INSTRUMENT TEST REPORT NUMBER 634

Calibration Check of a Vaisala PTB201A Barometer

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9 pages including 3 appendices

1. INTRODUCTION

Prior to despatching Platform Transmitter Terminal (P.T.T.) number 3101 to Heard Island, the pressure sensor (a Vaisala model no. PTB201A, serial no. 505299) was submitted by SRUM to the Physics Laboratory for testing. The aim of the test was to find the pressure sensor's measurement uncertainty for pressures from 900 hPa to 1050 hPa and temperatures -10°C to 10°C.

Heard Island is a sub-antarctic station positioned at longitude 53° South, latitude 73° East, and experiences mean air temperatures between -1°C to 3.5°C throughout the year [2]. The P.T.T. will be installed about 5 metres above sea level, sending physical measurement data, including pressure measurements, to the Bureau every 60 seconds via satellite communication (ARGOS).

It should be noted that comprehensive testing that would normally be conducted on the PTB201A was not carried out because the P.T.T. had to be despatched one day after testing was requested.

2. EXPERIMENTAL METHOD

The intended site for the P.T.T. implies the sensor would be operating in temperatures in the range 0°C ± 10°C. Therefore, the PTB201A pressure sensor was tested at -10°C and 10 °C. The PTB201A was placed in an environmental chamber at -10°C for 2.5 hours. The PTB201A pressure sensor and the reference pressure sensor were connected to pumps via hosing. The pressure was cycled once between 1050 and 900 hPa in 25 hPa steps and allowed at least 3 minutes to stabilise at each new pressure level. Pressure measurements were polled from the PTB201A at each pressure level every five seconds until five readings had been collected. The same method was used to calibrate the PTB201A at 10°C. A total of 70 readings at -10°C and 70 readings at 10°C were taken.

A personal computer (PC) was used to collect the PTB201A readings via the serial port and the reference pressure sensor readings via the IEEE-488 port. The reference pressure sensor used in these tests was a Druck DPI140 Digital Pressure Indicator (DPI140) serial number 279/89-2 with a total uncertainty of ±0.08 hPa.

In this report, a correction is defined as the reference sensor measurement minus the test sensor measurement. Uncertainty was calculated using the root sum square method to 95% confidence.

3. RESULTS

Table 1 contains the mean, standard deviation and 95% confidence interval (95% C.I.) of the corrections at -10°C, 10°C and the combined data. U_{95} is the uncertainty of AWS pressure measurements and were generated using the following formula;

$$U_{95} = \sqrt{(t_{95} \times \sigma)^2 + (\text{mean of corrections})^2 + (U_{ref})^2}$$

where U_{95} = the total uncertainty of measurements from the sensor
t_{95} = the t statistic to produce a 95% level of confidence
σ = the standard deviation of the corrections
U_{ref} = uncertainty of the reference sensor (0.08 hPa)

Table 1. Mean, standard deviation and 95% C.I. of the corrections

All measurements in hPa				
Temperature	Mean (bias)	Standard deviation	95% C.I.	U_{95}
-10°C	-0.18	0.040	0.08	±0.21
10°C	-0.01	0.029	0.06	±0.10
-10°C and 10°C	-0.10	0.090	0.18	±0.22

Figure 1 shows all the corrections calculated from the data at -10°C, while Figure 2 shows all the corrections calculated from the data at 10°C (see page 4).

Lines of best fit were calculated for the data at both temperatures and appear with the corrections in Figures 1 and 2. Results of the regression analysis are contained in Table 2.

Table 2. Lines of best fit - Regression analysis

Correction [hPa] **= (PTB201A reading** [hPa]**)*m + c**				
Temperature	**m**	**c** [hPa]	**r^2**	**U_{95}**[hPa]
-10°C	0.00075	-0.9	0.891	±0.08
10°C	0.0005	-0.5	0.769	±0.08
-10°C and 10°C	0.0006	-0.7	0.122	±0.18

Figure 1.

