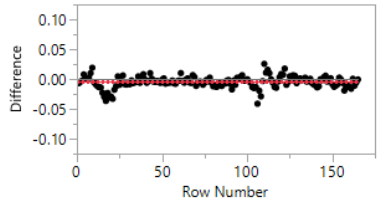
CTDA CTD: temperature	27.1508	t-Ratio	-17.9841
TR2A Temp 2: temperature	27.1865	DF	164
Mean Difference	-0.0356	Prob > |t|	<.0001*
Std Error	0.00198	Prob > t	1.0000
Upper 99%	-0.0305	Prob < t	<.0001*
Lower 99%	-0.0408		
N	165		
Correlation	0.99892		

Difference: CTDB CTD: temperature-TR2A Temp 2: temperature



CTDB CTD: temperature	27.1459	t-Ratio	-20.959
TR2A Temp 2: temperature	27.1865	DF	164
Mean Difference	-0.0406	Prob > |t|	<.0001*
Std Error	0.00194	Prob > t	1.0000
Upper 99%	-0.0356	Prob < t	<.0001*
Lower 99%	-0.0457		
N	165		
Correlation	0.99897		

Difference: CTDB CTD: temperature-CTDA CTD: temperature



CTDB CTD: temperature	27.1459	t-Ratio	-6.61735
CTDA CTD: temperature	27.1508	DF	164
Mean Difference	-0.005	Prob > |t|	<.0001*
Std Error	0.00075	Prob > t	1.0000
Upper 99%	-0.003	Prob < t	<.0001*
Lower 99%	-0.0069		
N	165		
Correlation	0.99979		

FIELD INTEGRATION TEST (FIT):

Re-assembled Network System will be deployed in multiple phases

1) Phase 1 is the deployment of the TRBM and the surface USM-R2 buoy with its anchors.
2) Phase 2 will utilize marker buoys deployed by a small surface vessel at predetermined distances to the location of the TRBM.
3) Once the marker buoys are deployed, individual node point anchors with sensor electronics attached to them will be deployed and connections to the node will be established by divers.
4) When completely assembled, a final test will be performed to confirm operational status of the Network System.
    - Test Wi-Fi connectivity with surface buoy
    - Test remote download of data via cell network from buoy

PHASE 1 (AFTER DEPLOYMENT OF NEXSENS CB-650 SURFACE DATA BUOY AND TRBM):

Establish buoy communications: The buoy is deployed after powering the system by switching the "Power" button on the buoy to "ON" position. The cellular network takes few (2 to 5) minutes to startup and establish the cellular connection. Then, after the buoy is deployed, a work laptop is connected to the buoy via Wi-Fi and cellular network. Once connected to the buoy, access the modem IP address and enter the username and password. Close and Open the I/O #1 and wait 50 seconds. Access VAK (The buoy Data Acquisition system): Enter http://<modem_ip>:4201. Once connected to VAK, press the Prevent Shutdown button to prevent it to enter sleep mode. In the Home Page, check the logs for any error messages.

Evaluate data communication functionality: Once the buoy is connected to a work laptop, each sensor is turned on one after another. Live charts menu is used to observe the data stream from the sensor that is turned on. Access the **Live Charts** menu and select the instrument from the **Measurement** dropdown menu. Click **Get Values** to fetch the received data from that particular sensor. Do it for all the sensors and check for any errors.

Evaluate observations data from the buoy: Make connection to the OceanCube server and access the Grafana page. Observe the data transmitted by the buoy to the database on corresponding Grafana dashboards for few data cycles. Check each corresponding dashboard of the sensors equipped on the buoy for any erroneous activity. The buoy is equipped with weather station, wind sensor and tide sensor.

Evaluate real time hydrophone data: The hydrophone data is not visualized on Grafana. To access the hydrophone, use the hydrophone IP address. Turn on the hydrophone and view the live charts on the webpage for any errors. Monitor the hydrophone data for few data cycles.

PHASE 2 (AFTER ALL NODE SENSOR MOORINGS HAVE BEEN DEPLOYED AND CONNECTED TO TRBM):

Evaluate all sensor data in real time: While the whole network system is deployed and operational, monitor the health of the system by checking the observations data on Grafana

dashboards. Check for any intermittent and/or erroneous data reception. Use calibration certificates to check the quality and the measurement accuracy of the sensors.

Evaluate data arrival at shore-based server: Monitor the through-put of the server and database while the network system is operational. Check if the power requirements of each sensor are within the safe limits by monitoring the "instrument Hub" dashboard of the corresponding sensor. Use "data transmitter" dashboard to make sure the data usage is within the bandwidth of the cellular modem.

PERFORMANCE EVALUATION DURING FIRST WEEK AFTER FIELD DEPLOYMENT

1) Evaluate weather data from buoy
2) Evaluate real time ADCP data
3) Evaluate real time hydrophone data
4) Evaluate all sensor data in real time
5) Evaluate data arrival at shore based server

Figure 1: Assembled Network System during testing phase at the MRC.

SYSTEM COMPONENTS:

NEXSENS CB-650 SURFACE DATA BUOY

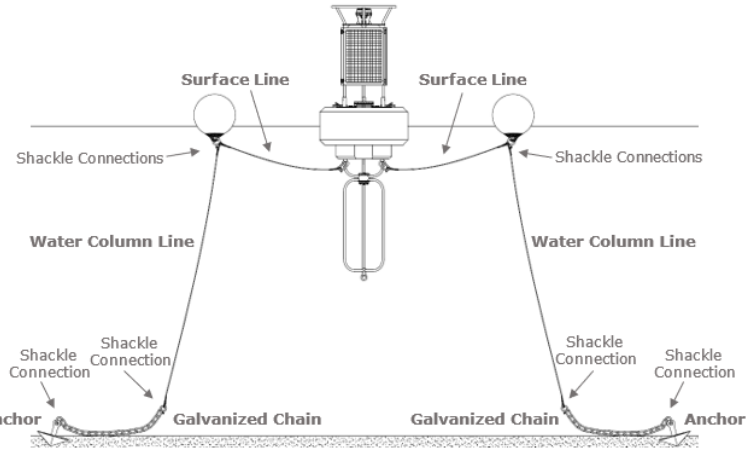


Figure 2: NexSens CB-650 Data Buoy Two-Point mooring setup

Figure 3: Surface Data Buoy

Table 1: NexSens CB-650 Buoy Specifications

Hull Dimensions	38 (96.52 cm) outside diameter; 22” (55.88 cm) tall
Tower Dimensions	40” (101.60 cm) tall; 7/8 tubular
Data Well Dimensions	10.3” (26.16 cm) inside diameter; 21.5” (54.61 cm) tall
Weight	215 lbs. (97.52 kg)
Buoyancy	650 lbs. (294.84 kg)
Hull Material	Cross-linked polyethylene foam with polyurea coating & stainless steel deck
Tower /Hardware Material	316 stainless steel
Mooring Attachments	1 or 2 point with ¾” eyenuts

Data are being transmitted by the buoy every 15 min. and transmitted to server at http://131.95.7.148:8888

INTEGRATED SENSORS

Vaisala WINDCAP © Ultrasonic Wind Sensor Series WMT700 (at Instrument Hub Buoy: WMT700)

Recorded Data:

1. wind_speed_avg
2. wind_speed_max
3. wind_speed_min
4. wind_direction_avg
5. wind_direction_min
6. wind_direction_max

Figure 4: Vaisala WINDCAP WMT700

Vaisala Weather Transmitter WXT534 (at Instrument Hub Buoy: WXT534)

Recorded Data:

1. wind_speed_avg
2. wind_speed_max
3. wind_speed_min
4. wind_direction_avg
5. wind_direction_min
6. wind_direction_max
7. air_temperature
8. air_humidity
9. air_pressure
10. rain_accumulation
11. rain_duration
12. rain_intensity
13. hail_accumulation
14. hail_duration
15. hail_intensity

Figure 5: Vaisala Weather Transmitter WXT534

Seaview Wave Sensor SVS-603

Recorded Data:

1. Heading
2. wave_height
3. dominant_period
4. dominant_period_FW
5. dominant_period_TW
6. wave_direction
7. max_wave_height
8. max_wave_period
9. angle_roll
10. angle_pitch
11. date_time

Figure 6: Seaview Wave Sensor SVS-603

Solar Charge Controller Renogy Rover

Recorded Data:

1. charging_status
2. load_power
3. load_current
4. load_voltage
5. solar_power
6. solar_voltage
7. solar_current
8. battery_voltage
9. battery_percentage
10. battery_temperature
11. controller_temperature
12. charging_amp_hours_today
13. discharging_amp_hours_today
14. power_generation_today

Figure 7: Solar Charge Controller Renogy Rover

TRAWL RESISTANT BOTTOM MOUNT (TRBM) BY *MOORING SYSTEMS, INC.*

General Purpose TRBM Specifications

Figure 8: General Purpose Trawl Resistant Bottom Mount (Mooring Systems Inc.)

Table 2: General Purpose TRBM Specifications

Cover Material	3/8” (9.5 mm) Urethane
Base Material	1” (25.4 mm) Fiberglass
Gimbaled Mount	Molded Urethane Ring
Fasteners	316 Stainless
Length	70” (1775 mm)
Width	50” (1270 mm)
Height (outside)	22” (558 mm)
Height (inside)	19” (480 mm)
Weight in Air	132 lbs. (60 kg) empty
Weight in Water	50 lbs. (23 kg) empty

INSTRUMENT HUB TRBM

Nortek ADCP

Recorded Data:

1. sound_speed
2. heading
3. pitch
4. roll
5. pressure
6. temperature

Figure 9: Nortek ADCP

RBRcoda³ D Tide Sensor (at Instrument Hub TRBM: Tidal Sensor")

Recorded Data:

1. pressure

Figure 10: RBRcoda³ D Tide Sensor

OCEAN SONICS LTD ICLISTEN HYDROPHONE MODEL RB9-ETH, S/N 6126

Figure 11: ICLISTEN HYDROPHONE

TEMPERATURE NODE SETUP:

A total of 9 small moorings, each with 2 RBRCoda^3-T sensors, connected to the central node computer in the TRBM via a single junction box located on the anchor.

Three of these moorings are combined in each of the three arms extending outward from the TRBM Node located at the center (see Figure 6 below).

Table 3:RBRCoda3 T Temperature Sensor

Sensor	S/N	Sample Interval (Seconds)	Sample period (cycles per hour)
TR-A-1-1	205778	10	5
TR-A-1-2	205766	10	5
TR-A-2-1	205768	10	5
TR-A-2-2	205770	10	5
TR-A-3-1	205779	10	5
TR-A-3-2	205764	10	5
TR-B-1-1	205772	10	5
TR-B-1-2	205773	10	5
TR-B-2-1	205769	10	5
TR-B-2-2	205762	10	5
TR-B-3-1	205771	10	5
TR-B-3-2	205777	10	5
TR-C-1-1	207219	10	5
TR-C-1-2	205775	10	5
TR-C-2-1	205767	10	5
TR-C-2-2	205763	10	5
TR-C-3-1	207220	10	5
TR-C-3-2	205765	10	5

Figure 12: Temperature Node.

CTD NODE SETUP:

Two moorings, each equipped with a RBR*concerto*^{3}-C.T.D. multi channel data logger are part of the Network System Setup. CTD-A and CTD-B, each a single mooring with 1 CTD and at the base to the Node-Communications junction box, connected by cable to the TRBM.

Name	Serial Number
CTD-A	205781
CTD-B	205782

Recorded Data:

1. Conductivity
2. Temperature
3. Pressure
4. odo_temperature
5. oxygen_concentration
6. sea_pressure
7. depth
8. salinity
9. speed_of_sound
10. specific_conductivity
11. oxygen_saturation

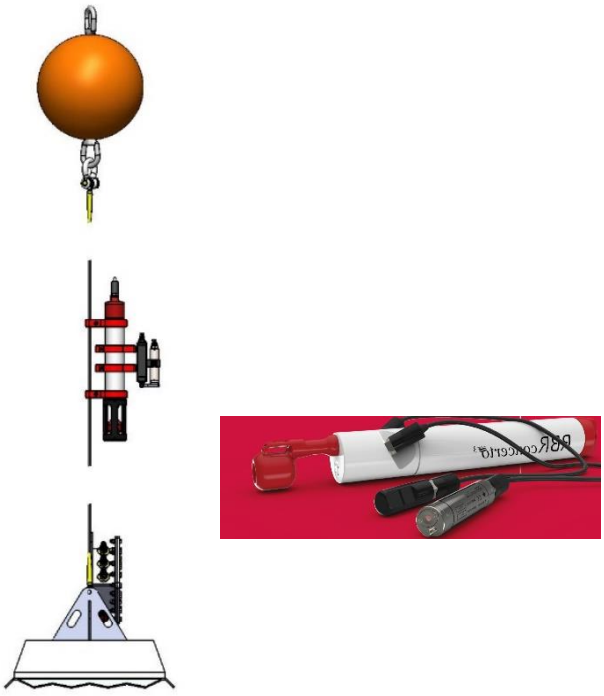


Figure 13:CTD Node wit RBR CTD.

