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Intercomparison in Gauge Pressure Range from 20 Pa to 13 kPa

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MIKES
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Intercomparison in Gauge Pressure Range from 20 Pa to 13 kPa

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Contents

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Abstract

An intercomparison in the gauge pressure range from 20 Pa to 13 kPa was arranged in 2004 in Finland by the Centre for Metrology and Accreditation (MIKES). Three pressure calibration laboratories participated in the comparison.

The transfer standard was an MKS Baratron 100 torr type 698 differential pressure transducer with an MKS type 670B signal conditioner. The participants used their routine methods and existing procedures, but a set of preferred nominal pressures was given.

All the pressure results were in a good agreement with the results of MIKES.

Tiivistelmä

Mittatekniikan keskus (MIKES) järjesti vuonna 2004 vertailumittauksen ylipainealueella 20 Pa … 13 kPa. Vertailumittaukseen osallistui kolme kalibrointilaboratorioa Suomesta.

Kiertävä vertailulaite oli 100 torrin paine-eroanturi MKS Baratron 698 varustettuna näyttölaitteella MKS 670B. Osanottajat tekivät mittaukset omien rutiinimenettelyjensä mukaisesti ohjeessa annetuilla nimellispaineilla.

Kaikki paineen mittaustulokset olivat mittausepävarmuuksien puitteissa samoja kuin MIKESin tulokset.

1 Introduction

The demand on low gauge calibrations is increasing, and some of the accredited pressure calibration laboratories have plans to extend their scopes to lower pressures or to improve their best measurement capability in this range, or they just want to check the quality of their non-accredited results. This was the background for the pressure intercomparison P16, arranged in 2004 by the Centre for Metrology and Accreditation (MIKES).

2 Participants

The following laboratories participated in the comparison:

Finnair Oy Test Equipment Calibration, Vantaa
Inspecta Oy Measuring Technology, Helsinki
Oy Beamex Ab, Calibration Laboratory, Pietarsaari

Only one of the laboratories was accredited for the whole range of the comparison.

3 Reference Laboratory

In the gauge pressure range from 0 to 15 kPa the reference standard of MIKES is a DH Instruments FPG 8601 digital piston manometer, which can be used in the absolute mode as well. The effective area is traceable to Laboratoire National d'Essais (BNM-LNE), Paris. The validation process of the instrument is described in reference 1.

For the FPG 8601 of MIKES the best measurement capability is estimated to be 0,02 Pa + $4 \cdot 10^{-5} \cdot p$, where p is pressure. The resolution of the display is 0,001 Pa in the range from 0 to 9999,999 Pa and 0,01 above 10000 Pa.

4 Transfer Standard

The transfer standard was an MKS Baratron 100 torr type 698 differential pressure transducer No. 93200104 with an MKS type 670B signal conditioner No. 238250. The

resolution of the display is 0,1 Pa when *pascal* is selected as the unit on the signal conditioner.

The transducer has been used in MIKES as a working standard almost ten years. By the time some error has been developed in the output but the short term stability of the instrument is generally good.

For the transport the transducer and the signal conditioner were packed in a metal box. The participants did not have to touch the transducer at all, they only connected their own plastic tubing to that of the transfer standard.

5 Measurement Instructions

The participants were asked to keep the transfer standard switched on for several hours, preferably overnight, before starting the calibration. They were asked to check and adjust the NUL of the display to 0,0000 V ± 0,0001 V and the FULL SCALE to 10,0000 V ± 0,0002 V. Further, they were asked to pre-pressurise the transfer standard twice to 13 kPa an then set the ZERO to 0,0 Pa.

The participants were advised to calibrate the transfer standard using their own procedures. However, the use of the following nominal pressures was recommended:

20 Pa, 50 Pa, 100 Pa, 200 Pa, 300 Pa, 500 Pa, 1000 Pa, 2000 Pa,
3000 Pa, 5000 Pa, 7000 Pa, 10000 Pa and 13000 Pa.

Finally, the participants were asked to send their results as calibration certificates to MIKES within two weeks after the measurements.

6 Calculation of the Reference Values

The transfer standard was calibrated six times at the reference laboratory MIKES. The first calibration was made at the end of April and the last in the beginning of July in 2004. The results were presented in certificates M-04P081 ... M-04P086. The test sequence in MIKES calibrations consisted of three up-and-down cycles.

Figure 1 shows the result points of the first MIKES calibration (M-04P081) and the third degree curve fitting best to the results.

Figure 2 shows all the result points from the six MIKES calibrations. The scatter seems to be higher between the calibrations than inside one calibration. The hysteresis effects were negligible.

The reference values were calculated as the averages of the MIKES results for each nominal pressure. The uncertainties of the reference values were calculated according

to document EA-4/02 and a coverage factor k = 2. The major uncertainty components taken into account were the following:

uncertainty in setting the zero of the transfer standard
resolution of the transfer standard
standard deviation of the results in each series
standard deviation of the averages of the six series
uncertainty of the measurement standard.

The reference values and their uncertainties are shown in Table 1. They are illustrated in Figure 3 as well as the results from the first calibration in MIKES on 28th of April and those from two other calibrations on 17th of May and on 30th of June 2004. These two calibrations seem to deviate most from the average values.

Table 1. The reference values based on the six calibrations in MIKES

Nominal pressure Pa	Reference value Pa	Uncertainty of ref. value Pa
20	0,28	0,15
50	0,62	0,15
100	1,22	0,18
200	2,43	0,13
300	3,62	0,18
500	5,99	0,30
1000	11,76	0,30
2000	22,63	0,54
3000	34,74	0,65
5000	50,9	1,1
7000	66,9	1,3
10000	89,2	1,6
13000	114,5	1,9

7 Results

All of the participating laboratories could not present their results as calibration certificates as the pressure range was outside their accredited scope. However, the results were given with uncertainties estimated using the document EA-4/02 and a coverage factor k = 2.

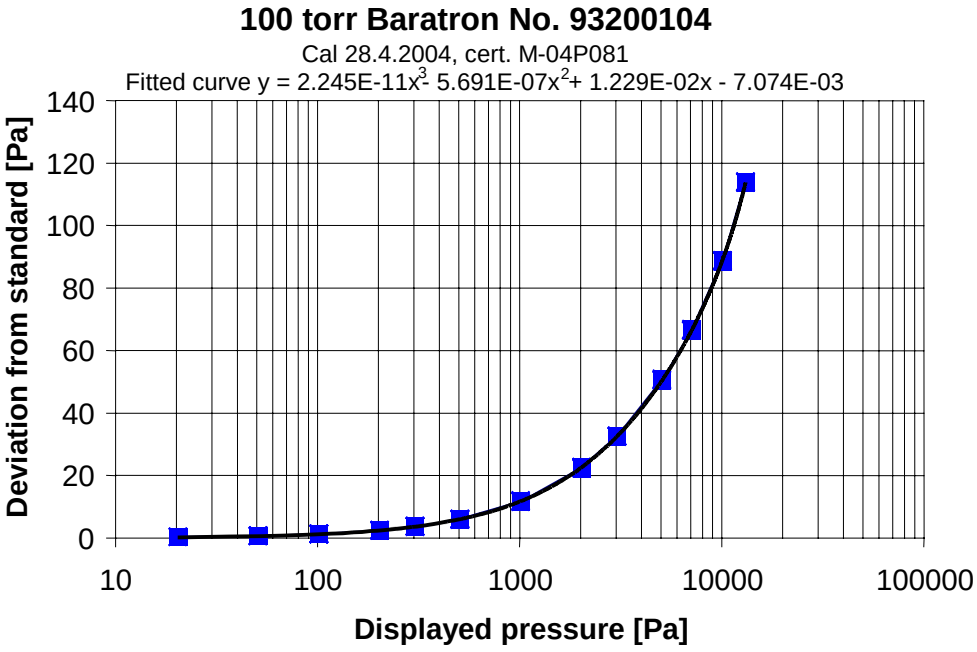

Figure 1. Results of the first calibration in MIKES and the best fitting third degree curve.

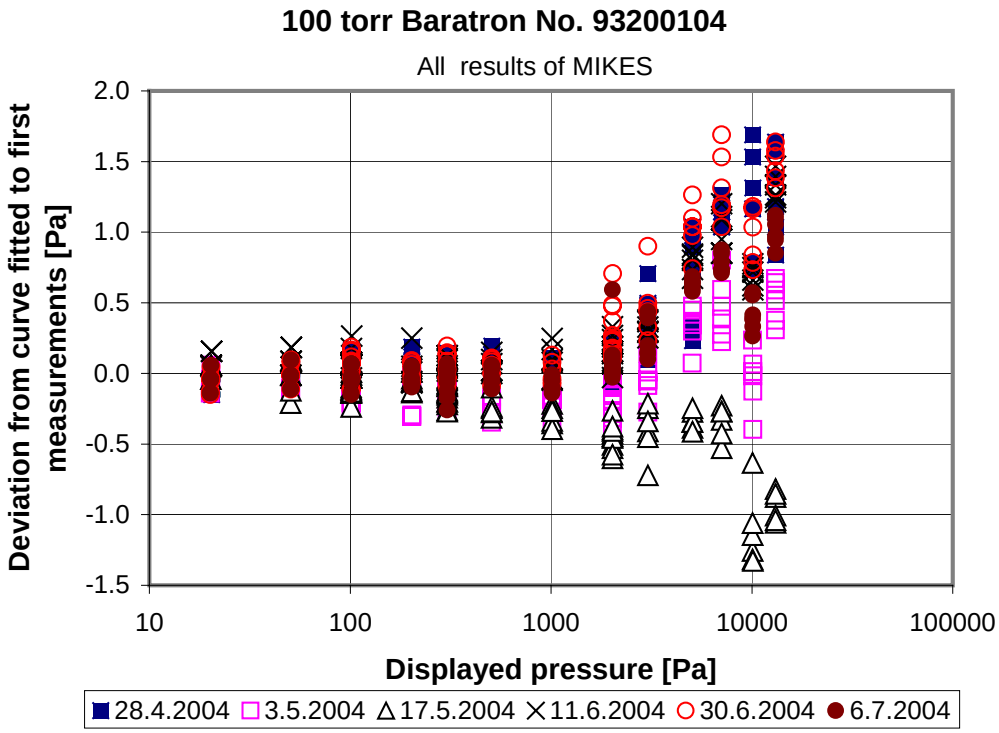

Figure 2. Results from all the six calibrations in MIKES (M1 to M6).

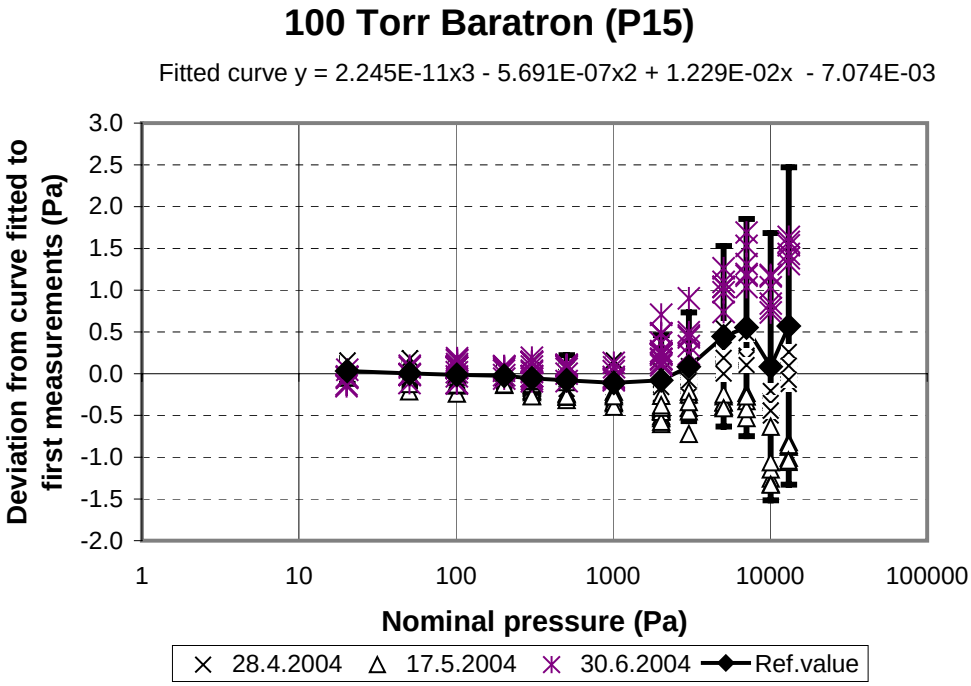

Figure 3. Reference values and results from calibrations M1, M3 and M5.

