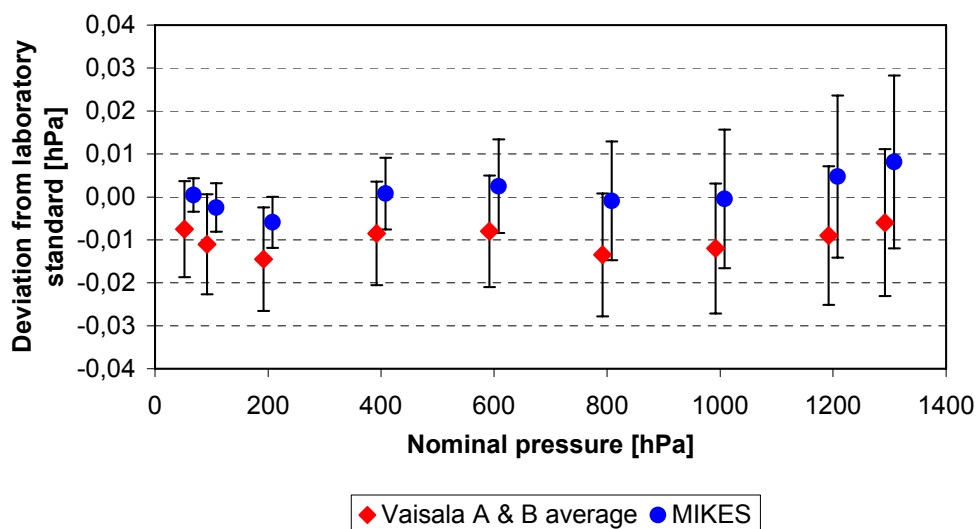


J5/2009

MIKES-Vaisala comparison May 2009
DHI PPC3 s/n 723 High range, increasing pressure



Barometric pressure comparison between MIKES and Vaisala

Range 6 kPa to 130 kPa

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Mittatekniikan keskus

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**Barometric pressure comparison between
MIKES and Vaisala**
Range from 6 kPa to 130 kPa

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Abstract

The pressure laboratories of the Centre for Metrology and Accreditation (MIKES) and Vaisala Oyj compared their absolute pressures in the barometric range from 6 kPa to 130 kPa in 2009. Participation in inter-laboratory comparisons is essential for calibration laboratories working with low uncertainties. An interesting point is also the fact that the traceability of MIKES pressure measurements is obtained from dimensional measurements, complemented with pressure measurements at Laboratoire national de métrologie et d'essais (LNE), France, whereas Vaisala pressures are traceable to the National Institute of Standards and Technology (NIST), USA.

Two DH Instruments PPC3 pressure controller/calibrators were used as transfer standards. Both instruments were equipped with two absolute pressure ranges: a low range from 0 to 110 kPa and a high range from 0 to 160 kPa.

The agreement of the results from MIKES and Vaisala was good.

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1 Introduction

A pressure comparison in the barometric range between Vaisala Oyj and MIKES was arranged in spring 2009. Vaisala Oyj is a well known manufacturer of barometers and other weather observation systems. Their Measurement Standards Laboratory is accredited by FINAS (Finnish Accreditation Service) for temperature, relative humidity and pressure calibrations with low uncertainties.

Vaisala and MIKES participated in a comparison with LNE in 2007 [1]. In 2009 it was decided to repeat essentially the same comparison between Vaisala and MIKES using the same or similar transfer standards.

2 Transfer standards

Two DH Instruments PPC3 pressure controller/calibrators (serial numbers 722 and 723) were used as transfer standards.

Both DHI PPC3s were equipped with two quartz reference pressure transducers (RPTs): High range from 0 to 160 kPa and Low range from 0 to 110 kPa. The RPTs were specially selected for low hysteresis by the manufacturer. The resolutions of the PPC3s were 0,0001 kPa (or 0,001 hPa as the pressure unit chosen for the comparison was hPa).

3 Measurement instructions

The measurement instructions for the earlier comparison were prepared at Vaisala Oyj by Antero Pitkääkoski (Measurement protocol, dated 27.08.2007). The same instructions with only minor modifications were followed in this instance. Two sets of nominal pressures were specified:

For the Low range of PPC3 (500 hPa to 1100 hPa)

500 hPa, 600 hPa, 700 hPa, 800 hPa, 900 hPa, 950 hPa, 1000 hPa, 1050 hPa and 1100 hPa.

For the High range of PPC3: 1 (60 hPa to 1300 hPa)

60 hPa, 100 hPa, 200 hPa, 400 hPa, 600 hPa, 800 hPa, 1000 hPa, 1200 hPa and 1300 hPa

The transmitting gas was specified as dry air or nitrogen.