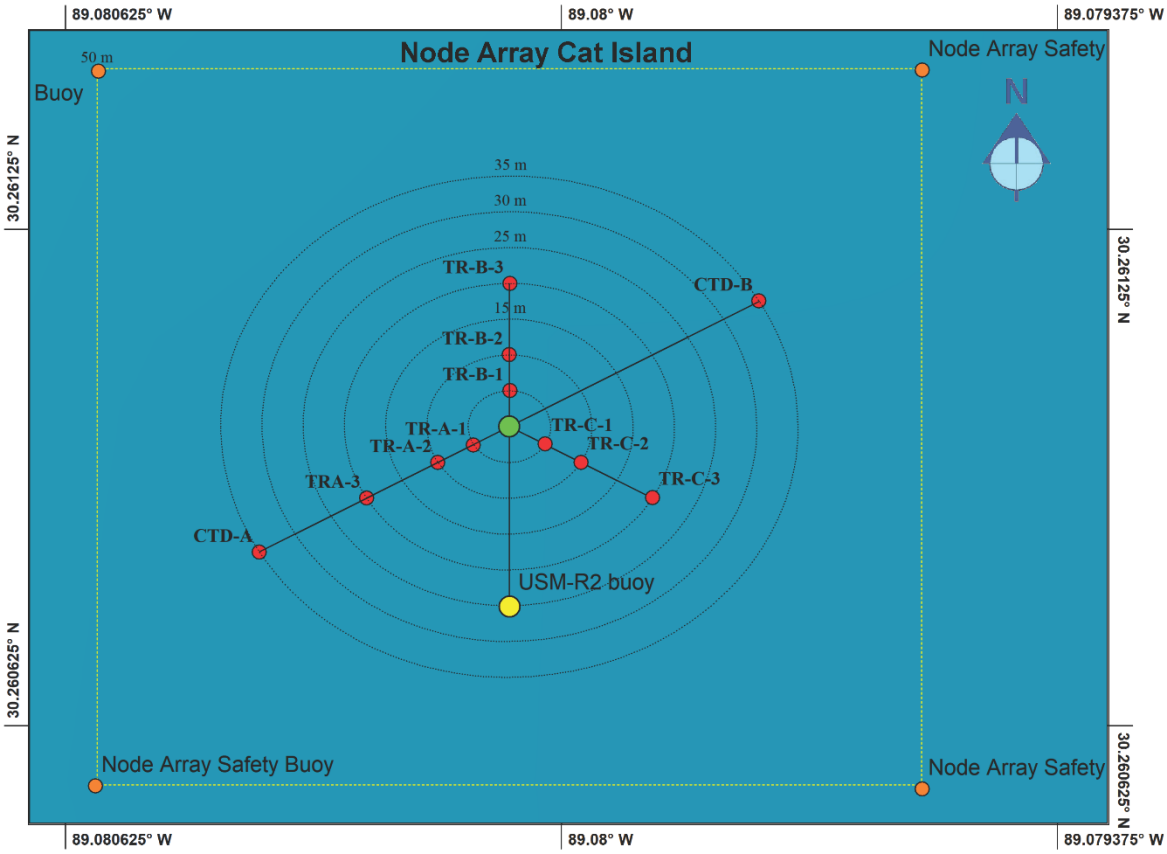


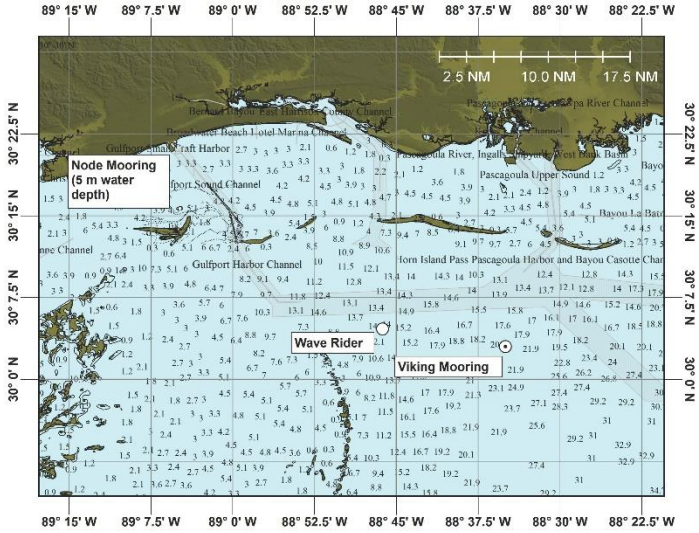
Figure 14: Planned Network System Deployment Layout after completed Phase 2.

Deployment Plan

M/V Tyson B

August 23 to August 27- 2021

1) Network system will be deployed north of Cat Island as part of a mooring deployment and recovery cruise



8/23/2021 MOBILIZATION AFTER 8AM IN GPT HARBOR.

Network-array surface buoy, two concrete anchors (500lbs each), TRBM and
4 safety buoys with 4 truck brake drum anchors (one drum per buoy).
Surface Marker buoys to mark node

After loading transit to Cat Island Deployment site

Deployment order:

Surface Buoy	30° 15.65998' N, 89° 4.80392' W
Network Array TRBM	30° 15.65998' N, 89° 4.80392' W
Network Array Safety Buoy 1	30° 15.65998' N, 89° 4.80392' W
Network Array Safety Buoy 2	30° 15.68701' N, 89° 4.77271' W
Network Array Safety Buoy 3	30° 15.63271' N, 89° 4.77271' W
Network Array Safety Buoy 4	30° 15.63294' N, 89° 4.83523' W

4 lifts within reach of crane (20m distance from each other, Tyson B crane has a 39m reach, with 8,000 lbs capacity at full extension)

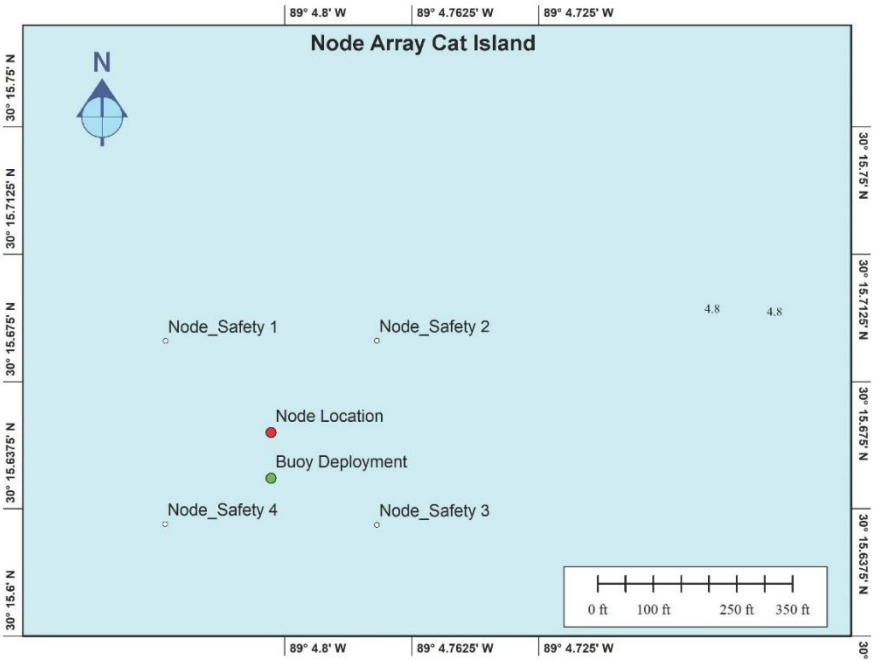
Suggested order of deployment:

1. concrete anchor #1
2. surface buoy
3. concrete anchor #2
4. TRBM /Node

We will mark the location of TRBM with a surface float to mark its position and to allow the diver an easy descent to the TRBM to connect the cables to the individual sensors.

4 additional lifts of safety moorings at 50m distance to TRBM, 1 truck brake drum anchor per mooring, those can be "man-handled"

During Phase 2 the small anchors with the temp and CTD sensors will be placed and connected by divers to the TRBM



APPENDIX OF CALIBRATION DATA SHEETS

RBR

Pressure Calibration Certificate

RBRcoda³ D|tide16 s/n: 205761
Sensor rating: 20 dbar s/n: L214795
Nominal accuracy: 0.05%FS (0.01 dbar)
Reference instrument: Mensor CPC6000 s/n: 612676

Applied pressure, P_{app} (dbar)	Voltage ratio, V	Measured pressure, P_c (dbar)	Calibration error (dbar)
10.027	0.129693	10.0274	-0.0000
12.000	0.154228	11.9999	-0.0001
14.000	0.179067	14.0001	-0.0001
16.000	0.203864	16.0001	0.0001
18.000	0.228615	17.9996	-0.0001
20.000	0.253333	20.0000	0.0001
22.000	0.278007	21.9999	-0.0001
24.000	0.302637	24.0001	0.0000
26.000	0.327224	26.0001	-0.0000
28.000	0.351765	28.0000	-0.0001
30.000	0.376263	29.9999	-0.0001

Coefficients

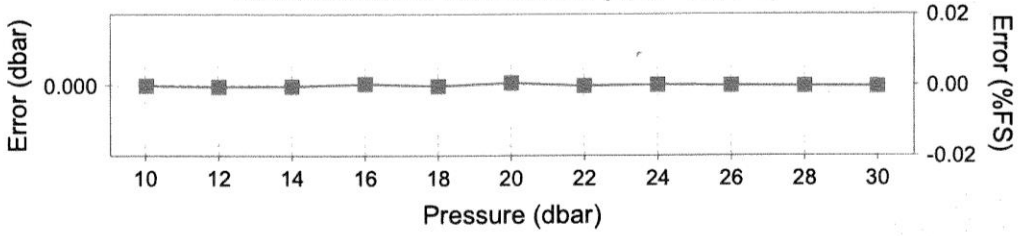
C0:	-39.147384E-3
C1:	79.71752
C2:	2.2275455
C3:	758.9983E-3
X0:	10.0296
X1:	7.623532E-3
X2:	66.76267E-6
X3:	-290.5105E-9
X4:	322.2121E-6
X5:	22.099691

$$P_c = X_0 + \frac{P_m - X_0 - X_1(T - X_5) - X_2(T - X_5)^2 - X_3(T - X_5)^3}{1 + X_4(T - X_5)}$$

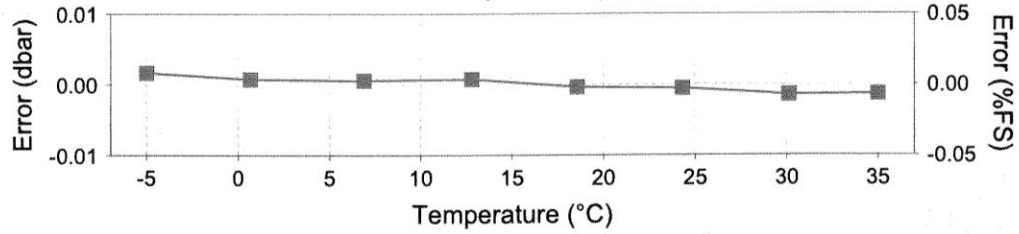
Head (mm) = 311

$$P_m = C_0 + C_1 V + C_2 V^2 + C_3 V^3$$

Calibration error vs. Pressure (Tcal = 22.1°C)



Calibration error vs. Temperature (Patm = 10.05 dbar)



Calibration Date: 2020-11-28
Issue Date: 2020-11-30
File Name: 205761_20201130_1120P.rsk

Operator: dluong

Approver: kmalorny

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RBR

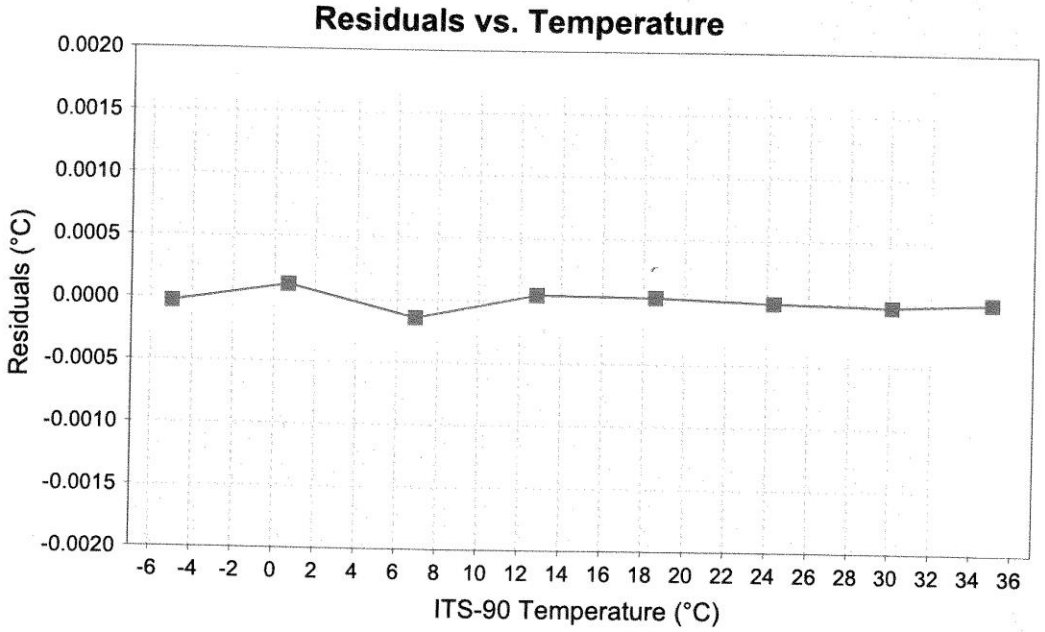
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205762 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.97140	0.739412	-4.97143	-0.00003
0.67275	0.677400	0.67287	0.00011
6.89799	0.603917	6.89784	-0.00014
12.80487	0.532249	12.80491	0.00005
18.57324	0.463383	18.57327	0.00003
24.31829	0.398359	24.31829	-0.00000
30.11210	0.338212	30.11207	-0.00002
34.99716	0.292554	34.99717	0.00001

Coefficients

C0:	3.464633E-3
C1:	-250.66652E-6
C2:	2.508184E-6
C3:	-64.72184E-9



Calibration Date: 2020-12-04
Issue Date: 2020-12-05
Calibration ID: 42925

Operator: T. Akuetteh
takuetteh

Approver:
kmalorny

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RBR

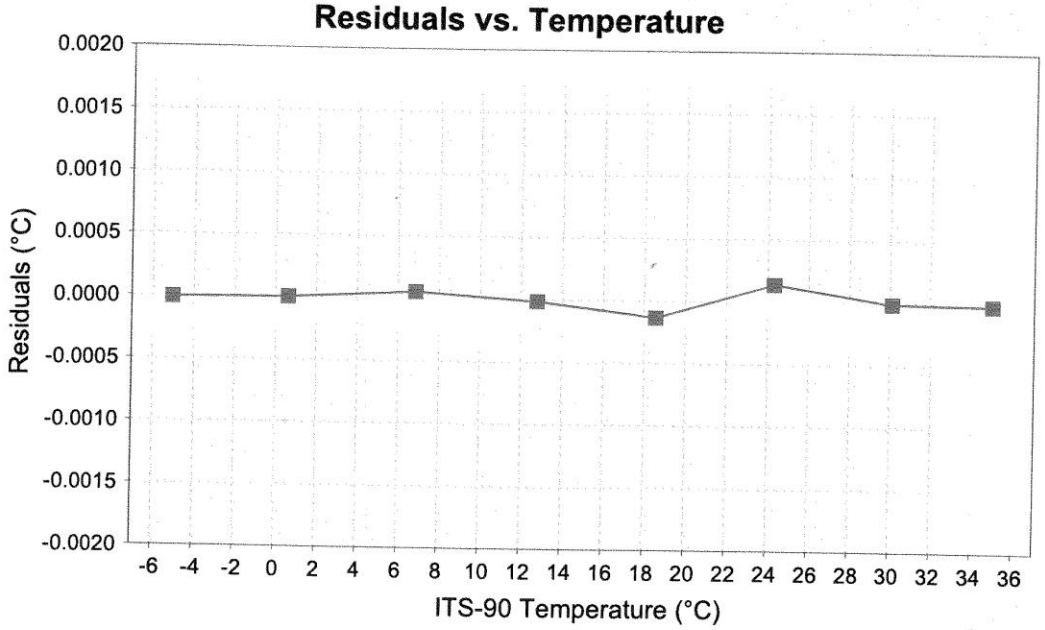
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205763 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.04009	0.714294	-5.04010	-0.00001
0.61087	0.649622	0.61087	0.00000
6.84389	0.574366	6.84394	0.00005
12.76131	0.502298	12.76129	-0.00002
18.54418	0.434186	18.54404	-0.00013
24.30144	0.370907	24.30158	0.00014
30.10570	0.313219	30.10569	-0.00001
35.00054	0.269917	35.00052	-0.00002