Following the EA intercomparison practice all laboratories were given letter codes. Each laboratory knows only its own code.

Laboratory A made the measurements using two different standards and sent two sets of results.

Laboratory B, too, made the measurements with two standards but gave only one set of results.

Laboratory C used two standards as well. Its combined results were presented separately for the increasing and the decreasing pressures.

All the results are shown in the Appendix. The results obtained on nominal pressures 100 Pa, 300 Pa, 1000 Pa, 3000 Pa and 10000 Pa are illustrated in Figures 4 to 8.

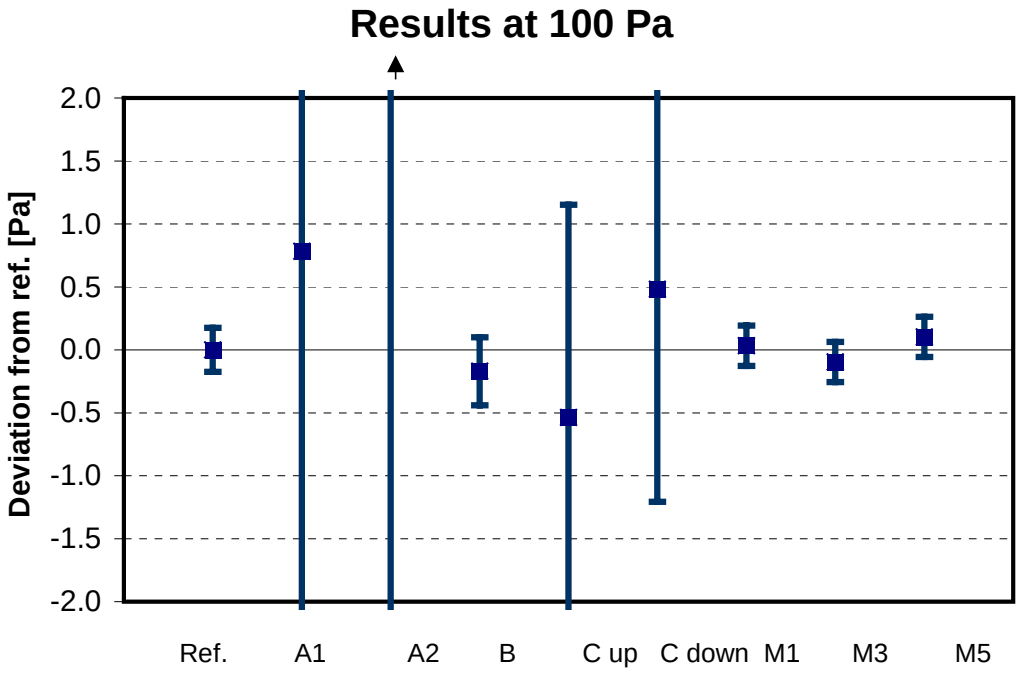

Figure 4. Results at nominal pressure 100 Pa.

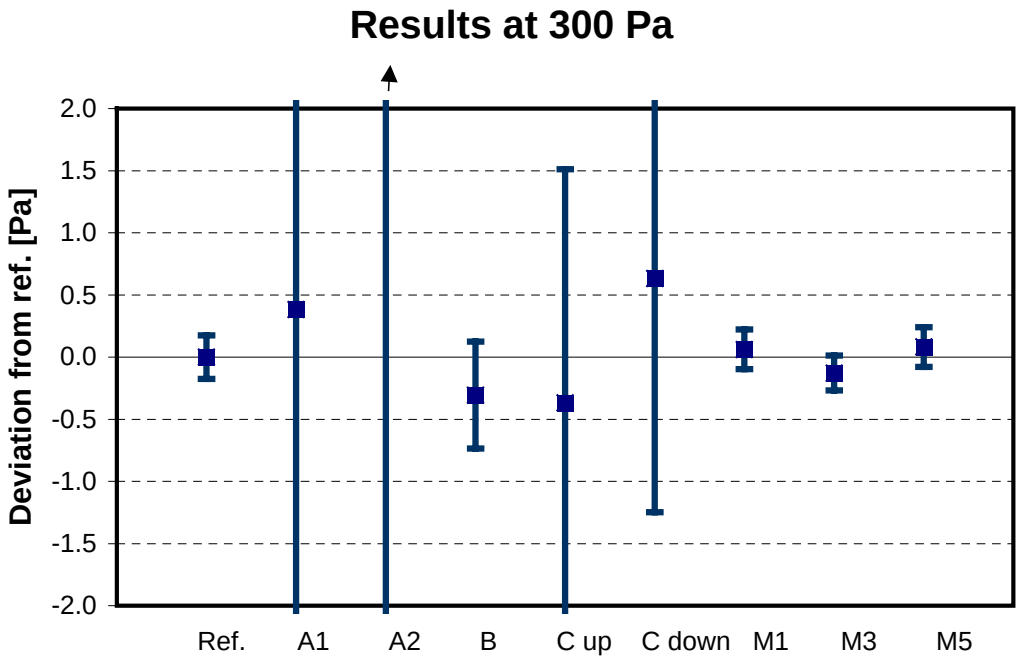

Figure 5. Results at nominal pressure 300 Pa.

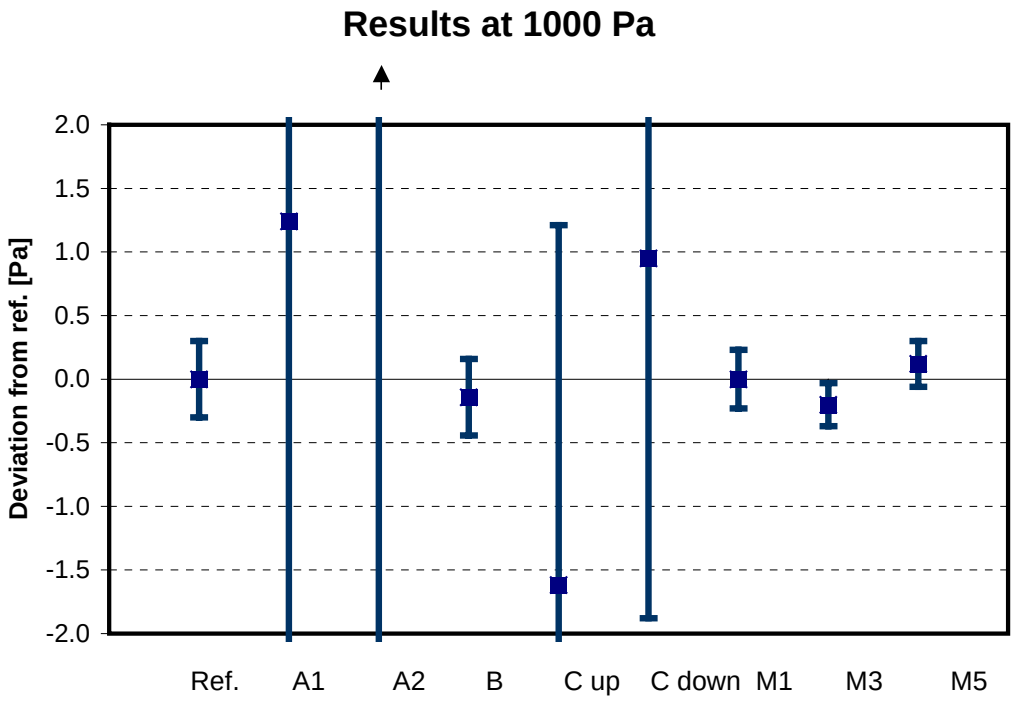

Figure 6. Results at nominal pressure 1000 Pa.

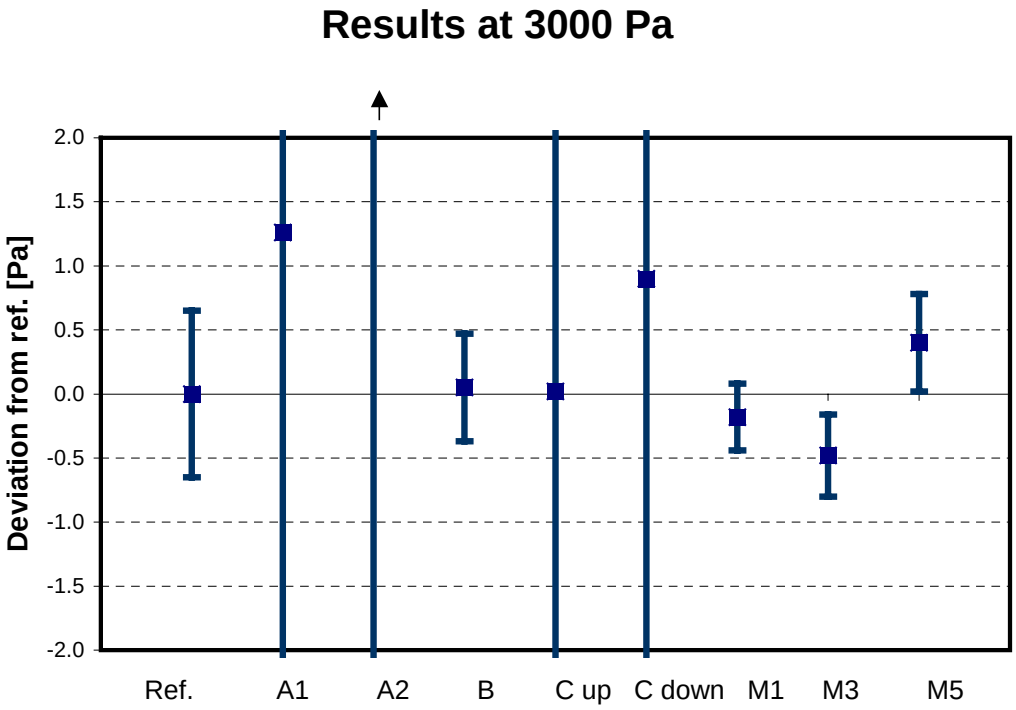

Figure 7. Results at nominal pressure 3000 Pa.

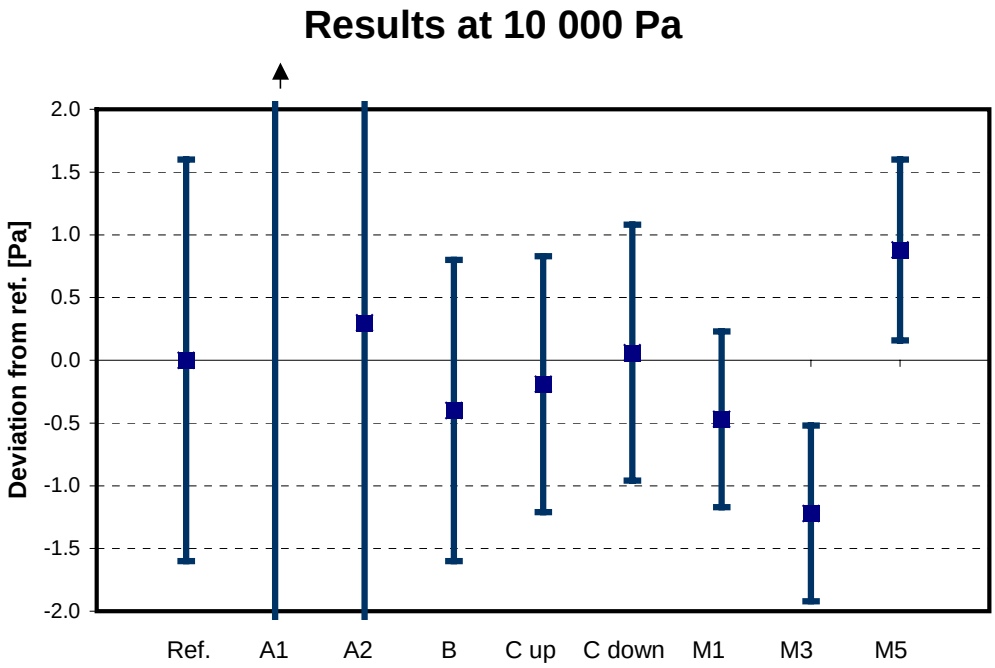

Figure 8. Results at nominal pressure 10 000 Pa.

A tool often used in analysing results from interlaboratory comparisons is the normalised error E_n, which takes into account both the result and its uncertainty. The normalised error E_n is calculated as

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

where

$p_{transfer}$	is 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 E_n-values of all the results are also shown in the Appendix, not only for the participating laboratories but for the MIKES calibrations dated 28th of April (M1), 17th of May (M3) and 30th of June 2004 (M5).