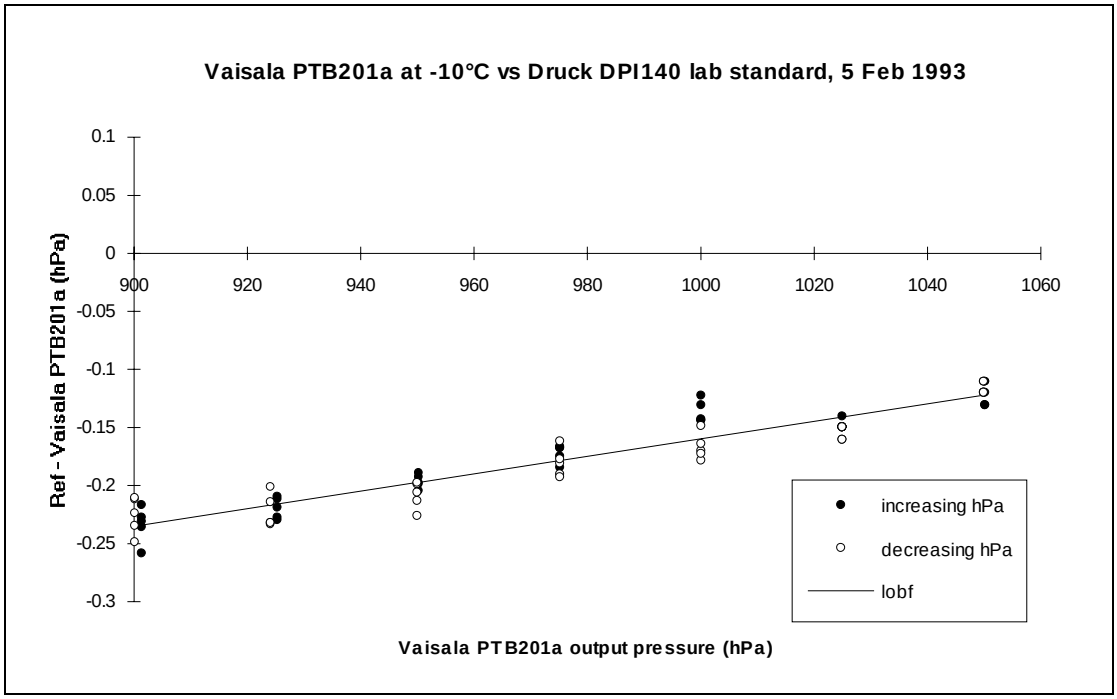
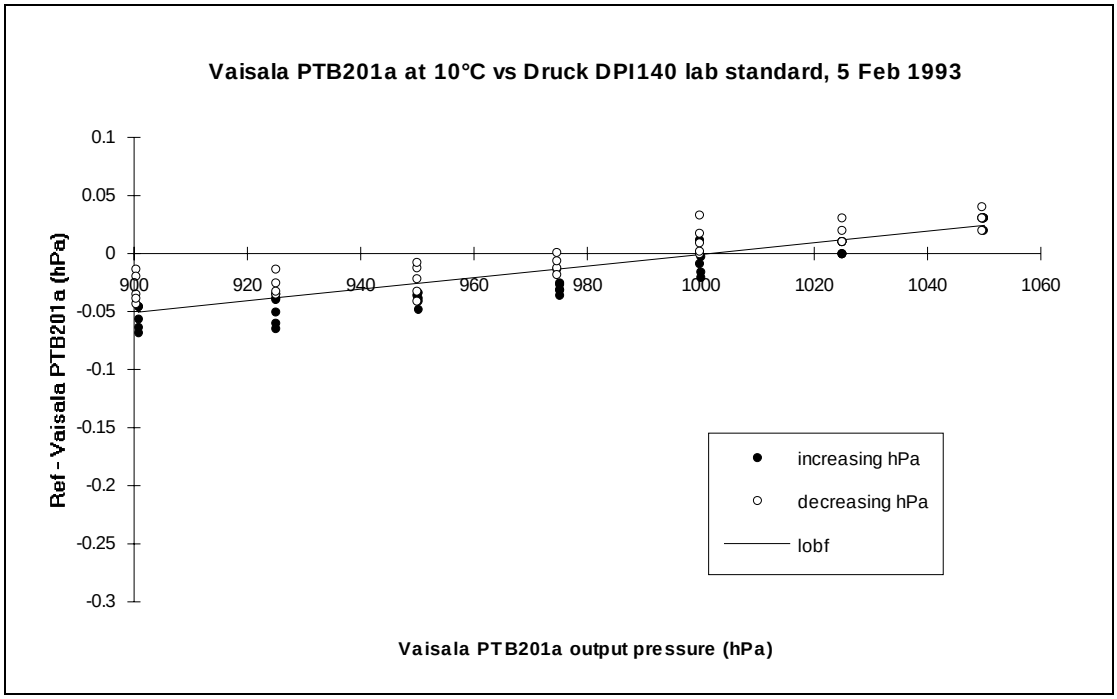


Figure 2.