For both measurement ranges a stabilisation time of 16 hours was specified, the mains power switched on and the pressure connection open to atmosphere. The pre-pressurisation stated was 5 minutes at the highest and the lowest nominal pressure for both measurement ranges.

At each nominal pressure, after the stabilisation, the readings of the transfer and reference standards were to be recorded ten times.

Two up-and-down pressure cycles were specified. The maximum pressure changing rate was set to 5 hPa/s.

The results were asked to be presented as average deviations and measurement uncertainties at each nominal pressure in decreasing and increasing directions separately.

4 Measurements and the presentation of results

The measurements in both ranges were carried out twice at Vaisala and once at MIKES according to the following schedule:

PPC3 s/n 722 Low range:

Vaisala 1	15.04.2009
MIKES	16.04.2009
Vaisala 2	17.04.2009

PPC3 s/n 723 High range:

Vaisala 1	08.05.2009
MIKES	11.05.2009
Vaisala 2	12.05.2009

The results of Vaisala were reported in four calibration certificates [2] and the results from MIKES in two certificates [3].

5 Reference standard of MIKES

The reference standard of MIKES used in this comparison was a DH Instruments PG7607 pressure balance s/n 397 equipped with a piston/cylinder assembly s/n 451. The effective area of the piston/cylinder unit, nominally 1960 mm², was deter-

mined with dimensional measurements at LNE in September - October 2007 (certificate H090649/1) and with pressure measurements at MIKES in July 2008 (certificate M-08P078). The pressure measurements of MIKES are traceable to LNE.

The 38 kg weight set DHI s/n 2376 used with the automatic mass handler AMH-38 on the pressure balance was calibrated at MIKES in August 2008 (certificate M-08M056).

The reference vacuum gauge of the DHI PG7607 was checked against a 1 torr MKS Baratron 690A vacuum gauge on April 4, 2009.

6 Reference standard of Vaisala

The reference standard of Vaisala was a Ruska 2465 pressure balance equipped with the piston/cylinder assembly TL-453 and the weight set s/n 24978. Both the effective area of the piston/cylinder assembly and the masses of the weights are traceable to the National Institute of Standards and Technology (NIST), USA. The calibration results from NIST in more than 20 years time show a very good stability of the instrument, which is backed up by a similar Ruska pressure balance.

The reference vacuum of the Ruska balance was measured with a spinning rotor vacuum gauge MKS SRG-2CE s/n 20825G / 92026G / 191123, traceable to PTB, Germany via MIKES.

7 Measurement results on PPC3 s/n 722 Low range

The results obtained on PPC3 Low range are shown in Table 1. The results are further illustrated in Figures 1 and 2.

A tool often used in analysing results from inter-laboratory comparisons is the normalised error E_n , which takes into account both the result and its uncertainty. The normalised error E_n for a pressure comparison is calculated as

$$E_n = \frac{(p_{transfer} - p_{std})_{lab} - (p_{transfer} - p_{std})_{ref}}{\sqrt{(U_{lab}^2 + U_{ref}^2)}}$$

where

$p_{transfer}$ is the pressure indicated by the transfer standard,
 p_{std} is the pressure of the laboratory standard,
 U_{lab} is the uncertainty of the laboratory result, and
 U_{ref} is the uncertainty of the reference value.

The results are regarded to be in agreement within the limits of uncertainty if the absolute value of the normalised error E_n is less than 1.

The average of the two results from Vaisala was compared to the result from MIKES at each nominal pressure. The differences between the two Vaisala result sets were small and they were included in the uncertainties of the average values.

The normalised error values E_n for the results on the PPC3 Low range are shown in Table 1.

Table 1. Results on PPC3 Low range.