A summary of the E_n-values is in the following table:

Laboratory	Range of E_n-values
A1	-0,57 … 0,29
A2	0,02 … 0,21
B	-0,66 … 0,04
C up	-0,57 … 0,24
C down	0,01 … 0,36
M1	-0,27 … 0,43
M3	-0,74 …-0,07
M5	-0,43 … 0,55

The result in an interlaboratory comparison is regarded as correct within the limits of uncertainty, if the absolute value of the normalised error E_n is less than 1.

In this case the E_n-values for all the results from all the laboratories are between -1 and +1.

The pressure standard of laboratory B that was used in this comparison was re-calibrated in November 2004. The re-calibration data applied to the comparison results would still improve the E_n-values for laboratory B. The range of E_n-values would now be from –0,23 to 0,33.

8 Conclusions

Three pressure calibration laboratories participated in an intercomparison in the gauge pressure range from 20 Pa to 130 kPa in May and June 2004.

All the results from all the participating laboratories were in a good agreement with the reference values from MIKES.

The transfer standard, an MKS Baratron 100 torr type 698 differential pressure. transducer with an MKS type 670B signal conditioner, was found to be stable enough for an intercomparison at this level. However, the uncertainty was a bit too high for a very critical assessment of the measurement capability of laboratory B on the lowest nominal pressures.

9 References

[1] Semenoja, Sari & Rantanen, Markku: Comparisons to establish a force-balanced piston gauge and a spinning rotor gauge as the new measurement standards of MIKES. Vacuum 73(2004) 269 – 274.
[2] EA-4/02: Expression of the Uncertainty of Measurement in Calibration
[3] Certificates of Calibration M-04P081 to M-04P086. Centre for Metrology and Accreditation

Appendix 1: Summary of results from each participating laboratory

Lab code A1

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	1	12	0.28	0.15	0.72	0.06
50	1	12	0.62	0.15	0.38	0.03
100	2	12	1.22	0.18	0.78	0.07
200	3	12	2.43	0.13	0.57	0.05
300	4	12	3.62	0.18	0.38	0.03
500	7	12	5.99	0.30	1.01	0.08
1000	13	12	11.76	0.30	1.24	0.10
2000	24	12	22.63	0.54	1.37	0.11
3000	34	12	32.74	0.65	1.26	0.10
5000	44	12	50.89	1.08	-6.89	-0.57
7000	69	12	66.9	1.3	2.10	0.17
10000	92	12	89.2	1.6	2.80	0.23
13000	118	12	114.5	1.9	3.50	0.29

Lab code A2

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	2.6	12	0.28	0.15	2.32	0.19
50	2.8	12	0.62	0.15	2.18	0.18
100	3.7	12	1.22	0.18	2.48	0.21
200	4.8	12	2.43	0.13	2.37	0.20
300	5.9	12	3.62	0.18	2.28	0.19
500	8.4	12	5.99	0.30	2.41	0.20
1000	14.2	12	11.76	0.30	2.44	0.20
2000	25.1	12	22.63	0.54	2.47	0.21
3000	35.1	12	32.74	0.65	2.36	0.20
5000	52.5	12	50.89	1.08	1.61	0.13
7000	67.2	12	66.9	1.3	0.30	0.02
10000	89.5	12	89.2	1.6	0.30	0.02
13000	115.2	12	114.5	1.9	0.70	0.06

Lab code B

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.106	0.25	0.28	0.15	-0.17	-0.58
50	0.446	0.25	0.62	0.15	-0.17	-0.59
100	1.047	0.27	1.22	0.18	-0.17	-0.53
200	2.278	0.31	2.43	0.13	-0.16	-0.46
300	3.312	0.43	3.62	0.18	-0.31	-0.66
500	5.796	0.25	5.99	0.30	-0.19	-0.50
1000	11.618	0.30	11.76	0.30	-0.14	-0.33
2000	22.593	0.28	22.63	0.54	-0.04	-0.06
3000	32.792	0.42	32.74	0.65	0.05	0.07
5000	50.831	0.60	50.89	1.08	-0.06	-0.05
7000	66.489	0.78	66.9	1.3	-0.41	-0.27
10000	88.80	1.2	89.2	1.6	-0.40	-0.20
13000	114.59	1.5	114.5	1.9	0.09	0.04

Lab code C up

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	-0.03	1.61	0.28	0.15	-0.31	-0.19
50	0.31	1.64	0.62	0.15	-0.31	-0.19
100	0.68	1.69	1.22	0.18	-0.54	-0.32
200	1.96	1.78	2.43	0.13	-0.47	-0.26
300	3.25	1.88	3.62	0.18	-0.37	-0.19
500	5.62	2.07	5.99	0.30	-0.37	-0.18
1000	10.14	2.83	11.76	0.30	-1.62	-0.57
2000	22.13	3.74	22.63	0.54	-0.50	-0.13
3000	32.76	4.69	32.74	0.65	0.02	0.00
5000	52.47	6.63	50.89	1.08	1.58	0.24
7000	66.76	1.02	66.9	1.3	-0.14	-0.08
10000	89.01	1.02	89.2	1.6	-0.19	-0.10
13000	114.53	1.32	114.5	1.9	0.03	0.01

Lab code C down

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.71	1.61	0.28	0.15	0.43	0.27
50	0.82	1.64	0.62	0.15	0.20	0.12
100	1.70	1.69	1.22	0.18	0.48	0.28
200	2.92	1.78	2.43	0.13	0.49	0.27
300	4.25	1.88	3.62	0.18	0.63	0.33
500	6.74	2.07	5.99	0.30	0.75	0.36
1000	12.71	2.83	11.76	0.30	0.95	0.33
2000	23.34	3.74	22.63	0.54	0.71	0.19
3000	33.64	4.69	32.74	0.65	0.90	0.19
5000	52.43	6.63	50.89	1.08	1.54	0.23
7000	67.01	1.02	66.9	1.3	0.11	0.07
10000	89.26	1.02	89.2	1.6	0.06	0.03
13000	114.53	1.32	114.5	1.9	0.03	0.01

Lab code M1 = MIKES 28.4.04

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.36	0.15	0.28	0.15	0.08	0.39
50	0.72	0.18	0.62	0.15	0.10	0.43
100	1.25	0.16	1.22	0.18	0.03	0.14
200	2.44	0.16	2.43	0.13	0.01	0.03
300	3.68	0.16	3.62	0.18	0.06	0.26
500	6.00	0.20	5.99	0.30	0.01	0.03
1000	11.76	0.23	11.76	0.30	0.00	0.00
2000	22.51	0.27	22.63	0.54	-0.12	-0.20
3000	32.56	0.26	32.74	0.65	-0.18	-0.26
5000	50.66	0.44	50.89	1.08	-0.23	-0.20
7000	66.57	0.52	66.9	1.3	-0.33	-0.24
10000	88.73	0.70	89.2	1.6	-0.47	-0.27
13000	113.96	0.90	114.5	1.9	-0.54	-0.26

Lab code M3 = MIKES 17.5.04

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.26	0.15	0.28	0.15	-0.02	-0.07
50	0.60	0.20	0.62	0.15	-0.02	-0.07
100	1.12	0.16	1.22	0.18	-0.10	-0.41
200	2.39	0.15	2.43	0.13	-0.04	-0.21
300	3.49	0.14	3.62	0.18	-0.13	-0.57
500	5.83	0.17	5.99	0.30	-0.16	-0.46
1000	11.56	0.17	11.76	0.30	-0.20	-0.58
2000	22.21	0.21	22.63	0.54	-0.42	-0.72
3000	32.26	0.32	32.74	0.65	-0.48	-0.66
5000	50.10	0.35	50.89	1.08	-0.79	-0.70
7000	66.00	0.48	66.9	1.3	-0.90	-0.65
10000	87.98	0.70	89.2	1.6	-1.22	-0.70
13000	112.97	0.82	114.5	1.9	-1.53	-0.74

Lab code M5 = MIKES 30.6.04

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.18	0.16	0.28	0.15	-0.10	-0.43
50	0.62	0.16	0.62	0.15	0.00	0.01
100	1.32	0.16	1.22	0.18	0.10	0.43
200	2.49	0.15	2.43	0.13	0.06	0.28
300	3.70	0.16	3.62	0.18	0.08	0.35
500	6.11	0.17	5.99	0.30	0.12	0.35
1000	11.88	0.18	11.76	0.30	0.12	0.34
2000	22.93	0.22	22.63	0.54	0.30	0.51
3000	33.14	0.38	32.74	0.65	0.40	0.53
5000	51.47	0.42	50.89	1.08	0.58	0.50
7000	67.68	0.57	66.9	1.3	0.78	0.55
10000	90.08	0.72	89.2	1.6	0.88	0.50
13000	115.42	0.89	114.5	1.9	0.92	0.44

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J1/2002 T. Weckström, *Lämpötilan mittaus*

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All the pressure results were in a good agreement with the results of MIKES.

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Mittatekniikan keskus (MIKES) järjesti vuonna 2004 vertailumittauksen ylipainealueella 20 Pa … 13 kPa. Vertailumittaukseen osallistui kolme kalibrointilaboratorioa Suomesta.

Kiertävä vertailulaite oli 100 torrin paine-eroanturi MKS Baratron 698 varustettuna näyttölaitteella MKS 670B. Osanottajat tekivät mittaukset omien rutiinimenettelyjensä mukaisesti ohjeessa annetuilla nimellispaineilla.

Kaikki paineen mittaustulokset olivat mittausepävarmuuksien puitteissa samoja kuin MIKESin tulokset.

1 Introduction

The demand on low gauge calibrations is increasing, and some of the accredited pressure calibration laboratories have plans to extend their scopes to lower pressures or to improve their best measurement capability in this range, or they just want to check the quality of their non-accredited results. This was the background for the pressure intercomparison P16, arranged in 2004 by the Centre for Metrology and Accreditation (MIKES).

2 Participants

The following laboratories participated in the comparison:

Finnair Oy Test Equipment Calibration, Vantaa
Inspecta Oy Measuring Technology, Helsinki
Oy Beamex Ab, Calibration Laboratory, Pietarsaari

Only one of the laboratories was accredited for the whole range of the comparison.

3 Reference Laboratory

In the gauge pressure range from 0 to 15 kPa the reference standard of MIKES is a DH Instruments FPG 8601 digital piston manometer, which can be used in the absolute mode as well. The effective area is traceable to Laboratoire National d'Essais (BNM-LNE), Paris. The validation process of the instrument is described in reference 1.

For the FPG 8601 of MIKES the best measurement capability is estimated to be 0,02 Pa + $4 \cdot 10^{-5} \cdot p$, where p is pressure. The resolution of the display is 0,001 Pa in the range from 0 to 9999,999 Pa and 0,01 above 10000 Pa.

4 Transfer Standard

The transfer standard was an MKS Baratron 100 torr type 698 differential pressure transducer No. 93200104 with an MKS type 670B signal conditioner No. 238250. The

resolution of the display is 0,1 Pa when *pascal* is selected as the unit on the signal conditioner.

The transducer has been used in MIKES as a working standard almost ten years. By the time some error has been developed in the output but the short term stability of the instrument is generally good.

For the transport the transducer and the signal conditioner were packed in a metal box. The participants did not have to touch the transducer at all, they only connected their own plastic tubing to that of the transfer standard.

5 Measurement Instructions

The participants were asked to keep the transfer standard switched on for several hours, preferably overnight, before starting the calibration. They were asked to check and adjust the NUL of the display to 0,0000 V ± 0,0001 V and the FULL SCALE to 10,0000 V ± 0,0002 V. Further, they were asked to pre-pressurise the transfer standard twice to 13 kPa an then set the ZERO to 0,0 Pa.

The participants were advised to calibrate the transfer standard using their own procedures. However, the use of the following nominal pressures was recommended:

20 Pa, 50 Pa, 100 Pa, 200 Pa, 300 Pa, 500 Pa, 1000 Pa, 2000 Pa,
3000 Pa, 5000 Pa, 7000 Pa, 10000 Pa and 13000 Pa.

Finally, the participants were asked to send their results as calibration certificates to MIKES within two weeks after the measurements.

6 Calculation of the Reference Values

The transfer standard was calibrated six times at the reference laboratory MIKES. The first calibration was made at the end of April and the last in the beginning of July in 2004. The results were presented in certificates M-04P081 ... M-04P086. The test sequence in MIKES calibrations consisted of three up-and-down cycles.

Figure 1 shows the result points of the first MIKES calibration (M-04P081) and the third degree curve fitting best to the results.

Figure 2 shows all the result points from the six MIKES calibrations. The scatter seems to be higher between the calibrations than inside one calibration. The hysteresis effects were negligible.

