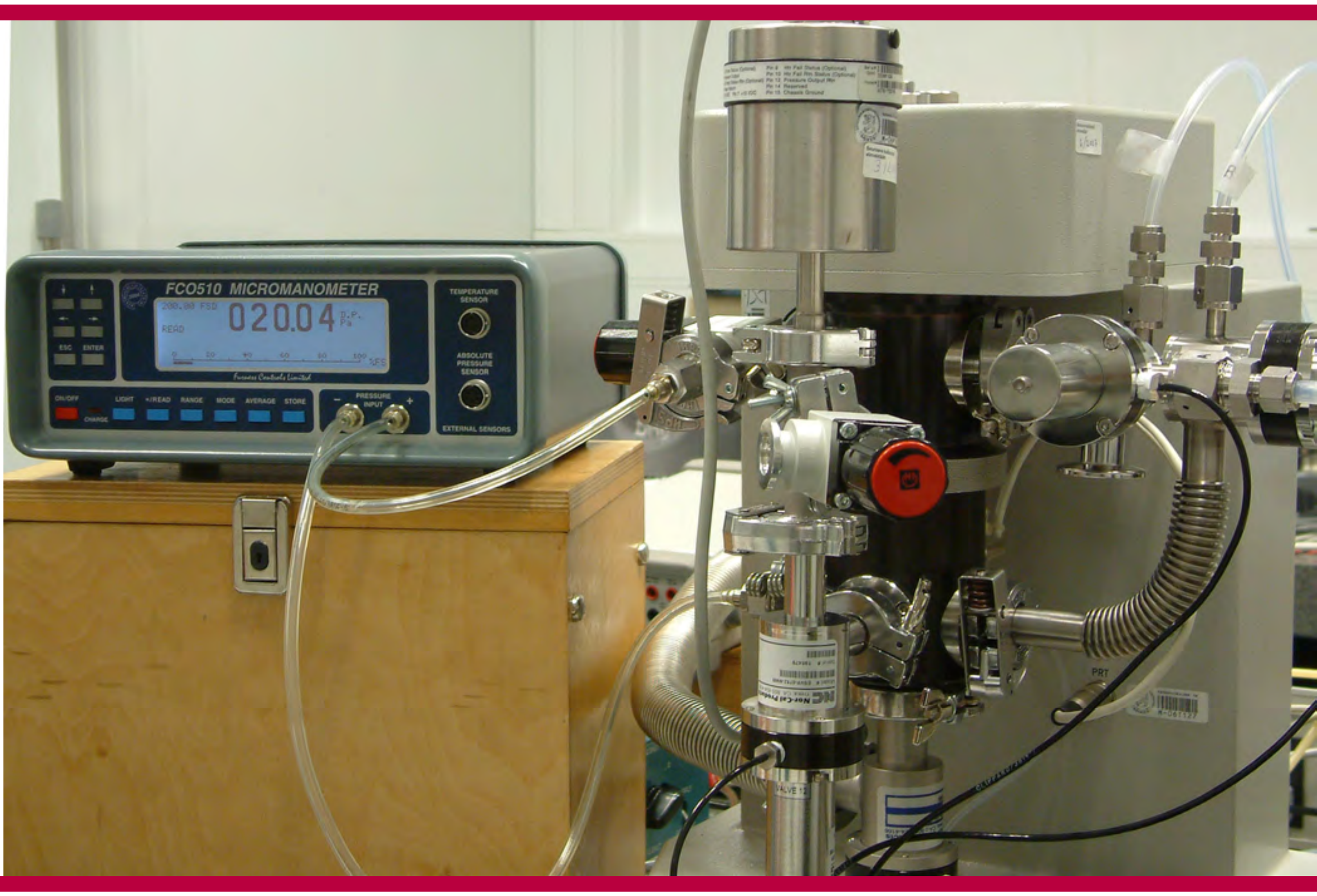
MIKES METROLOGIA

J2/2007



Low gauge pressure comparisons between MIKES, Metrosert and FORCE Technology

Range -2000 Pa to +2000 Pa, gauge

Report on EUROMET Project 921

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Mittatekniikan keskus

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Abstract

MIKES (FI), Metrosert (EE) and FORCE Technology (DK) compared their low gauge pressures in 2006. The reference standards of the three laboratories for low gauge pressures apply dissimilar operating principles: a digital piston manometer at MIKES, a water column manometer at Metrosert and a diving bell-type standard at FORCE Technology.

The comparison covered the range from -2000 Pa to + 2000 Pa. The transfer standard was a Furness FCO510 micro-manometer. The stability of the transfer standard was not as good as expected.

The results of MIKES and Metrosert were in a good agreement except at nominal pressures -20 Pa and +20 Pa where the absolute values for the normalised error E_n were slightly higher than 1. The uncertainties given for the Metrosert results at these nominal pressures were much lower than the accredited uncertainties at present.

