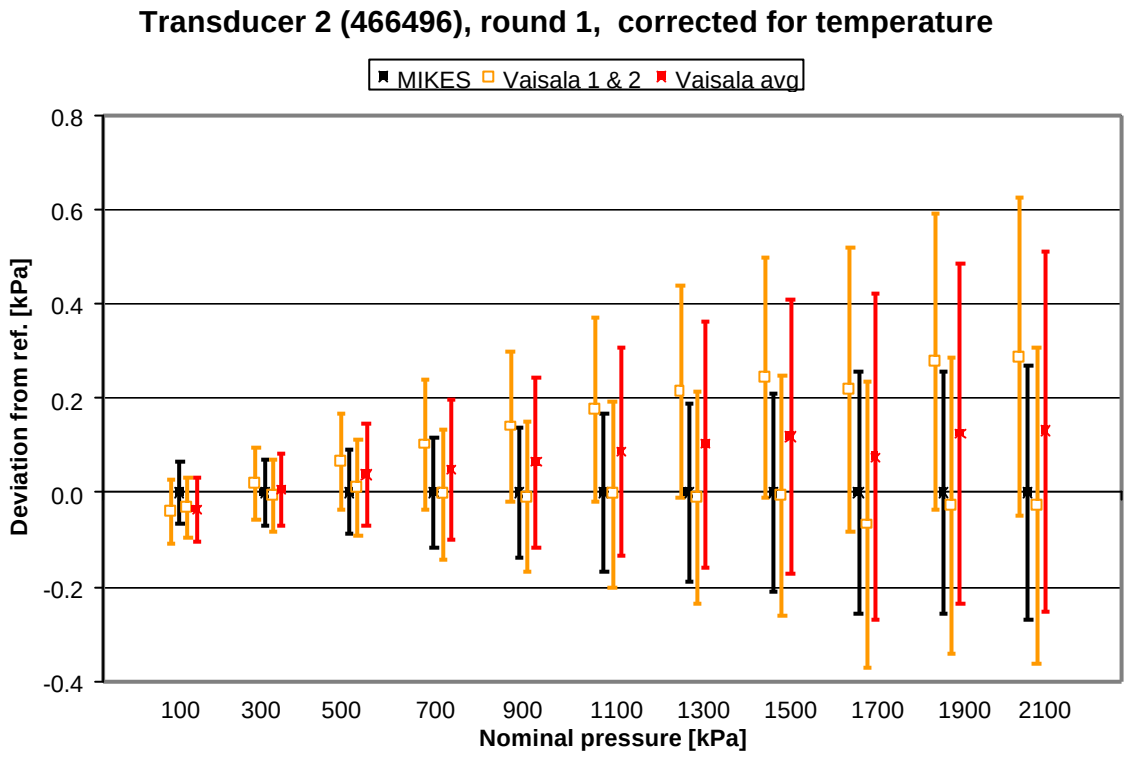
MIKES

METROLOGIA

J2/2004



Comparison in the absolute pressure range 100 kPa to 2100 kPa between MIKES and Vaisala Oyj

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Helsinki 2004

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ABSTRACT

Centre for Metrology and Accreditation (MIKES) and the Measurement Standards Laboratory of Vaisala Oyj arranged in 2002 - 2003 a bilateral comparison in the absolute pressure range from 100 kPa to 2100 kPa. The transfer standard was a set of two 2100 kPa absolute pressure transducers.

The original procedure for the comparison consisted of three subsequent calibrations: the first one at Vaisala, the second at MIKES and finally the third one again at Vaisala. The intention was to compare the averages of the two Vaisala results to the MIKES results.

As there were unexpected deviations in the results, the procedure above was repeated. The results of the second round were much the same as before. Finally, it was found out that the temperature sensitivity of the transfer standards was much higher than expected. Further, the zero stability of one of the transfer standards was not good.

The results were corrected for temperature differences and the uncertainty in temperature was taken into account in calculating the measurement uncertainty. Now it could be concluded that the results of MIKES and Vaisala were in a good agreement. The uncertainty level, however, was clearly higher than the best measurement capabilities of the two laboratories.

The unexpected features of the transfer standards caused a lot of extra work and several delays in the original schedule of the comparison.

CONTENTS

ABSTRACT

COMPARISON IN THE ABSOLUTE PRESSURE RANGE FROM 100 kPa TO 2100 kPa BETWEEN MIKES AND VAISALA OYJ

1 INTRODUCTION

In the spring of 2002 the Centre for Metrology and Accreditation (MIKES) and the Measurement Standards Laboratory of Vaisala Oyj started a bilateral comparison in the absolute pressure range from 100 kPa to 2100 kPa. The transfer standard was a set of two 2100 kPa absolute pressure transducers connected side-by-side to one tubing.

The Measurement Standards Laboratory (MSL) of Vaisala Oyj has accreditation for pressure, temperature and humidity calibrations. In the field of pressure the Vaisala laboratory is a special case among the Finnish accredited laboratories as their traceability is obtained directly from the National Institute of Standards and Technology (NIST), USA.

The pressure laboratory of MIKES is the national standards laboratory for pressure in Finland. The pressure balances of MIKES are traceable to BNM-LNE, France, and the vacuum gauges to PTB, Germany.

2 TRANSFER STANDARD

The transfer standard consisted of two absolute pressure transducers. The identifications of the transmitters are given in the following table.

Table 1. *Identifications of the pressure transducers.*

	Transducer no.1	**Transducer no. 2**
Manufacturer:	Sensotec	Sensotec
Model:	060-B 754-03	060-B 754-03
Serial number:	704595	466496
Instrument number:	PA 10648	PA 9300

The transducers belong to Vaisala Oyj. They have been in use for several years in the test section of Vaisala.

3 FIRST MEASUREMENT ROUND

The original procedure for the comparison consisted of three subsequent calibrations: the first one at Vaisala, the second at MIKES and finally the third one again at Vaisala. The intention was to compare the averages of the two Vaisala results to the MIKES results.

3.1 First measurements of round 1 at Vaisala

The first measurements were performed at Vaisala in May 2002 The measurement standards were an absolute pressure balance equipped with a spinning rotor vacuum gauge for reference pressure control, and a digital multimeter for the output of the transfer standards. The pressure balance was a Ruska 2465 no. V-730 / 24978 for the pressure range from 0,13 MPa to 5,1 MPa. The piston cylinder assembly is traceable to the National Institute of

Standards and Technology (NIST), USA via MSL (Measurement Standards Laboratory of Vaisala Oyj). Its latest calibration was in 1.2.2002.

The spinning rotor vacuum gauge used in the measurements was an MKS SRG-2CE no. 20825G / 92026G. It has traceability to NIST, USA, with the latest calibration in 20.12.1999. The digital multimeter was an Agilent 34970A no. EM 10371, calibrated in 9.8.2001. The digital multimeter is also traceable to NIST, USA via Transcat, USA and via MSL.

The first measurements in Vaisala Oyj Measurement Standards Laboratory (MSL) were made 21.5.2002 [1][2]. The measured range was from 100 kPa to 2100 kPa absolute pressure. The measurements were made by Jouni Leskinen. The conditions in the laboratory in May was as follows:

Temperature:	20,4 °C ± 0,3 °C
Air pressure:	1014,3 hPa ± 0,2 hPa
Relative humidity:	40 % ± 3 %

The pressure transducers were allowed to stabilise and to warm-up for more than 2 hours. The supply voltage to the transducers (15,0 V ± 0,3 V DC) was switched on during that time. The pressure transducers were mounted in horizontal position at the reference level of the pressure balance to avoid height correction.

The medium used in the calibration was air and/or nitrogen. Before the calibrations the pressure transducers were pre-pressurised two times with 2100 kPa. No zeroing was performed.

The measurements were made in the nominal pressure range 100 kPa to 2100 kPa in steps of 200 kPa. Two up-and-down cycles were made, resulting in four measurement points at each nominal pressure. Each result point was an average of 10 readings recorded by the data logging system.

The output voltages of the transducers were measured with 0,00001 V resolution with the digital multimeter.

