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Calibration of a 130 Pa CDG: Comparison of the results from MIKES and PTB

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Contents

1 Introduction

A 130 Pa capacitance diaphragm vacuum gauge (CDG) is one of the reference standards in the pressure laboratory of the Centre for Metrology and Accreditation (MIKES). This instrument is calibrated once a year in the vacuum laboratory of Physikalisch-Technische Bundesanstalt (PTB). As the same CDG can be calibrated using other standards of MIKES, there is an opportunity to compare the results from MIKES and PTB.

2 Low absolute pressure standards of MIKES

The absolute pressure range from $5 \cdot 10^{-4}$ Pa to 15 kPa in the pressure laboratory of MIKES is covered with three reference standards. An MKS spinning rotor gauge covers the range from $5 \cdot 10^{-4}$ Pa to 0,5 Pa, and a 130 Pa MKS CDG the range from 0,5 Pa to 20 Pa. Traceability for both of these two instruments is obtained from PTB, calibration interval 12 months.

In the range from 20 Pa to 15 kPa the reference standard is a DH Instruments digital piston manometer FPG 8601 s/n 105. The lower limit of the operational range is about 1,5 Pa.

The pressure in the FPG is defined by means of the force measured using a high precision load cell and the effective area of the piston-cylinder assembly. The piston is not rotating and it is maintained in the centred position by a constant gas flow trough the annular gap. For operation in the absolute mode a capacitance diaphragm gauge (CDG) is used to measure the residual pressure, which typically is about 0,2 Pa.

The effective area of the FPG is calibrated once a year in MIKES with a conventional pressure balance, having traceability to BNM-LNE, France. The residual vacuum is measured with a 10 Pa CDG, which is calibrated with the spinning rotor gauge and the 130 Pa CDG mentioned above.

In reference 1 there is a description of the validation process of the MIKES FPG, as well as a more detailed description of the instrument itself.

3 Transfer standard

The 130 Pa capacitance diaphragm gauge calibrated at MIKES and at PTB was a MKS Baratron 690A01TRA s/n 96018200A with a control unit type 270C s/n 93236214.

If *mbar* is selected for the unit in the pressure display and the range multiplier is in the normal (1) position, the resolution is 0,00001 mbar. With the range multiplier in position 0,1 the resolution of 0,000001 mbar is obtained.

The gauge and the control unit have been used in the pressure laboratory of MIKES since 1997. Unfortunately the early calibration history was lost in a transport damage in 2002. Since June 2004 the gauge is connected directly to the control unit, without the channel selector between them. This is another reason why it is not easy to compare new results to previous ones.

4 Measurements in PTB

Physikalisch-Technishe Bundeanstalt (PTB) is the national metrology institute of Germany. The vacuum laboratory is located in Berlin.

The measurements on the transfer standard on 17 nominal pressures in the range from 0,13 Pa to 129 Pa were carried out on the 4th of November 2004 using a primary standard applying the static expansion method. The results were presented in a calibration certificate no. 1838 PTB 04 dated on the 8th of November 2004 [2]. A summary of the results is given in the table in the Appendix with the code PTB.

5 Measurements in MIKES

5.1 Measurements in June 2004

The measurements using the FPG were made in the pressure range from 1,3 Pa to 100 Pa on the 8th of June 2004 by Sari Semenoja and Markku Rantanen. The results were given in the certificate of calibration no. M-04P060. Two up-and-down measurement cycles were performed. The results, as mean values, are shown in the table in the Appendix with the code M 6/2004.

The uncertainty of the FPG was estimated as 0,025 Pa + 4 · 10^{-5} · p (k = 2, p = pressure). This uncertainty value is smaller than in the CMC tables at present. The uncertainties could be reduced due to the improvements done in the installation. Now the

zero setting on both the device under test and on the residual pressure gauge was made using a turbo molecular pump and without any re-assembly of the gauges.

5.2 Measurements in December 2004

The measurements on the 7th of December 2004 were made in the pressure range from 1,3 Pa to 100 Pa by the same personnel and the same instrument as well as the same arrangements were used in the zero settings.

The results were given in the certificate of calibration no. M-04P128. Again two up-and-down measurement cycles were performed and the results are shown in the table in the Appendix with the code M 12/2004.

6 Discussion of the results

A summary of the results is shown in the Appendix and illustrated in Fig. 1.

The table in the Appendix gives the results and the uncertainties in pascals. The uncertainties are given with the coverage factor k = 2.

Some of the results from June 2004 in Table 1 (for nominal pressures 6 Pa, 9 Pa and 13 Pa) are interpolated values. The nominal values used in this measurement differed from those used in PTB. The uncertainties were interpolated, too. These values are marked with a star (*).

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 results and uncertainties of PTB were taken as reference values. The minor uncertainty components due to the zero setting and the instability of the transfer standard were ignored for simplicity.