The results of MIKES and FORCE Technology in the range from -200 Pa to +200 Pa were in a good agreement, using the uncertainties given in the CMC tables. The results outside this range could not be assessed due to the instability of the transfer standard.

Contents

1 Introduction

A comparison on low gauge pressures between MIKES and Metrosert was agreed in the meeting of the Baltic and Nordic national pressure laboratories, held on April 20th 2006 at MIKES. Later, FORCE Technology of Denmark joined in the comparison, which was registered as EUROMET Project number 921.

The transfer standard, a Furness FCO510 micro-manometer for the range -2000 Pa to + 2000 Pa was provided by MIKES. The measurements were made between 28th of August and 12th of October 2006:

MIKES 1	28.8.2006
MIKES 2	4.9.2006
Metrosert	18.9.-20.9.2006
MIKES 3	22.9.2006
FORCE	5.-6.10.2006
MIKES 4	12.10.2006.

Gauge pressure is measured on a scale where zero is set to the ambient atmospheric pressure. Pressure modes are illustrated in Figure 1.

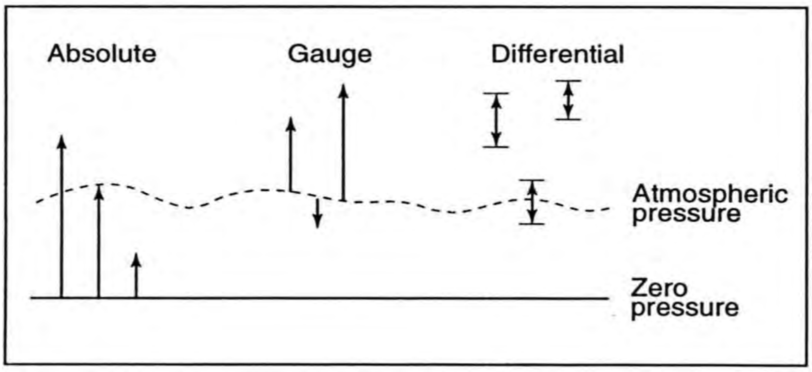

Fig. 1. Pressure modes [1]

2 Transfer standard

The transfer standard, micro-manometer Furness FCO 510 s/n 406144 was purchased to MIKES in 2004 originally for measurements on air conditioning systems in the new laboratory premises. There are two pressure measurement ranges in a Furness FCO510. One is from -2000 Pa to +2000 Pa with the resolution of the display 0,1 Pa and the other from -200 Pa to +200 Pa with the resolution of 0,01 Pa.

3 Measurement instructions

As the transfer standard was known to have some hysteresis, only increasing pressures were selected as nominal pressures on the positive side, and decreasing pressures in the negative side, respectively.

The following nominal pressures were specified:

Range -200 Pa to +200 Pa:
-200 Pa, -100 Pa, -50 Pa, -20 Pa, +20 Pa, +50 Pa, +100 Pa and +200 Pa

Range -2000 Pa to +2000 Pa:
-2000 Pa, -1500 Pa, -1000 Pa, -500 Pa, +500 Pa, +1000 Pa, +1500 Pa and +2000 Pa

4 Low gauge pressure standard of MIKES

The reference standard of MIKES in the gauge pressure range from 0 to 15 kPa is a DH Instruments FPG8601 digital piston manometer. The pressure is defined by means of the force measured by a high precision load cell and the effective area of the piston cylinder assembly. The nominal value of the effective area is 980 mm^2. The piston is not rotating, and it is maintained in the centred position by a constant lubricating gas flow through the annular gap. This instrument can be operated in the absolute mode as well.

The effective area is traceable to Laboratoire National d'Essais (LNE), Paris. The load cell of the instrument is calibrated with a weight set whose masses are traceable to the Mass laboratory of MIKES. The instrument and its validation process is described in the Reference 1.

The best measurement capability for the FPG8601 of MIKES in the gauge mode is estimated as 0,02 Pa + 4 · 10^{-5} · p, where p is pressure. This CMC value was approved into the BIPM database in October 2005.