3.2 Measurements of round 1 at MIKES

The first measurements were performed in MIKES Pressure Laboratory in May 2002. At MIKES the measurements were performed using an indirect method. The pressures supplied to the transfer standards were generated with a gauge pressure balance and simultaneously the atmospheric pressure was recorded.

The pressure balance body was type Desgranges et Huot 5203 no. 4401 equipped with a piston cylinder assembly Desgranges et Huot no. 4994 for the pressure range from 0,2 MPa to 5 MPa. The piston cylinder assembly was calibrated in MIKES 15.1.2002 and it has traceability to the national measurement standards of France.

The weight set used was Desgranges et Huot ring weight set no. 2926. The set was calibrated in MIKES in January 2002.

The barometer used in the measurements was the Vaisala PTB 200AD no. 533521. It was calibrated in MIKES 3.4.2002. The digital multimeter for reading the transducer output voltages was an Agilent 34401A no. US36134097 and it was calibrated in August 2002.

The measurements in MIKES Pressure Laboratory were made 23.5.2003 [3][4]. The measurements were made by Sari Semenoja and Markku Rantanen. The conditions in the laboratory was as follows:

Temperature:	22,5 °C ± 1 °C
Air pressure:	1014,3 hPa ± 2 hPa
Relative humidity:	45 % ± 10 %

The pressure transducers were allowed to stabilise in the laboratory conditions for at least 16 hours. The supply voltage to the transducers (15,0 V ± 0,3 V DC) was switched on during that time. Here, too, the pressure transducers were mounted in horizontal position at the reference level of the pressure balance.

Before the calibrations the pressure transducers were pre-pressurised three times with 2100 kPa. No zeroing was performed.

The measurement procedure and the medium used were the same as applied in the measurements at Vaisala with the exception of the pressure generating method. The gauge pressures generated by the pressure balance were fed in the transducers, and the gauge pressures were converted to absolute ones by adding the simultaneous barometer readings. Here, however, only single readings were taken for each point.

The output voltages of the transducers were measured with 0,00001 V resolution using the Agilent multimeter.

3.3 Second measurements of round 1 at Vaisala

The second part of the first measurement round was made on 4.6.2002 [5][6] by Jouni Leskinen, using the same equipment and the procedure as in the first measurements.

The conditions in the laboratory in June were as follows:

Temperature:	19,7 °C ± 0,3 °C
Air pressure:	1014,1 hPa ± 0,3 hPa
Relative humidity:	45 % ± 3 %

3.4 Results of the first round

Both Vaisala and MIKES presented their measurement results as certificates of calibration. The transducer output voltages were converted to pressure values using the formula

$$p\ [\mathrm{kPa}] = \left[\frac{U_{out}\ [\mathrm{V}]}{5\ \mathrm{V}} * (6{,}894757\ \mathrm{kPapsi}^{-1} * 300\ \mathrm{psi}) \right]$$

The results for each nominal pressure were given as the differences between the pressures indicated by the transfer standard and the laboratory standard, with the uncertainties calculated using coverage factor k = 2. The results of MIKES were given as errors, and the Vaisala results as corrections.

A summary of the measurement results is given in the Appendix. The MIKES results were used as reference values. Figure 1 illustrates the results for the transducer no. 1. Figure 2 shows the results for the transducer no. 2 in a similar manner.

The results were rather confusing. The latter of the Vaisala series for the transducer 1 is close to the MIKES results at the lowest and the highest pressures but the first one is in a better agreement in the mid-range. For transducer no. 2 both of the Vaisala results deviate from the results of MIKES except at the lowest nominal pressures.

For the transducer no. 1 the first and the second Vaisala results seem to differ from each other by a factor of 0,2 kPa, which is a large value compared to the uncertainties. For the other transducer the mutual agreement of the two Vaisala result series is much better.

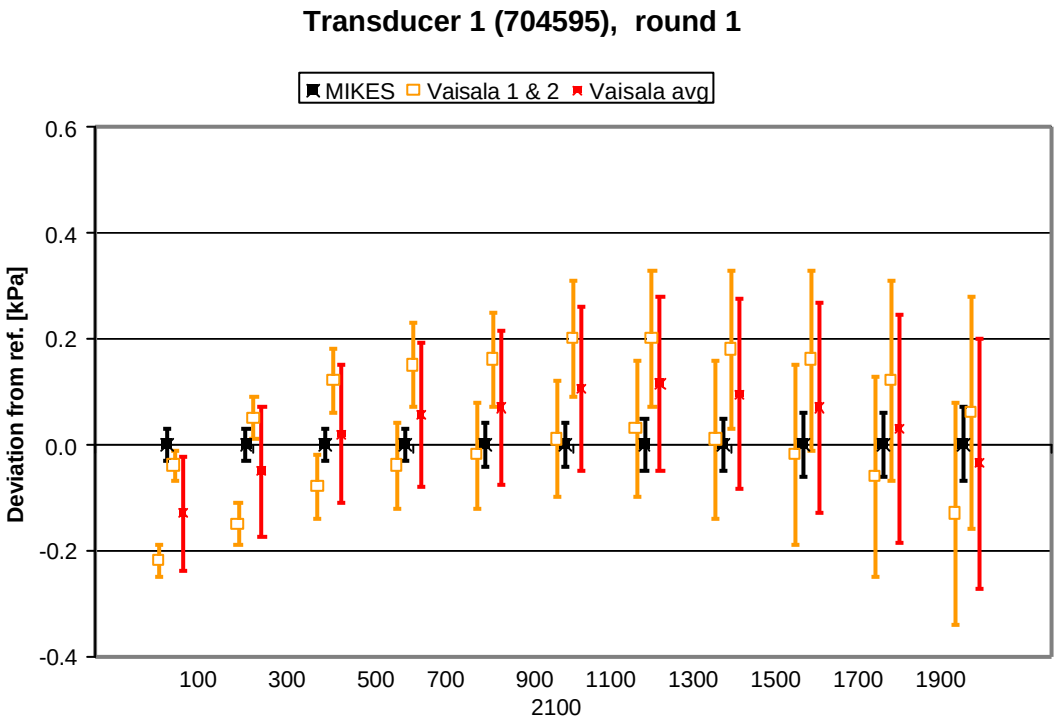

Figure 1. *Results for transducer no. 1 (704595)*

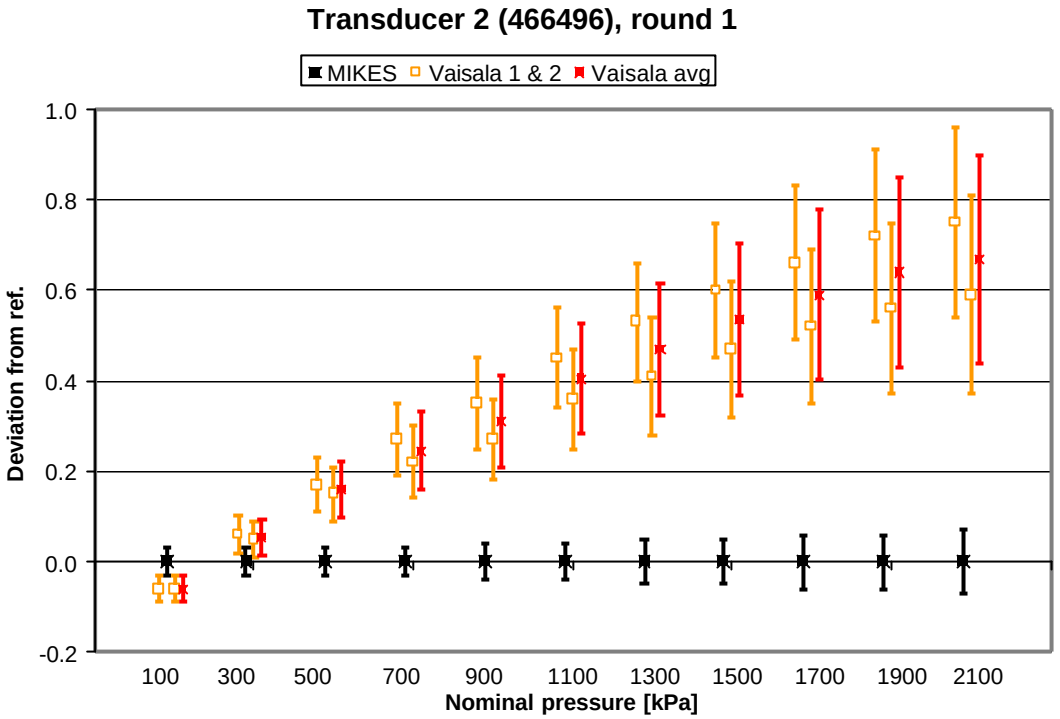

Figure 2. *Results for transducer no. 2 (466496)*

No obvious explanation for the anomalous results could be found in this stage. It was decided to make another measurement round to obtain more data.