Coefficients

C0:	3.4952562E-3
C1:	-253.69474E-6
C2:	2.4322385E-6
C3:	-61.200296E-9



Calibration Date: 2020-12-01
Issue Date: 2020-12-03
Calibration ID: 42846

Operator: dluong

Approver: kmalorny

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RBR

Temperature Calibration Certificate

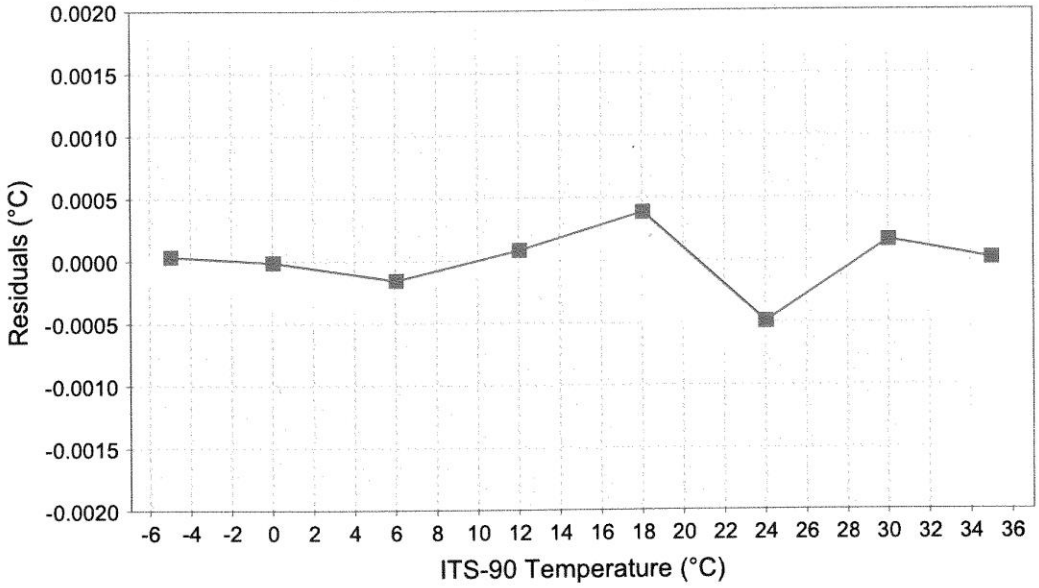
Logger ID: RBRcoda³ Serial No: 205764 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.95948	0.721911	-4.95944	0.00003
0.03846	0.665777	0.03845	-0.00001
6.03589	0.594387	6.03574	-0.00016
12.03283	0.521556	12.03291	0.00008
18.02303	0.450492	18.02341	0.00038
24.02040	0.383698	24.01990	-0.00049
30.02043	0.323066	30.02059	0.00016
35.01691	0.278061	35.01692	0.00001

Coefficients

C0:	3.4846377E-3
C1:	-253.43886E-6
C2:	2.4425478E-6
C3:	-69.63962E-9

Residuals vs. Temperature



Calibration Date: 2020-11-29
Issue Date: 2020-11-30
Calibration ID: 42770

Operator: dluong

Approver: kmalorny

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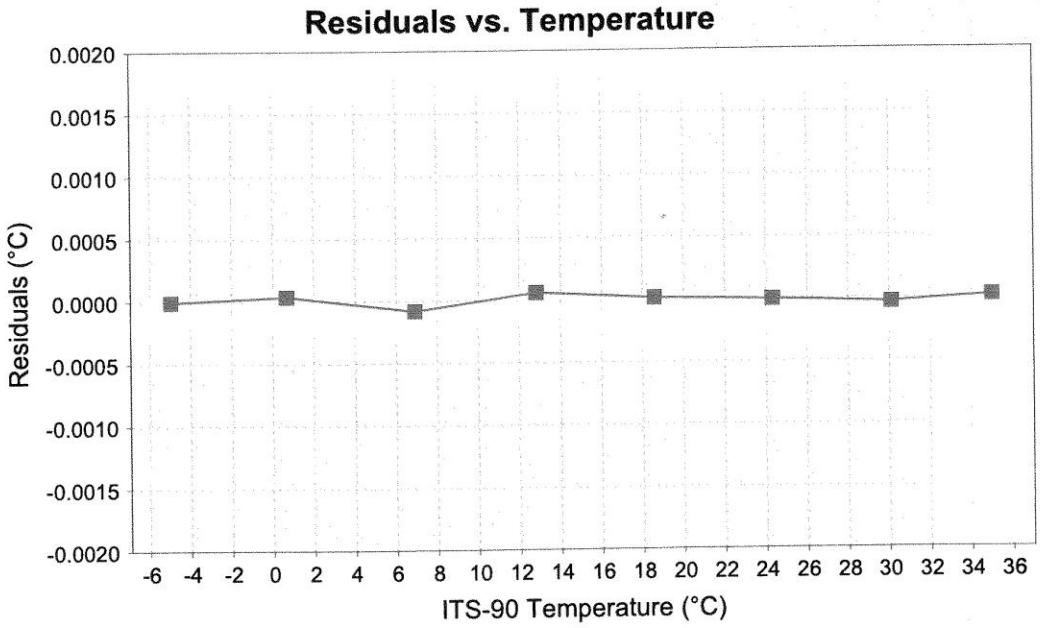
RBR

Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205765 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.97162	0.705818	-4.97163	-0.00001
0.67277	0.639777	0.67281	0.00004
6.89799	0.563314	6.89791	-0.00008
12.80492	0.490547	12.80498	0.00006
18.57309	0.422248	18.57310	0.00001
24.31798	0.359167	24.31797	-0.00001
30.11181	0.301995	30.11177	-0.00003
34.99659	0.259334	34.99661	0.00002

Coefficients	
C0:	3.5065676E-3
C1:	-251.66976E-6
C2:	2.5902216E-6
C3:	-87.77939E-9



Calibration Date: 2020-11-29
Issue Date: 2020-12-01
Calibration ID: 42818

Operator: dluong

Approver: kmalorny

RBR

Temperature Calibration Certificate

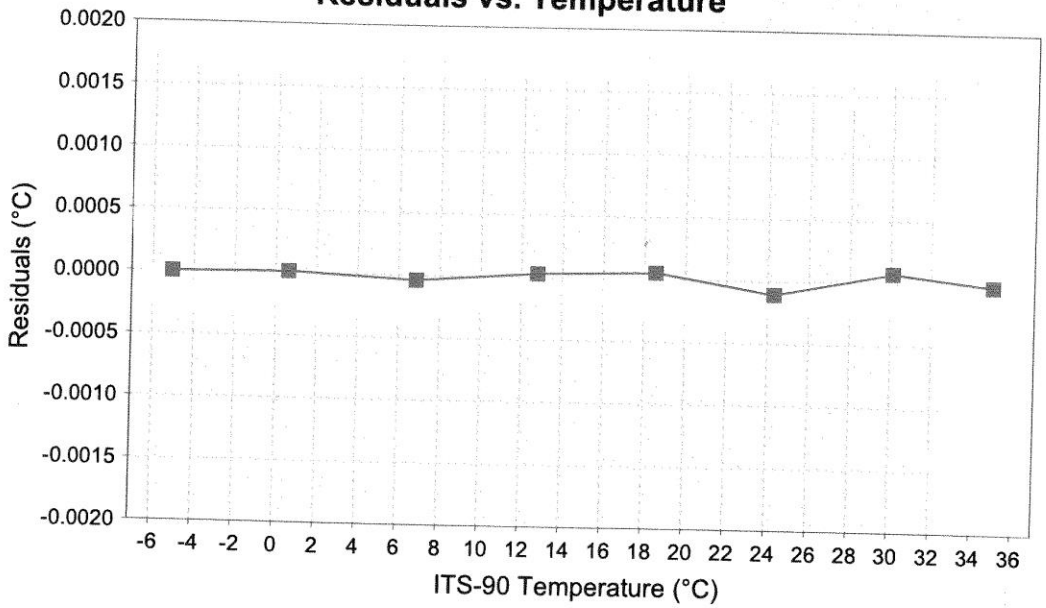
Logger ID: RBRcoda³ Serial No: 205766 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.04040	0.691465	-5.04040	-0.00000
0.61067	0.624225	0.61068	0.00001
6.84380	0.547189	6.84376	-0.00004
12.76129	0.474611	12.76132	0.00003
18.54418	0.407080	18.54423	0.00005
24.30170	0.345252	24.30160	-0.00011
30.10624	0.289635	30.10632	0.00007
35.00115	0.248358	35.00113	-0.00002

Coefficients

C0:	3.523364E-3
C1:	-253.83904E-6
C2:	2.4265228E-6
C3:	-59.18108E-9

Residuals vs. Temperature



Calibration Date: 2020-11-30
Issue Date: 2020-12-01
Calibration ID: 42809

Operator: dluong

Approver: kmalorny

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RBR

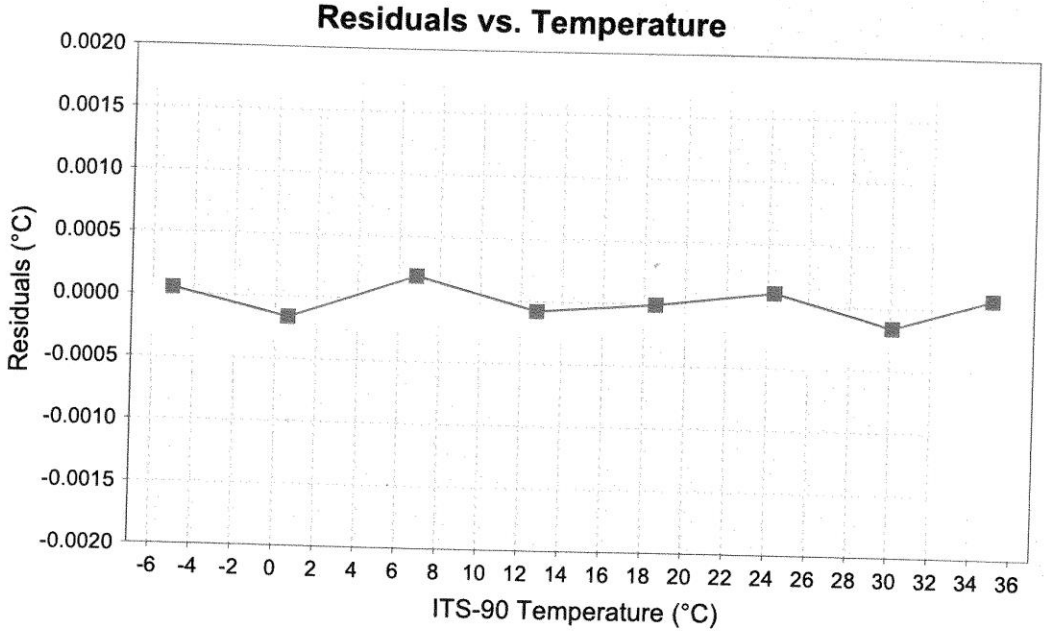
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205767 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.03906	0.732612	-5.03901	0.00005
0.61168	0.670254	0.61152	-0.00017
6.84446	0.596760	6.84464	0.00018
12.76180	0.525424	12.76172	-0.00008
18.54426	0.457122	18.54425	-0.00001
24.30149	0.392880	24.30159	0.00010
30.10544	0.333643	30.10528	-0.00016
35.00035	0.288741	35.00042	0.00008

Coefficients

C0:	3.4717575E-3
C1:	-253.4823E-6
C2:	2.437434E-6
C3:	-74.36366E-9



Calibration Date: 2020-12-02
Issue Date: 2020-12-04
Calibration ID: 42877

Operator: dluong

Approver: kmalorny

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RBR

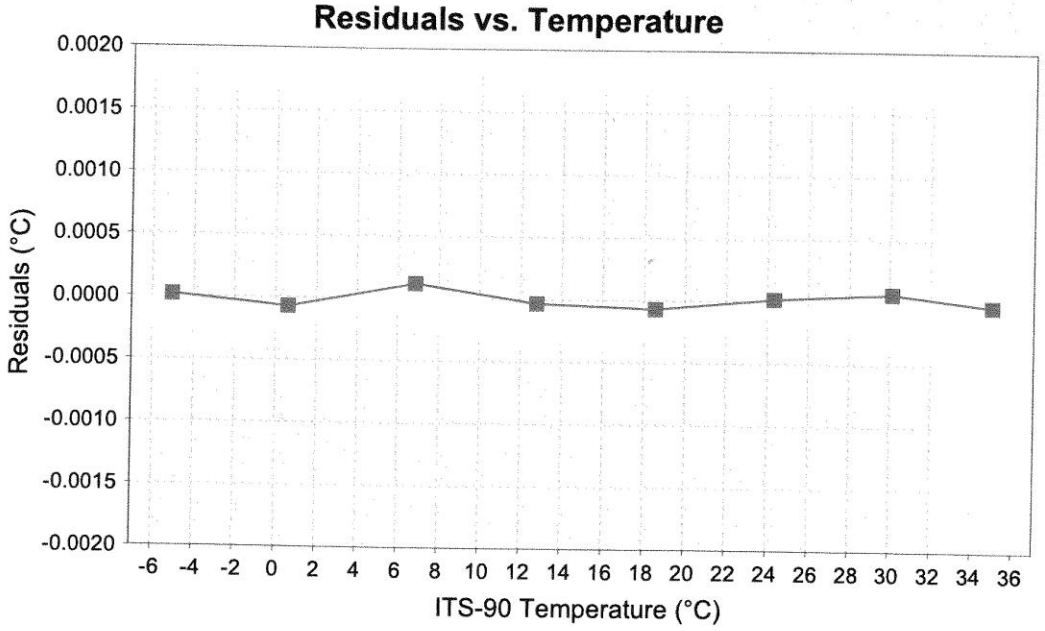
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205768 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.04009	0.740572	-5.04007	0.00002
0.61087	0.678190	0.61080	-0.00007
6.84389	0.604162	6.84400	0.00012
12.76131	0.531887	12.76127	-0.00003
18.54417	0.462394	18.54411	-0.00007
24.30145	0.396854	24.30146	0.00002
30.10570	0.336332	30.10576	0.00006
35.00055	0.290455	35.00051	-0.00003