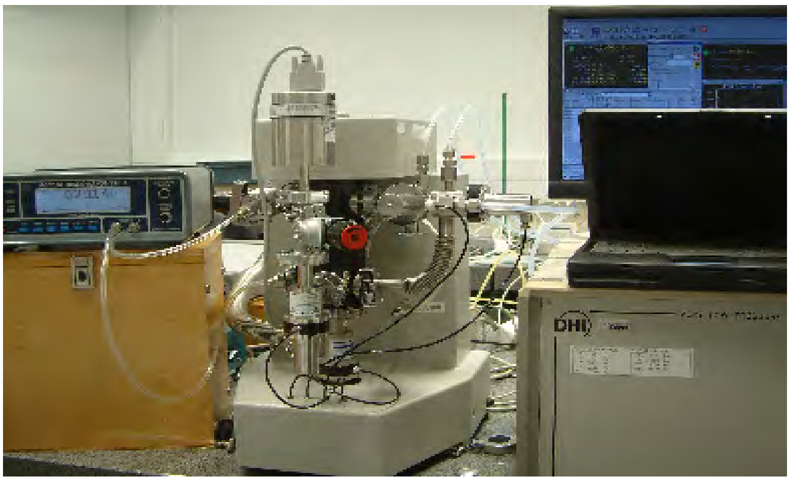

Fig. 2. The transfer standard (on the left) and the reference standard of MIKES

5 Stability of transfer standard and calculation of reference values

The four measurements at MIKES showed that the stability of the transfer standard was much worse than expected. The results of the MIKES measurements are shown in Figures 3 and 4. Each result point is the deviation of the transfer standard indication from the pressure defined by the MIKES standard:

Deviation = transfer standard indication – pressure from MIKES standard

Furness FCO510 range -2000 Pa to + 2000 Pa

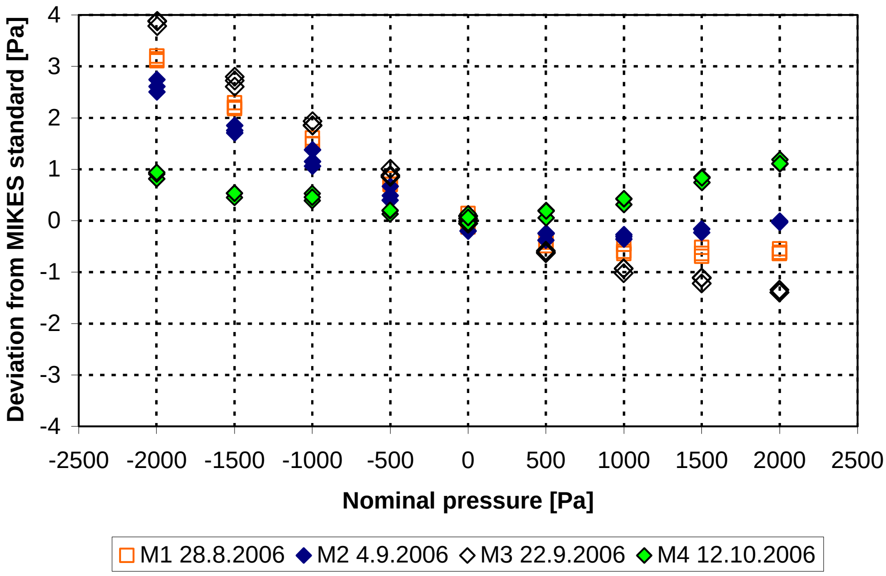

Fig. 3. MIKES results in the range from -2000 Pa to +2000 Pa.

Furness FCO510 range -200 Pa to + 200 Pa

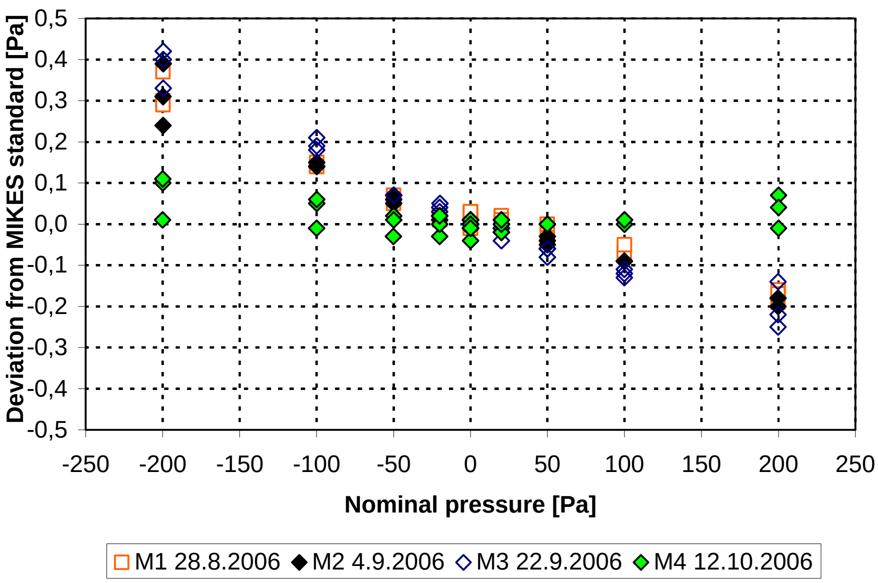

Fig. 4 MIKES results in the range from -200 Pa to +200 Pa.