4 SECOND MEASUREMENT ROUND

4.1 First measurements of round 2 at Vaisala

The second round of measurements was started at Vaisala 26.9.2002 [7][8]. The equipment and the pressure range were the same as in the first round.

The measurements were made again by Jouni Leskinen. The calibration procedure and the actions before and during the calibration were the same as described in the previous chapter. The conditions in the laboratory were now as follows:

Temperature:	20,5 °C ± 0,3 °C
Air pressure:	1007,1 hPa ± 0,2 hPa
Relative humidity:	38 % ± 3 %

4.2 Measurements of round 2 at MIKES

The MIKES measurements in the second round were made on 7.10.2002 [9][10].

The measurements were made again by Sari Semenoja and Markku Rantanen. The conditions in the laboratory were now the following:

Temperature:	22,6 °C ± 1 °C
Air pressure:	1023,0 hPa ± 2 hPa
Relative humidity:	45 % ± 10 %

The calibration procedure and the actions before and during the calibration were the same as before. However, the barometer was re-calibrated in August.

4.3 Second measurements of round 2 at Vaisala

The second round was completed by measurements at Vaisala on 12.10.2002 [11][12]. Jouni Leskinen was again the operator and the conditions in the laboratory were as follows:

Temperature:	20,7 °C ± 0,3 °C
Air pressure:	1031,5 hPa ± 0,2 hPa
Relative humidity:	35 % ± 3 %

4.4 Results of the second round

The results are again presented as a summary in the Appendix, and illustrated in Figures 3 and 4.

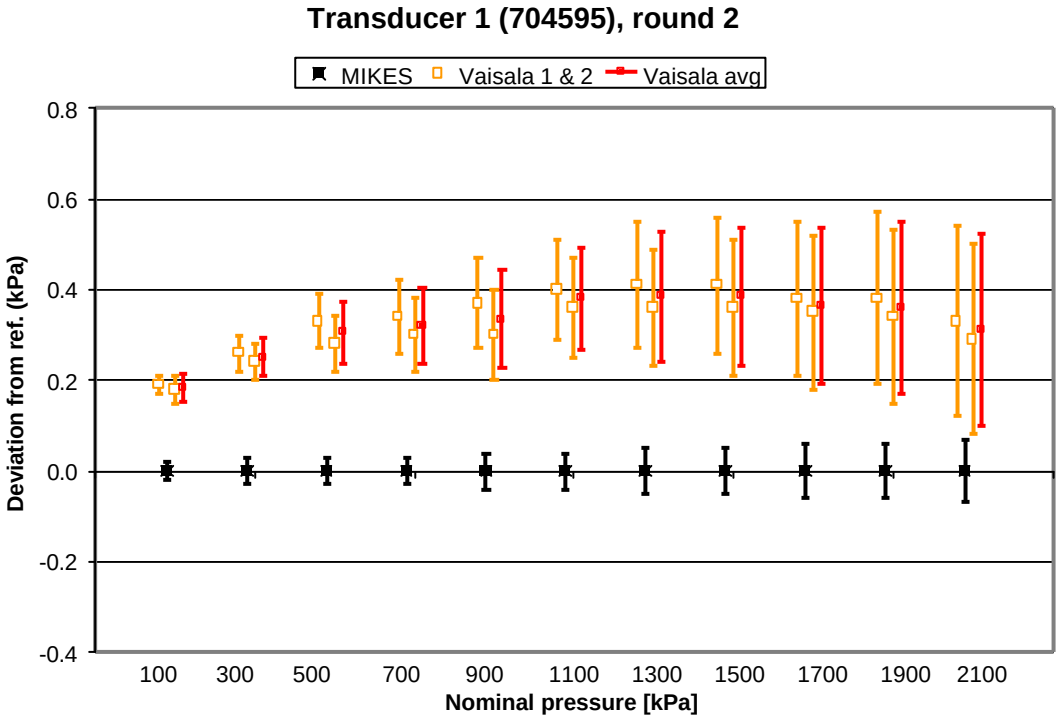

Figure 3. *Results from round 2 for transducer no.1.*

The results of the second measurement round seem to repeat the pattern of the first one. This time, however, the Vaisala results for the transducer no. 1 deviate much more from the MIKES results than in the first round. Now the two Vaisala series for both transducers were in a good agreement with each other.

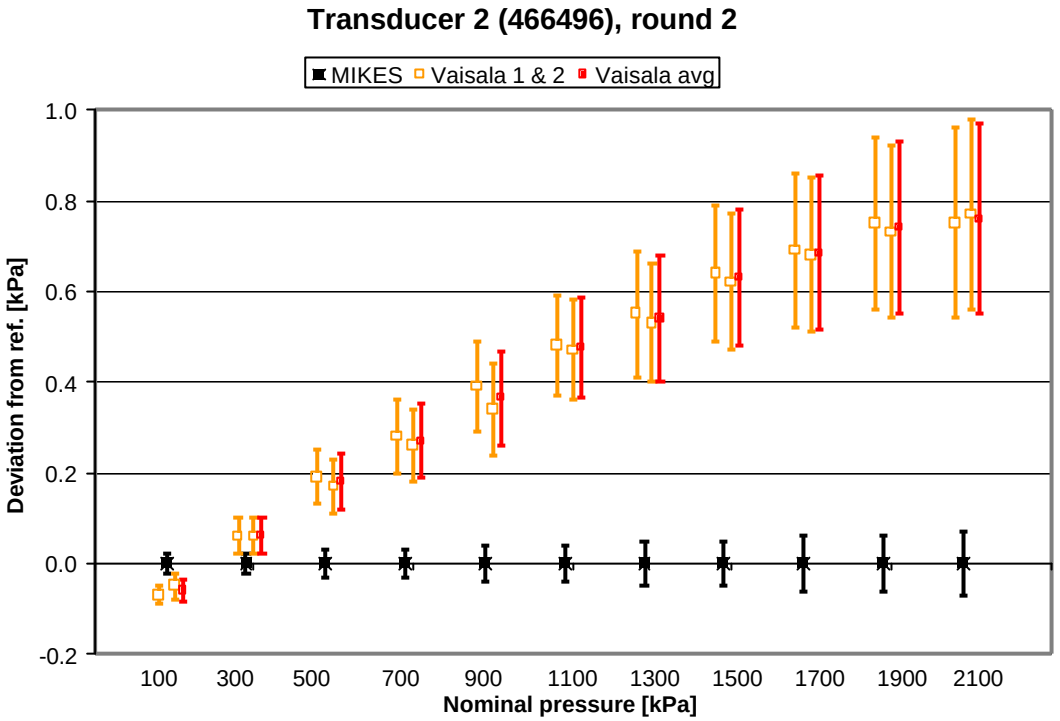

Figure 4. *Results from round 2 for transducer no. 2*

The two transfer standard transducers were clearly behaving in different way at MIKES and at Vaisala.

4.5 Measurements on the temperature sensitivity

As the temperature at the Vaisala measurements was 2 - 3 °C lower than that of MIKES, a test on the temperature dependency of the transducers was made at Vaisala in February 2003. The measurements of the two transducers were made at first at 21 °C and then at 29 °C. Figures 5 and 6 show the results.