U_{95} values were calculated for the three data sets with the bias (from Table 1) removed. The results of this analysis appear in Table 3.

Table 3. PTB201A performance when bias was removed

Pressure = PTB201A pressure + bias[hPa]		
Temperature	bias (hPa)	U_{95} (hPa)
-10°C	-0.18	±0.11
10°C	-0.01	±0.10
-10°C and 10°C	-0.10	±0.19

4. DISCUSSION

Based on the data collected, the uncertainty of the PTB201A at 10°C is significantly better than its uncertainty at -10°C (compare U_{95} values in Table 1).

The linear regression statistics show that the lines of best fit have only small gradients. Because of this, the additional calculations involved correcting for slope do little to improve the overall uncertainty of the PTB201A (compare the U_{95} values of Table 3 to Table 2). Almost the same improvement in uncertainty that are achieved with slope corrections can be gained by removing the bias from PTB201A readings.

The PTB201A appears to be temperature dependent because the mean bias changed by about 0.2 hPa for a temperature change of 20°C, while the slope and standard deviation remained the same (see Figures 1 and 2). As a consequence of a temperature dependence, a regression on the combined data will result in a poor correlation coefficient, r^2 (c.f. r^2 values in Table 2). Further testing of the PTB201A at different temperatures would conclude if it has a temperature coefficient.

The PTB201A exhibited negligible hysteresis, as can be seen in both Figure 1 and Figure 2. However, in Figure 1, the data collected at 1000 hPa showed a discepancy that appeared to be hysteresis. The PTB201A was tested in this pressure region more rigorously. The original test method was altered to increase and decrease pressure across the range 975 hPa to 1025 hPa in 5 hPa steps, taking 3 readings at each step and allowing at least 30 seconds settling time at each new pressure level. The results appear in Figure 3 (see page 6). These results show there is no hysteresis over the pressure range 975 to 1025 hPa..

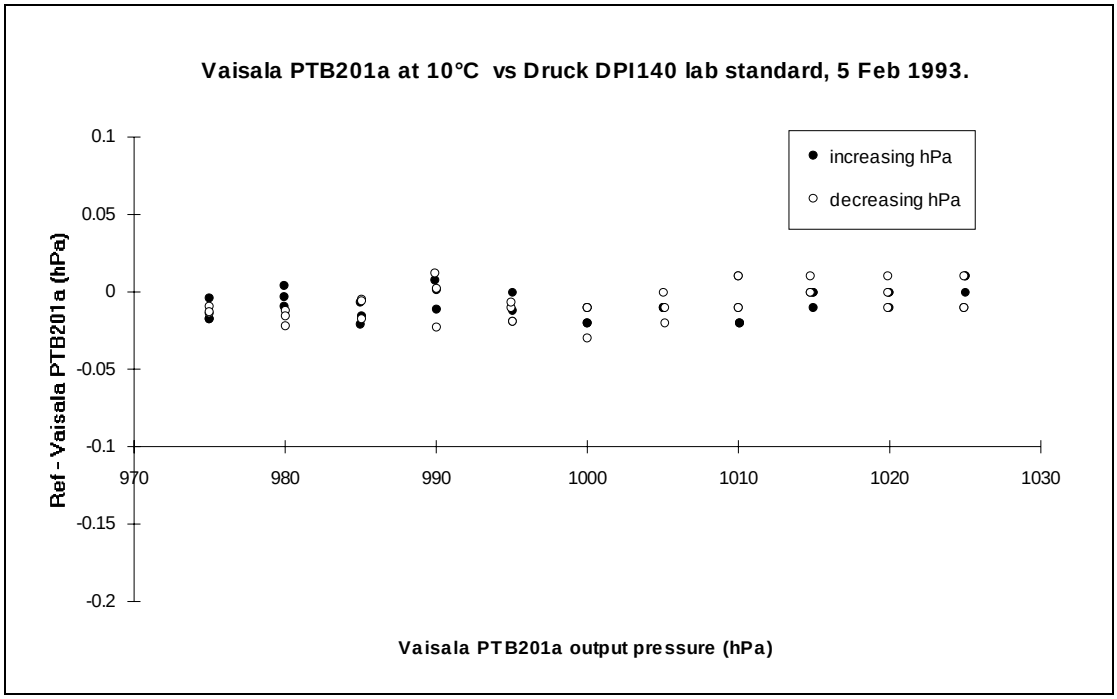
5. CONCLUSION

At the time of testing, the Vaisala PTB201A pressure sensor serial no. 505299 inside AWS P.T.T. 3101 had an uncertainty of ±0.22 hPa for the temperature range -10 to 10°C. Bureau of Meteorology specification number A2659 requires that pressure sensors have an uncertainty of better than 0.5 hPa for the temperature range over which they operate [1]. The PTB201A therefore meets the uncertainty requirement outlined in A2659.