The uncertainties for the results in each calibration were typically less than 0,05 Pa in the range -100 Pa to +100 Pa, and less than 0,2 Pa in the ranges from -2000 Pa to -500 Pa and from +500 Pa to +2000 Pa. The drift between calibrations was found to be much higher. Further, the drift was not linear and its direction varied.

Most of the instability was obviously caused by mechanical shocks and vibrations during transport. Between the measurements M1 and M2 the instrument was moved only from one table to another in the laboratory room. The trips after M2 to Metrosert in Tallinn and back were made using a careful personal transport. After the MIKES measurement M3 the transfer standard was sent to Denmark with a courier service, and the return trip was similar. The highest drift values were observed during the trip to Denmark and back to Espoo, between the results of M3 and the final MIKES measurement M4.

The instability of the transfer standard made it difficult if not impossible to find a solid basis for reference values. The solution selected was to treat comparisons MIKES-Metrosert and MIKES-FORCE separately.

For simplicity the reference values in the MIKES-Metrosert comparison were calculated as averages of the MIKES results of M1, M2 and M3, and their uncertainties (with coverage factor k =2) were based on the width of variation.

Respectively, in the MIKES-FORCE comparison the reference values and the uncertainties were based on the results of M2, M3 and M4 but only in the range from -200 Pa to +200 Pa. In the ranges from -2000 Pa to -500 Pa and from +500 Pa to + 2000 Pa the uncertainty of the reference values would be so much higher than the measurement uncertainties of MIKES and FORCE that the comparison is not meaningful.

Table 1. MIKES reference values for Metrosert and FORCE

Nominal pressure Pa	Reference value for Metrosert Pa	Uncertainty of reference value for Metrosert Pa	Reference value for FORCE Pa	Uncertainty of reference value for FORCE Pa
-2000	3,21	0,73		
-1500	2,23	0,56		
-1000	1,53	0,42		
-500	0,73	0,27		
-200	0,343	0,084	0,260	0,200
-100	0,163	0,041	0,123	0,101
-50	0,063	0,031	0,043	0,052
-20	0,027	0,032	0,020	0,043
+20	-0,003	0,038	-0,010	0,035
+50	-0,043	0,044	-0,037	0,050
+100	-0,090	0,048	-0,067	0,081
+200	-0,187	0,056	-0,117	0,151
+500	-0,45	0,20		
+1000	-0,61	0,40		
+1500	-0,65	0,56		
+2000	-0,67	0,80		

6 Measurements at Metrosert

The measurements in the pressure laboratory of Metrosert were carried out 18.-20.9.2006. The pressure standard used for the comparison was an MKM-4 micromanometer for the range -3000 Pa to +3000 Pa, Fig. 5.

The MKM-4 uses liquid column principle. There are two liquid containers whose height difference is set with gauge blocks and a dial indicator. The liquid levels are observed with a microscope.

The generated pressure p is calculates as

$$p = \Delta h \cdot g \cdot (\rho_l - \rho_a)$$

where Δh is height difference of the liquid levels
g is local acceleration of gravity
ρ_l is liquid density during measurement
ρ_a is air density during measurement

The pressure measurements with MKM-4 at Metrosert are traceable to the Estonian national standards of length.

The pressure laboratory of Metrosert is accredited by the Estonian Accreditation Centre EAK. In the gauge pressure range -3,5 kPa to + 3,5 kPa the accredited uncertainty is 0,1 Pa + 1,3 · 10-4 ·p, where p is pressure.

There are no pressure entries yet in the CMC tables of Metrosert in the BIPM database.