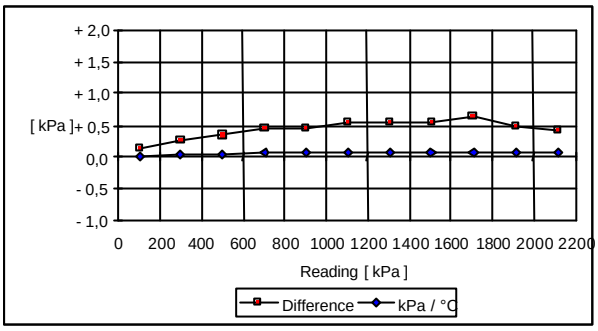

Figure 5. *Temperature dependency. Transducer no.1.*

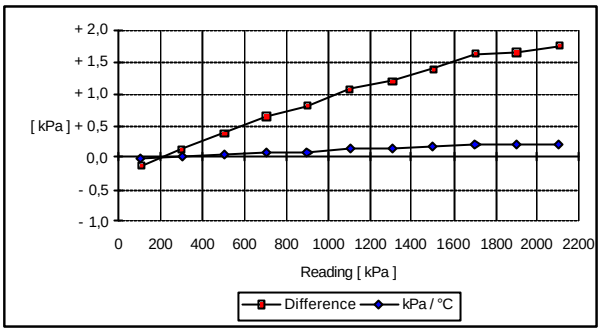

Figure 6. *Temperature dependency. Transducer no. 2.*

In the both Figures: "Difference" is the difference between the transducer readings in the temperatures +21 °C and +29 °C. "kPa/°C" is the change in the transducer reading when the temperature changes 1 °C.

According to the manufacturer's specifications the temperature sensitivity of the transducers is less than (0,0025 % of reading + 0,0025 % of range) / 1 °C. For the nominal pressure 100 kPa this equals to 0,055 kPa and respectively 0,105 kPa for 2100 kPa.

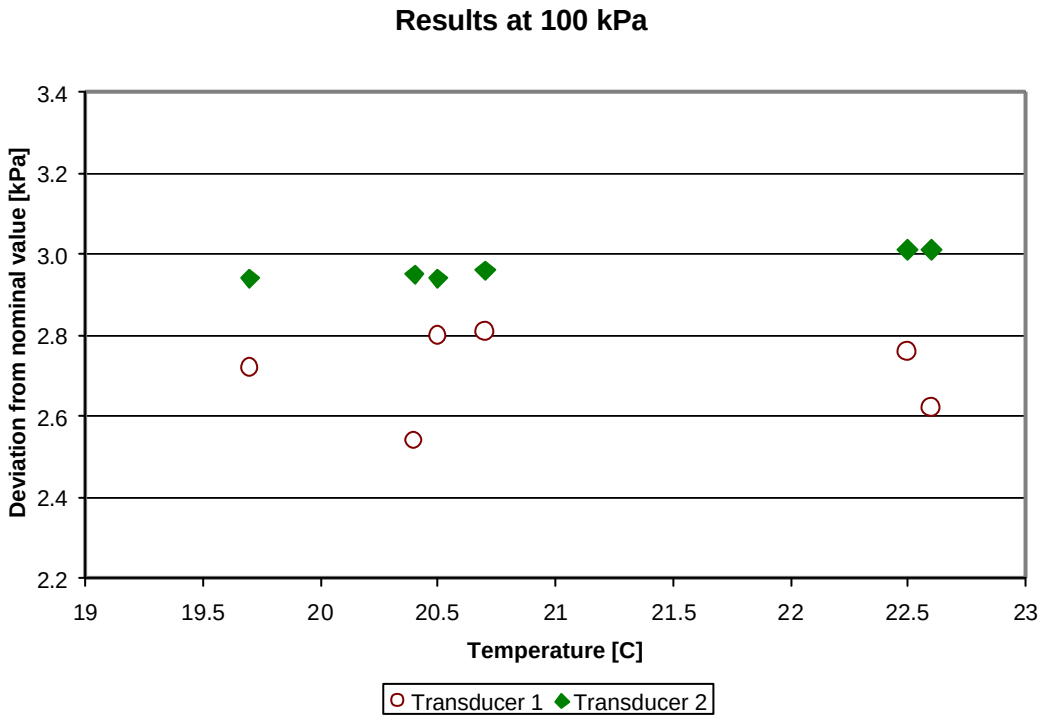

Figure 7. *All results for 100 kPa and the measurement temperatures*

The pressure dependent part in the specification (0,0025 % of reading /) corresponds to the slope of the curves in Figures 5 and 6. For transducer no. 1 the measured average slope is approximately 0,00375 % / 1 °C, which is 50 % higher than the specified value. For transducer no. 2. the measured average slope is about 0,0122 % / 1 °C. This is almost 400 % higher than the original specification.

Figure 7 shows all the results at the lowest nominal pressure (100 kPa) as a function of measurement temperature. This can be taken as an example on the effect of temperature on the zero readings of the two transducers. On the transducer no 1. the apparently random scatter covers any temperature effects in the results. On the transducer no. 2 the effect is clear but very small.

4.6 Results corrected to 20 °C

All the results of rounds 1 and 2 were recalculated to 20 °C to take the temperature effects into account. The corrections on the results were based on the results shown in Figures 6 and 7. Further, an additional uncertainty component equalling to the uncertainty of 1 °C was included in the results of both Vaisala and MIKES. The pressure dependent part in the temperature uncertainty was based on the results above. For the zero shift, however, the value *0,0025 % of range* was taken from the original manufacturers specification.

The corrected results of rounds 1 and 2 are shown in the Appendix and illustrated in Figures 8 to 11.