The table in the Appendix 1 shows the deviation from the reference value and the normalised error value E_n for each result. All the absolute values of E_n are well below 1.

In the pressure range above 20 Pa the results of MIKES, obtained with the FPG and a direct pressure measurement, have smaller uncertainties than the results of PTB. This is due to the intrinsic uncertainty of the static expansion process.

The drift indicated by the two MIKES calibrations with the interval of six months is within the uncertainty limits.

A similar comparison on the calibration results of a 130 Pa CDG between MIKES and PTB was arranged in 2002 [4]. The CDG and the display unit were the same in both comparisons but the channel selector was not used in 2004. Thus the immediate results cannot be compared but the differences between MIKES and PTB pressures can. A summary of the differences is illustrated in Fig. 2. All the differences are within the uncertainty limits and the general pattern of the data seems to be the same in 2004 as it was in 2002.

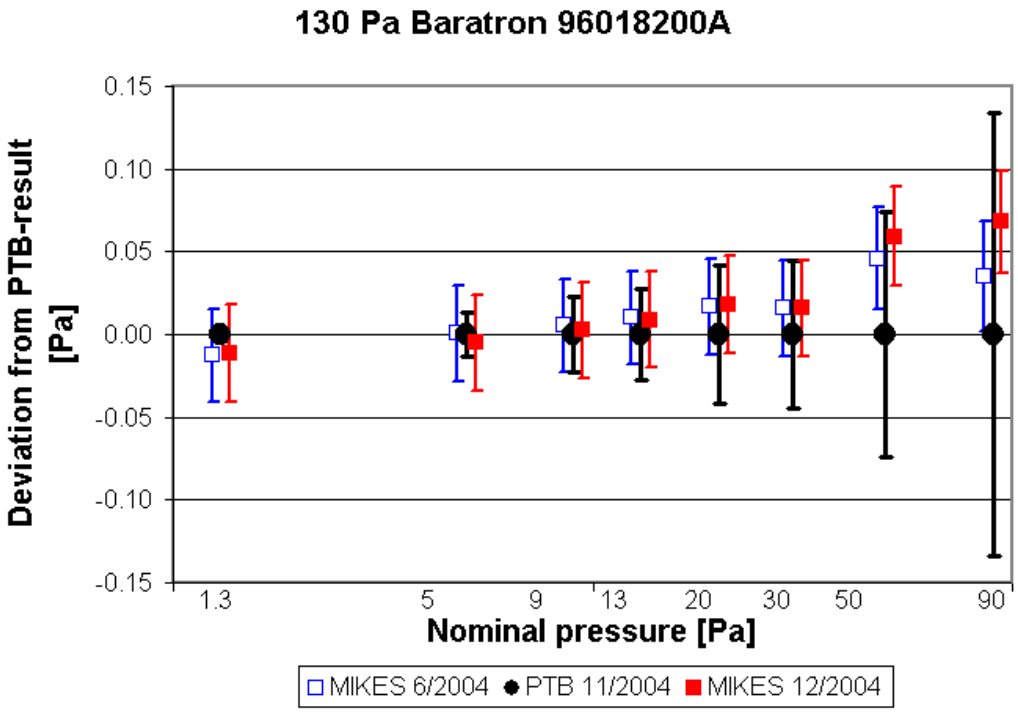

Figure 1. A summary of the results in 2004

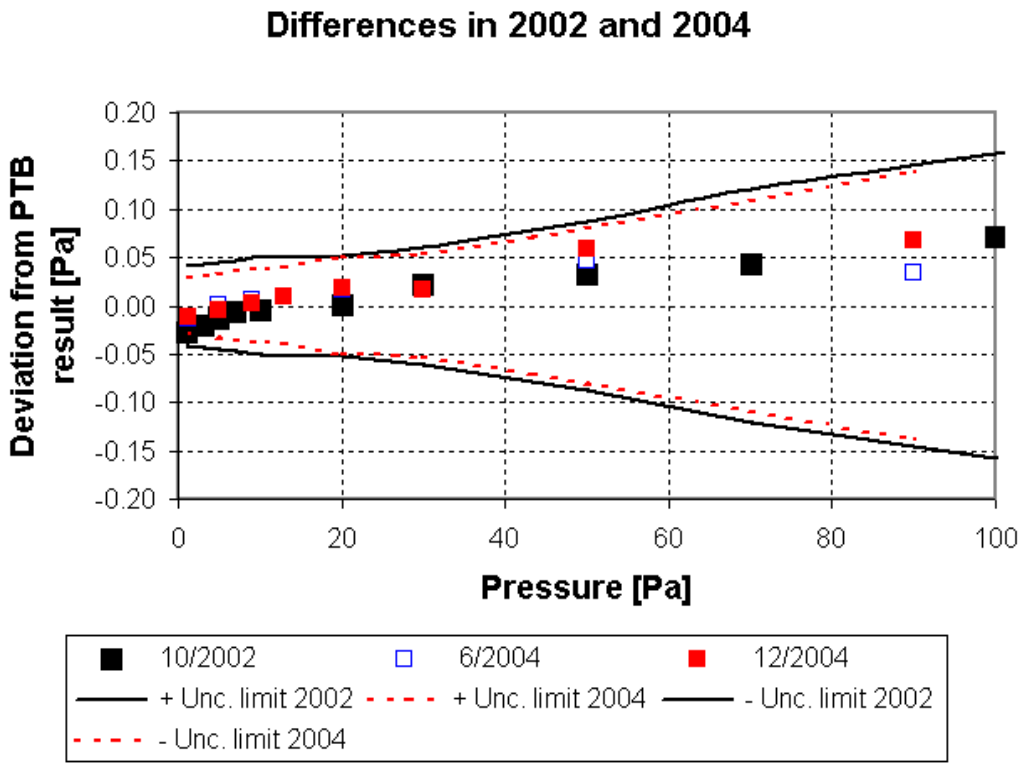

Figure 2. Comparison of the results of 2002 and 2004

7 Conclusions

The results obtained by PTB and MIKES in 2004 in the pressure range 1,5 Pa to 90 Pa are in a good agreement with each other and with the results obtained in a similar comparison two years earlier.

8 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] Kalibrierschein vom 2004-11-08, Kalibrierzeichen: 1838 PTB 04

[3] Certificates of calibration M-04P060 and M-04P128. MIKES 2004

[4] Rantanen, Markku and Semenoja, Sari: Calibration of a 130 Pa CDG: Comparison of the results from MIKES, PTB and MKS Deutschland. MIKES Publication J6/2002. 11 p.

Appendix 1.

Calibration of the 130 Pa MKS Baratron 690A01TRA s/n 96018200A with a control unit type 270C s/n 93236214. Summary of the results.

Result [Pa] = $p_{transfer} - p_{lab}$

Nominal pressure Pa	Laboratory code	Result Pa		Uncert. k=2 Pa	PTB result as reference E(n)
1.3	PTB	0.0334		0.0036	0.00
	M 6/2004	0.021		0.028	-0.44