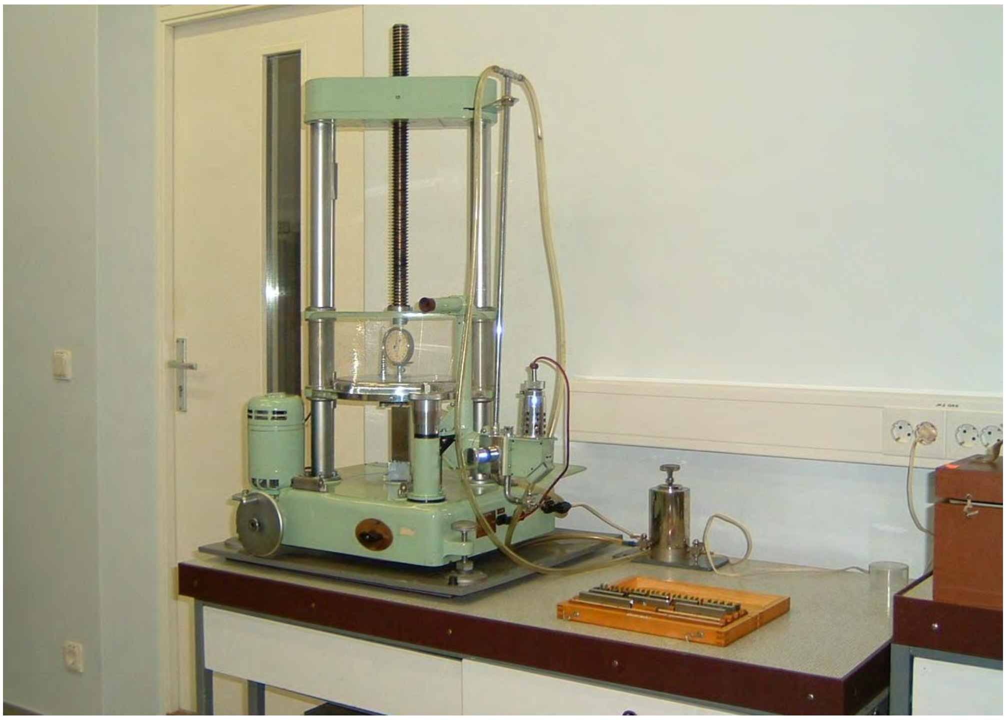

Fig. 5. MKM-4 used in comparison

The results of Metrosert (as deviations of the transfer standard indications from the pressures defined by the Metrosert standard) and their uncertainties are shown in Table 2 and in Figures 6 and 7. In the range from -200 Pa to + 200 Pa the given uncertainties are smaller than the accredited ones.

Table 2. The results of Metrosert and corresponding normalised errors.

Nominal pressure Pa	Result = deviation Pa	Uncertainty of result Pa	Reference value Pa	Uncertainty of ref. value Pa	Normalised error E(n)
-2000	3,1	0,5	3,21	0,73	-0,12
-1500	2,2	0,4	2,23	0,56	-0,05
-1000	1,6	0,3	1,53	0,42	0,13
-500	0,7	0,2	0,73	0,27	-0,08
-200	0,33	0,03	0,343	0,084	-0,15
-100	0,14	0,03	0,163	0,041	-0,46
-50	0,04	0,02	0,063	0,031	-0,64
-20	-0,02	0,02	0,027	0,032	**-1,23**
+20	0,05	0,02	-0,003	0,038	**1,25**
+50	0,00	0,03	-0,043	0,044	0,81
+100	-0,04	0,04	-0,090	0,048	0,8
+200	-0,18	0,06	-0,187	0,056	0,08
+500	-0,50	0,3	-0,45	0,20	-0,15
+1000	-0,80	0,3	-0,61	0,40	-0,38
+1500	-1,00	0,3	-0,65	0,56	-0,55
+2000	-1,00	0,3	-0,67	0,80	-0,39