The reference values were calculated as the averages of the MIKES results for each nominal pressure. The uncertainties of the reference values were calculated according

to document EA-4/02 and a coverage factor k = 2. The major uncertainty components taken into account were the following:

uncertainty in setting the zero of the transfer standard
resolution of the transfer standard
standard deviation of the results in each series
standard deviation of the averages of the six series
uncertainty of the measurement standard.

The reference values and their uncertainties are shown in Table 1. They are illustrated in Figure 3 as well as the results from the first calibration in MIKES on 28th of April and those from two other calibrations on 17th of May and on 30th of June 2004. These two calibrations seem to deviate most from the average values.

Table 1. The reference values based on the six calibrations in MIKES

Nominal pressure Pa	Reference value Pa	Uncertainty of ref. value Pa
20	0,28	0,15
50	0,62	0,15
100	1,22	0,18
200	2,43	0,13
300	3,62	0,18
500	5,99	0,30
1000	11,76	0,30
2000	22,63	0,54
3000	34,74	0,65
5000	50,9	1,1
7000	66,9	1,3
10000	89,2	1,6
13000	114,5	1,9

7 Results

All of the participating laboratories could not present their results as calibration certificates as the pressure range was outside their accredited scope. However, the results were given with uncertainties estimated using the document EA-4/02 and a coverage factor k = 2.

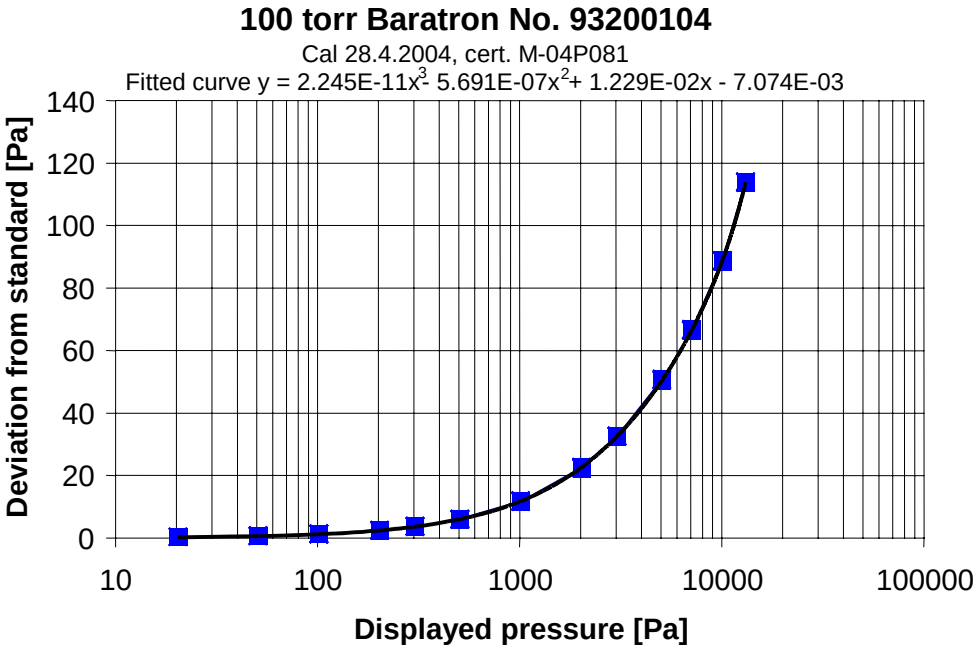

Figure 1. Results of the first calibration in MIKES and the best fitting third degree curve.

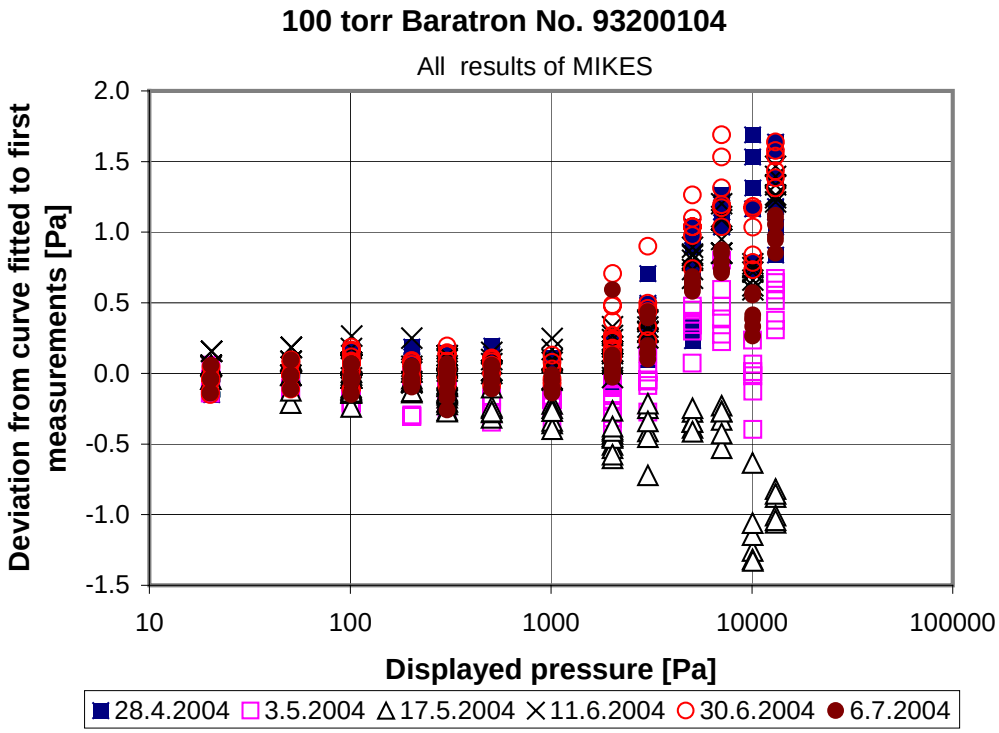

Figure 2. Results from all the six calibrations in MIKES (M1 to M6).

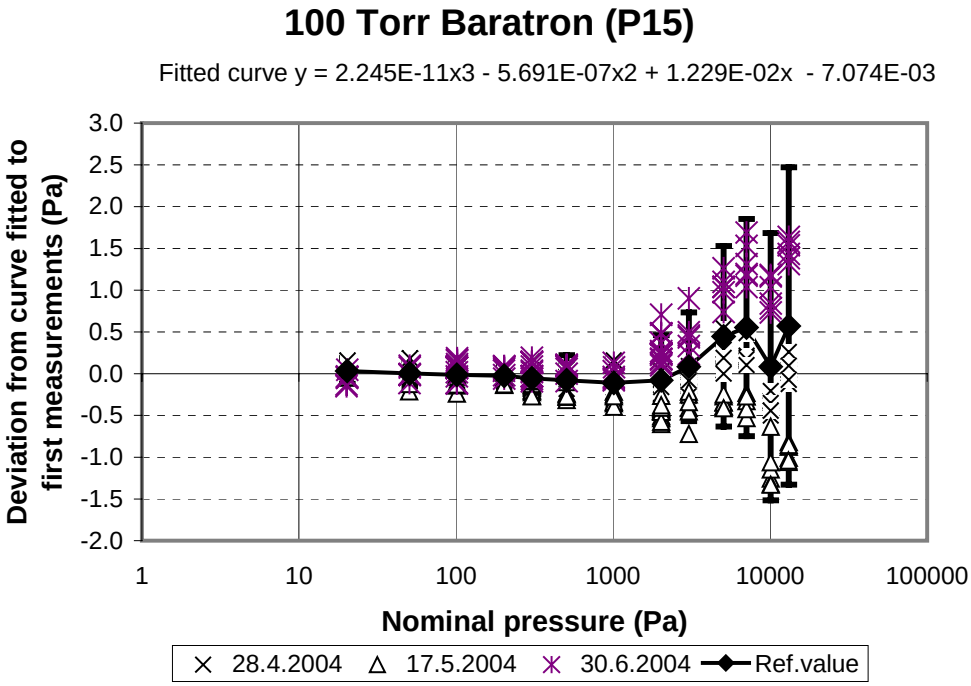

Figure 3. Reference values and results from calibrations M1, M3 and M5.

Following the EA intercomparison practice all laboratories were given letter codes. Each laboratory knows only its own code.

Laboratory A made the measurements using two different standards and sent two sets of results.

Laboratory B, too, made the measurements with two standards but gave only one set of results.

Laboratory C used two standards as well. Its combined results were presented separately for the increasing and the decreasing pressures.

All the results are shown in the Appendix. The results obtained on nominal pressures 100 Pa, 300 Pa, 1000 Pa, 3000 Pa and 10000 Pa are illustrated in Figures 4 to 8.

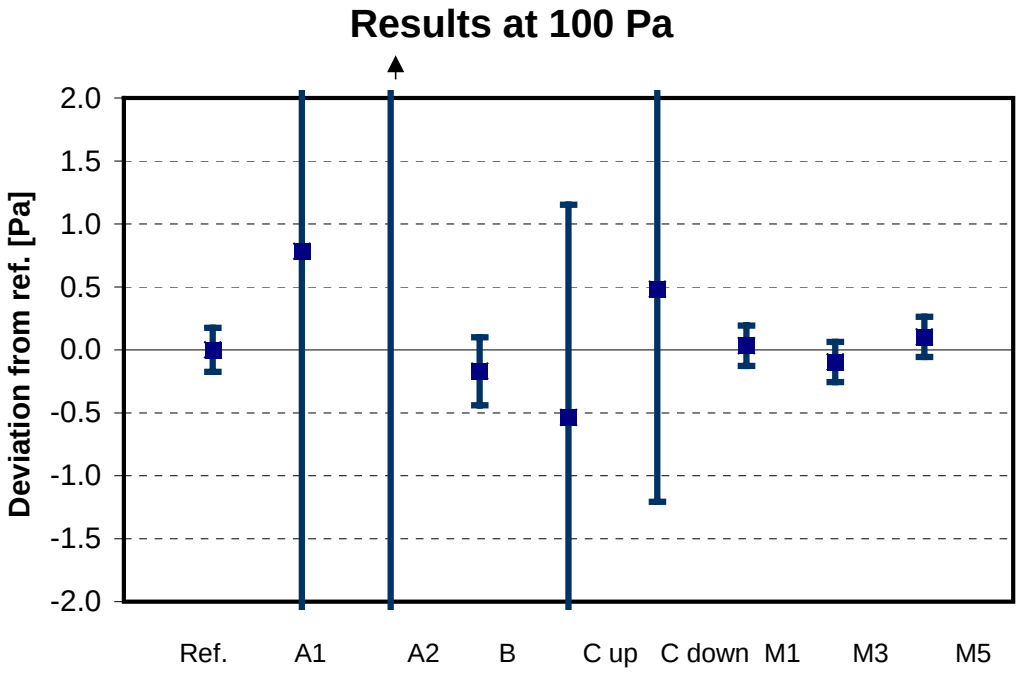

Figure 4. Results at nominal pressure 100 Pa.

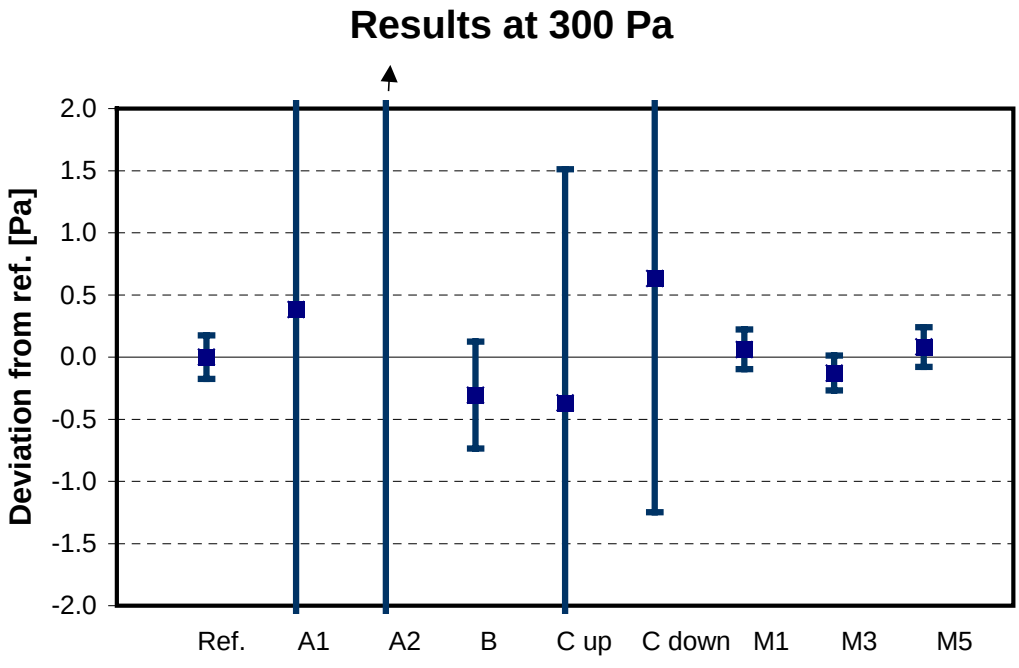

Figure 5. Results at nominal pressure 300 Pa.