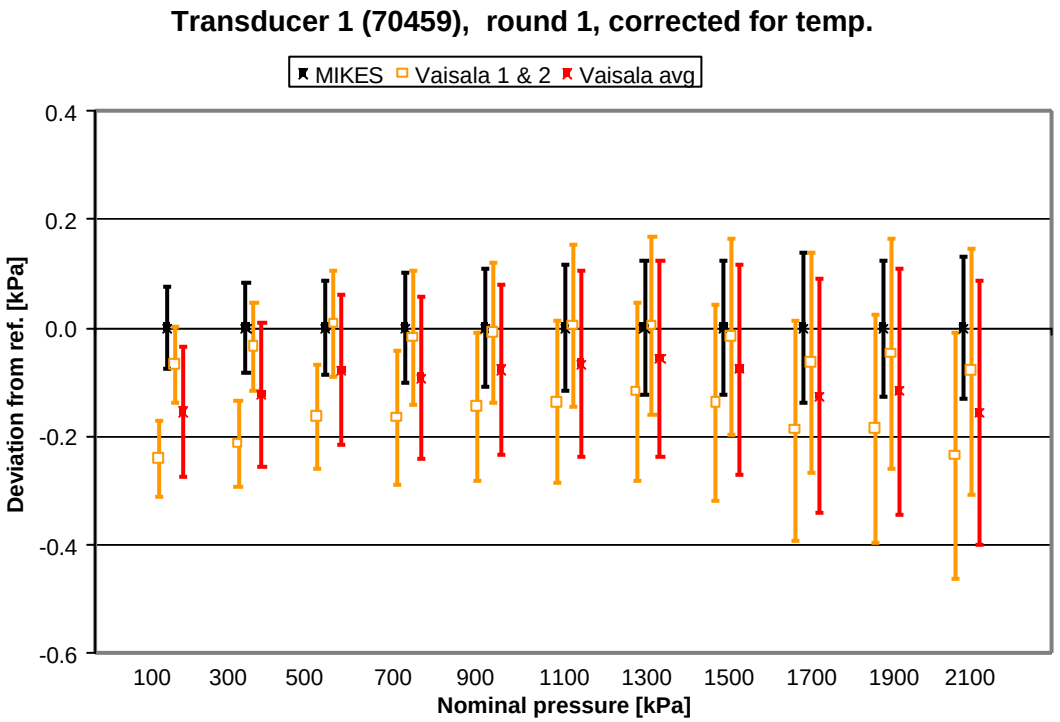

Figure 8. *Results of transducer no. 1 of round 1, corrected for temperature.*

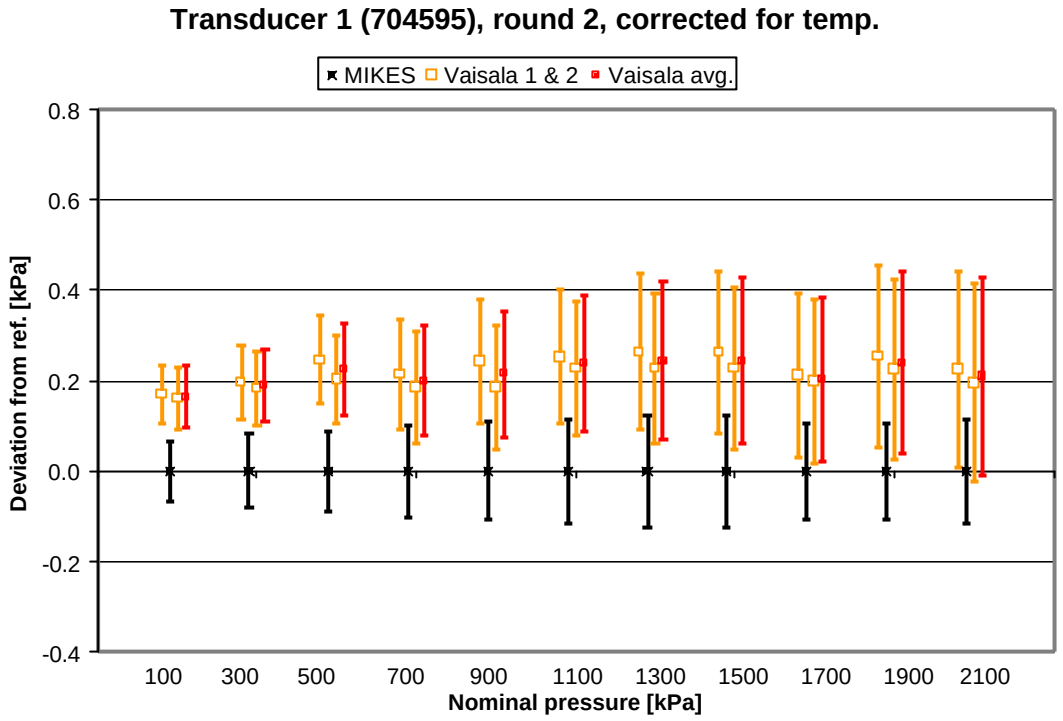

Figure 9. *Results of transducer no. 1 of round 2, corrected for temperature.*

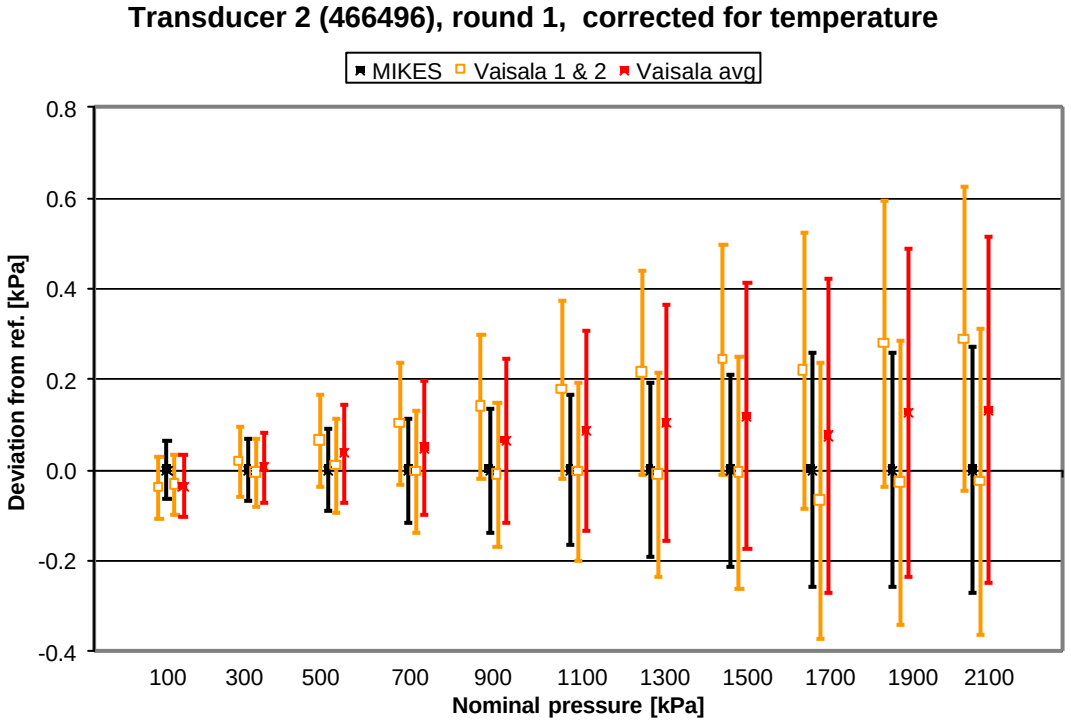

Figure 10. *Results of transducer no. 2 of round 1, corrected for temperature.*

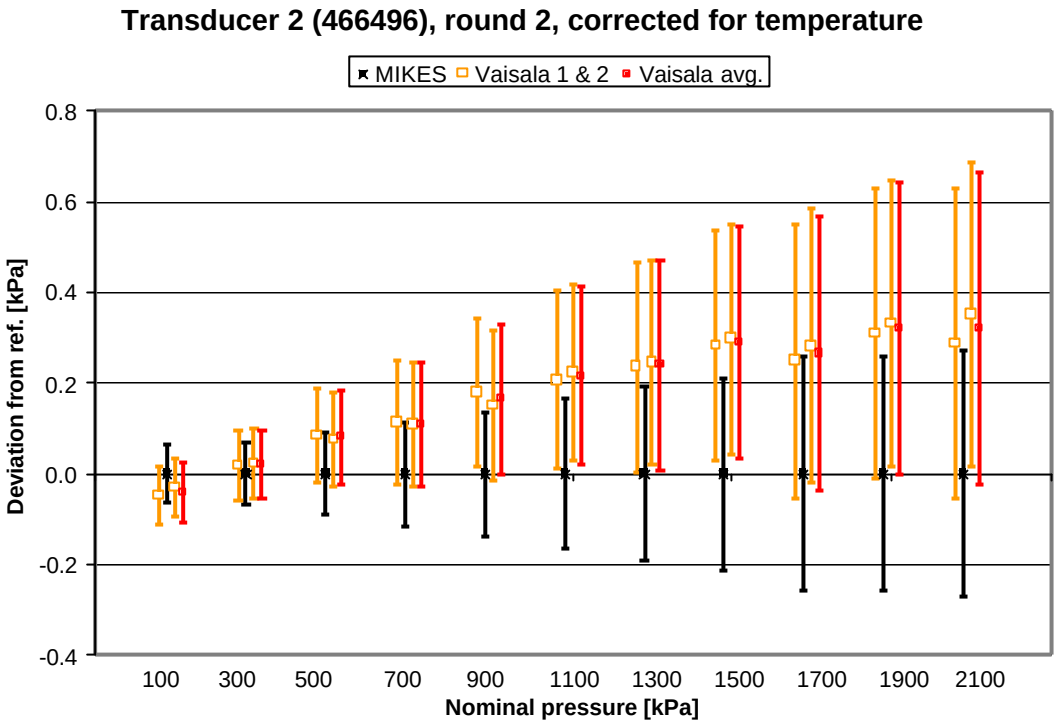

Figure 11. *Results of transducer no. 2 of round 2, corrected for temperature.*

After the temperature corrections and taking the uncertainty of temperature into account the results for the transducer no. 2 seem to be in good agreement. For the transducer no. 1 the deviations are now smaller for the round 1 results, but there is no big improvement in the round 2 results. The transducer no. 1 obviously suffers from zero instability.

A tool often used in comparing the results from two sources A and B is the normalised error E_n. [13]. It takes into account both the measurement result and the uncertainty. The normalised error for the each measurement is calculated as presented in the Formula 1:

$$E_n = \frac{(result_A - result_B)}{\sqrt{U_{resultA}^2 + U_{resultB}^2}} \qquad (1)$$

where $U_{resultA}$ and $U_{resultB}$ are the uncertainties, respectively.

