Absolute pressure range 95…105 kPa

Nordic Intercomparison in Barometric Pressure

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A Nordic intercomparison P12 in the barometric pressure range 95…105 kPa was arranged in 1998 by Finland's Centre for Metrology and Accreditation (MIKES). Five national pressure laboratories, and nine accredited and five non-accredited pressure calibration laboratories from six countries, participated in the comparison. The transfer standard, a Vaisala PTB 220TS barometer, was found to be very stable and insensitive to variations in the ambient temperature.

Figure 7. Vaisala's PTB 220TS barometer was found to be very stable in the Nordic Intercomparison in barometric pressure.

Pressure

The results of the national laboratories – the Centre for Metrology and Accreditation (MIKES) in Finland, the Flygtekniska Försökanstalten (FFA) in Sweden, the FORCE Institute in Denmark, and the Netherlands Meetinstituut (NMi) in the Netherlands – were in very good agreement with each other and with the low-uncertainty results from the National Physical Laboratory (NPL) in the United Kingdom.

All the results from accredited laboratories were in good agreement with the results from MIKES and from NPL as well. In one of the non-accredited laboratories, the comparison revealed an error in the calibration system. Two other non-accredited participants should re-evaluate their calibration uncertainties.

The accuracy of pressure measurements in the barometric range is important not only in meteorology and avionics, but in most fields of metrology as the results generally need to be corrected for ambient pressure.

Transfer standard: Vaisala PTB 220TS barometer

The transfer standard was a Vaisala PTB 220TS barometer s/n RD469733, made available by Vaisala Oyj, Finland. The operating range of this instrument is 500…1100 hPa, and the resolution of the display 0.01 hPa.

Before starting the circulation, the pressure laboratory of Vaisala Oyj introduced a small pressure-dependent error into the transfer standard.

Reference laboratory MIKES

The reference standard for the barometric range in the pressure laboratory MIKES is a Desgranges & Huot 24610 digital pressure balance. The effective areas of the pressure balances of MIKES are traceable to Laboratoire National d'Essais (LNE), Paris. The reference vacuum gauges are traceable to Flygtekniska Försökanstalten (FFA), Stockholm.

The intercomparison started as a joint national intercomparison in Finland and Sweden. Later, six laboratories from Denmark, Norway and the Netherlands joined in. As the transfer standard stability was found to be very good, the comparison was finally completed with the results from NPL, one of the leading pressure laboratories in the world.

In addition to MIKES, four other national pressure laboratories participated in the comparison.

Stability of the transfer standard

During the intercomparison, the transfer standard was calibrated five times in the reference laboratory. The first calibration was made at the end of March 1998, and the fifth in the middle of November 1998. The stability of the instrument

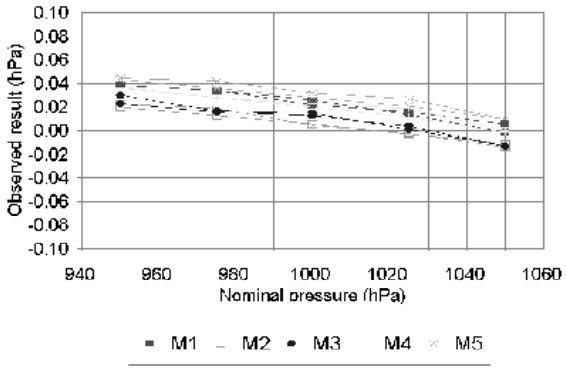

Figure 1. Summary of MIKES results, including five calibrations.

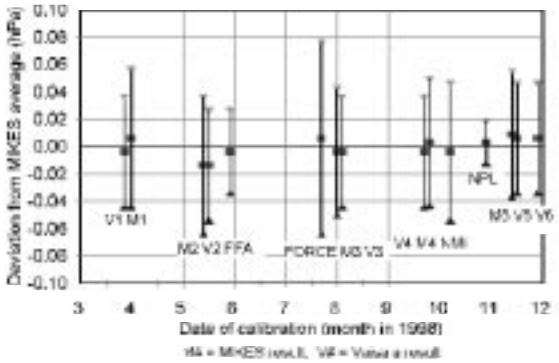

Figure 2. Transfer standard stability: 950 hPa increasing pressure.

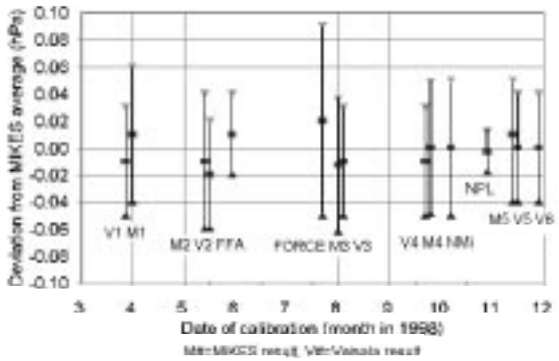

Figure 3. Transfer standard stability: 1050 hPa increasing pressure.