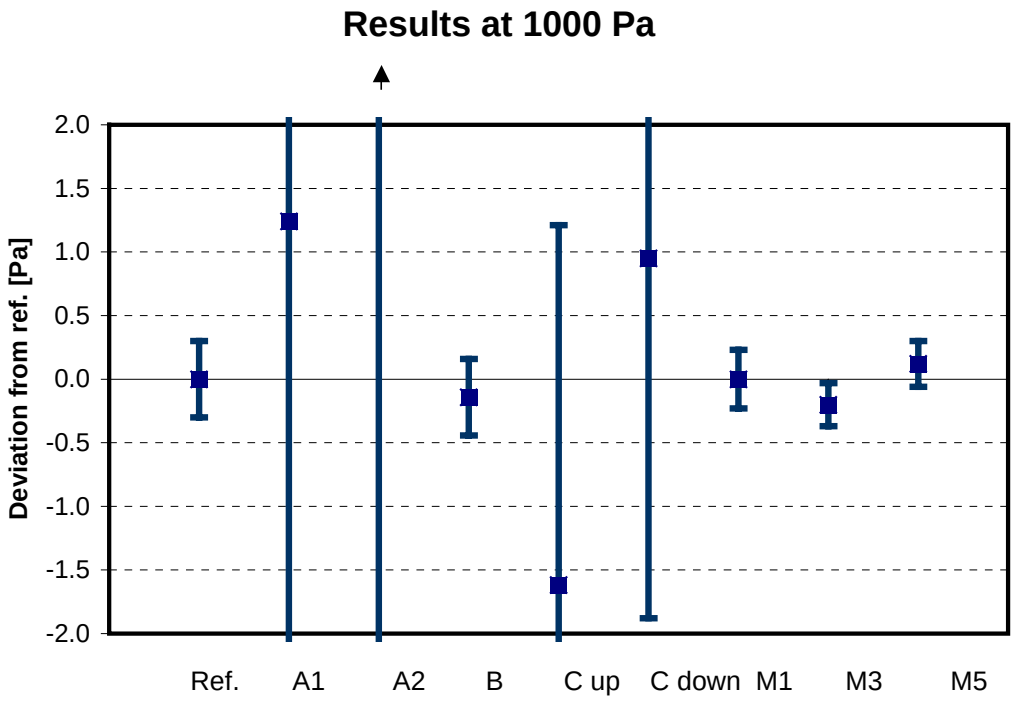

Figure 6. Results at nominal pressure 1000 Pa.

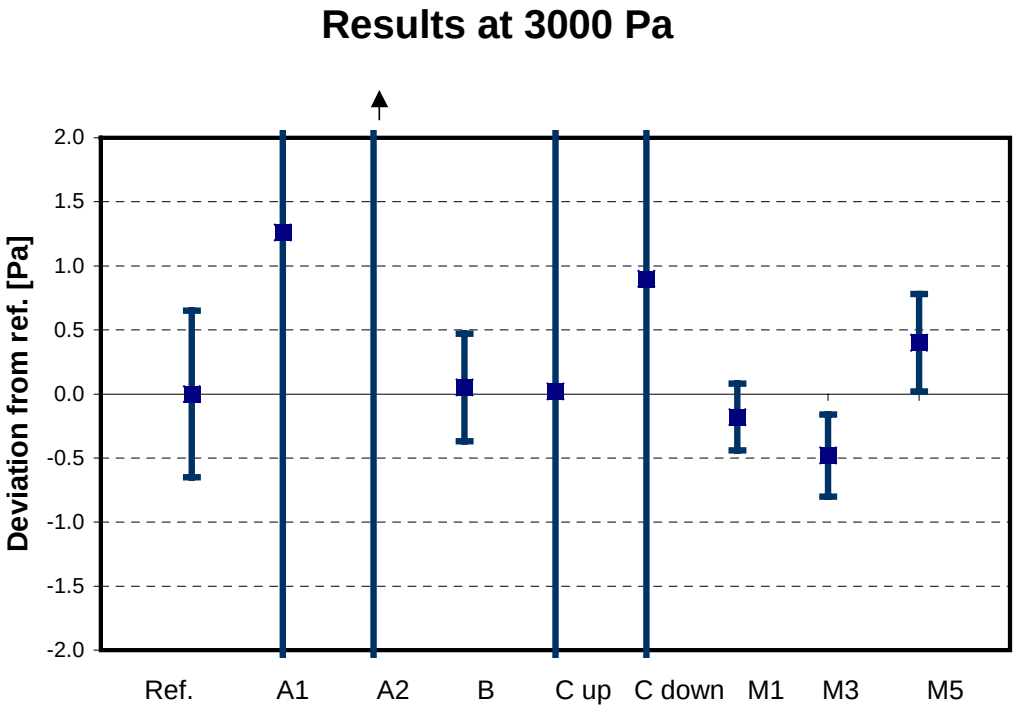

Figure 7. Results at nominal pressure 3000 Pa.

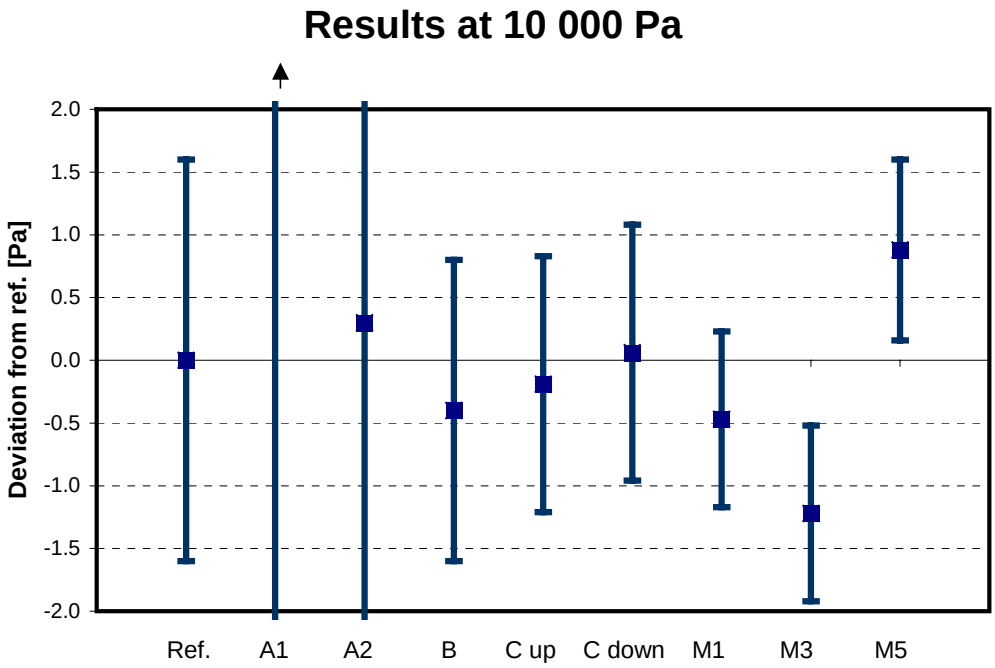

Figure 8. Results at nominal pressure 10 000 Pa.

A tool often used in analysing results from interlaboratory comparisons is the normalised error E_n, which takes into account both the result and its uncertainty. The normalised error E_n is calculated as

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

where

$p_{transfer}$	is 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 E_n-values of all the results are also shown in the Appendix, not only for the participating laboratories but for the MIKES calibrations dated 28th of April (M1), 17th of May (M3) and 30th of June 2004 (M5).

A summary of the E_n-values is in the following table:

Laboratory	Range of E_n-values
A1	-0,57 … 0,29
A2	0,02 … 0,21
B	-0,66 … 0,04
C up	-0,57 … 0,24
C down	0,01 … 0,36
M1	-0,27 … 0,43
M3	-0,74 …-0,07
M5	-0,43 … 0,55

The result in an interlaboratory comparison is regarded as correct within the limits of uncertainty, if the absolute value of the normalised error E_n is less than 1.

In this case the E_n-values for all the results from all the laboratories are between -1 and +1.

The pressure standard of laboratory B that was used in this comparison was re-calibrated in November 2004. The re-calibration data applied to the comparison results would still improve the E_n-values for laboratory B. The range of E_n-values would now be from –0,23 to 0,33.

8 Conclusions

Three pressure calibration laboratories participated in an intercomparison in the gauge pressure range from 20 Pa to 130 kPa in May and June 2004.

All the results from all the participating laboratories were in a good agreement with the reference values from MIKES.

The transfer standard, an MKS Baratron 100 torr type 698 differential pressure. transducer with an MKS type 670B signal conditioner, was found to be stable enough for an intercomparison at this level. However, the uncertainty was a bit too high for a very critical assessment of the measurement capability of laboratory B on the lowest nominal pressures.

9 References

[1] Semenoja, Sari & Rantanen, Markku: Comparisons to establish a force-balanced piston gauge and a spinning rotor gauge as the new measurement standards of MIKES. Vacuum 73(2004) 269 – 274.
[2] EA-4/02: Expression of the Uncertainty of Measurement in Calibration
[3] Certificates of Calibration M-04P081 to M-04P086. Centre for Metrology and Accreditation

Appendix 1: Summary of results from each participating laboratory

Lab code A1

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	1	12	0.28	0.15	0.72	0.06
50	1	12	0.62	0.15	0.38	0.03
100	2	12	1.22	0.18	0.78	0.07
200	3	12	2.43	0.13	0.57	0.05
300	4	12	3.62	0.18	0.38	0.03
500	7	12	5.99	0.30	1.01	0.08
1000	13	12	11.76	0.30	1.24	0.10
2000	24	12	22.63	0.54	1.37	0.11
3000	34	12	32.74	0.65	1.26	0.10
5000	44	12	50.89	1.08	-6.89	-0.57
7000	69	12	66.9	1.3	2.10	0.17
10000	92	12	89.2	1.6	2.80	0.23
13000	118	12	114.5	1.9	3.50	0.29

Lab code A2

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	2.6	12	0.28	0.15	2.32	0.19
50	2.8	12	0.62	0.15	2.18	0.18
100	3.7	12	1.22	0.18	2.48	0.21
200	4.8	12	2.43	0.13	2.37	0.20
300	5.9	12	3.62	0.18	2.28	0.19
500	8.4	12	5.99	0.30	2.41	0.20
1000	14.2	12	11.76	0.30	2.44	0.20
2000	25.1	12	22.63	0.54	2.47	0.21
3000	35.1	12	32.74	0.65	2.36	0.20
5000	52.5	12	50.89	1.08	1.61	0.13
7000	67.2	12	66.9	1.3	0.30	0.02
10000	89.5	12	89.2	1.6	0.30	0.02
13000	115.2	12	114.5	1.9	0.70	0.06

Lab code B

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.106	0.25	0.28	0.15	-0.17	-0.58
50	0.446	0.25	0.62	0.15	-0.17	-0.59
100	1.047	0.27	1.22	0.18	-0.17	-0.53
200	2.278	0.31	2.43	0.13	-0.16	-0.46
300	3.312	0.43	3.62	0.18	-0.31	-0.66
500	5.796	0.25	5.99	0.30	-0.19	-0.50
1000	11.618	0.30	11.76	0.30	-0.14	-0.33
2000	22.593	0.28	22.63	0.54	-0.04	-0.06
3000	32.792	0.42	32.74	0.65	0.05	0.07
5000	50.831	0.60	50.89	1.08	-0.06	-0.05
7000	66.489	0.78	66.9	1.3	-0.41	-0.27
10000	88.80	1.2	89.2	1.6	-0.40	-0.20
13000	114.59	1.5	114.5	1.9	0.09	0.04

Lab code C up

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	-0.03	1.61	0.28	0.15	-0.31	-0.19
50	0.31	1.64	0.62	0.15	-0.31	-0.19
100	0.68	1.69	1.22	0.18	-0.54	-0.32
200	1.96	1.78	2.43	0.13	-0.47	-0.26
300	3.25	1.88	3.62	0.18	-0.37	-0.19
500	5.62	2.07	5.99	0.30	-0.37	-0.18
1000	10.14	2.83	11.76	0.30	-1.62	-0.57
2000	22.13	3.74	22.63	0.54	-0.50	-0.13
3000	32.76	4.69	32.74	0.65	0.02	0.00
5000	52.47	6.63	50.89	1.08	1.58	0.24
7000	66.76	1.02	66.9	1.3	-0.14	-0.08
10000	89.01	1.02	89.2	1.6	-0.19	-0.10
13000	114.53	1.32	114.5	1.9	0.03	0.01