In this case the E_n-values were calculated as

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

The factors $(p_{transfer} - p_{std})$ are the deviations recorded at each nominal pressure at both laboratories, and the values U are the uncertainties which now take into account the 1 ^{o}C uncertainty in temperature measurement. The coverage factor in the uncertainty values is k = 2

The E_n-values for each measurement series are shown in the Appendix, and a summary of them is presented in the Table 2.

Table 2. *E_n- values for the results corrected for temperature. The uncertainty of temperature measurements is taken into account.*

Nominal pressure [kPa]	Transducer no.1 round 1	Transducer no.1 round 2	Transducer no. 2 round 1	Transducer no. 2 round 2
100	***-1,15***	***1,92***	-0,46	-0,46
300	-0,85	***1,84***	-0,04	0,21
500	-0,50	***1,83***	0,20	0,62
700	-0,54	***1,34***	0,21	0,65
900	-0,43	***1,31***	0,33	0,81
1100	-0,34	***1,35***	0,30	0,88
1300	-0,28	***1,23***	0,31	0,85
1500	-0,35	***1,18***	0,33	0,92
1700	-0,52	0,89	0,16	0,70
1900	-0,47	***1,03***	0,27	0,83
2100	-0,60	0,85	0,23	0,78

The two results in comparison can be regarded as equivalent if $|E_n| < 1$. This is the case for all the results for transducer no. 2 and for the round 1 results for transducer no. 1 with the exception of the nominal pressure 100 kPa. The large deviations in the results for transducer no.1 are obviously due to unpredictable shifts in the zero level of the transducer and not to differences in the laboratory standards.

The measurement uncertainties of MIKES and Vaisala are compared in Table 3. The results for transducer no. 2 on round 1 were taken as examples. The same data are illustrated in Figure 12.

Table 3. *Comparison of relative uncertainty values in the results of MIKES and Vaisala for transducer no. 2 on round 1, coverage factor k = 2.*

Nominal pressure [kPa]	Relative uncertainty in MIKES certificate	Relative uncertainty in Vaisala certificate	Relative uncertainty in MIKES, temp. unc. included	Relative uncertainty in Vaisala temp. unc. included
100	$170 \cdot 10^{-6}$	$300 \cdot 10^{-6}$	$561 \cdot 10^{-6}$	$687 \cdot 10^{-6}$
300	$63 \cdot 10^{-6}$	$133 \cdot 10^{-6}$	$198 \cdot 10^{-6}$	$254 \cdot 10^{-6}$
500	$44 \cdot 10^{-6}$	$120 \cdot 10^{-6}$	$152 \cdot 10^{-6}$	$206 \cdot 10^{-6}$
700	$39 \cdot 10^{-6}$	$114 \cdot 10^{-6}$	$142 \cdot 10^{-6}$	$195 \cdot 10^{-6}$
900	$36 \cdot 10^{-6}$	$105 \cdot 10^{-6}$	$130 \cdot 10^{-6}$	$176 \cdot 10^{-6}$
1100	$34 \cdot 10^{-6}$	$100 \cdot 10^{-6}$	$132 \cdot 10^{-6}$	$178 \cdot 10^{-6}$
1300	$33 \cdot 10^{-6}$	$100 \cdot 10^{-6}$	$127 \cdot 10^{-6}$	$173 \cdot 10^{-6}$
1500	$32 \cdot 10^{-6}$	$100 \cdot 10^{-6}$	$123 \cdot 10^{-6}$	$170 \cdot 10^{-6}$
1700	$32 \cdot 10^{-6}$	$100 \cdot 10^{-6}$	$131 \cdot 10^{-6}$	$178 \cdot 10^{-6}$
1900	$32 \cdot 10^{-6}$	$100 \cdot 10^{-6}$	$118 \cdot 10^{-6}$	$165 \cdot 10^{-6}$
2100	$31 \cdot 10^{-6}$	$100 \cdot 10^{-6}$	$112 \cdot 10^{-6}$	$160 \cdot 10^{-6}$

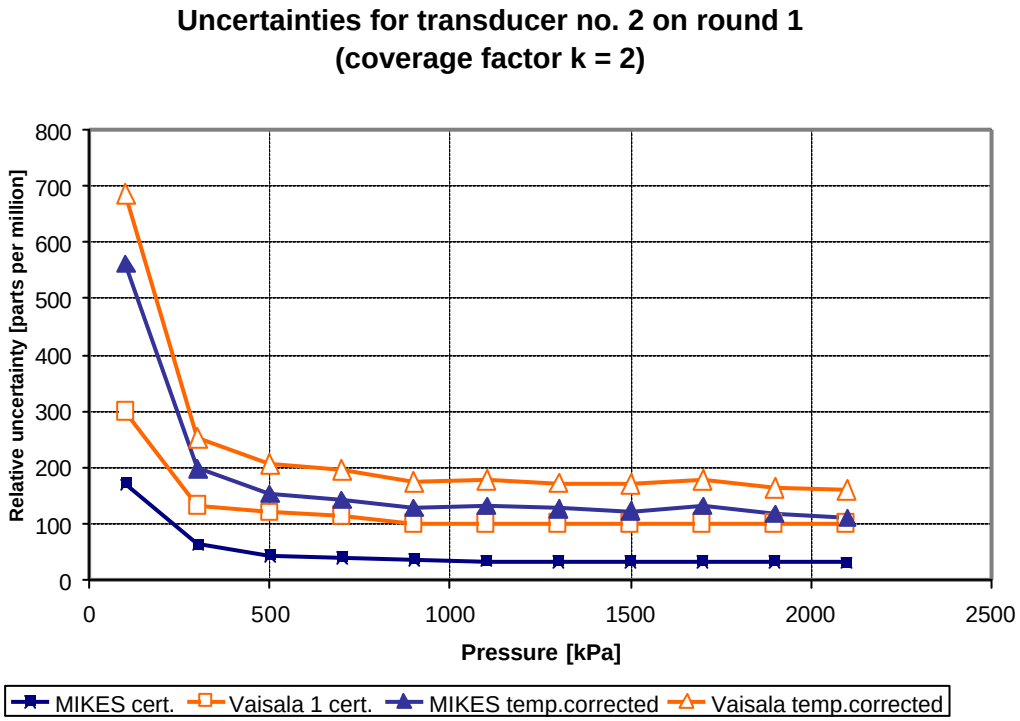

Figure 12. *The uncertainties given for the transducer no. 2 on measurement round 1 and the same values with the additional uncertainty due to temperature measurement.*

5 CONCLUSIONS

The agreement of the results of MIKES and Vaisala is good. However, the uncertainty level is clearly higher than the best measurement capabilities of the two laboratories.

The effects of temperature to the transfer standards were higher than expected. In general, this kind of feature may lead to over-optimistic uncertainty values if the temperature sensitivity of the transducers is neglected in calibration.

The zero stability of one of the two transducers used as transfer standards was not good.

The unexpected features in the transfer standards caused a lot of extra work and several delays in the original schedule of the comparison.

6 REFERENCES

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MR, SS 12.5.2004

First round on transducer 1 (704595)

Lab. code	MIKES		Vaisala 1				Vaisala 2				Vaisala average			
Date	23.5.2002		21.5.2002				4.6.2002							
Temperature	22,5 °C		20,4 °C				19,7 °C							
Nominal pressure	Result = ref.	Uncert.	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)
kPa	kPa	kPa	kPa	kPa	kPa		kPa	kPa	kPa		kPa	kPa	kPa	
100	2,76	0,021	2,54	0,03	-0,22	***-6,01***	2,72	0,03	-0,04	***-1,09***	2,63	0,11	-0,13	***-1,18***
300	3,45	0,021	3,30	0,04	-0,15	***-3,32***	3,50	0,04	0,05	***1,11***	3,40	0,12	-0,05	-0,40
500	4,15	0,025	4,07	0,06	-0,08	***-1,23***	4,27	0,06	0,12	***1,85***	4,17	0,13	0,02	0,15
700	4,85	0,029	4,81	0,08	-0,04	-0,47	5,00	0,08	0,15	***1,76***	4,91	0,14	0,05	0,40
900	5,54	0,032	5,52	0,10	-0,02	-0,19	5,70	0,09	0,16	***1,68***	5,61	0,14	0,07	0,47
1100	6,21	0,039	6,22	0,11	0,01	0,09	6,41	0,11	0,20	***1,71***	6,32	0,16	0,11	0,66
1300	6,84	0,044	6,87	0,13	0,03	0,22	7,04	0,13	0,20	***1,46***	6,96	0,16	0,12	0,68
1500	7,44	0,049	7,45	0,15	0,01	0,06	7,62	0,15	0,18	***1,14***	7,54	0,18	0,09	0,51
1700	7,97	0,054	7,95	0,17	-0,02	-0,11	8,13	0,17	0,16	0,90	8,04	0,20	0,07	0,34
1900	8,43	0,060	8,37	0,19	-0,06	-0,30	8,55	0,19	0,12	0,60	8,46	0,22	0,03	0,13
2100	8,81	0,066	8,68	0,21	-0,13	-0,59	8,87	0,22	0,06	0,26	8,78	0,24	-0,04	-0,14