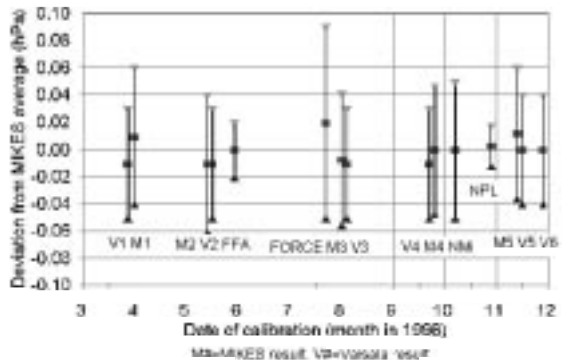

Figure 4. Transfer standard stability: 1000 hPa decreasing pressure.

was found to be very good. Figure 1 shows all the results of MIKES. The width of the scatter band is less than 3 Pa. Naturally, this value includes variations due to the reference standard of MIKES. Thus, 0.75 Pa is used as a rough estimate for the standard uncertainty due to the unstability of the transfer standard.

The good stability of the transfer standard was confirmed by six calibrations in the accredited pressure laboratory of Vaisala Oyj. The reference standard of Vaisala is a Ruska type 2465 pressure balance. Contrary to the other accredited pressure laboratories in Finland, the pressure laboratory of Vaisala is not traceable to MIKES in the barometric range but to the National Institute of Standards and Technology (NIST), USA. Both the effective area of the Ruska balance piston-cylinder unit and the reference vacuum gauge are regularly calibrated at NIST. In fact, the pressure laboratory of Vaisala is today able to reach a slightly lower uncertainty than MIKES in the barometric range. The width of the scatter band in the six Vaisala calibrations was only 2 Pa.

The stability of the transfer standard was further confirmed by the results from other national pressure laboratories. The calibration at NPL was performed against their best mercury column manometer. Consequently, the uncertainty of the NPL calibration was much lower than that of the other participants.

All results from national pressure laboratories were in good agreement. A summary of the results on three nominal pressures is shown in Figures 2, 3 and 4.

In addition to the calibration of the transfer standard at a temperature of +20 °C, NMi made some measurements at +17 °C and +23.5 °C to check the effects of temperature variation. The temperature sensitivity of the pressure indication was negligible within the resolution of the instrument.

Measurement instructions

The participants were asked to keep the transfer standard turned on for at least 8 hours, and then to calibrate the instrument by comparing its readings to those of the laboratory standard at nominal pressures of 950 hPa, 975 hPa, 1000 hPa, 1025 hPa and 1050 hPa, first in an increasing and then in a decreasing direction and following the laboratory's own procedures. This measurement cycle was to be repeated at least three times.

Further, the participants were asked to present the results as a calibration certificate and to send it to FINAS (the Finnish Accreditation Service) within two weeks of taking the measurements.

Comparison results

Following the EA (European Accreditation Laboratories) intercomparison practice, all laboratories (except the national ones and Vaisala) were given letter codes. Each laboratory knows only its own code.

The results for decreasing pressure 1000 hPa are illustrated in Figures 5 and 6.

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

$$E_n = \frac{(P_{transfer} - P_{std})_{Lab} - (P_{transfer} - P_{std})_{Ref}}{\sqrt{(U_{Lab}^2 + U_{Ref}^2)}}$$

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.

In the first place, the E_n values were calculated using the MIKES average values as references. The uncertainty of the reference values was calculated by combining the calibration uncertainty of the reference (4.6 to 4.9 Pa, depending on pressure) with the estimated uncertainty due to unstability (1.5 Pa). The coverage factor is k=2.

Additionally, the low uncertainty results from NPL were exploited by using them as reference values as well. Even here the estimated uncertainty due to unstability (1.5 Pa) was combined with the calibration uncertainty (1.5 Pa).

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

In this case, all the absolute E_n values for national and accredited laboratories are less than 1 – in fact less than 0.7 – in comparison to both MIKES and NPL reference values.

The value $E_n = 1$ is exceeded only in the results of the non-accredited laboratories g and m.

The results from g do not differ much from the reference values, but the claimed uncertainty is unrealistically low.

After receiving the preliminary reference values, the laboratory m checked their measurement system, and found and corrected an error. Now the agreement should be better.

While the E_n values of the laboratory f are acceptable as such, the results indicate, perhaps, that there is an opportunity to reconsider and reduce uncertainties.

It is clear that the group of non-accredited laboratories is less familiar with the calculation of uncertainties and with the expression of uncertainty according to the EA documents.