Coefficients

C0:	3.4657335E-3
C1:	-249.09156E-6
C2:	2.4666078E-6
C3:	-71.95062E-9



Calibration Date: 2020-12-01
Issue Date: 2020-12-03
Calibration ID: 42845

Operator: dluong

Approver: kmalorny

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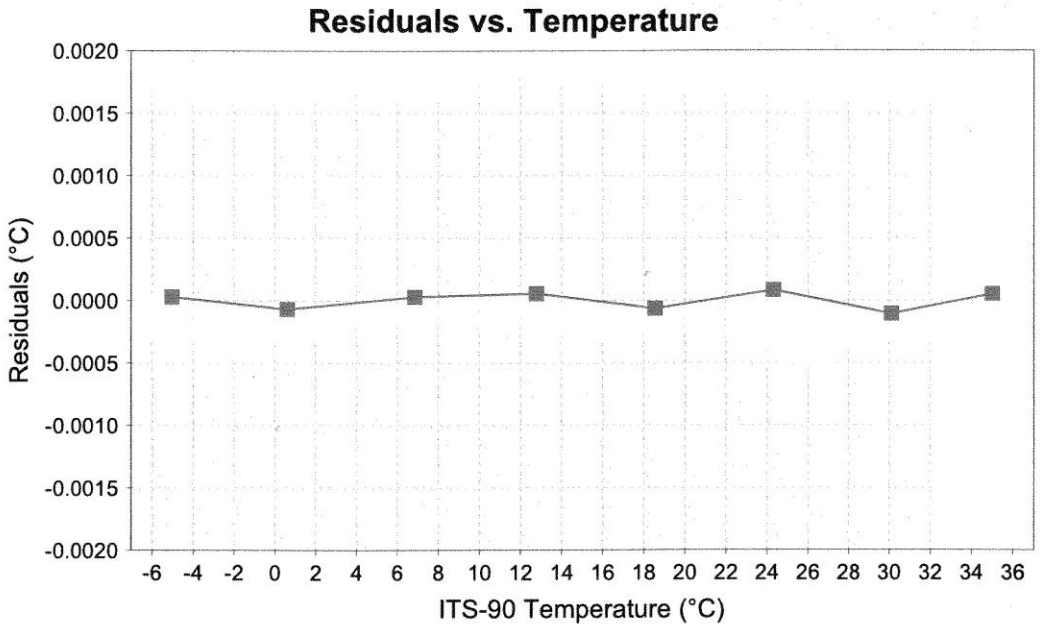
RBR

Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205769 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.04009	0.744078	-5.04007	0.00003
0.61087	0.682341	0.61080	-0.00007
6.84389	0.608908	6.84392	0.00003
12.76131	0.537017	12.76136	0.00006
18.54418	0.467698	18.54411	-0.00007
24.30144	0.402132	24.30152	0.00008
30.10570	0.341414	30.10559	-0.00011
35.00054	0.295267	35.00059	0.00005

Coefficients	
C0:	3.4605055E-3
C1:	-249.61677E-6
C2:	2.4619599E-6
C3:	-77.07981E-9



Calibration Date: 2020-12-01
Issue Date: 2020-12-02
Calibration ID: 42843

Operator: dluong

Approver: kmalorny

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RBR

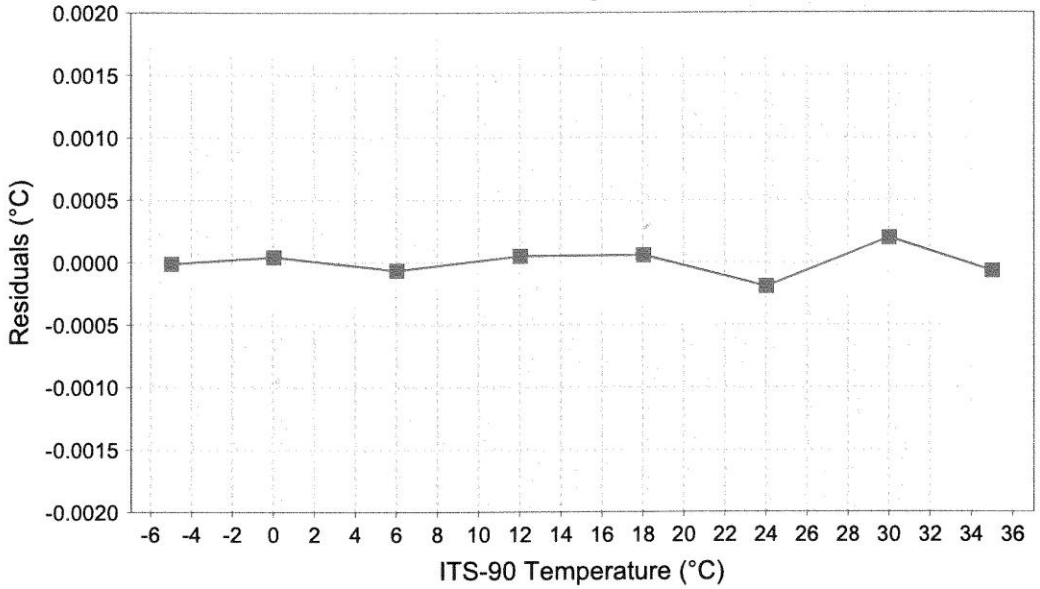
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205770 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.95948	0.673137	-4.95949	-0.00001
0.03846	0.612036	0.03851	0.00004
6.03589	0.536619	6.03583	-0.00007
12.03283	0.462249	12.03288	0.00005
18.02303	0.392107	18.02308	0.00006
24.02040	0.328284	24.02020	-0.00019
30.02043	0.272086	30.02062	0.00020
35.01691	0.231413	35.01684	-0.00007

Coefficients	
C0:	3.5446994E-3
C1:	-252.7399E-6
C2:	2.647061E-6
C3:	-81.622694E-9

Residuals vs. Temperature



Calibration Date: 2020-11-29
Issue Date: 2020-11-30
Calibration ID: 42771

Operator: dluong

Approver: kmalorny

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RBR

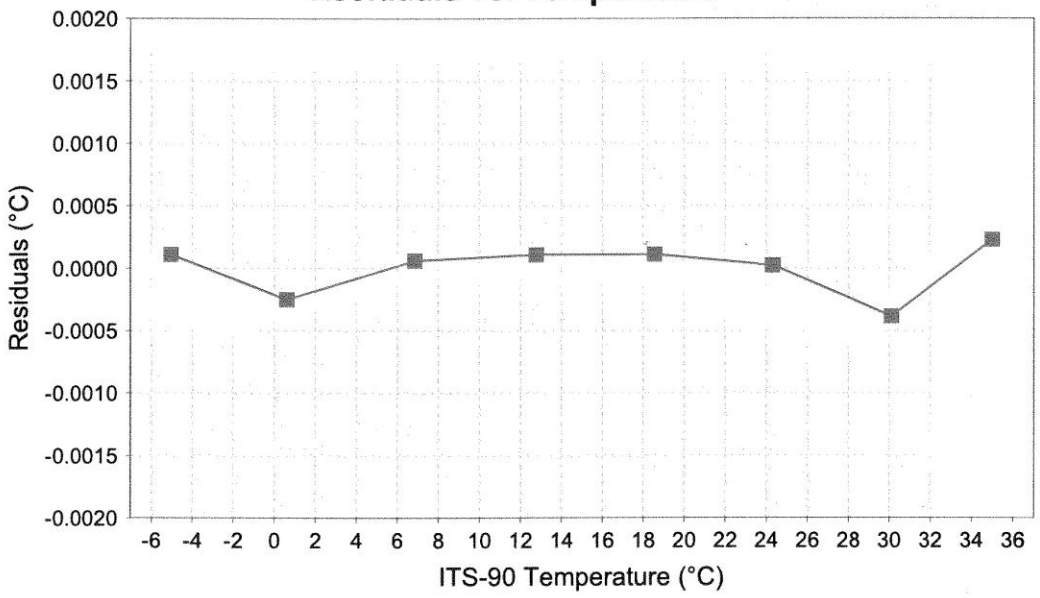
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205771 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.03906	0.745803	-5.03896	0.00011
0.61168	0.684488	0.61143	-0.00025
6.84446	0.611454	6.84452	0.00006
12.76180	0.539835	12.76191	0.00011
18.54426	0.470657	18.54437	0.00011
24.30150	0.405103	24.30152	0.00002
30.10544	0.344286	30.10505	-0.00039
35.00035	0.297979	35.00058	0.00023

Coefficients	
C0:	3.4575902E-3
C1:	-250.03048E-6
C2:	2.5742302E-6
C3:	-83.24676E-9

Residuals vs. Temperature



Calibration Date: 2020-12-02
Issue Date: 2020-12-04
Calibration ID: 42878

Operator: dluong

Approver: kmalorny

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RBR

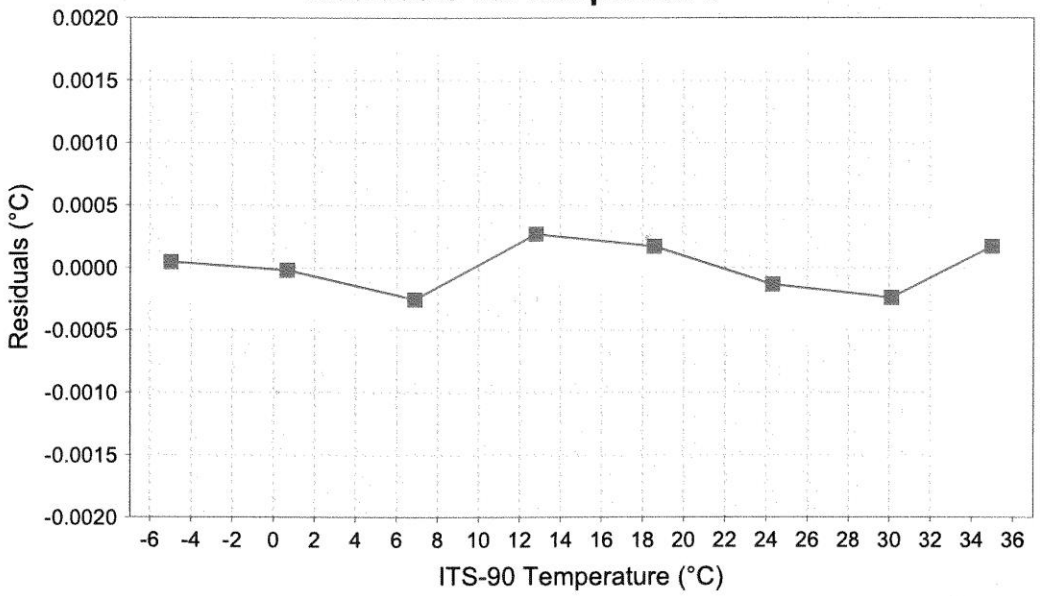
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205772 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.97893	0.706033	-4.97888	0.00004
0.66288	0.639595	0.66286	-0.00002
6.88391	0.562669	6.88366	-0.00025
12.78907	0.489448	12.78934	0.00027
18.55706	0.420762	18.55723	0.00017
24.30274	0.357388	24.30260	-0.00014
30.10055	0.300004	30.10031	-0.00024
34.99010	0.257241	34.99027	0.00017

Coefficients	
C0:	3.5078009E-3
C1:	-250.14993E-6
C2:	2.5093887E-6
C3:	-82.14832E-9

Residuals vs. Temperature



Calibration Date: 2020-12-04
Issue Date: 2020-12-05
Calibration ID: 42922

Operator: dluong

Approver: kmalorny

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RBR

Temperature Calibration Certificate

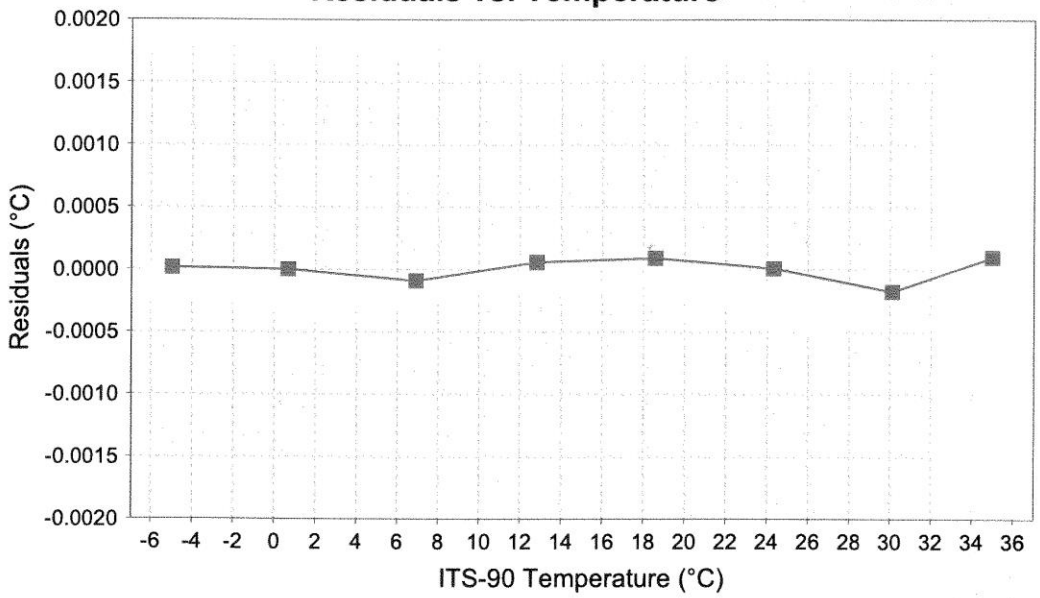
Logger ID: RBRcoda³ Serial No: 205773 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.97162	0.693558	-4.97161	0.00001
0.67278	0.626649	0.67278	0.00000
6.89800	0.549878	6.89791	-0.00009
12.80491	0.477457	12.80497	0.00006
18.57306	0.410003	18.57315	0.00009
24.31798	0.348112	24.31798	0.00001
30.11180	0.292328	30.11162	-0.00018
34.99660	0.250870	34.99670	0.00010

Coefficients

C0:	3.5199283E-3
C1:	-253.72457E-6
C2:	2.4669785E-6
C3:	-79.008785E-9

Residuals vs. Temperature



Calibration Date: 2020-11-29
Issue Date: 2020-12-01
Calibration ID: 42819

Operator: dluong

Approver: kmalorny

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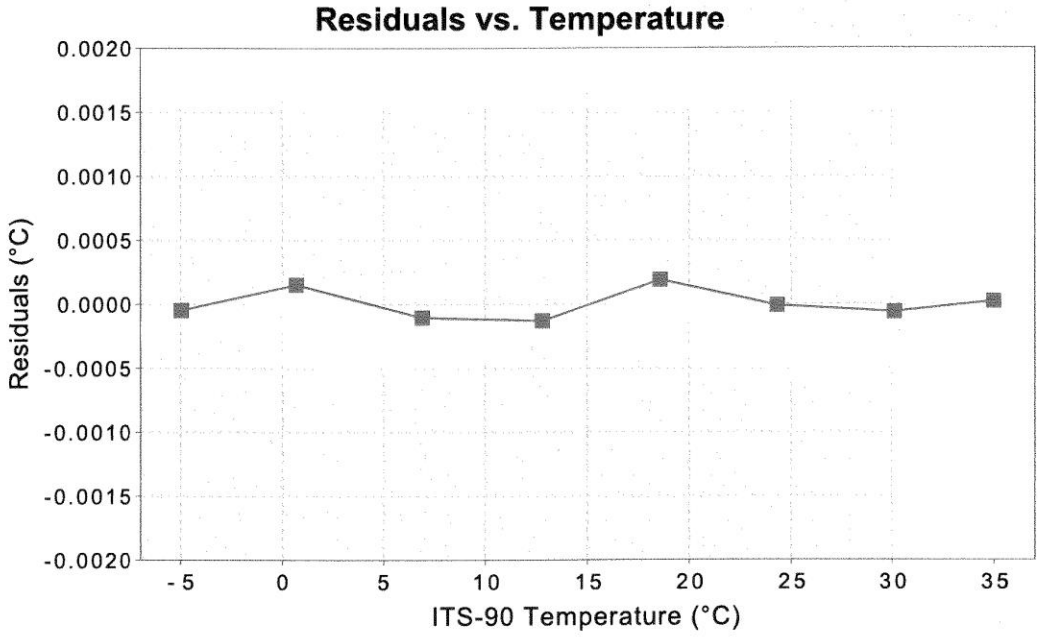
RBR

Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205774 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.97162	0.707877	-4.97167	-0.00005
0.67278	0.642375	0.67293	0.00015
6.89800	0.566479	6.89789	-0.00011
12.80492	0.494158	12.80479	-0.00013
18.57307	0.426156	18.57326	0.00019
24.31798	0.363231	24.31796	-0.00001
30.11180	0.306072	30.11174	-0.00006
34.99660	0.263326	34.99662	0.00002

Coefficients	
c0:	3.5029673E-3
c1:	-252.98411E-6
c2:	2.4501758E-6
c3:	-86.66383E-9



Calibration Date: 2020-11-29
Issue Date: 2020-12-01
Calibration ID: 42817

Operator: Jeff Walker
jwalker

Approver:
kmalorny

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RBR

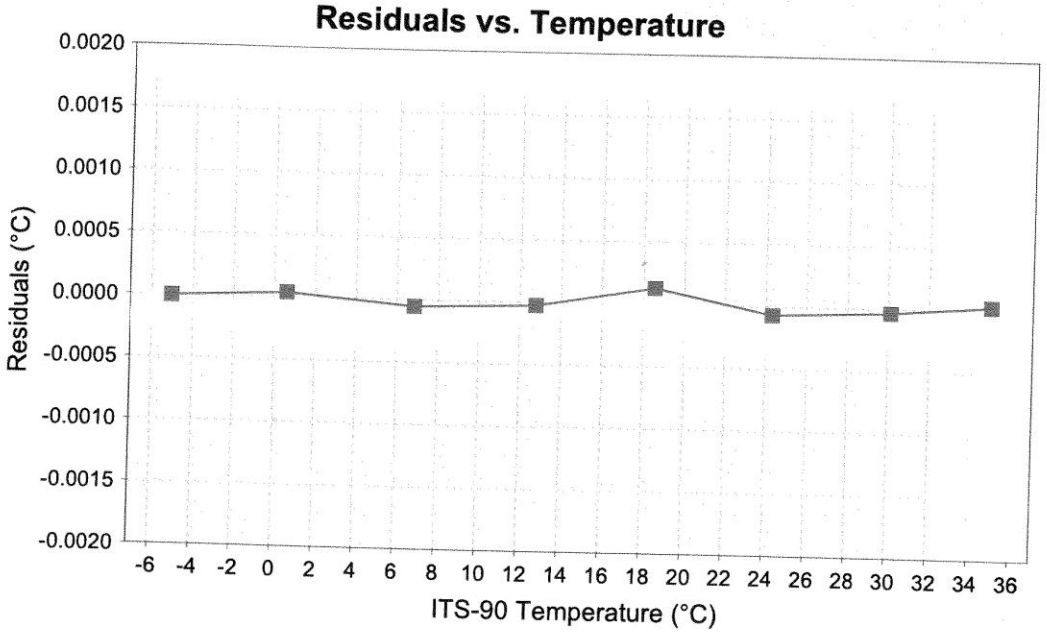
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205775 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.04040	0.750721	-5.04040	-0.00001
0.61067	0.689554	0.61070	0.00003
6.84381	0.616408	6.84376	-0.00005
12.76129	0.544421	12.76127	-0.00003
18.54418	0.474688	18.54431	0.00013
24.30169	0.408479	24.30162	-0.00007
30.10624	0.346962	30.10621	-0.00003
35.00115	0.300104	35.00118	0.00003

Coefficients

C0:	3.4533427E-3
C1:	-247.91146E-6
C2:	2.5102906E-6
C3:	-82.994326E-9



Calibration Date: 2020-11-30
Issue Date: 2020-12-01
Calibration ID: 42812

Operator: dluong

Approver: kmalorny

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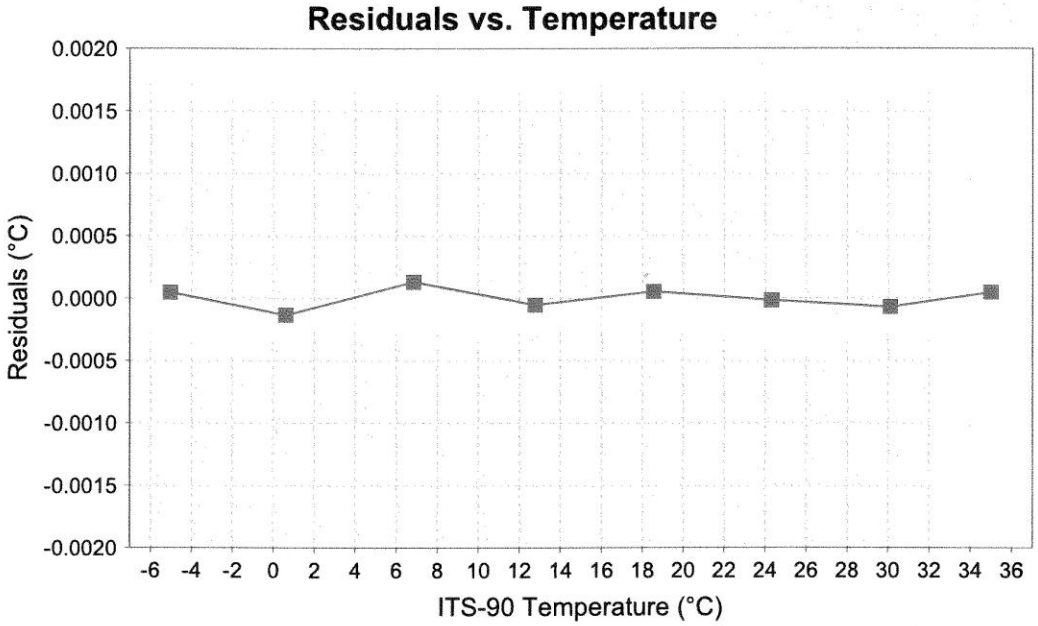
RBR

Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205776 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.04009	0.734829	-5.04005	0.00005
0.61087	0.672743	0.61074	-0.00014
6.84389	0.599454	6.84402	0.00013
12.76131	0.528202	12.76125	-0.00005
18.54418	0.459871	18.54423	0.00005
24.30144	0.395515	24.30143	-0.00002
30.10570	0.336090	30.10563	-0.00007
35.00054	0.291002	35.00059	0.00005

Coefficients	
C0:	3.4689445E-3
C1:	-253.38135E-6
C2:	2.4242124E-6
C3:	-82.56047E-9



Calibration Date: 2020-12-01
Issue Date: 2020-12-03
Calibration ID: 42844

Operator: dluong

Approver: kmalorny

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RBR

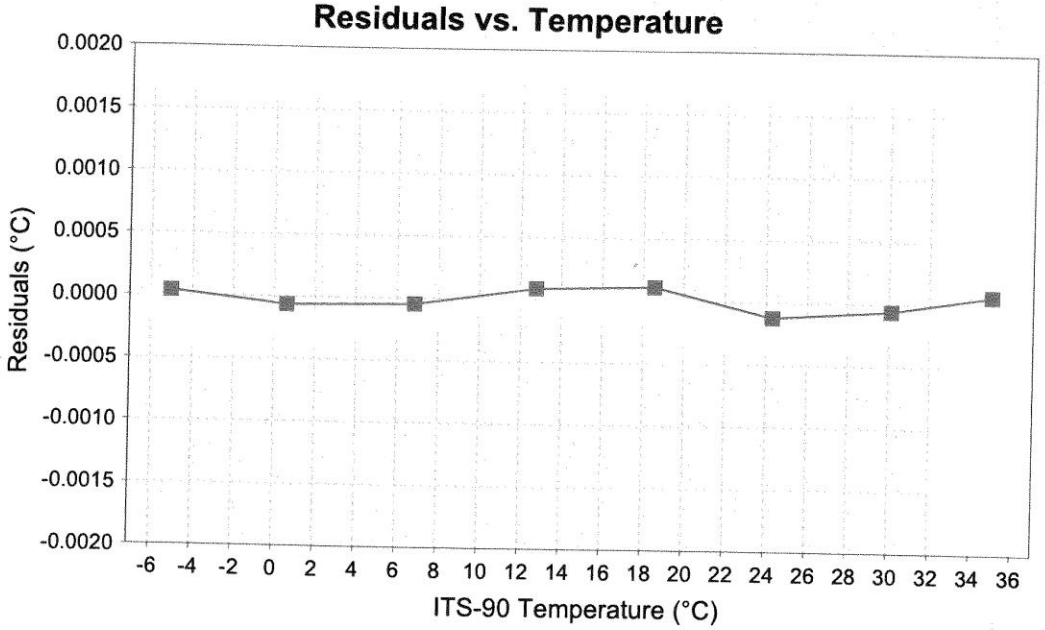
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205777 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.04039	0.677952	-5.04036	0.00004
0.61067	0.609576	0.61060	-0.00007
6.84381	0.531939	6.84376	-0.00005
12.76129	0.459462	12.76138	0.00009
18.54418	0.392592	18.54429	0.00011
24.30171	0.331837	24.30159	-0.00012
30.10624	0.277557	30.10618	-0.00006
35.00115	0.237492	35.00121	0.00007

Coefficients

C0:	3.5388966E-3
C1:	-254.60086E-6
C2:	2.4745598E-6
C3:	-74.0124E-9



Calibration Date: 2020-11-30
Issue Date: 2020-12-01
Calibration ID: 42808

Operator: dluong

Approver: kmalorny

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RBR

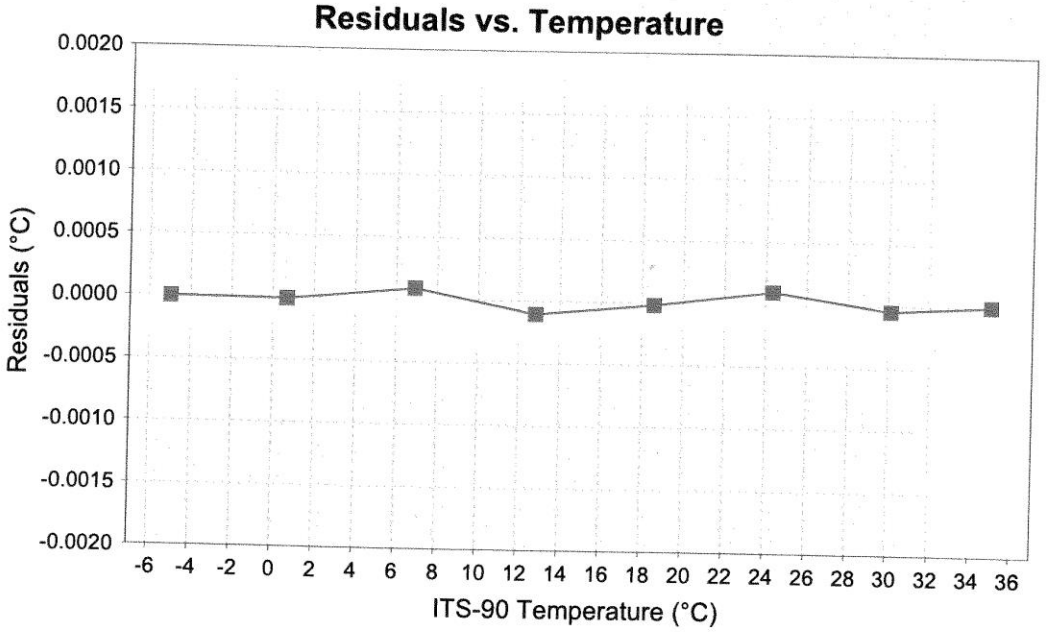
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205778 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.97140	0.715467	-4.97141	-0.00000
0.67275	0.650486	0.67274	-0.00001
6.89799	0.574749	6.89807	0.00009
12.80488	0.502182	12.80477	-0.00011
18.57325	0.433615	18.57323	-0.00002
24.31829	0.369899	24.31838	0.00010
30.11210	0.311832	30.11205	-0.00004
34.99716	0.268296	34.99716	0.00000

Coefficients

C0:	3.494863E-3
C1:	-251.34353E-6
C2:	2.5636348E-6
C3:	-70.948616E-9



Calibration Date: 2020-12-04
Issue Date: 2020-12-05
Calibration ID: 42926

Operator: T. Akuetteh
takuetteh

Approver:
kmalorny

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RBR

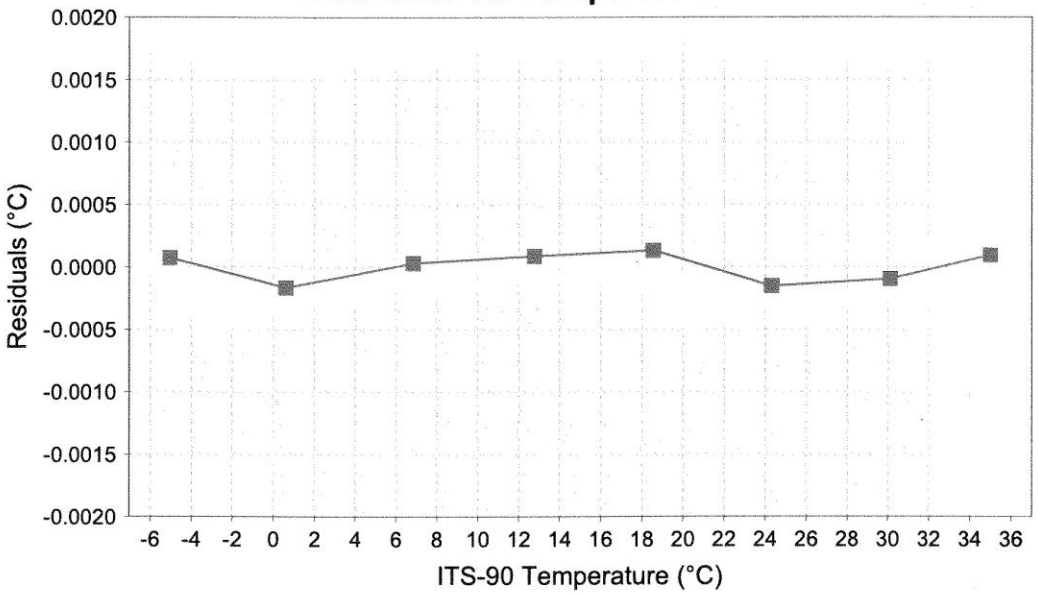
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 205779 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.04040	0.713517	-5.04032	0.00007
0.61067	0.648856	0.61050	-0.00017
6.84380	0.573637	6.84383	0.00003
12.76129	0.501631	12.76138	0.00009
18.54418	0.433599	18.54431	0.00013
24.30170	0.370415	24.30154	-0.00015
30.10624	0.312820	30.10615	-0.00010
35.00115	0.269596	35.00125	0.00010