First round on transducer 1 (704595) Results corrected to 20°C

Lab. code	MIKES		Vaisala 1				Vaisala 2				Vaisala average			
Date	23.5.2002		21.5.2002				4.6.2002							
Temperature	22,5 °C		20,4 °C				19,7 °C							
Nominal pressure	Result = ref.	Uncert.	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)
kPa	kPa	kPa	kPa	kPa	kPa		kPa	kPa	kPa		kPa	kPa	kPa	
100	2,79	0,057	2,54	0,07	-0,24	***-2,69***	2,72	0,07	-0,07	-0,76	2,63	0,12	-0,15	***-1,15***
300	3,53	0,064	3,31	0,08	-0,21	***-2,07***	3,49	0,08	-0,03	-0,33	3,40	0,13	-0,12	-0,85
500	4,25	0,071	4,09	0,10	-0,16	***-1,37***	4,26	0,10	0,01	0,07	4,17	0,14	-0,08	-0,50
700	5,00	0,085	4,83	0,12	-0,17	***-1,12***	4,98	0,12	-0,02	-0,12	4,91	0,15	-0,09	-0,54
900	5,69	0,086	5,54	0,14	-0,15	-0,91	5,68	0,13	-0,01	-0,05	5,61	0,16	-0,08	-0,43
1100	6,39	0,096	6,25	0,15	-0,14	-0,77	6,39	0,15	0,00	0,02	6,32	0,17	-0,07	-0,34
1300	7,02	0,098	6,90	0,16	-0,12	-0,61	7,02	0,16	0,00	0,02	6,96	0,18	-0,06	-0,28
1500	7,62	0,100	7,48	0,18	-0,14	-0,66	7,60	0,18	-0,02	-0,08	7,54	0,19	-0,08	-0,35
1700	8,17	0,110	7,98	0,20	-0,19	-0,82	8,11	0,20	-0,06	-0,28	8,04	0,22	-0,13	-0,52
1900	8,58	0,100	8,39	0,21	-0,19	-0,80	8,53	0,21	-0,05	-0,21	8,46	0,23	-0,12	-0,47
2100	8,94	0,098	8,70	0,23	-0,24	-0,95	8,86	0,24	-0,08	-0,31	8,78	0,24	-0,16	-0,60

First round on transducer 2 (466496)

Lab. code	MIKES		Vaisala 1				Vaisala 2				Vaisala average			
Date	23.5.2002		21.5.2002				4.6.2002							
Temperature	22,5 °C		20,4 °C				19,7 °C							
Nominal pressure	Result = ref.	Uncert.	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)
kPa	kPa	kPa	kPa	kPa	kPa		kPa	kPa	kPa		kPa	kPa	kPa	
100	3,01	0,017	2,95	0,03	-0,06	***-1,74***	2,94	0,02	-0,07	***-2,67***	2,95	0,03	-0,06	***-1,86***
300	3,02	0,019	3,08	0,04	0,06	***1,35***	3,05	0,04	0,03	0,68	3,07	0,04	0,04	0,95
500	2,97	0,022	3,14	0,06	0,17	***2,66***	3,10	0,06	0,13	***2,03***	3,12	0,06	0,15	***2,21***
700	2,85	0,027	3,12	0,08	0,27	***3,20***	3,05	0,08	0,20	***2,37***	3,09	0,09	0,24	***2,51***
900	2,66	0,032	3,01	0,09	0,35	***3,66***	2,94	0,1	0,28	***2,67***	2,98	0,10	0,32	***3,04***
1100	2,38	0,037	2,83	0,11	0,45	***3,88***	2,73	0,11	0,35	***3,02***	2,78	0,12	0,40	***3,09***
1300	2,02	0,043	2,55	0,13	0,53	***3,87***	2,42	0,14	0,40	***2,73***	2,49	0,15	0,47	***2,98***
1500	1,55	0,048	2,15	0,15	0,60	***3,81***	2,01	0,15	0,46	***2,92***	2,08	0,17	0,53	***2,99***
1700	0,97	0,054	1,63	0,17	0,66	***3,70***	1,47	0,17	0,50	***2,80***	1,55	0,19	0,58	***2,89***
1900	0,27	0,060	0,99	0,19	0,72	***3,61***	0,81	0,19	0,54	***2,71***	0,90	0,22	0,63	***2,80***
2100	-0,56	0,066	0,19	0,21	0,75	***3,41***	-0,02	0,22	0,54	***2,35***	0,09	0,24	0,65	***2,57***

First round on transducer 2 (466496) Results corrected to 20°C

Lab. code	MIKES		Vaisala 1				Vaisala 2				Vaisala average			
Date	23.5.2002		21.5.2002				4.6.2002							
Temperature	22,5 °C		20,4 °C				19,7 °C							
Nominal pressure	Result = ref.	Uncert.	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)	Result.	Uncert.	Deviation from ref.	E(n)
kPa	kPa	kPa	kPa	kPa	kPa		kPa	kPa	kPa		kPa	kPa	kPa	
100	2,99	0,056	2,95	0,07	-0,04	-0,44	2,94	0,06	-0,04	-0,49	2,94	0,07	-0,04	-0,46
300	3,07	0,059	3,09	0,08	0,02	0,19	3,04	0,08	-0,03	-0,27	3,07	0,08	0,00	-0,04
500	3,10	0,076	3,16	0,10	0,06	0,51	3,09	0,10	-0,01	-0,08	3,12	0,11	0,03	0,20
700	3,05	0,099	3,15	0,14	0,10	0,60	3,03	0,14	-0,02	-0,14	3,09	0,15	0,04	0,21
900	2,91	0,117	3,05	0,16	0,14	0,71	2,91	0,16	0,00	0,00	2,98	0,18	0,07	0,33
1100	2,71	0,145	2,88	0,20	0,18	0,73	2,69	0,20	-0,01	-0,06	2,79	0,22	0,08	0,30
1300	2,40	0,165	2,61	0,23	0,21	0,77	2,38	0,23	-0,02	-0,07	2,49	0,26	0,10	0,31
1500	1,98	0,184	2,22	0,25	0,24	0,77	1,96	0,25	-0,02	-0,05	2,09	0,30	0,11	0,33
1700	1,50	0,223	1,71	0,30	0,22	0,58	1,41	0,30	-0,09	-0,23	1,56	0,35	0,07	0,16
1900	0,80	0,225	1,07	0,31	0,28	0,72	0,75	0,31	-0,05	-0,12	0,91	0,37	0,12	0,27
2100	-0,01	0,236	0,28	0,34	0,29	0,70	-0,09	0,34	-0,08	-0,18	0,10	0,40	0,11	0,23

Second round on transducer 1 (704595)