Lab code C down

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.71	1.61	0.28	0.15	0.43	0.27
50	0.82	1.64	0.62	0.15	0.20	0.12
100	1.70	1.69	1.22	0.18	0.48	0.28
200	2.92	1.78	2.43	0.13	0.49	0.27
300	4.25	1.88	3.62	0.18	0.63	0.33
500	6.74	2.07	5.99	0.30	0.75	0.36
1000	12.71	2.83	11.76	0.30	0.95	0.33
2000	23.34	3.74	22.63	0.54	0.71	0.19
3000	33.64	4.69	32.74	0.65	0.90	0.19
5000	52.43	6.63	50.89	1.08	1.54	0.23
7000	67.01	1.02	66.9	1.3	0.11	0.07
10000	89.26	1.02	89.2	1.6	0.06	0.03
13000	114.53	1.32	114.5	1.9	0.03	0.01

Lab code M1 = MIKES 28.4.04

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.36	0.15	0.28	0.15	0.08	0.39
50	0.72	0.18	0.62	0.15	0.10	0.43
100	1.25	0.16	1.22	0.18	0.03	0.14
200	2.44	0.16	2.43	0.13	0.01	0.03
300	3.68	0.16	3.62	0.18	0.06	0.26
500	6.00	0.20	5.99	0.30	0.01	0.03
1000	11.76	0.23	11.76	0.30	0.00	0.00
2000	22.51	0.27	22.63	0.54	-0.12	-0.20
3000	32.56	0.26	32.74	0.65	-0.18	-0.26
5000	50.66	0.44	50.89	1.08	-0.23	-0.20
7000	66.57	0.52	66.9	1.3	-0.33	-0.24
10000	88.73	0.70	89.2	1.6	-0.47	-0.27
13000	113.96	0.90	114.5	1.9	-0.54	-0.26

Lab code M3 = MIKES 17.5.04

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.26	0.15	0.28	0.15	-0.02	-0.07
50	0.60	0.20	0.62	0.15	-0.02	-0.07
100	1.12	0.16	1.22	0.18	-0.10	-0.41
200	2.39	0.15	2.43	0.13	-0.04	-0.21
300	3.49	0.14	3.62	0.18	-0.13	-0.57
500	5.83	0.17	5.99	0.30	-0.16	-0.46
1000	11.56	0.17	11.76	0.30	-0.20	-0.58
2000	22.21	0.21	22.63	0.54	-0.42	-0.72
3000	32.26	0.32	32.74	0.65	-0.48	-0.66
5000	50.10	0.35	50.89	1.08	-0.79	-0.70
7000	66.00	0.48	66.9	1.3	-0.90	-0.65
10000	87.98	0.70	89.2	1.6	-1.22	-0.70
13000	112.97	0.82	114.5	1.9	-1.53	-0.74

Lab code M5 = MIKES 30.6.04

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.18	0.16	0.28	0.15	-0.10	-0.43
50	0.62	0.16	0.62	0.15	0.00	0.01
100	1.32	0.16	1.22	0.18	0.10	0.43
200	2.49	0.15	2.43	0.13	0.06	0.28
300	3.70	0.16	3.62	0.18	0.08	0.35
500	6.11	0.17	5.99	0.30	0.12	0.35
1000	11.88	0.18	11.76	0.30	0.12	0.34
2000	22.93	0.22	22.63	0.54	0.30	0.51
3000	33.14	0.38	32.74	0.65	0.40	0.53
5000	51.47	0.42	50.89	1.08	0.58	0.50
7000	67.68	0.57	66.9	1.3	0.78	0.55
10000	90.08	0.72	89.2	1.6	0.88	0.50
13000	115.42	0.89	114.5	1.9	0.92	0.44

Recent publications

J1/2002 T. Weckström, *Lämpötilan mittaus*

J2/2002 J. Järvinen, M. Heinonen and A. Lassila (Eds.), *Annual Report 2001*

J3/2002 S.I. Niemelä, *Uncertainty of quantitative determinations derived by cultivation of microorganisms*

J4/2002 A. Lassila, *Calibration of gauge blocks by mechanical comparison. Final Report*

J5/2002 V. König, A. Pitkäkoski, M. Rantanen and S. Semenoja, *Comparison of spinning rotor vacuum gauges between MIKES, SP and Vaisala Oyj*

J6/2002 M. Rantanen and S. Semenoja, *Calibration of a 130 Pa CDG: Comparison of the results from MIKES PTB and MKS Deutschland*

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J8/2003 J. Järvinen (Toim.*), Kansallinen mittanormaalitoiminta ja sen kehittäminen 2003 - 2007*

J1/2004 J. Järvinen et al. (Eds.) *Annual Report 2003*

J2/2004 S. Semenoja, M. Rantanen, J. Leskinen and A. Pitkäkoski, *Comparison in the absolute pressure range 100 kPa to 2100 kPa between MIKES and Vaisala Oyj*

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Intercomparison in Gauge Pressure Range from 20 Pa to 13 kPa

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Publication J7/2004

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Sari Semenoja

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Helsinki 2004

Contents

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Abstract

An intercomparison in the gauge pressure range from 20 Pa to 13 kPa was arranged in 2004 in Finland by the Centre for Metrology and Accreditation (MIKES). Three pressure calibration laboratories participated in the comparison.

The transfer standard was an MKS Baratron 100 torr type 698 differential pressure transducer with an MKS type 670B signal conditioner. The participants used their routine methods and existing procedures, but a set of preferred nominal pressures was given.

All the pressure results were in a good agreement with the results of MIKES.

Tiivistelmä

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3 Reference Laboratory

In the gauge pressure range from 0 to 15 kPa the reference standard of MIKES is a DH Instruments FPG 8601 digital piston manometer, which can be used in the absolute mode as well. The effective area is traceable to Laboratoire National d'Essais (BNM-LNE), Paris. The validation process of the instrument is described in reference 1.

For the FPG 8601 of MIKES the best measurement capability is estimated to be 0,02 Pa + $4 \cdot 10^{-5} \cdot p$, where p is pressure. The resolution of the display is 0,001 Pa in the range from 0 to 9999,999 Pa and 0,01 above 10000 Pa.

4 Transfer Standard

The transfer standard was an MKS Baratron 100 torr type 698 differential pressure transducer No. 93200104 with an MKS type 670B signal conditioner No. 238250. The

resolution of the display is 0,1 Pa when *pascal* is selected as the unit on the signal conditioner.

The transducer has been used in MIKES as a working standard almost ten years. By the time some error has been developed in the output but the short term stability of the instrument is generally good.

For the transport the transducer and the signal conditioner were packed in a metal box. The participants did not have to touch the transducer at all, they only connected their own plastic tubing to that of the transfer standard.

5 Measurement Instructions

The participants were asked to keep the transfer standard switched on for several hours, preferably overnight, before starting the calibration. They were asked to check and adjust the NUL of the display to 0,0000 V ± 0,0001 V and the FULL SCALE to 10,0000 V ± 0,0002 V. Further, they were asked to pre-pressurise the transfer standard twice to 13 kPa an then set the ZERO to 0,0 Pa.

The participants were advised to calibrate the transfer standard using their own procedures. However, the use of the following nominal pressures was recommended:

20 Pa, 50 Pa, 100 Pa, 200 Pa, 300 Pa, 500 Pa, 1000 Pa, 2000 Pa,
3000 Pa, 5000 Pa, 7000 Pa, 10000 Pa and 13000 Pa.

Finally, the participants were asked to send their results as calibration certificates to MIKES within two weeks after the measurements.

6 Calculation of the Reference Values

The transfer standard was calibrated six times at the reference laboratory MIKES. The first calibration was made at the end of April and the last in the beginning of July in 2004. The results were presented in certificates M-04P081 ... M-04P086. The test sequence in MIKES calibrations consisted of three up-and-down cycles.

Figure 1 shows the result points of the first MIKES calibration (M-04P081) and the third degree curve fitting best to the results.

Figure 2 shows all the result points from the six MIKES calibrations. The scatter seems to be higher between the calibrations than inside one calibration. The hysteresis effects were negligible.

The reference values were calculated as the averages of the MIKES results for each nominal pressure. The uncertainties of the reference values were calculated according

to document EA-4/02 and a coverage factor k = 2. The major uncertainty components taken into account were the following:

uncertainty in setting the zero of the transfer standard
resolution of the transfer standard
standard deviation of the results in each series
standard deviation of the averages of the six series
uncertainty of the measurement standard.

The reference values and their uncertainties are shown in Table 1. They are illustrated in Figure 3 as well as the results from the first calibration in MIKES on 28th of April and those from two other calibrations on 17th of May and on 30th of June 2004. These two calibrations seem to deviate most from the average values.

Table 1. The reference values based on the six calibrations in MIKES

Nominal pressure Pa	Reference value Pa	Uncertainty of ref. value Pa
20	0,28	0,15
50	0,62	0,15
100	1,22	0,18
200	2,43	0,13
300	3,62	0,18
500	5,99	0,30
1000	11,76	0,30
2000	22,63	0,54
3000	34,74	0,65
5000	50,9	1,1
7000	66,9	1,3
10000	89,2	1,6
13000	114,5	1,9

7 Results

All of the participating laboratories could not present their results as calibration certificates as the pressure range was outside their accredited scope. However, the results were given with uncertainties estimated using the document EA-4/02 and a coverage factor k = 2.

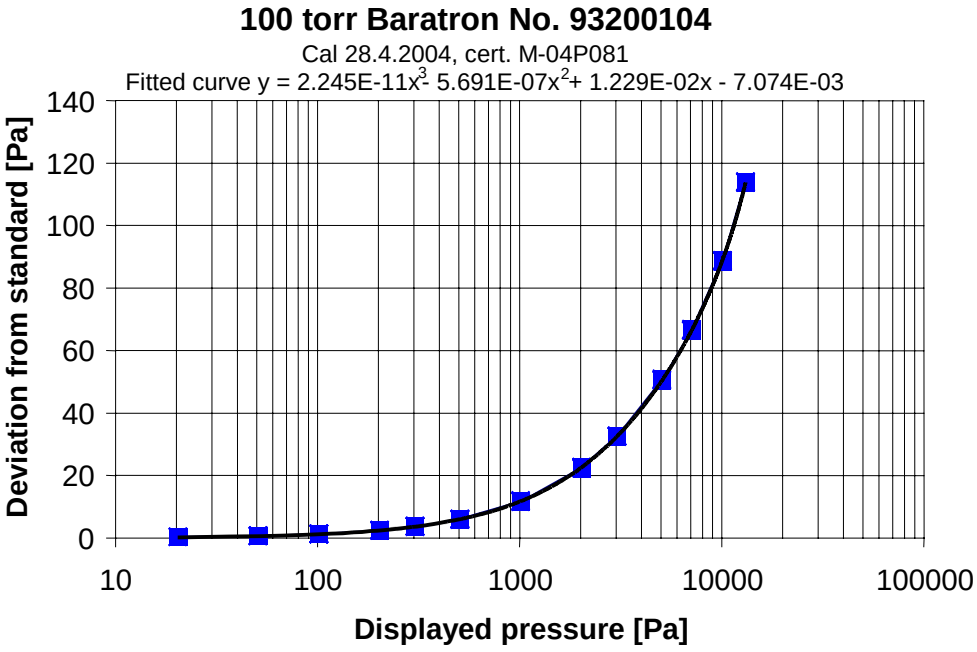

Figure 1. Results of the first calibration in MIKES and the best fitting third degree curve.