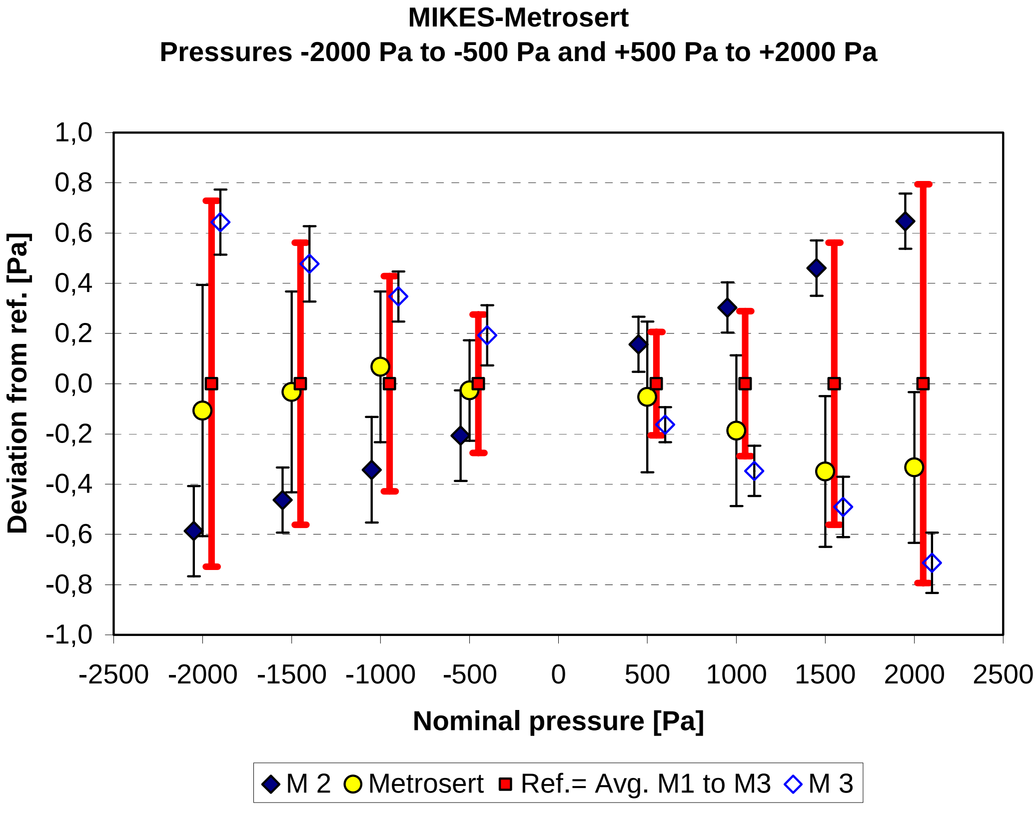

Fig. 6. Metrosert results compared to MIKES results.

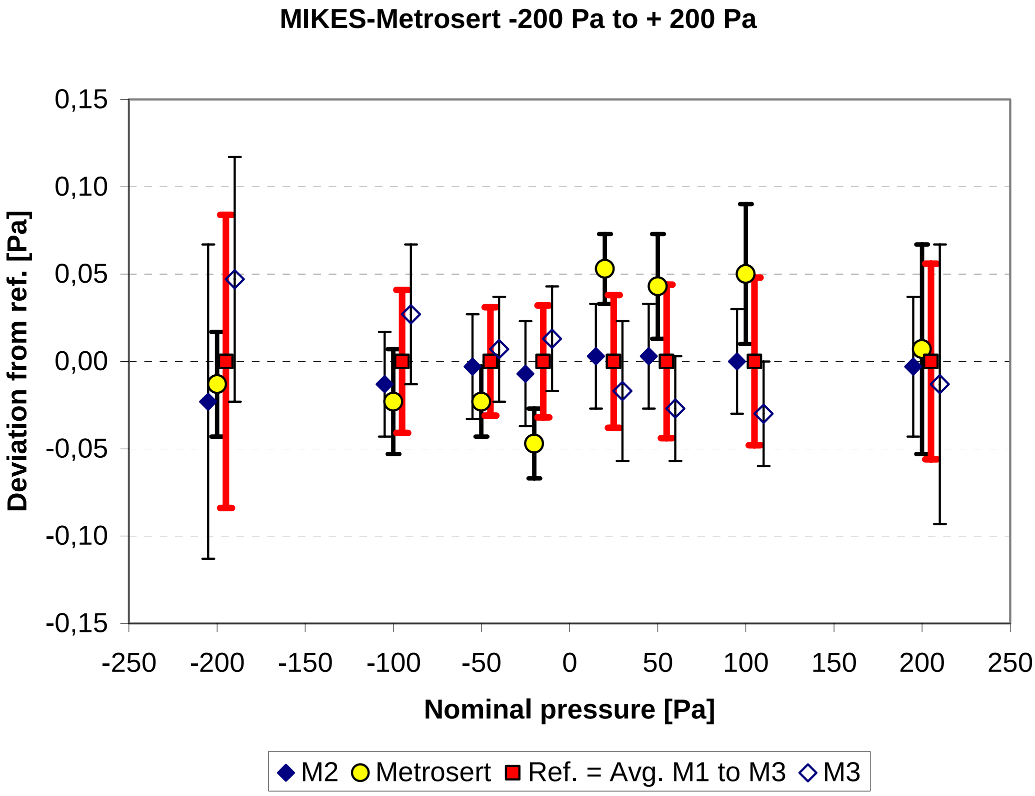

Fig. 7. Metrosert results compared to MIKES results.