A summary of the E_n values is as follows:

National laboratories + Vaisala		
Laboratory code	MIKES as reference range of E_n values	NPL as reference range of E_n values
MIKES (M5)	0.13 … 0.23	0.10 … 0.27
Vaisala (V5)	-0.03 … 0.12	-0.07 … 0.07
FFA	-0.31 … 0.24	-0.69 … 0.36
FORCE	0.07 … 0.26	0.00 … 0.31
NMi	-0.10 … 0.16	-0.18 … 0.13

Accredited laboratories		
Laboratory code	MIKES as reference range of E_n values	NPL as reference range of E_n values
b	0.09 … 0.18	0.09 … 0.15
c	0.06 … 0.13	0.04 … 0.12
e	-0.38 … 0.25	-0.41 …-0.30
h	-0.60 …-0.45	-0.61 …-0.46
i	-0.24 …-0.14	-0.29 …-0.15
j	-0.39 …-0.10	0.60 …-0.22
k	0.25 …-0.35	0.23 … 0.38
l	0.00 … 0.07	-0.01 … 0.05

Non-accredited laboratories		
Laboratory code	MIKES as reference range of E_n values	NPL as reference range of E_n values
a	-0.56 …-0.38	-0.61 …-0.43
d	-0.21 … 0.02	-0.31 …-0.04
f	-0.10 … -0.03	-0.11 … -0.04
g	-0.67 …-0.27	-1.83 …-0.33
m	1.20 … 1.31	1.33 … 1.49

Conclusions

The following conclusions can be drawn:

- The transfer standard, a Vaisala PTB 220TS barometer, was found to be very stable and insensitive to variations in the ambient temperature.
- The results of the national laboratories MIKES, FFA, FORCE Institute and NMi as well as the results of Vaisala were in very good agreement with each other and with the low-uncertainty results from NPL.
- All the results from accredited laboratories were in good agreement with the reference values from MIKES and with the reference values from NPL as well. ■

*) Markku Rantanen has been the head of the pressure laboratory of the Centre for Metrology and Accreditation (MIKES) since 1991. The pressure laboratory is a small one, with a technical staff of two people only.

The absolute pressure range covered by MIKES is 0.2 Pa to 350 kPa (indirectly up to 500 MPa) and the gauge pressure range is 0 to 500 MPa.

MIKES arranges regularly pressure comparisons for the Finnish accredited pressure calibration laboratories. During the last years, some of the comparisons were arranged jointly with the Swedish national laboratory for pressure SP/FFA, and both Finnish and Swedish pressure laboratories have participated in these comparisons.

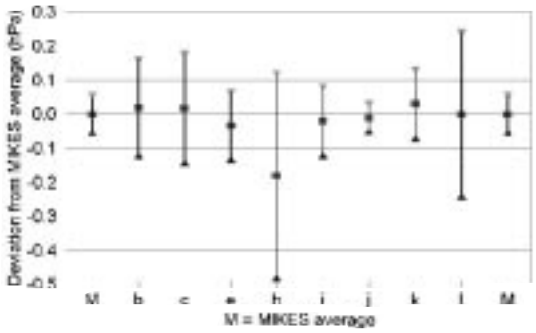

Figure 5. Accredited laboratories: 1000 hPa decreasing pressure.

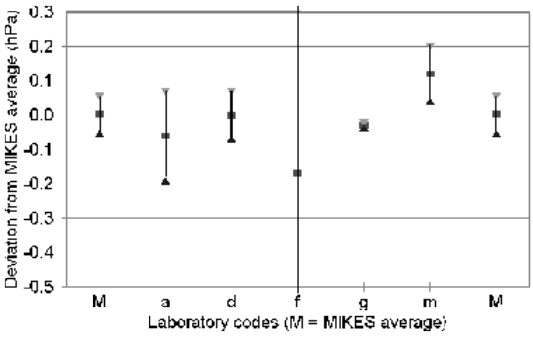

Figure 6. Non-accredited laboratories: 1000 hPa decreasing pressure.

References

EAL-R2/1997: Expression of the Uncertainty of Measurement in Calibration
Certificates of Calibration M-98P037, M-98P045, M-98P068, M-98P082 and M-98P111.
Centre of Metrology and Accreditation.
Certificates of Calibration K08-F03260, K08-F05140, K08-F08031, K08-F09210, K08-F11170 and K08-F11270. Vaisala Oyj, Measurement Standards Laboratory.
Certificate of Calibration 03-5505.FFA – Flygtekniska Försökanstalten.
Certificate of Calibration D27214. FORCE Instituttet.
Certificate of Calibration 3804244. Nederlands Meetinstituut.
Certificate of Calibration 08C032/98B9275. National Physical Laboratory.