Lab. code	MIKES		Vaisala 1				Vaisala 2				Vaisala average			
Date	7.10.2002		26.9.2002				12.10.2002							
Temperature	22,6 °C		20,5 °C				20,7 °C							
Nominal pressure	Result = ref.	Uncert.	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)
kPa	kPa	kPa	kPa	kPa	kPa		kPa	kPa	kPa		kPa	kPa	kPa	
100	2,62	0,018	2,81	0,02	0,19	***7,06***	2,80	0,03	0,18	***5,14***	2,81	0,02	0,19	***6,72***
300	3,34	0,022	3,60	0,04	0,26	***5,70***	3,58	0,04	0,24	***5,26***	3,59	0,04	0,25	***5,31***
500	4,07	0,026	4,40	0,06	0,33	***5,05***	4,35	0,06	0,28	***4,28***	4,38	0,07	0,31	***4,27***
700	4,80	0,028	5,14	0,08	0,34	***4,01***	5,10	0,08	0,30	***3,54***	5,12	0,08	0,32	***3,64***
900	5,51	0,034	5,88	0,10	0,37	***3,50***	5,81	0,10	0,30	***2,84***	5,85	0,11	0,34	***2,96***
1100	6,19	0,037	6,59	0,11	0,40	***3,45***	6,55	0,11	0,36	***3,10***	6,57	0,11	0,38	***3,21***
1300	6,84	0,043	7,25	0,14	0,41	***2,80***	7,20	0,13	0,36	***2,63***	7,23	0,14	0,39	***2,58***
1500	7,44	0,049	7,85	0,15	0,41	***2,60***	7,80	0,15	0,36	***2,28***	7,83	0,15	0,38	***2,40***
1700	7,98	0,054	8,36	0,17	0,38	***2,13***	8,33	0,17	0,35	***1,96***	8,35	0,17	0,36	***2,04***
1900	8,43	0,060	8,81	0,19	0,38	***1,91***	8,77	0,19	0,34	***1,71***	8,79	0,19	0,36	***1,79***
2100	8,81	0,066	9,14	0,21	0,33	***1,50***	9,10	0,21	0,29	***1,32***	9,12	0,21	0,31	***1,40***

Second round on transducer 1 (704595) Results corrected to 20°C

Lab. code	MIKES		Vaisala 1				Vaisala 2				Vaisala average			
Date	7.10.2002		26.9.2002				12.10.2002							
Temperature	22,6 °C		20,5 °C				20,7 °C							
Nominal pressure	Result = ref.	Uncert.	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)
kPa	kPa	kPa	kPa	kPa	kPa		kPa	kPa	kPa		kPa	kPa	kPa	
100	2,65	0,056	2,82	0,06	0,17	***1,96***	2,81	0,07	0,16	***1,81***	2,81	0,07	0,17	***1,92***
300	3,42	0,064	3,62	0,08	0,20	***1,91***	3,60	0,08	0,18	***1,78***	3,61	0,08	0,19	***1,84***
500	4,17	0,071	4,42	0,10	0,25	***2,05***	4,38	0,10	0,20	***1,70***	4,40	0,10	0,22	***1,83***
700	4,96	0,085	5,17	0,12	0,21	***1,44***	5,14	0,12	0,19	***1,25***	5,16	0,12	0,20	***1,34***
900	5,67	0,087	5,91	0,14	0,24	***1,51***	5,85	0,14	0,19	***1,15***	5,88	0,14	0,22	***1,31***
1100	6,37	0,095	6,63	0,15	0,25	***1,43***	6,60	0,15	0,23	***1,28***	6,61	0,15	0,24	***1,35***
1300	7,02	0,097	7,29	0,17	0,26	***1,33***	7,25	0,16	0,23	***1,19***	7,27	0,17	0,25	***1,23***
1500	7,62	0,100	7,89	0,18	0,26	***1,27***	7,85	0,18	0,23	***1,10***	7,87	0,18	0,24	***1,18***
1700	8,19	0,110	8,40	0,20	0,21	0,92	8,39	0,20	0,20	0,86	8,39	0,20	0,20	0,89
1900	8,59	0,100	8,84	0,21	0,25	***1,09***	8,81	0,21	0,23	0,97	8,83	0,21	0,24	***1,03***
2100	8,94	0,098	9,17	0,23	0,23	0,91	9,14	0,23	0,19	0,79	9,15	0,23	0,21	0,85

Second round on transducer 2 (466496)

Lab. code	MIKES		Vaisala 1				Vaisala 2				Vaisala average			
Date	7.10.2002		26.9.2002				12.10.2002							
Temperature	22,6 °C		20,5 °C				20,7 °C							
Nominal pressure	Result = ref.	Uncert.	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)
kPa	kPa	kPa	kPa	kPa	kPa		kPa	kPa	kPa		kPa	kPa	kPa	
100	3,01	0,018	2,94	0,02	-0,07	***-2,60***	2,96	0,03	-0,05	***-1,43***	2,95	0,02	-0,06	***-2,05***
300	2,99	0,022	3,05	0,04	0,06	***1,31***	3,05	0,04	0,06	***1,31***	3,05	0,04	0,06	***1,31***
500	2,91	0,026	3,10	0,06	0,19	***2,91***	3,08	0,06	0,17	***2,60***	3,09	0,06	0,18	***2,71***
700	2,77	0,028	3,05	0,08	0,28	***3,30***	3,03	0,08	0,26	***3,07***	3,04	0,08	0,27	***3,16***
900	2,55	0,034	2,94	0,10	0,39	***3,69***	2,89	0,10	0,34	***3,22***	2,92	0,10	0,37	***3,33***
1100	2,25	0,037	2,73	0,11	0,48	***4,14***	2,72	0,11	0,47	***4,05***	2,73	0,11	0,48	***4,09***
1300	1,87	0,043	2,42	0,14	0,55	***3,76***	2,40	0,13	0,53	***3,87***	2,41	0,14	0,54	***3,68***
1500	1,37	0,049	2,01	0,15	0,64	***4,06***	1,99	0,15	0,62	***3,93***	2,00	0,15	0,63	***3,98***
1700	0,78	0,054	1,47	0,17	0,69	***3,87***	1,46	0,17	0,68	***3,81***	1,47	0,17	0,69	***3,84***
1900	0,06	0,060	0,81	0,19	0,75	***3,76***	0,79	0,19	0,73	***3,66***	0,80	0,19	0,74	***3,71***
2100	-0,77	0,066	-0,02	0,21	0,75	***3,41***	0,00	0,21	0,77	***3,50***	-0,01	0,21	0,76	***3,45***

Second round on transducer 2 (466496) Results corrected to 20°C

Lab. code	MIKES		Vaisala 1				Vaisala 2				Vaisala average			
Date	7.10.2002		26.9.2002				12.10.2002							
Temperature	22,6 °C		20,5 °C				20,7 °C							
Nominal pressure	Result = ref.	Uncert.	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)	Result	Uncert.	Deviation from ref.	E(n)
kPa	kPa	kPa	kPa	kPa	kPa		kPa	kPa	kPa		kPa	kPa	kPa	
100	2,98	0,056	2,94	0,06	-0,05	-0,57	2,95	0,07	-0,03	-0,35	2,94	0,07	-0,04	-0,46
300	3,04	0,060	3,06	0,08	0,02	0,19	3,06	0,08	0,02	0,23	3,06	0,08	0,02	0,21
500	3,04	0,077	3,13	0,10	0,09	0,66	3,12	0,10	0,08	0,58	3,12	0,10	0,08	0,62
700	2,98	0,100	3,09	0,14	0,11	0,66	3,09	0,14	0,11	0,64	3,09	0,14	0,11	0,65
900	2,81	0,118	2,99	0,16	0,18	0,89	2,96	0,16	0,15	0,74	2,98	0,17	0,17	0,81
1100	2,59	0,145	2,80	0,20	0,21	0,85	2,81	0,20	0,22	0,92	2,80	0,20	0,22	0,88
1300	2,26	0,165	2,50	0,23	0,24	0,83	2,51	0,23	0,25	0,88	2,50	0,23	0,24	0,85
1500	1,81	0,185	2,10	0,25	0,28	0,90	2,11	0,25	0,30	0,94	2,10	0,25	0,29	0,92
1700	1,33	0,223	1,58	0,30	0,25	0,66	1,61	0,30	0,28	0,75	1,59	0,30	0,26	0,70
1900	0,61	0,225	0,92	0,31	0,31	0,80	0,94	0,31	0,33	0,86	0,93	0,31	0,32	0,83
2100	-0,20	0,236	0,09	0,34	0,29	0,70	0,15	0,34	0,35	0,86	0,12	0,34	0,32	0,78

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