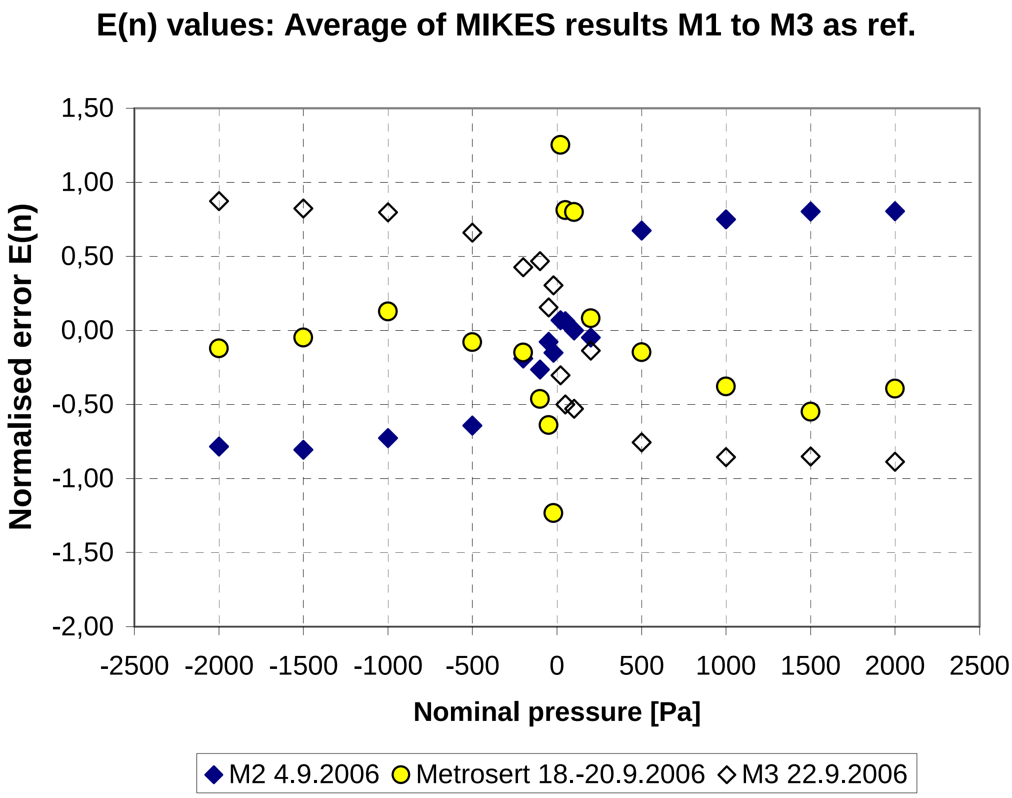

Fig. 8. Values for normalised errors E(n) in MIKES-Metrosert comparison

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

The values of normalised errors E_n for the Metrosert results are given in Table 2 and illustrated in Fig. 8. The E_n -values for all the results were between -1 and +1 except for the results at nominal pressures -20 Pa and + 20 Pa. It must be noted that the uncertainties given for the Metrosert results are much smaller than the accredited uncertainties at present.

7 Measurements at FORCE Technology

The measurements in the pressure laboratory of FORCE Technology were carried out 5.-6.10.2006 by Lene Schou and Birgit Jorgensen in the pressure range from -1500 Pa to +1500 Pa.

The pressure standard of FORCE Technology used in this comparison is a diving bell type instrument, traceable to PTB, Braunschweig (Fig. 9).

The best measurement capability of the FORCE standard is estimated as 0,3 Pa in the range from 0 to 1000 Pa, and $3 \cdot 10^{-4} \cdot p$ in the range from 1000 to 1500 Pa (p is pressure). These CMC values were approved into the BIPM database in October 2005.

Fig.9. The low gauge pressure standard of FORCE Technology.

The results of FORCE (as deviations of the transfer standard indications from the pressures defined by the FORCE standard) and their uncertainties are shown in Table 3 and in Figure 10. The given uncertainties were in agreement with the CMC tables of FORCE.

The results on ranges from -1500 Pa to -500 Pa and from +500 Pa to +1500 Pa have been omitted because the uncertainties of the reference values were so high in this range.

Table 3. The results of FORCE Technology and corresponding normalised errors.

Nominal pressure Pa	Result = deviation Pa	Uncertainty of result Pa	Reference value Pa	Uncertainty of ref. value Pa	Normalised error E(n)
-200	0,06	0,30	0,260	0,200	-0,55
-100	0,03	0,31	0,123	0,101	-0,29
-50	0,01	0,31	0,043	0,052	-0,11
-20	-0,06	0,31	0,020	0,043	-0,26
+20	0,06	0,31	-0,010	0,035	0,23
+50	0,09	0,31	-0,037	0,050	0,40
+100	0,07	0,32	-0,067	0,081	0,41
+200	0,04	0,30	-0,117	0,151	0,47

The values of normalised errors E_n for the results of FORCE technology are given in Table 3 and illustrated in Fig. 11. The E_n -values for all the results were between -1 and +1.