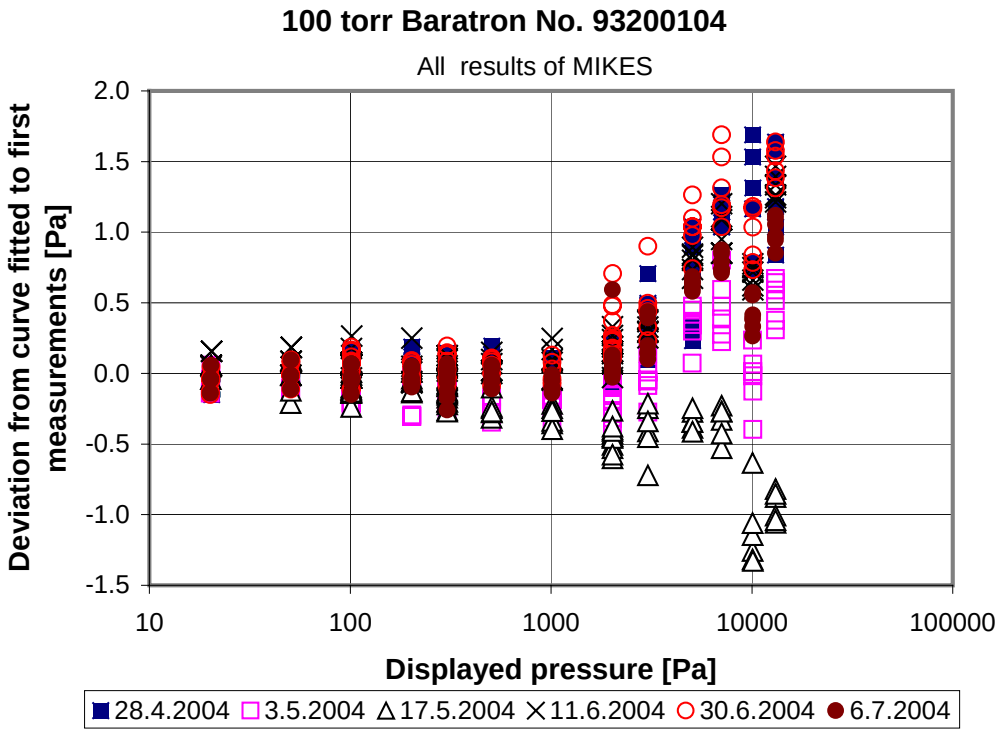

Figure 2. Results from all the six calibrations in MIKES (M1 to M6).

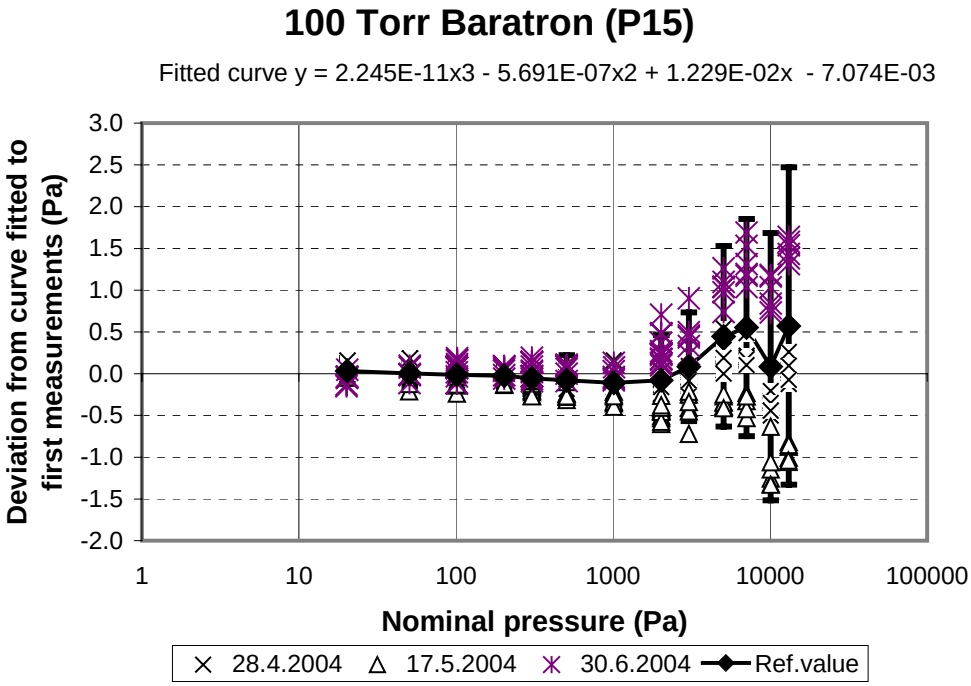

Figure 3. Reference values and results from calibrations M1, M3 and M5.

Following the EA intercomparison practice all laboratories were given letter codes. Each laboratory knows only its own code.

Laboratory A made the measurements using two different standards and sent two sets of results.

Laboratory B, too, made the measurements with two standards but gave only one set of results.

Laboratory C used two standards as well. Its combined results were presented separately for the increasing and the decreasing pressures.

All the results are shown in the Appendix. The results obtained on nominal pressures 100 Pa, 300 Pa, 1000 Pa, 3000 Pa and 10000 Pa are illustrated in Figures 4 to 8.

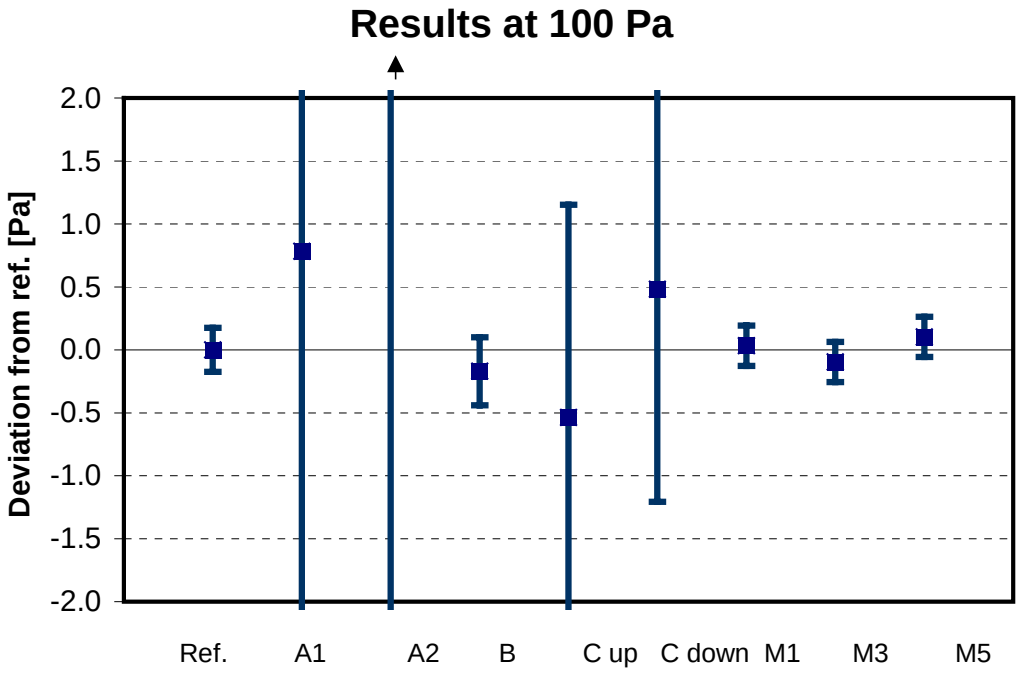

Figure 4. Results at nominal pressure 100 Pa.

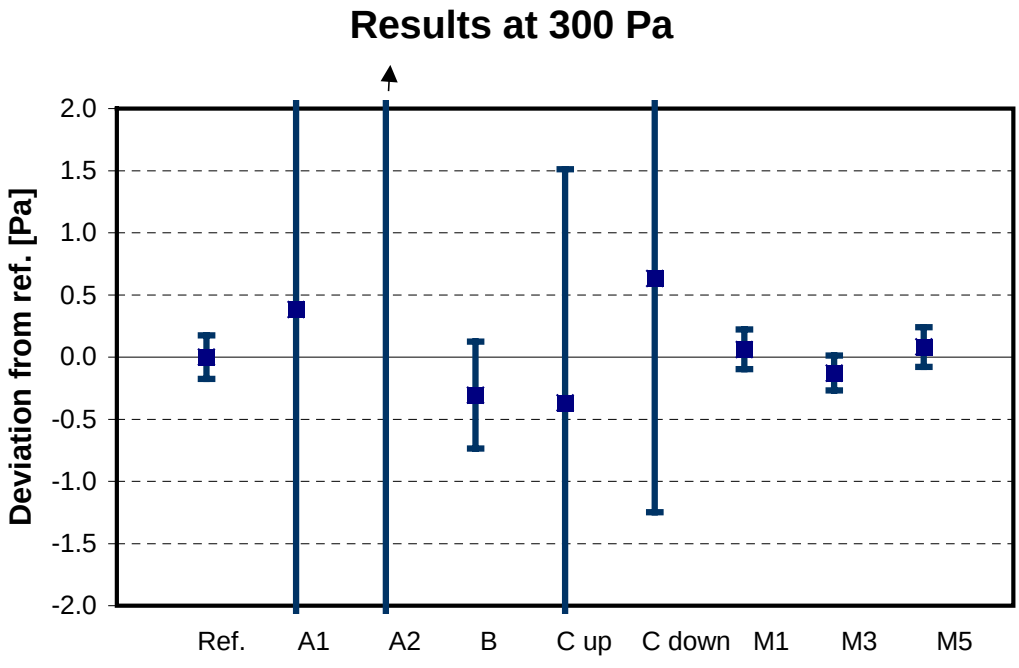

Figure 5. Results at nominal pressure 300 Pa.

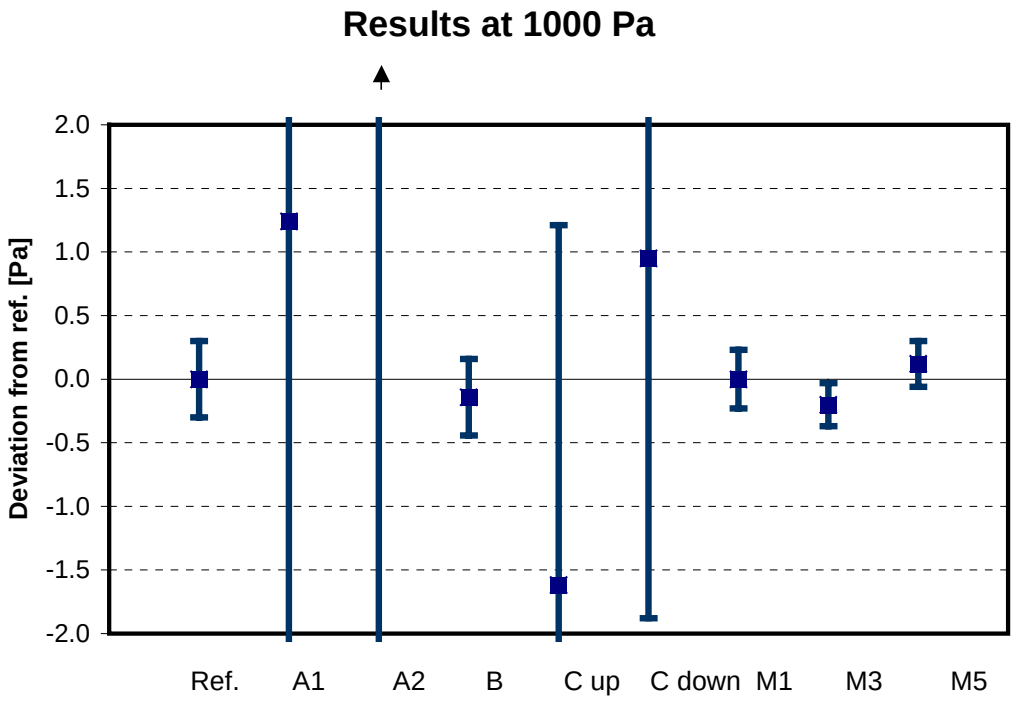

Figure 6. Results at nominal pressure 1000 Pa.

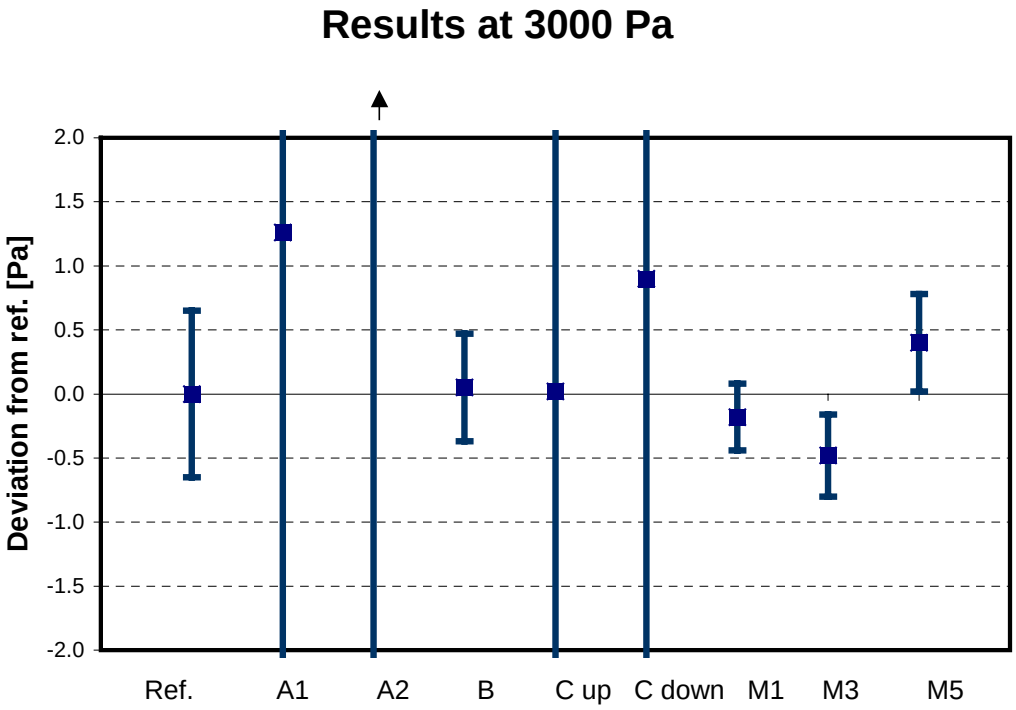

Figure 7. Results at nominal pressure 3000 Pa.