Coefficients	
C0:	3.4959305E-3
C1:	-253.97725E-6
C2:	2.4689934E-6
C3:	-91.898855E-9

Residuals vs. Temperature



Calibration Date: 2020-11-30
Issue Date: 2020-12-01
Calibration ID: 42810

Operator: dluong

Approver: kmalorny

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RBR

Conductivity Calibration Certificate

RBRconcerto³ C.T.D.ODO s/n: 205781

References: Autosal8400B#66289, MS-315#15506, SSW P162, RC#002

Reference Resistance (ohm)	Reference Conductivity (mS/cm)	Voltage Ratio, V	Measured Conductivity (mS/cm)	Calibration Error (mS/cm)
open	0.0000	-0.000147	-0.0002	-0.0002
694.023	6.1588	0.039084	6.1582	-0.0006
331.918	12.8777	0.081886	12.8772	-0.0006
150.011	28.4936	0.181372	28.4944	0.0008
100.007	42.7405	0.272132	42.7416	0.0010
75.013	56.9815	0.362847	56.9820	0.0005
55.511	77.0001	0.490368	77.0000	-0.0001
47.018	90.9088	0.578967	90.9080	-0.0009

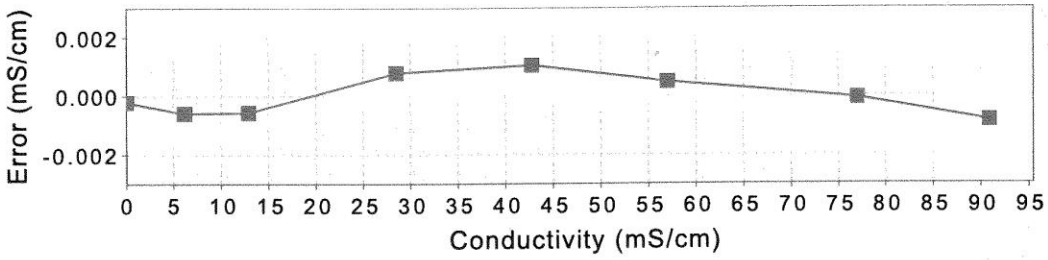
Coefficients	
C0:	22.852829E-3
C1:	156.97823
X0:	373.78885E-6
X1:	-7.940543E-6
X2:	600E-9
X3:	15.004712
X4:	10

Bath	Voltage Ratio	Temperature (ITS-90)	Salinity (PSS-78)	Conductivity (mS/cm)
T15S35	0.2733414	15.00471	35.0085	42.9315
T25S35	0.3303040	23.86290	34.9901	51.8737

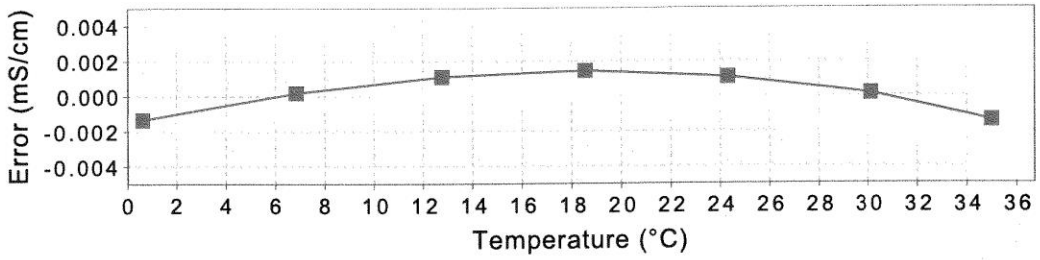
Cell Constant @T15S35 = 4.27435 1/cm

$$C_{cor} = \frac{C_0 + C_1 * V - X_0 * (T - X_3)}{1 + X_1 * (T - X_3) + X_2 * (P - X_4))}$$

Calibration error vs. Conductivity



Calibration error vs. Temperature



Calibration Date: 2020-12-04
Issue Date: 2020-12-04
File Name: 205781_20201204_1720C.rsk

Operator: Jeff Walker
jwalker

Approver:
kmalorny

RBR

Temperature Calibration Certificate

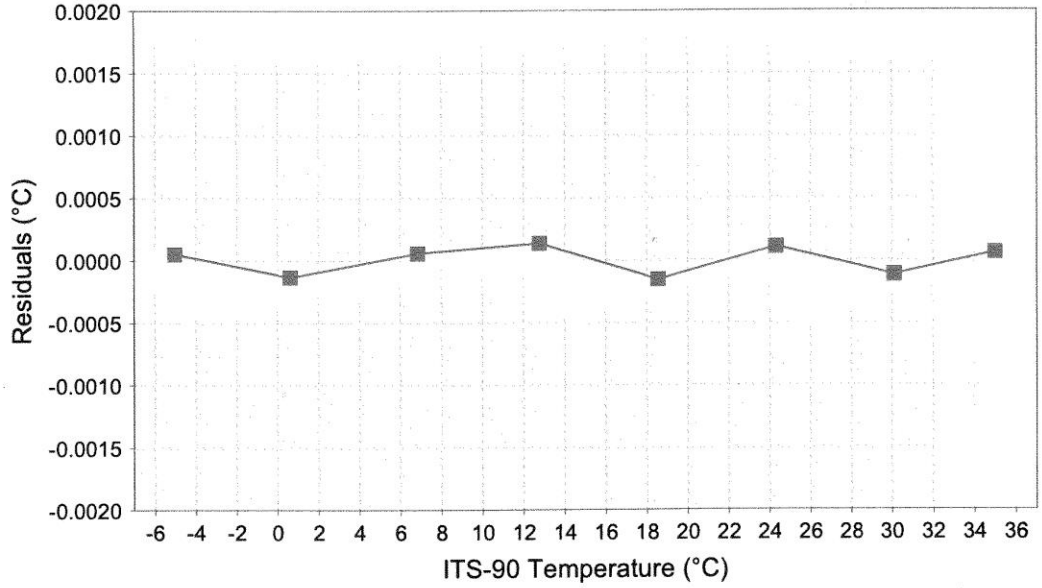
Logger ID: RBRconcerto³ Serial No: 205781 Channel No: 2

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.04009	0.695860	-5.04004	0.00005
0.61087	0.629284	0.61074	-0.00014
6.84389	0.552776	6.84394	0.00006
12.76131	0.480456	12.76144	0.00014
18.54417	0.412937	18.54402	-0.00016
24.30144	0.350907	24.30155	0.00011
30.10570	0.294934	30.10558	-0.00012
35.00054	0.253268	35.00060	0.00006

Coefficients

C0:	3.5174747E-3
C1:	-254.46268E-6
C2:	2.480297E-6
C3:	-53.564086E-9

Residuals vs. Temperature



Calibration Date: 2020-12-01
Issue Date: 2020-12-02
Calibration ID: 42837

Operator: T. Akuetteh
takuetteh

Approver:
kmalorny

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RBR

Pressure Calibration Certificate

RBRconcerto³ C.T.D.ODO s/n: 205781
Sensor rating: 20 dbar s/n: L214796
Nominal accuracy: 0.05%FS (0.01 dbar)
Reference instrument: Mensor CPC6000 s/n: 612676

Applied pressure, P_{app} (dbar)	Voltage ratio, V	Measured pressure, P_c (dbar)	Calibration error (dbar)
10.024	0.129494	10.0240	-0.0004
12.000	0.153844	11.9999	-0.0002
14.000	0.178457	13.9998	-0.0001
16.000	0.203034	15.9998	-0.0002
18.000	0.227577	18.0000	-0.0001
20.000	0.252078	19.9999	-0.0001
22.000	0.276545	22.0000	-0.0000
24.000	0.300971	23.9999	-0.0001
26.000	0.325360	26.0001	-0.0000
28.000	0.349708	28.0001	-0.0000
30.000	0.374014	29.9999	0.0000

Coefficients

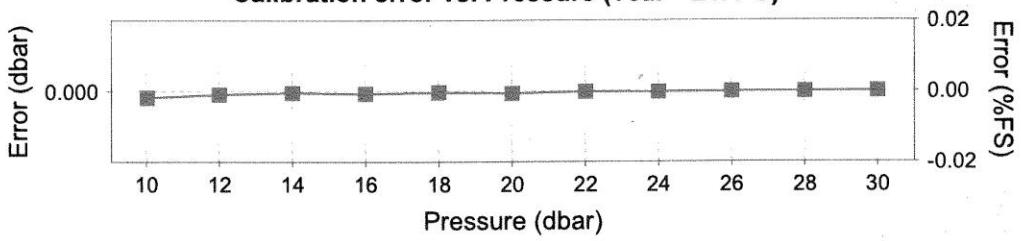
C0:	-112.48907E-3
C1:	80.49681
C2:	2.1269863
C3:	608.57624E-3
X0:	10.0273
X1:	6.897866E-3
X2:	69.23961E-6
X3:	284.70654E-9
X4:	330.06948E-6
X5:	21.406427

$$P_c = X_0 + \frac{P_m - X_0 - X_1(T - X_5) - X_2(T - X_5)^2 - X_3(T - X_5)^3}{1 + X_4(T - X_5)}$$

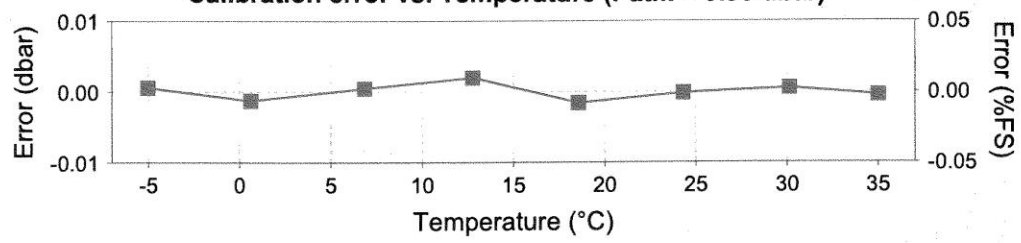
Head (mm) = 323

$$P_m = C_0 + C_1 V + C_2 V^2 + C_3 V^3$$

Calibration error vs. Pressure (Tcal = 21.4°C)



Calibration error vs. Temperature (Patm = 9.90 dbar)



Calibration Date: 2020-12-03
Issue Date: 2020-12-03
File Name: 205781_20201203_1645P.rsk

Operator: T. Akuetteh
takuetteh

Approver:
kmalorny

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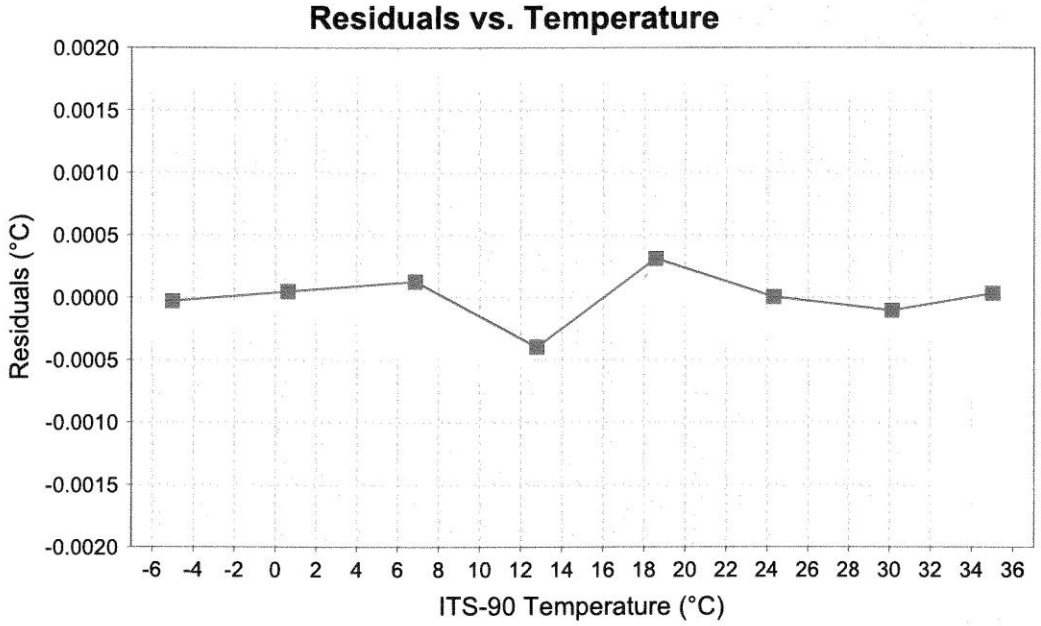
RBR

Temperature Calibration Certificate

Logger ID: RBRcoda Serial No: 202309 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.03651	0.699107	-5.03654	-0.00003
0.61375	0.632729	0.61380	0.00005
6.84563	0.556272	6.84575	0.00013
12.76296	0.483823	12.76256	-0.00040
18.54566	0.416028	18.54597	0.00031
24.30290	0.353654	24.30290	0.00000
30.10683	0.297287	30.10672	-0.00010
35.00142	0.255286	35.00146	0.00003

Coefficients	
C0:	3.5139888E-3
C1:	-253.76776E-6
C2:	2.5431632E-6
C3:	-48.16859E-9



Calibration Date: 12/Aug/2019
Issue Date: 13/Aug/2019
Calibration ID: 34434

Operator: dluong

Approver: kmalorny

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RBR

Optical DO Calibration Certificate

RBRcoda ODO s/n: 202309
Foil batch: 160530-001
Salinity: 0 PSU
Temperature range: 0 - 35 °C

C0:	0.0	**C12:**	8.03775
C1:	1.0	**C13:**	-79.12303E-3
C2:	0.0	**C14:**	287.52E-6
C3:	1.0	**C15:**	0.0
C4:	5.296227E3	**C16:**	-94.67624E-3
C5:	-127.5013	**C17:**	429.7717E-6
C6:	1.672486	**C18:**	0.0
C7:	-10.7012E-3	**C19:**	0.0
C8:	-321.7648	**C20:**	426.7697E-6
C9:	5.298149	**C21:**	0.0
C10:	-44.59722E-3	**C22:**	0.0
C11:	180.123E-6	**C23:**	0.0