The Physics Laboratory is currently testing another PTB201A over a longer term and over a wider temperature range. These tests will conclude if the sensor meets the

remaining requirements of A2659, allowing it to be considered for further applications.

Figure 3.



6. REFERENCES

[1]. Guidance Specification (Functional) for a General Purpose Automatic Weather Station, Bureau of Meteorology Specification no. A2659, June 1989.

[2]. Selected Surface Climate Data for Antarctic Stations, July 1967, Bureau of Meteorology, page 27.

APPENDIX A Comparison of Reference barometer with PTB201A at -10°C

Time	Reference [hPa]	PTB201A [hPa]
13:42:06	901.024	901.26
13:42:11	901.039	901.27
13:42:16	901.054	901.27
13:42:21	901.062	901.32
13:42:25	901.073	901.30
13:47:17	925.023	925.25
13:47:22	925.041	925.25
13:47:27	925.041	925.27
13:47:31	925.038	925.25
13:47:35	925.041	925.26
13:52:18	949.925	950.13
13:52:22	949.921	950.12
13:52:30	949.898	950.09
13:52:36	949.913	950.11
13:52:41	949.921	950.11
13:57:34	974.996	975.18
13:57:38	975.015	975.19
13:57:44	975.042	975.21
13:57:48	975.042	975.21
13:57:52	975.054	975.22
14:03:25	999.956	1000.10
14:03:55	999.937	1000.08
14:04:01	999.960	1000.09
14:04:05	999.968	1000.09
14:04:09	999.956	1000.10
14:09:29	1024.89	1025.04
14:09:33	1024.90	1025.04
14:09:36	1024.91	1025.06
14:09:39	1024.91	1025.06
14:09:43	1024.92	1025.07
14:16:37	1050.10	1050.23
14:16:40	1050.09	1050.22
14:16:44	1050.09	1050.21
14:16:48	1050.09	1050.20
14:16:52	1050.08	1050.19
14:23:54	1049.79	1049.91
14:23:57	1049.79	1049.90
14:24:01	1049.79	1049.91
14:24:05	1049.79	1049.91
14:24:08	1049.79	1049.90
14:30:10	1024.74	1024.89
14:30:23	1024.71	1024.86
14:30:27	1024.71	1024.87
14:30:32	1024.72	1024.88
14:30:38	1024.73	1024.88

Time	Reference [hPa]	PTB201A [hPa]
14:39:19	999.950	1000.12
14:39:22	999.946	1000.11
14:39:25	999.942	1000.09
14:39:30	999.942	1000.12
14:39:35	999.938	1000.11
14:44:49	974.91	975.10
14:44:52	974.907	975.10
14:44:56	974.899	975.08
14:45:01	974.899	975.06
14:45:04	974.903	975.08
14:48:57	949.692	949.89
14:49:02	949.677	949.89
14:49:06	949.673	949.87
14:49:12	949.654	949.86
14:49:18	949.654	949.88
14:56:36	923.908	924.14
14:56:39	923.916	924.13
14:56:42	923.927	924.16
14:56:45	923.938	924.17
14:56:48	923.949	924.15
15:03:28	899.918	900.13
15:03:32	899.921	900.17
15:03:40	899.940	900.15
15:03:43	899.936	900.16
15:03:47	899.936	900.17