	M 12/2004	0.022		0.029	-0.39
5	PTB	0.0791		0.0129	0.00
	M 6/2004	0.080	*	0.029	0.03
	M 12/2004	0.074		0.029	-0.16
9	PTB	0.0904		0.0232	0.00
	M 6/2004	0.096	*	0.028	0.15
	M 12/2004	0.093		0.029	0.07
13	PTB	0.089		0.027	0.00
	M 6/2004	0.099	*	0.028	0.26
	M 12/2004	0.098		0.029	0.23
20	PTB	0.081		0.042	0.00
	M 6/2004	0.098		0.029	0.33
	M 12/2004	0.099		0.029	0.35
30	PTB	0.083		0.045	0.00
	M 6/2004	0.099		0.029	0.30
	M 12/2004	0.099		0.029	0.30
50	PTB	0.061		0.075	0.00
	M 6/2004	0.107		0.031	0.57
	M 12/2004	0.120		0.030	0.73
90	PTB	0.072		0.134	0.00
	M 6/2004	0.107		0.033	0.25
	M 12/2004	0.140		0.031	0.49

*) The result and uncertainty are interpolated. The nominal pressures differed from those used in PTB.

Recent publications

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

J1/2003 J. Järvinen, M. Heinonen and A. Lassila (Eds.), *Finnish National Standards Laboratories Annual Report 2002*

J2/2003 K. Riski, *Basic formula for mass calibration*

J3/2003 M. Rantanen , *Intercomparison in gauge pressure range 0…60 Mpa*

J4/2003 S.I. Niemelä, *Uncertainty of quantitative determinations derived by cultivation of microorganism*

J5/2003 K. Riski, *Mass comparison: 5 kg laboratory balance*

J6/2003 M. Rantanen, S. Semenoja, *Comparison in absolute pressure range 0,02 hPa … 10 hPa between MIKES and Beamex*

J7/2003 M. Heinonen, *Comparison of dew-point temperature calibrations*

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

J1/2004 J. Järvinen, M. Heinonen, A. Lassila, R. Rajala (Eds.) *Finnish National standards Laboratories 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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J4/2004 J. Halttunen, *Coriolis-mittarin vertailumittaus, syksy 2002. Interlaboratory comparison of a Coriolis flowmeter, Autumn 2002*

J5/2004 L. Uusipaikka, *Suhteellisen kosteuden kalibrointien vertailu, loppuraportti.*

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J2/2005 M. Rantanen, G. Peterson, *Pressure comparisons between MIKES and Metrosert: Ranges 95 kPa to 105 kPa absolute and 0,5 MPa to 1,75 MPa gauge*

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