Nominal pressure hPa	Vaisala 1		Vaisala 2		Vaisala 1 & 2 avg.		MIKES		E(n)
	Result hPa	Uncert. hPa	Result hPa	Uncert. hPa	Result hPa	Uncert. hPa	Result hPa	Uncert. hPa	
1100 down	0,0075	0,016	0,0090	0,016	0,0082	0,0161	0,0169	0,0173	-0,37
1050 down	0,0215	0,015	0,0223	0,015	0,0219	0,0150	0,0285	0,0167	-0,29
1000 down	0,0082	0,015	0,0099	0,015	0,0091	0,0152	0,0151	0,0161	-0,27
950 down	0,0086	0,015	0,0100	0,015	0,0093	0,0151	0,0153	0,0155	-0,28
850 down	0,0083	0,014	0,0095	0,014	0,0089	0,0141	0,0144	0,0143	-0,27
750 down	0,0088	0,014	0,0094	0,014	0,0091	0,0140	0,0149	0,0129	-0,30
650 down	0,0095	0,013	0,0093	0,013	0,0094	0,0130	0,0153	0,0117	-0,34
550 down	0,0106	0,013	0,0099	0,013	0,0102	0,0130	0,0159	0,0103	-0,34
500 down	0,0118	0,012	0,0103	0,012	0,0111	0,0122	0,0165	0,0097	-0,35
500 up	0,0076	0,012	0,0065	0,012	0,0070	0,0121	0,0139	0,0099	-0,44
550 up	0,0048	0,013	0,0037	0,013	0,0042	0,0131	0,0121	0,0104	-0,47
650 up	0,0024	0,013	0,0021	0,013	0,0022	0,0130	0,0093	0,0117	-0,40
750 up	0,0014	0,014	0,0002	0,014	0,0008	0,0141	0,0085	0,0129	-0,40
850 up	-0,0003	0,014	-0,0002	0,014	-0,0003	0,0140	0,0086	0,0143	-0,44
950 up	0,0009	0,015	0,0004	0,015	0,0007	0,0150	0,0109	0,0157	-0,47
1000 up	0,0023	0,015	0,0021	0,015	0,0022	0,0150	0,0108	0,0164	-0,39
1050 up	0,0162	0,015	0,0162	0,015	0,0162	0,0150	0,0266	0,0169	-0,46
1100 up	0,0058	0,016	0,0045	0,016	0,0052	0,0161	0,0167	0,0178	-0,48

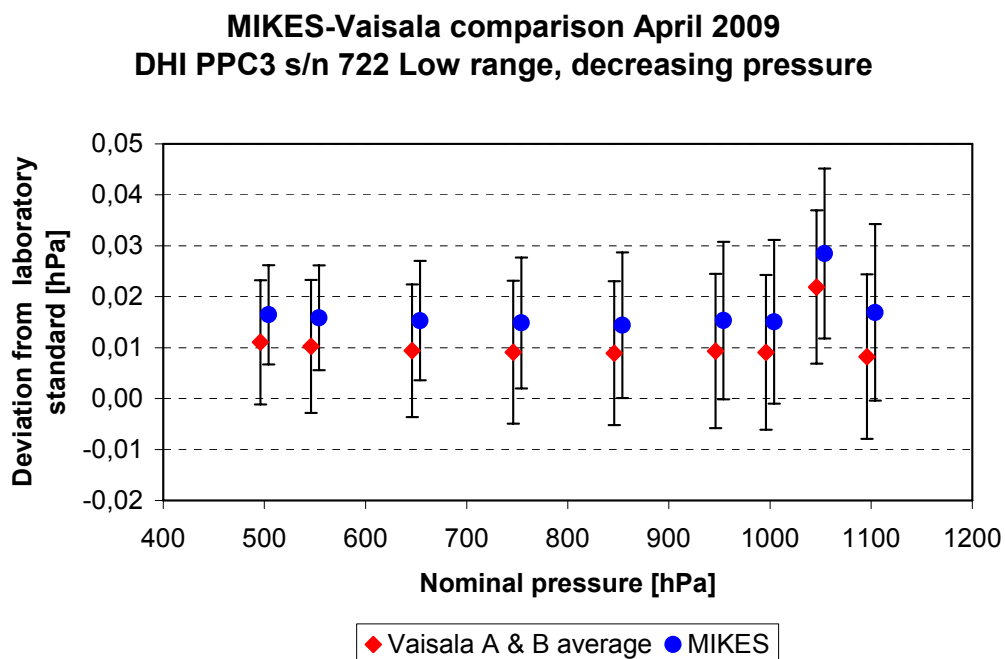


Figure 1. The results on PPC3 Low range for decreasing pressure.

MIKES-Vaisala comparison April 2009
DHI PPC3 s/n 722 Low range, increasing pressure