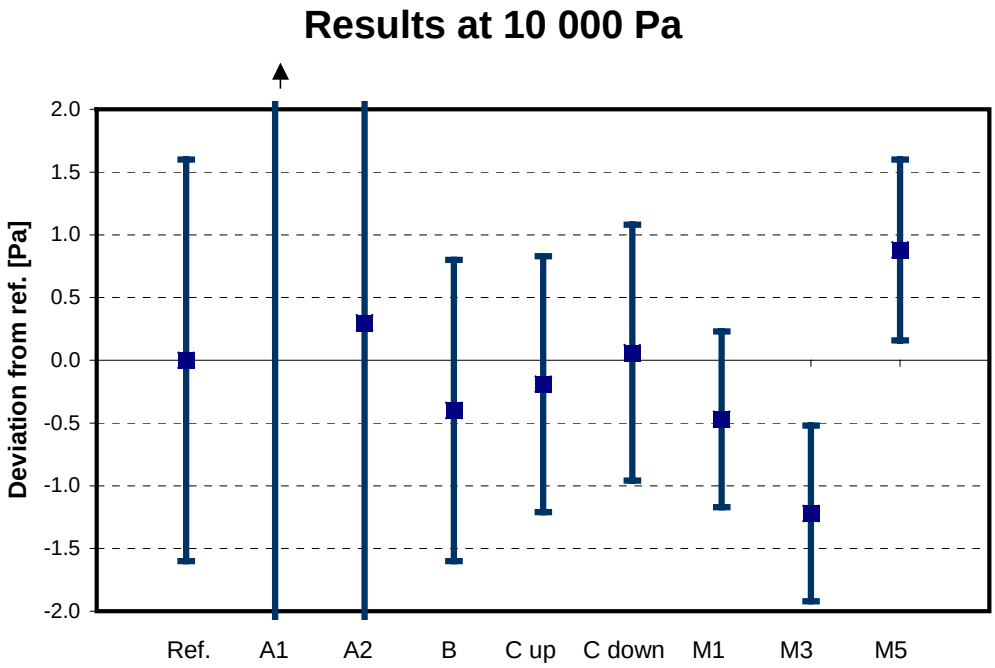

Figure 8. Results at nominal pressure 10 000 Pa.

A tool often used in analysing results from interlaboratory comparisons is the normalised error E_n, which takes into account both the result and its uncertainty. The normalised error E_n is calculated as

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

where

$p_{transfer}$	is 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 E_n-values of all the results are also shown in the Appendix, not only for the participating laboratories but for the MIKES calibrations dated 28th of April (M1), 17th of May (M3) and 30th of June 2004 (M5).

A summary of the E_n-values is in the following table:

Laboratory	Range of E_n-values
A1	-0,57 … 0,29
A2	0,02 … 0,21
B	-0,66 … 0,04
C up	-0,57 … 0,24
C down	0,01 … 0,36
M1	-0,27 … 0,43
M3	-0,74 …-0,07
M5	-0,43 … 0,55

The result in an interlaboratory comparison is regarded as correct within the limits of uncertainty, if the absolute value of the normalised error E_n is less than 1.

In this case the E_n-values for all the results from all the laboratories are between -1 and +1.

The pressure standard of laboratory B that was used in this comparison was re-calibrated in November 2004. The re-calibration data applied to the comparison results would still improve the E_n-values for laboratory B. The range of E_n-values would now be from –0,23 to 0,33.

8 Conclusions

Three pressure calibration laboratories participated in an intercomparison in the gauge pressure range from 20 Pa to 130 kPa in May and June 2004.

All the results from all the participating laboratories were in a good agreement with the reference values from MIKES.

The transfer standard, an MKS Baratron 100 torr type 698 differential pressure. transducer with an MKS type 670B signal conditioner, was found to be stable enough for an intercomparison at this level. However, the uncertainty was a bit too high for a very critical assessment of the measurement capability of laboratory B on the lowest nominal pressures.

9 References

[1] Semenoja, Sari & Rantanen, Markku: Comparisons to establish a force-balanced piston gauge and a spinning rotor gauge as the new measurement standards of MIKES. Vacuum 73(2004) 269 – 274.
[2] EA-4/02: Expression of the Uncertainty of Measurement in Calibration
[3] Certificates of Calibration M-04P081 to M-04P086. Centre for Metrology and Accreditation

Appendix 1: Summary of results from each participating laboratory

Lab code A1

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	1	12	0.28	0.15	0.72	0.06
50	1	12	0.62	0.15	0.38	0.03
100	2	12	1.22	0.18	0.78	0.07
200	3	12	2.43	0.13	0.57	0.05
300	4	12	3.62	0.18	0.38	0.03
500	7	12	5.99	0.30	1.01	0.08
1000	13	12	11.76	0.30	1.24	0.10
2000	24	12	22.63	0.54	1.37	0.11
3000	34	12	32.74	0.65	1.26	0.10
5000	44	12	50.89	1.08	-6.89	-0.57
7000	69	12	66.9	1.3	2.10	0.17
10000	92	12	89.2	1.6	2.80	0.23
13000	118	12	114.5	1.9	3.50	0.29

Lab code A2

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	2.6	12	0.28	0.15	2.32	0.19
50	2.8	12	0.62	0.15	2.18	0.18
100	3.7	12	1.22	0.18	2.48	0.21
200	4.8	12	2.43	0.13	2.37	0.20
300	5.9	12	3.62	0.18	2.28	0.19
500	8.4	12	5.99	0.30	2.41	0.20
1000	14.2	12	11.76	0.30	2.44	0.20
2000	25.1	12	22.63	0.54	2.47	0.21
3000	35.1	12	32.74	0.65	2.36	0.20
5000	52.5	12	50.89	1.08	1.61	0.13
7000	67.2	12	66.9	1.3	0.30	0.02
10000	89.5	12	89.2	1.6	0.30	0.02
13000	115.2	12	114.5	1.9	0.70	0.06

Lab code B

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.106	0.25	0.28	0.15	-0.17	-0.58
50	0.446	0.25	0.62	0.15	-0.17	-0.59
100	1.047	0.27	1.22	0.18	-0.17	-0.53
200	2.278	0.31	2.43	0.13	-0.16	-0.46
300	3.312	0.43	3.62	0.18	-0.31	-0.66
500	5.796	0.25	5.99	0.30	-0.19	-0.50
1000	11.618	0.30	11.76	0.30	-0.14	-0.33
2000	22.593	0.28	22.63	0.54	-0.04	-0.06
3000	32.792	0.42	32.74	0.65	0.05	0.07
5000	50.831	0.60	50.89	1.08	-0.06	-0.05
7000	66.489	0.78	66.9	1.3	-0.41	-0.27
10000	88.80	1.2	89.2	1.6	-0.40	-0.20
13000	114.59	1.5	114.5	1.9	0.09	0.04

Lab code C up

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	-0.03	1.61	0.28	0.15	-0.31	-0.19
50	0.31	1.64	0.62	0.15	-0.31	-0.19
100	0.68	1.69	1.22	0.18	-0.54	-0.32
200	1.96	1.78	2.43	0.13	-0.47	-0.26
300	3.25	1.88	3.62	0.18	-0.37	-0.19
500	5.62	2.07	5.99	0.30	-0.37	-0.18
1000	10.14	2.83	11.76	0.30	-1.62	-0.57
2000	22.13	3.74	22.63	0.54	-0.50	-0.13
3000	32.76	4.69	32.74	0.65	0.02	0.00
5000	52.47	6.63	50.89	1.08	1.58	0.24
7000	66.76	1.02	66.9	1.3	-0.14	-0.08
10000	89.01	1.02	89.2	1.6	-0.19	-0.10
13000	114.53	1.32	114.5	1.9	0.03	0.01

Lab code C down

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.71	1.61	0.28	0.15	0.43	0.27
50	0.82	1.64	0.62	0.15	0.20	0.12
100	1.70	1.69	1.22	0.18	0.48	0.28
200	2.92	1.78	2.43	0.13	0.49	0.27
300	4.25	1.88	3.62	0.18	0.63	0.33
500	6.74	2.07	5.99	0.30	0.75	0.36
1000	12.71	2.83	11.76	0.30	0.95	0.33
2000	23.34	3.74	22.63	0.54	0.71	0.19
3000	33.64	4.69	32.74	0.65	0.90	0.19
5000	52.43	6.63	50.89	1.08	1.54	0.23
7000	67.01	1.02	66.9	1.3	0.11	0.07
10000	89.26	1.02	89.2	1.6	0.06	0.03
13000	114.53	1.32	114.5	1.9	0.03	0.01

Lab code M1 = MIKES 28.4.04

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.36	0.15	0.28	0.15	0.08	0.39
50	0.72	0.18	0.62	0.15	0.10	0.43
100	1.25	0.16	1.22	0.18	0.03	0.14
200	2.44	0.16	2.43	0.13	0.01	0.03
300	3.68	0.16	3.62	0.18	0.06	0.26
500	6.00	0.20	5.99	0.30	0.01	0.03
1000	11.76	0.23	11.76	0.30	0.00	0.00
2000	22.51	0.27	22.63	0.54	-0.12	-0.20
3000	32.56	0.26	32.74	0.65	-0.18	-0.26
5000	50.66	0.44	50.89	1.08	-0.23	-0.20
7000	66.57	0.52	66.9	1.3	-0.33	-0.24
10000	88.73	0.70	89.2	1.6	-0.47	-0.27
13000	113.96	0.90	114.5	1.9	-0.54	-0.26

Lab code M3 = MIKES 17.5.04

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.26	0.15	0.28	0.15	-0.02	-0.07
50	0.60	0.20	0.62	0.15	-0.02	-0.07
100	1.12	0.16	1.22	0.18	-0.10	-0.41
200	2.39	0.15	2.43	0.13	-0.04	-0.21
300	3.49	0.14	3.62	0.18	-0.13	-0.57
500	5.83	0.17	5.99	0.30	-0.16	-0.46
1000	11.56	0.17	11.76	0.30	-0.20	-0.58
2000	22.21	0.21	22.63	0.54	-0.42	-0.72
3000	32.26	0.32	32.74	0.65	-0.48	-0.66
5000	50.10	0.35	50.89	1.08	-0.79	-0.70
7000	66.00	0.48	66.9	1.3	-0.90	-0.65
10000	87.98	0.70	89.2	1.6	-1.22	-0.70
13000	112.97	0.82	114.5	1.9	-1.53	-0.74

Lab code M5 = MIKES 30.6.04

Nominal pressure Pa	Result Pa	Uncert. Pa	Reference value Pa	Reference uncert Pa	Deviation from ref. Pa	E(n)
20	0.18	0.16	0.28	0.15	-0.10	-0.43
50	0.62	0.16	0.62	0.15	0.00	0.01
100	1.32	0.16	1.22	0.18	0.10	0.43
200	2.49	0.15	2.43	0.13	0.06	0.28
300	3.70	0.16	3.62	0.18	0.08	0.35
500	6.11	0.17	5.99	0.30	0.12	0.35
1000	11.88	0.18	11.76	0.30	0.12	0.34
2000	22.93	0.22	22.63	0.54	0.30	0.51
3000	33.14	0.38	32.74	0.65	0.40	0.53
5000	51.47	0.42	50.89	1.08	0.58	0.50
7000	67.68	0.57	66.9	1.3	0.78	0.55
10000	90.08	0.72	89.2	1.6	0.88	0.50
13000	115.42	0.89	114.5	1.9	0.92	0.44

Recent publications

J1/2002 T. Weckström, *Lämpötilan mittaus*

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J4/2002 A. Lassila, *Calibration of gauge blocks by mechanical comparison. Final Report*

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