Calibration Date: 2020-04-30
Issue Date: 2020-04-30
Calibration ID: C-078821

Operator: takuetteh

Approver: kmalorny

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RBR

Conductivity Calibration Certificate

RBRconcerto³ C.T.D.ODO s/n: 205782

References: Autosal8400B#66289, MS-315#15506, SSW P162, RC#002

Reference Resistance (ohm)	Reference Conductivity (mS/cm)	Voltage Ratio, V	Measured Conductivity (mS/cm)	Calibration Error (mS/cm)
open	0.0000	-0.000134	-0.0005	-0.0005
694.023	6.1611	0.039109	6.1603	-0.0007
331.918	12.8825	0.081925	12.8820	-0.0005
150.011	28.5041	0.181439	28.5047	0.0007
100.007	42.7563	0.272227	42.7576	0.0014
75.013	57.0025	0.362972	57.0036	0.0012
55.511	77.0284	0.490527	77.0285	0.0001
47.018	90.9423	0.579145	90.9407	-0.0016

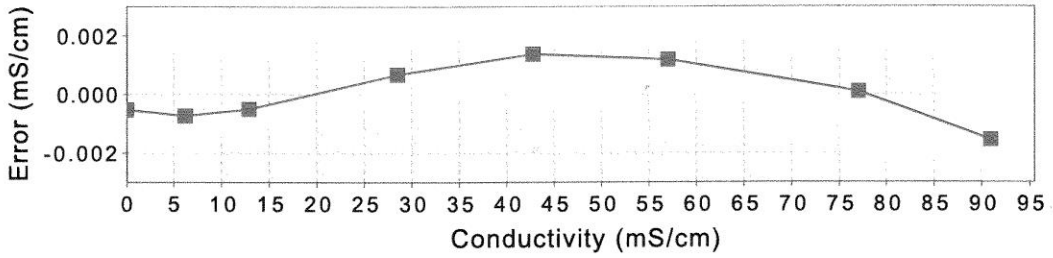
Coefficients	
C0:	20.529384E-3
C1:	156.99046
X0:	272.71733E-6
X1:	-12.285235E-6
X2:	600E-9
X3:	15.008923
X4:	10

Bath	Voltage Ratio	Temperature (ITS-90)	Salinity (PSS-78)	Conductivity (mS/cm)
T15S35	0.2733613	15.00892	35.0085	42.9356
T25S35	0.3302891	23.86382	34.9911	51.8760

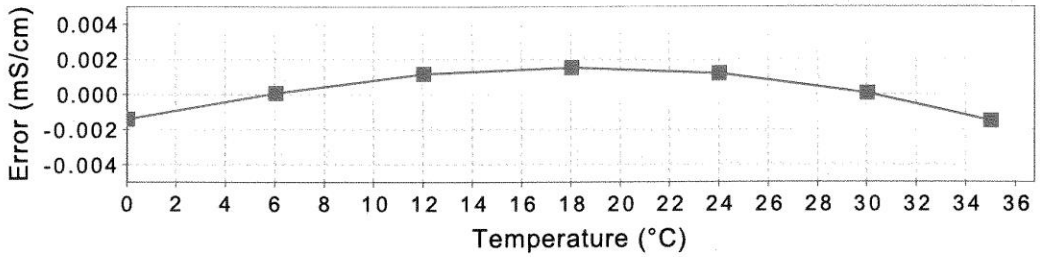
Cell Constant @T15S35 = 4.27593 1/cm

$$C_{cor} = \frac{C_0 + C_1 * V - X_0 * (T - X_3)}{1 + X_1 * (T - X_3) + X_2 * (P - X_4))}$$

Calibration error vs. Conductivity



Calibration error vs. Temperature



Calibration Date: 2020-12-04
Issue Date: 2020-12-04
File Name: 205782_20201204_1732C.rsk

Operator: Jeff Walker
jwalker

Approver:
kmalorny

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RBR

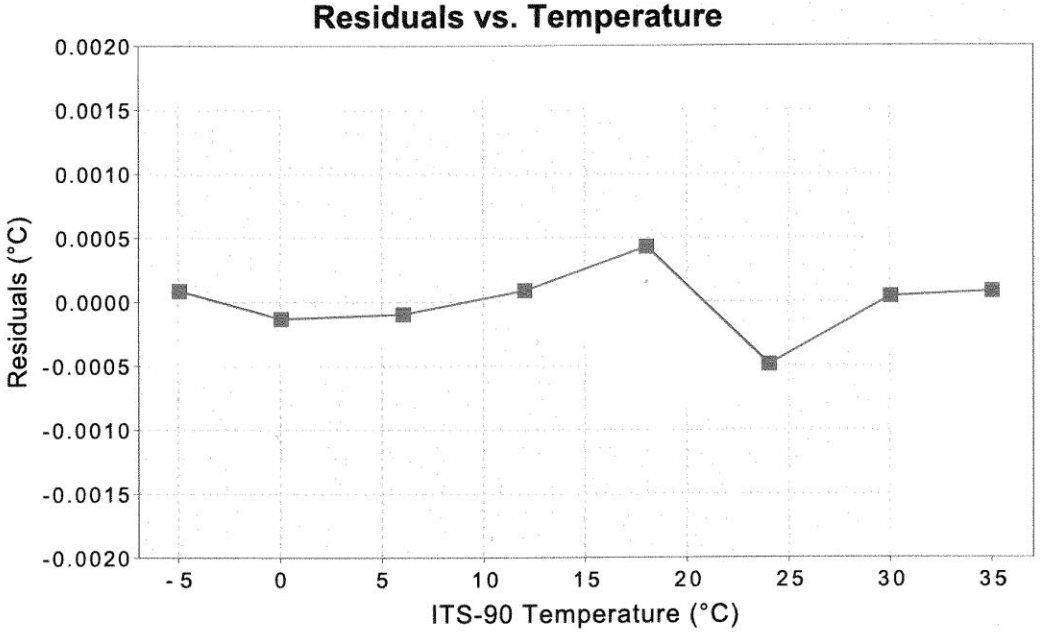
Temperature Calibration Certificate

Logger ID: RBRconcerto³ Serial No: 205782 Channel No: 2

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.95942	0.693651	-4.95934	0.00008
0.03873	0.634739	0.03860	-0.00013
6.03616	0.561141	6.03607	-0.00010
12.03305	0.487543	12.03314	0.00009
18.02350	0.417124	18.02393	0.00043
24.02055	0.352160	24.02006	-0.00049
30.02118	0.294175	30.02122	0.00004
35.01774	0.251731	35.01782	0.00008

Coefficients

C0:	3.5191863E-3
C1:	-254.29667E-6
C2:	2.4613857E-6
C3:	-70.66773E-9



Calibration Date: 2020-11-30
Issue Date: 2020-12-01
Calibration ID: 42778

Operator: Jeff Walker
jwalker

Approver:
kmalorny

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RBR

Pressure Calibration Certificate

RBRconcerto³ C.T.D.ODO s/n: 205782
Sensor rating: 20 dbar s/n: L214788
Nominal accuracy: 0.05%FS (0.01 dbar)
Reference instrument: Mensor CPC6050 s/n: 41000CAM

Applied pressure, P_{app} (dbar)	Voltage ratio, V	Measured pressure, P_c (dbar)	Calibration error (dbar)
9.962	0.126295	9.9618	0.0002
12.000	0.151216	12.0001	-0.0003
14.000	0.175625	13.9994	-0.0001
15.999	0.200006	15.9994	0.0001
18.000	0.224353	17.9996	0.0001
20.000	0.248660	19.9996	0.0001
22.000	0.272941	22.0004	0.0000
24.000	0.297164	23.9996	0.0001
26.000	0.321356	25.9995	-0.0004
27.999	0.345508	27.9992	-0.0001
29.999	0.369625	29.9994	0.0001

Coefficients

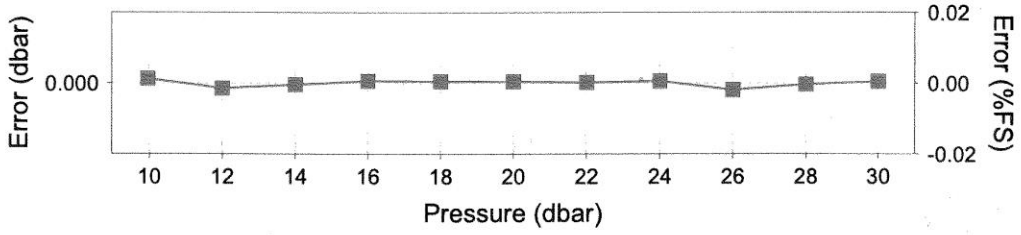
C0:	8.427022E-3
C1:	81.16047
C2:	2.1374688
C3:	637.3461E-3
X0:	9.9658
X1:	7.0297155E-3
X2:	63.714535E-6
X3:	107.89746E-9
X4:	329.78624E-6
X5:	22.352448

$$P_c = X_0 + \frac{P_m - X_0 - X_1(T - X_5) - X_2(T - X_5)^2 - X_3(T - X_5)^3}{1 + X_4(T - X_5)}$$

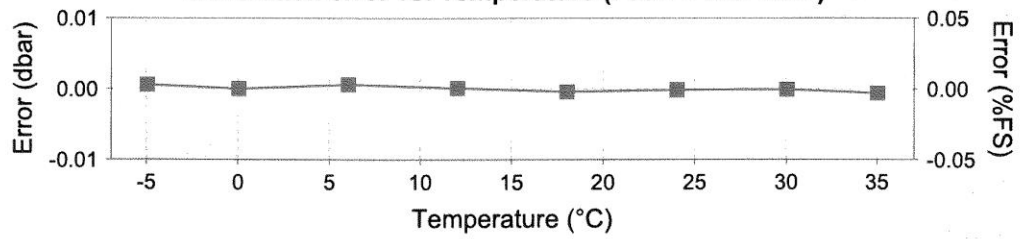
Head (mm) = 332

$$P_m = C_0 + C_1 V + C_2 V^2 + C_3 V^3$$

Calibration error vs. Pressure (Tcal = 22.4°C)



Calibration error vs. Temperature (Patm = 9.87 dbar)



Calibration Date: 2020-12-02
Issue Date: 2020-12-02
File Name: 205782_20201202_1259P.rsk

Operator: takuetteh

Approver: kmalorny

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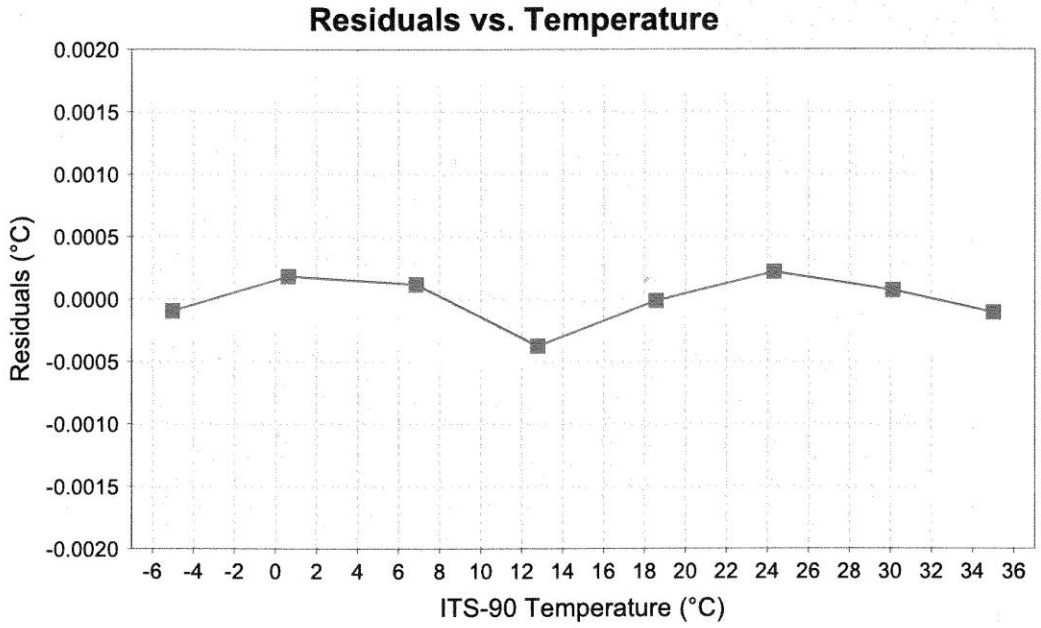
RBR

Temperature Calibration Certificate

Logger ID: RBRcoda Serial No: 204593 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-5.03843	0.728118	-5.03853	-0.00009
0.61194	0.665108	0.61212	0.00018
6.84426	0.591087	6.84437	0.00012
12.76153	0.519475	12.76115	-0.00038
18.54419	0.451128	18.54418	-0.00001
24.30163	0.387051	24.30185	0.00022
30.10608	0.328147	30.10615	0.00007
35.00061	0.283627	35.00050	-0.00011

Coefficients	
C0:	3.4778328E-3
C1:	-253.30816E-6
C2:	2.4339122E-6
C3:	-68.051904E-9



Calibration Date: 2020-06-11
Issue Date: 2020-06-12
Calibration ID: 39926

Operator: dluong

Approver: kmalorny

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RBR

Optical DO Calibration Certificate

RBRcoda ODO s/n: 204593
Foil batch: 181002-101_PSt3-1111-02
Salinity: 0 PSU
Temperature range: 0 - 35 °C

C0:	0.0	**C12:**	8.0462
C1:	1.0	**C13:**	-82.12904E-3
C2:	0.0	**C14:**	313.9571E-6
C3:	1.0	**C15:**	0.0
C4:	4.824596E3	**C16:**	-98.98348E-3
C5:	-117.6729	**C17:**	468.9997E-6
C6:	1.56718	**C18:**	0.0
C7:	-10.22726E-3	**C19:**	0.0
C8:	-307.3719	**C20:**	465.5301E-6
C9:	5.184242	**C21:**	0.0
C10:	-44.91426E-3	**C22:**	0.0
C11:	186.9222E-6	**C23:**	0.0

Calibration Date: 2020-07-15
Issue Date: 2020-07-15
Calibration ID: C-083674

Operator: T. Akuetteh
takuetteh

Approver:
kmalorny

RBR Limited, 95 Hines Road, Ottawa, Canada K2K 2M5 | +1 (613) 599-8900 | www.rbr-global.com