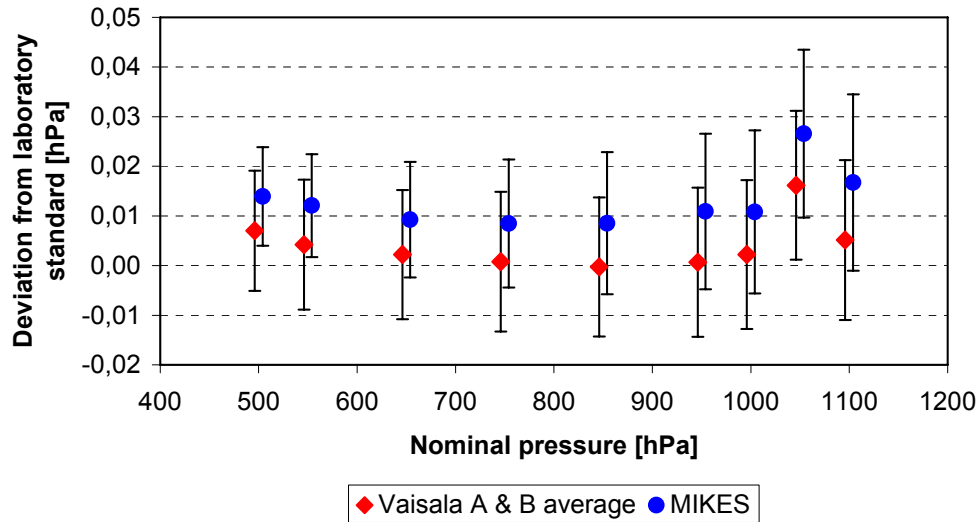


Figure 2. The results on PPC3 Low range for increasing pressure.

All E_n values lie well within the limits from -1 to +1, indicating that the results agree within the claimed uncertainties. However, the difference between the results is practically constant and independent of the nominal pressure. This is probably due to a minor systematic error in the measurement of residual pressure under the bell jar of one or both of the pressure balances.

The deviation from the laboratory standard at nominal pressure 1050 hPa is a little higher than at other nominal pressures. This feature was found by both Vaisala and MIKES.

8 Measurement results on PPC3 s/n 723 High range

The results obtained on PPC3 High range are shown in Table 2 and illustrated in Figures 3 and 4.

The average of the two results from Vaisala was compared to the result from MIKES at each nominal pressure. The differences between the two Vaisala result sets were again small and they were included in the uncertainties of the average values.

The normalised error values E_n for the results on the PPC3 Low range are shown in Table 2.

Table 2. Results on PPC3 High range.

Nominal pressure hPa	Vaisala 1		Vaisala 2		Vaisala 1 & 2 avg.		MIKES		E(n)
	Result hPa	Uncert. hPa	Result hPa	Uncert. hPa	Result hPa	Uncert. hPa	Result hPa	Uncert. hPa	
1300 down	-0,0040	0,017	0,0000	0,017	-0,0020	0,0175	0,0119	0,0206	-0,51
1200 down	-0,0040	0,016	-0,0030	0,016	-0,0035	0,0160	0,0101	0,0188	-0,55
1000 down	-0,0070	0,015	-0,0050	0,015	-0,0060	0,0151	0,0045	0,0164	-0,47
800 down	-0,0080	0,014	-0,0070	0,014	-0,0075	0,0140	0,0030	0,0138	-0,53
600 down	0,0000	0,013	0,0000	0,013	0,0000	0,0130	0,0104	0,0110	-0,61
400 down	0,0040	0,012	0,0020	0,012	0,0030	0,0122	0,0113	0,0089	-0,55
200 down	0,0010	0,011	-0,0010	0,011	0,0000	0,0112	0,0056	0,0061	-0,44
100 down	0,0020	0,010	-0,0010	0,010	0,0005	0,0104	0,0075	0,0048	-0,61
60 down	0,0040	0,010	0,0000	0,010	0,0020	0,0108	0,0068	0,0061	-0,38
60 up	-0,0050	0,010	-0,0100	0,010	-0,0075	0,0112	0,0005	0,0039	-0,67
100 up	-0,0080	0,010	-0,0140	0,010	-0,0110	0,0116	-0,0025	0,0056	-0,66
200 up	-0,0120	0,011	-0,0170	0,011	-0,0145	0,0121	-0,0059	0,0060	-0,64
400 up	-0,0080	0,012	-0,0090	0,012	-0,0085	0,0120	0,0008	0,0083	-0,63
600 up	-0,0080	0,013	-0,0080	0,013	-0,0080	0,0130	0,0025	0,0109	-0,62
800 up	-0,0150	0,014	-0,0120	0,014	-0,0135	0,0143	-0,0009	0,0139	-0,63
1000 up	-0,0130	0,015	-0,0110	0,015	-0,0120	0,0151	-0,0005	0,0161	-0,52
1200 up	-0,0100	0,016	-0,0080	0,016	-0,0090	0,0161	0,0048	0,0189	-0,55
1300 up	-0,0070	0,017	-0,0050	0,017	-0,0060	0,0171	0,0082	0,0202	-0,54