APPENDIX B Comparison of Reference barometer with PTB201A at 10°C

Time	Reference [hPa]	PTB201A [hPa]
16:28:11	900.682	900.75
16:28:15	900.693	900.75
16:28:22	900.686	900.75
16:28:26	900.674	900.72
16:28:30	900.674	900.72
16:32:18	925.021	925.06
16:32:21	925.025	925.09
16:32:25	925.040	925.09
16:32:30	925.040	925.08
16:32:35	925.040	925.10
16:36:26	950.024	950.06
16:36:39	950.089	950.13
16:36:45	950.066	950.10
16:36:49	950.062	950.10
16:36:53	950.062	950.11
16:41:52	975.024	975.06
16:41:57	975.039	975.07
16:42:05	975.054	975.08
16:42:10	975.043	975.07
16:42:15	975.039	975.07
16:46:43	999.944	999.96
16:47:01	999.909	999.93
16:47:08	999.901	999.91
16:47:16	999.921	999.91
16:47:23	999.917	999.92
16:54:35	1024.97	1024.96
16:54:40	1024.97	1024.97
16:54:46	1024.98	1024.98
16:54:52	1025.00	1025.00
16:54:59	1025.00	1024.99
16:58:11	1049.96	1049.93
16:58:16	1049.98	1049.96
16:58:22	1049.98	1049.95
16:58:26	1049.98	1049.95
16:58:32	1049.99	1049.96
17:04:30	1049.70	1049.68
17:04:34	1049.69	1049.66
17:04:37	1049.69	1049.65
17:04:40	1049.68	1049.65
17:04:44	1049.68	1049.65
17:07:43	1025.00	1024.99
17:07:48	1024.99	1024.98
17:07:52	1024.99	1024.96
17:07:57	1024.99	1024.98
17:08:01	1025.00	1024.98

Time	Reference [hPa]	PTB201A [hPa]
17:13:31	999.863	999.83
17:13:38	999.859	999.85
17:13:44	999.840	999.84
17:13:50	999.832	999.83
17:13:54	999.828	999.81
17:18:04	974.637	974.65
17:18:08	974.618	974.63
17:18:16	974.591	974.59
17:18:21	974.583	974.59
17:18:25	974.572	974.59
17:23:08	949.998	950.01
17:23:11	949.998	950.02
17:23:15	950.009	950.05
17:23:20	950.017	950.05
17:23:25	950.002	950.01
17:30:49	924.995	925.03
17:30:53	924.995	925.03
17:30:56	924.995	925.02
17:31:00	924.987	925.02
17:31:03	924.987	925.00
17:33:56	900.385	900.42
17:34:00	900.377	900.39
17:34:04	900.377	900.42
17:34:09	900.381	900.42
17:34:13	900.381	900.40

APPENDIX C Hysteresis check of PTB201A near 1000 hPa at 10°C

Time	Reference [hPa]	PTB201A [hPa]
17:37:59	974.943	974.96
17:38:04	974.966	974.97
17:38:08	974.993	975.01
17:39:07	979.971	979.98
17:39:10	979.974	979.97
17:39:14	979.967	979.97
17:40:36	984.989	985.01
17:40:40	984.993	985.00
17:40:44	985.004	985.02
17:42:06	989.968	989.96
17:42:08	989.979	989.99
17:42:11	989.991	989.99
17:43:02	995.011	995.03
17:43:07	995.030	995.03
17:43:10	995.038	995.05
17:44:12	1000.01	1000.03
17:44:16	1000.01	1000.03
17:44:19	1000.02	1000.03
17:45:03	1005.05	1005.06
17:45:07	1005.07	1005.08
17:45:11	1005.07	1005.08
17:45:54	1010.04	1010.03
17:45:57	1010.04	1010.06
17:46:00	1010.04	1010.06
17:47:14	1014.95	1014.95
17:47:17	1014.96	1014.96
17:47:21	1014.97	1014.98
17:48:35	1019.98	1019.99
17:48:38	1019.99	1019.99
17:48:41	1019.99	1019.99
17:49:28	1024.99	1024.99
17:49:32	1025.00	1024.99
17:49:35	1025.02	1025.01
17:50:46	1024.90	1024.91
17:50:49	1024.90	1024.91
17:50:52	1024.91	1024.90
17:51:46	1019.91	1019.90
17:51:49	1019.90	1019.91
17:51:52	1019.89	1019.89
17:53:35	1014.76	1014.75
17:53:38	1014.77	1014.77
17:53:41	1014.77	1014.77

Time	Reference [hPa]	PTB201A [hPa]
17:55:00	1010.02	1010.03
17:55:03	1010.02	1010.01
17:55:07	1010.02	1010.03
17:56:16	1005.08	1005.09
17:56:18	1005.07	1005.09
17:56:20	1005.07	1005.07
17:57:30	1000.03	1000.04
17:57:32	1000.02	1000.03
17:57:34	1000.01	1000.04
17:58:17	994.991	995.01
17:58:23	994.960	994.97
17:58:26	994.953	994.96
17:59:13	989.987	990.01
17:59:17	989.972	989.97
17:59:19	989.972	989.96
18:00:49	985.043	985.06
18:00:52	985.035	985.04
18:00:55	985.024	985.03
18:01:58	980.028	980.05
18:02:01	980.028	980.04
18:02:03	980.024	980.04
18:03:06	975.016	975.03
18:03:09	975.001	975.01
18:03:12	974.997	975.01