RBR

Temperature Calibration Certificate

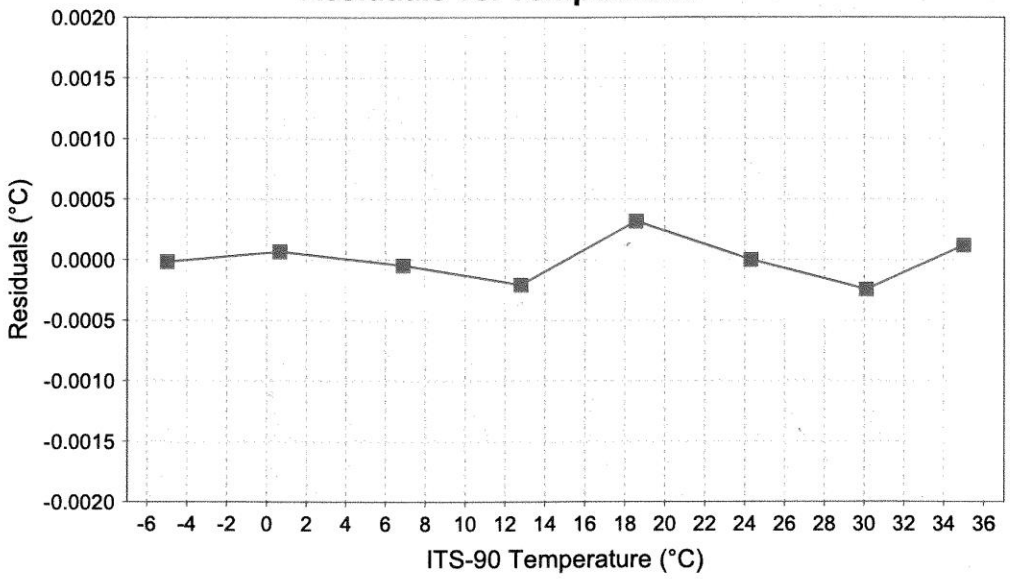
Logger ID: RBRcoda³ Serial No: 207219 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.97476	0.678831	-4.97478	-0.00002
0.66627	0.610259	0.66634	0.00007
6.88686	0.532334	6.88682	-0.00004
12.79259	0.459529	12.79239	-0.00021
18.56003	0.392367	18.56035	0.00032
24.30631	0.331309	24.30631	0.00000
30.10419	0.276739	30.10395	-0.00024
34.99336	0.236487	34.99348	0.00012

Coefficients

C0:	3.5381648E-3
C1:	-252.86997E-6
C2:	2.6041919E-6
C3:	-79.656296E-9

Residuals vs. Temperature



Calibration Date: 2021-05-14
Issue Date: 2021-05-17
Calibration ID: 46631

Operator: dluong

Approver: kmalorny

RBR

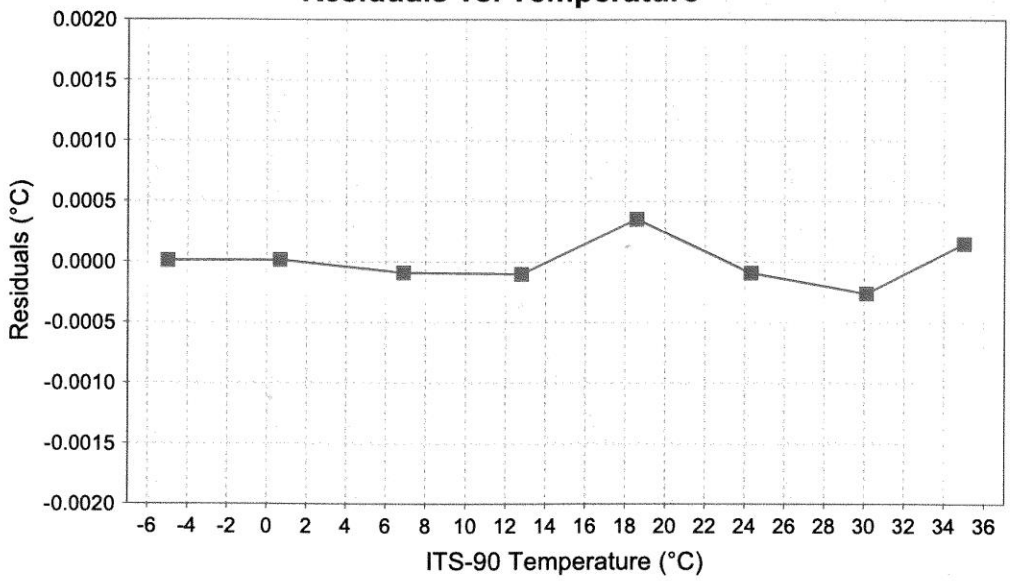
Temperature Calibration Certificate

Logger ID: RBRcoda³ Serial No: 207220 Channel No: 1

Reference Temperature, ITS-90	Voltage ratio, V	Measured Temperature, ITS-90	Calibration error
-4.97476	0.693416	-4.97475	0.00001
0.66626	0.626729	0.66627	0.00002
6.88686	0.550237	6.88678	-0.00009
12.79258	0.478036	12.79248	-0.00010
18.56003	0.410751	18.56038	0.00035
24.30631	0.348969	24.30622	-0.00009
30.10415	0.293222	30.10389	-0.00026
34.99336	0.251757	34.99352	0.00015

Coefficients	
C0:	3.5195563E-3
C1:	-254.43753E-6
C2:	2.475926E-6
C3:	-80.28237E-9

Residuals vs. Temperature



Calibration Date: 2021-05-14
Issue Date: 2021-05-17
Calibration ID: 46632

Operator: dluong

Approver: kmalorny

OCEAN SONICS

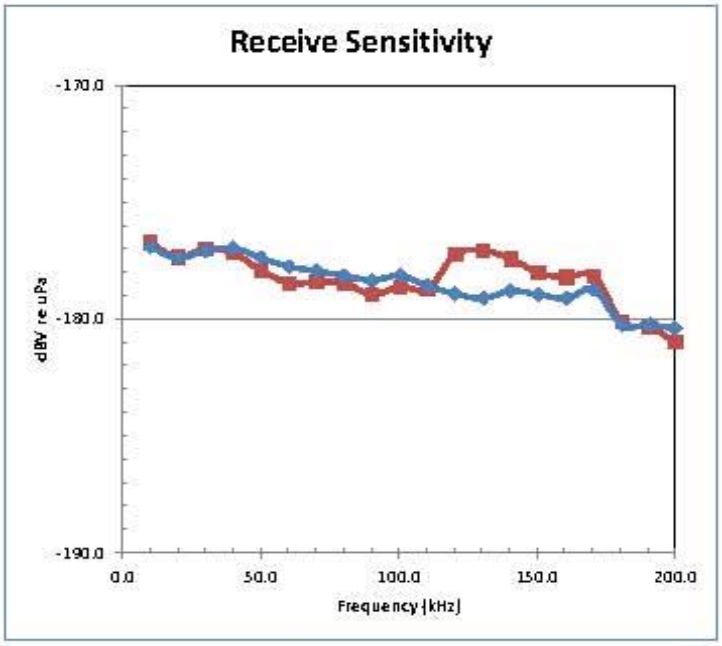
Certificate of Calibration

Ocean Sonics, Ltd.

Calibration Certificate Number: C5341

Test Result: 10 kHz to 100 kHz: -177.9 ± 1.1
10 kHz to 200 kHz: -178.9 ± 2.1

Model Number	RB9-ETH	Projector Manufacturer	Ocean Sonics
Serial Number	6126	Projector Model	TH2-SER-4F
Manufacture Date	5-Oct-2020	Projector Serial	2225
Measurement Date	8-Oct-2020	Measurement Distance	1 m
Certificate Date	8-Oct-2020	Output Level	130 dB re uPa @ 1 m
Sensitivity @ 250 Hz	-177 dB re V / uPa	Tone Burst	100.0 us / 300 ms
Case Type	R-Type	Reference Manufacturer	Ocean Sonics
Element Manufacturer	Reson	Reference Model	RB9-ETH
Element Model	TC4059-1	Reference Serial	2080
Element Serial	620130	Primary Calibration	20-Jan-2020
Preamp Model	04-300449-01	Preamp Manufacturer	Ocean Sonics
Calibrated By	Cody Ellis	Preamp Model	04-300449-01
Work Order Number	W1234	Preamp Serial	M58
Test Type	RX Sensitivity	Preamp Gain	36 dB
Test Procedure	Complex RMS	ADC Manufacturer	Ocean Sonics
Test Location	Tank #3, 1 m	ADC Model Number	04-300426-01
Water Temperature	16 °C	ADC Serial Number	M59



Frequency	Sensitivity [dBV re µPa]	
kHz	0 deg	90 deg
10.0	-176.7	-176.9
20.1	-177.4	-177.4
30.1	-177.0	-177.1
40.2	-177.2	-177.0
50.2	-177.9	-177.4
60.2	-178.5	-177.8
70.3	-178.4	-178.0
80.3	-178.5	-178.2
90.4	-179.0	-178.4
100.4	-178.6	-178.2
110.4	-178.7	-178.6
120.5	-177.2	-178.9
130.5	-177.1	-179.1
140.5	-177.4	-178.8
150.6	-178.0	-179.0
160.6	-178.2	-179.1
170.7	-178.2	-178.7
180.7	-180.1	-180.3
190.7	-180.3	-180.3
200.0	-181.0	-180.4

Final test checklist

Order number: 45059-1-794

Head ID:	AQP 10565
Hardware ID:	AQD 16166
Frequency:	1 MHz
Firmware version:	3.43

NORTEK
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Norway
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www.nortek.no

Harness test
[X] OK
Type: RS 232a.in

Recorder erased
[X] OK
Rec size: 16 GB

Label checked [X] OK

Dock test [X] OK

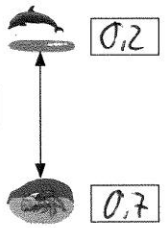
RS422 cable [ ] OK
Length [ ] m
Interfacebox 18/48V [ ] OK

System type:
Aquadopp [ ] Vector [ ] Continental [ ]
Aquadopp Profiler [X] Awac [ ] Other [ ] Specify: .....

Tilt check
[X] Pitch up
[X] Roll up
[X] Status bit
[X] Pitch down
[X] Roll down
pitch & roll within +/- 0.2 °

Heading
[X] Up
[X] Down
tolerance: +/- 2 °

Pressure
High Accuracy sensor
tolerance: +/- 0.1 % of [ ] m
Standard sensor
tolerance: +/- 0.5 % of 20 m



[X] OK

Temperature
[X] OK
tolerance: +/- 0.1 °

Beam check

	Correct order	Noise floor	Amplitude in tank	Range
Beam 1	[X] OK	10 Counts	> 180 Counts	[X] OK
Beam 2	[X] OK	10 Counts	> 180 Counts	[X] OK
Beam 3	[X] OK	10 Counts	> 180 Counts	[X] OK
~~Beam 4~~	~~[ ] OK~~	~~ Counts~~	~~> Counts~~	~~[ ] OK~~

Velocity direction

XYZ coordinate system	ENU coordinate system
X [X] OK	E [X] OK
Y [X] OK	N [X] OK
Z [X] OK	U [X] OK

Head file
[X] Headfile checked
[X] Saved as read only

Comments:

External sensors

Power down
[X] OK

Date
Day 17 Month 11 Year 2020

Hans Tillemarken

Pressure Report

Order No:	45059-1-794	**Date:**	16.11.2020 12:21:54
Head Id:	AQP 10565	**Operator:**	Faramarz Torkzad
Board Id:	AQD16166	**Location:**	Nortek factory in Norway
Pressure Range:	20 dBar		

Method: The instrument is put in an automated pressure chamber. Samples are taken at different pressures between 0 dBar and the instrument maximum pressure range. The calibration coefficients are calculated using linear regression with the formula:
*Pressure= (A0 + A1 * X) / (scaling constant)*

Verification: After the instrument has been updated with the calibration coefficients the instrument is again put in the pressure chamber and sampled at new pressures.
Criteria of acceptance is +/- 0.5% of full scale.

Reference: Paroscientific, Inc. Digiquartz 9000-1K-242. Accuracy 0.01% of 689dBar

Verification

Ref (dBar)	Pressure	Diff	Diff (% of FS)
1.08	1.08	0.01	0.04
2.34	2.36	0.02	0.09
4.38	4.41	0.04	0.18
6.34	6.38	0.04	0.22
7.87	7.92	0.05	0.26
10.74	10.80	0.06	0.30
12.28	12.34	0.06	0.31
14.08	14.14	0.06	0.30
16.23	16.29	0.06	0.28
18.10	18.15	0.05	0.23
19.56	19.59	0.04	0.18

Coefficients

A0	13983
A1	5657
A2	0
A3	0

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NQM03-400-03 Certificate of Calibration and Test

Tilt Report

Order No:	45059-1-794	**Date:**	11.11.2020 15:23:26
Head Id:	AQP 10565	**Operator:**	Asle Martinsen
Board Id:	AQD16166	**Location:**	Nortek factory in Norway

Method: The instrument is fixed in a two axis automated tilt calibration robot that puts the instrument in 5 different positions between -30 degree and + 30 degree for both pitch and roll axes. This is done with the instrument in both up and down orientation. The calibration coefficients are calculated using linear regression with the formula:
*Tilt angle = (A0+A1*X+A2*X^2+A3*X^3) / (scaling constant)*

Verification: After the instrument has been calibrated with the calibration coefficients, the calibration robot puts the instrument in 5 new positions to verify pitch and roll axes in both up and down orientation.
Criteria of acceptance is +/- 0.2º

Reference: Digital Protractor Series 950 Pro 3600. Accuracy 0.05º

Verification

	Up		Down	
	Pitch	**Roll**	**Pitch**	**Roll**
-30°	-0.03	-0.01	0.00	-0.07
-15°	0.02	0.03	-0.01	-0.03
0°	-0.03	-0.00	0.01	-0.01
15°	-0.01	0.05	0.01	-0.01
30°	0.00	0.01	-0.01	-0.03

Coefficients

	Up		Down	
	Pitch	**Roll**	**Pitch**	**Roll**
A0	18	-284	14	170
A1	13396	13590	13374	13484
A2	-546	1551	-67	-1481
A3	-26180	-27539	-27552	-27981

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Compass Report

Order No:	45059-1-794	**Date:**	11.11.2020 15:35:49
Head Id:	AQP 10565	**Operator:**	Asle Martinsen
Board Id:	AQD16166	**Location:**	Nortek factory in Norway

Method: The instrument is fixed in a two axis magnetometer calibration jig. The instrument is slowly rotated around the three magnetometer axes. The gain for all axes is calculated and adjusted. Cross correlation between the axes is calculated and adjusted.

Verification: The heading is derived from the magnetometer and tilt sensor measurements. The heading is verified at every 45th degree both with the instrument pointing up and down.
Criteria of acceptance is +/- 2⁰

Reference: Digital Protractor Series 950 Pro 3600. Accuracy 0.05⁰

Verification

	Measured (°)		Error (°)	
	Up	**Down**	**Up**	**Down**
0°	1.5	1.3	1.5	1.3
45°	46.5	45.9	1.5	0.9
90°	91.5	90.5	1.5	0.5
135°	136.5	135.8	1.5	0.8
180°	181.4	181.4	1.4	1.4
225°	226.6	226.5	1.6	1.5
270°	271.9	271.7	1.9	1.7
315°	316.9	316.9	1.9	1.9

Transformation matrix

31741	1582	-1466
-135	32767	-101
98	47	32644

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Certificate of Calibration and Test

Customer reference:	45059-1-794
Instrument type:	Aquapro
Head Id:	AQP 10565
Board Id:	AQD16166

Calibrations and tests performed

Tilt	OK
Compass	OK
Pressure	OK

Date of approval: 17.11.2020

All the tested values are within Nortek AS specifications

Reviewed and approved by

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