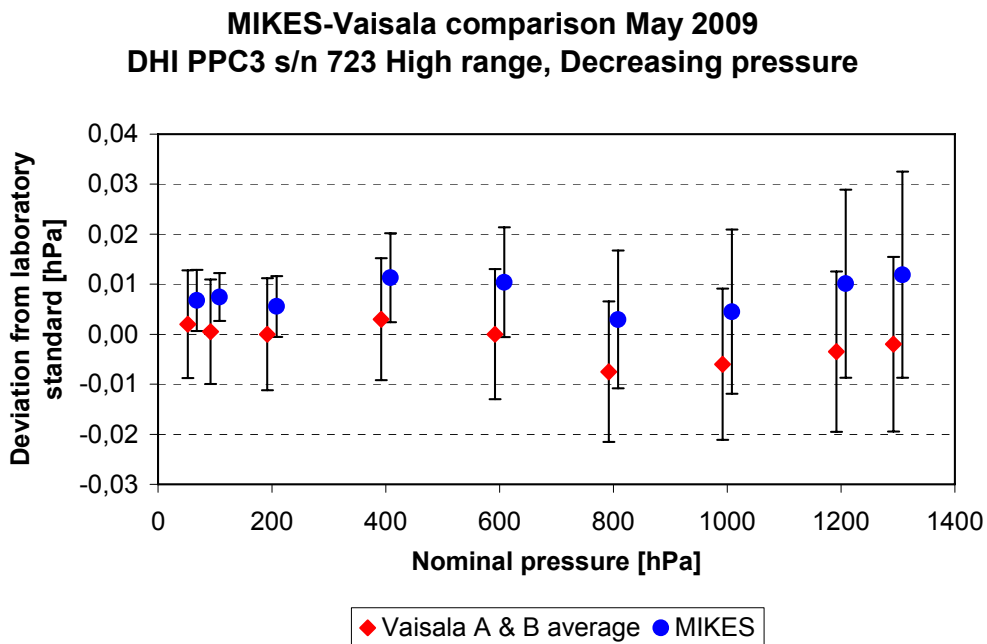


Figure 3. The results on PPC3 High range for decreasing pressure.

MIKES-Vaisala comparison May 2009
DHI PPC3 s/n 723 High range, increasing pressure

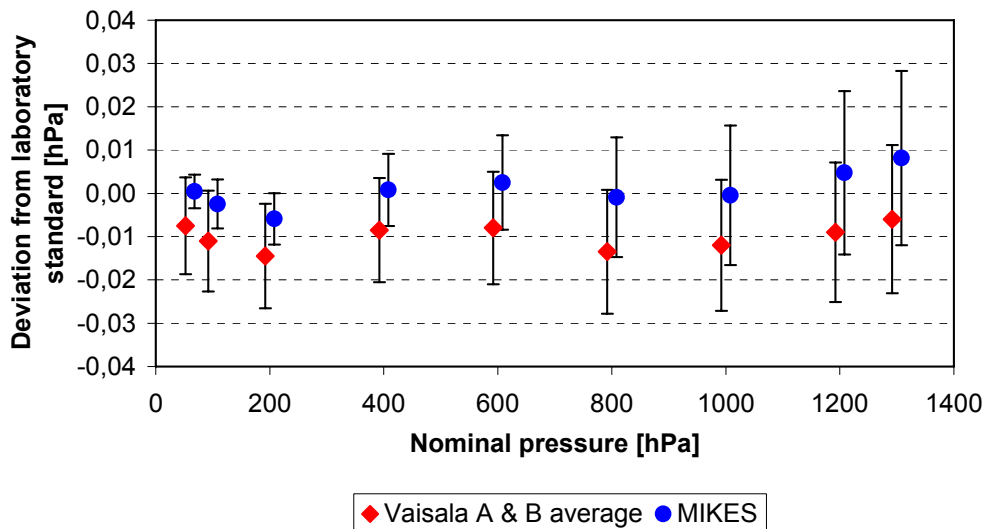


Figure 4. The results on PPC3 High range for increasing pressure.

Again all E_n values lie well within the limits from -1 to +1, indicating that the results agree within the claimed uncertainties. Here again the difference between the results is practically constant and independent of the nominal pressure.

9 Conclusion

All the results from Vaisala were in agreement with the results from MIKES within specified uncertainties as all normalised errors E_n were inside the limits from -1 to +1. However, the nearly constant difference in the results at all nominal pressures suggests a minor error in the measurement of residual pressures.

10 References

- [1] Rantanen, M., Semenoja, S., Pitkäkoski A., and Goguel, F.: Barometric pressure comparison between MIKES, Vaisala and LNE. Range 5 kPa to 130 kPa. MIKES Publication J1/2008.
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