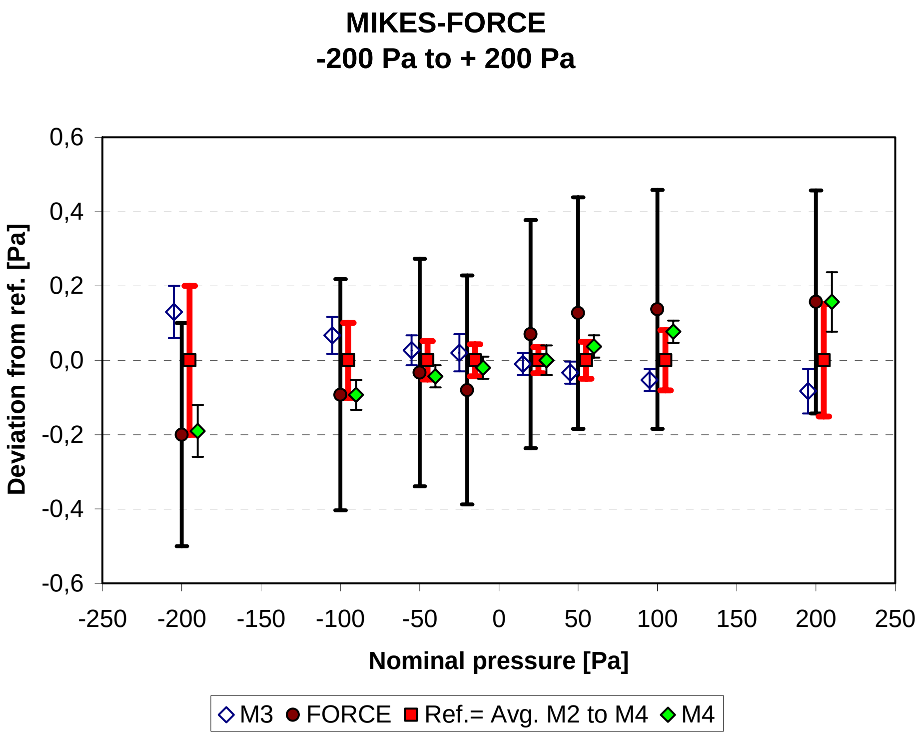

Fig.10. Results of FORCE Technology compared to MIKES results.

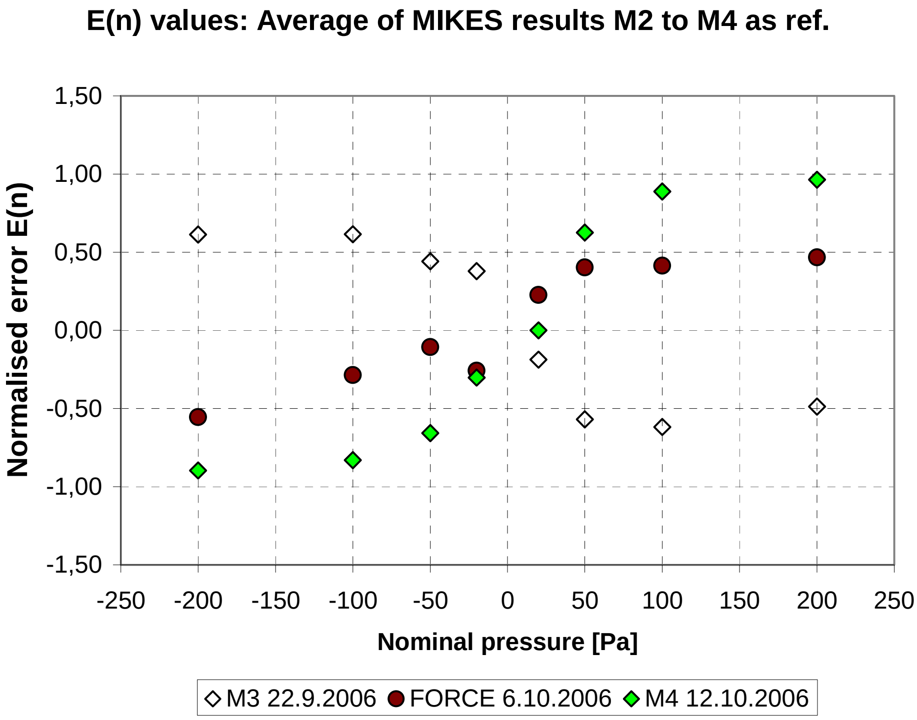

Fig. 11. Values for normalised errors E(n) in MIKES-FORCE comparison

8 Conclusions

The transfer standard, a Furness FCO 510 micro-manometer was not as stable as expected. Its uncertainty was too high for a very critical comparison of the measurement capabilities in the ranges from -2000 Pa to -500 Pa and from +500 Pa to +2000 Pa.

However, the results of MIKES and Metrosert were in a good agreement in the range from -2000 Pa to + 2000 Pa. Only at nominal pressures -20 Pa and +20 Pa the absolute values for the normalised error E_n were slightly higher than 1. It must be noted that the uncertainties of the Metrosert results in the range from -200 Pa to +200 Pa were much lower than their accredited uncertainties at present.

The results of MIKES and FORCE Technology were in a good agreement in the range from -200 Pa to +200 Pa. The uncertainties of the FORCE results were in agreement with their CMC tables. Outside this range the results of FORCE Technology were not assessed due to the high uncertainty of the reference values.

9 References

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