MIKES

METROLOGIA

J4/2010

Intercomparison in gauge pressure 0 – 25 MPa

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Centre for Metrology and Accreditation

Espoo 2010

MIKES
Mittatekniikan keskus
Centre for metrology
and accreditation

Publication J4/2010

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Abstract

An inter-laboratory comparison in the gauge pressure range from 0 MPa to 25 MPa was arranged in 2010 by the Centre for Metrology and Accreditation (MIKES). Nine accredited pressure calibration laboratories participated in the comparison, four from Finland and five from other European countries.

The transfer standard was a Beamex MC5 multifunction calibrator equipped with an external pressure transducer EXT250, operating on oil. The instrument was provided for the comparison by the manufacturer Beamex Oy Ab, Pietarsaari, Finland.

The results from all laboratories were in a good agreement with the results of MIKES within the limits of the claimed uncertainties. One laboratory first sent slightly deviating results, and was asked to check their results. The new measurements after corrective actions gave a good agreement.

Tiivistelmä

Mittatekniikan keskus (MIKES) järjesti vuonna 2010 paineen vertailumittauksen öljyn ylipainealueella 0 MPa … 25 MPa. Vertailumittaukseen osallistui yhdeksän akkreditoitua paineen kalibrointilaboratoriota, joista neljä oli Suomesta ja viisi muista Euroopan maista.

Kiertävänä vertailulaitteena oli Beamex MC5 -kalibraattori varustettuna ulkoisella EXT250-paineanturilla. Laitteen luovutti käyttöön Beamex Oy Ab.

Kahdeksan laboratorion tulokset olivat ilmoitettujen mittausepävarmuuksien puitteissa heti samoja kuin MIKESin tulokset. Yhdeltä laboratoriolta saadut tulokset olivat aluksi poikkeavia, ja sitä pyydettiin tarkistamaan antamansa tiedot. Uusittujen mittausten tulokset olivat yhteensopivia MIKESin tulosten kanssa.

Contents

1 Introduction

The Centre for Metrology and Accreditation (MIKES) has arranged several inter-comparisons for the Finnish pressure calibration laboratories during the last 20 years, trying to cover the entire pressure range. The gauge pressure in oil up to 25 MPa was selected in 2010. Participation was also opened to laboratories in other countries.

2 Participants

The following laboratories participated in the comparison:

AS Metrosert, Tallinn, Estonia
Beamex Oy Ab, Calibration Laboratory, Pietarsaari, Finland
Exova METECH A/S, Karup, Denmark
Finnair Technical Services Oy, Vantaa, Finland
Finnish Air Force, Air Materiel Command, Tampere, Finland
Inspecta Oy, Measuring Technology, Espoo, Finland
Teknologisk institutt as, Calibration department, Aagotnes, Norway
Trescal A/S, Silkeborg, Denmark
University of Ljubjana, Faculty of Mech. E., Ljubjana, Slovenia

All laboratories are accredited for pressure calibrations.

3 Reference Laboratory

The reference standard used at MIKES for the inter-comparison was a Desgranges & Huot 5306 pressure balance s/n 4572 with a piston/cylinder unit s/n 5806 for gauge pressure range from 0,5 MPa to 50 MPa. The piston cylinder unit has been used as a working standard at MIKES since 1994. The latest calibration for the effective area, nominally 19,6 mm^2, was carried out at MIKES in August 2009 (certificate M-09P091). The high pressure measurements of MIKES are traceable to Laboratoire National de Métrologie et d'Essais (LNE), France.

In 2010 the CMC value in the BIPM database for the oil pressure range 0,5 MPa to 50 MPa of MIKES was 12 Pa + 2,5 x 10^{-5} x p (k = 2, p in Pa).

4 Transfer Standard

The transfer standard was a Beamex MC5 multifunction calibrator s/n 25516865 equipped with an external transducer EXT250 s/n 40795, for the gauge pressure range 0 MPa to 25 MPa, operating on oil. The resolution of the display is 1 kPa when kPa is selected for pressure unit.

5 Measurement Instructions

The measurement instructions are attached as Appendix 1.

The participants were asked to allow the transfer standard a stabilisation time of at least three hours with the instrument switched on. A pre-pressuration of three times to 25000 kPa and zeroing at atmospheric pressure after 3 to 5 minutes was specified. Then the laboratories were asked to calibrate the instrument using their routine methods at 0 kPa, 5000 kPa, 10000 kPa, 15000 kPa, 20000 kPa and 25000 kPa.

The participating laboratories were asked to report their results with typical calibration certificates and a summary of the results in the following table:

Calibration point	Nominal pressure kPa	Pressure supplied to travelling standard kPa	Pressure displayed by travelling standard kPa	Deviation kPa	Uncertainty of deviation (k=2) kPa
1	0				
2	5000				
3	10000				
4	15000				
5	20000				
6	25000				

Deviation = Displayed pressure – Supplied pressure

Following a common inter-comparison practice all laboratories were given letter codes. Each laboratory knows only its own code.

6 Reference Values

The calculation of reference values was based on the results from MIKES. The transfer standard was calibrated at MIKES six times [2]. The first measurement was made on April 19 before starting the circulation and the last on September 28 when all participants had carried out their measurements.

Some drift was found in the results. Assuming a linear time-dependent drift, a straight line was fitted to the results from MIKES using the method of least squares at each nominal pressure. The procedure is illustrated in Figure 1 using the results at 20000 kPa as an example. The reference values for each laboratory were calculated from these lines. The uncertainty for each reference value was calculated as the average uncertainty of MIKES results, taking into account the scatter around the fitted line.

The drift rate observed at 25000 kPa was 0,285 kPa per month which is equivalent to 3,42 kPa per year or 0,014% of the range per year.

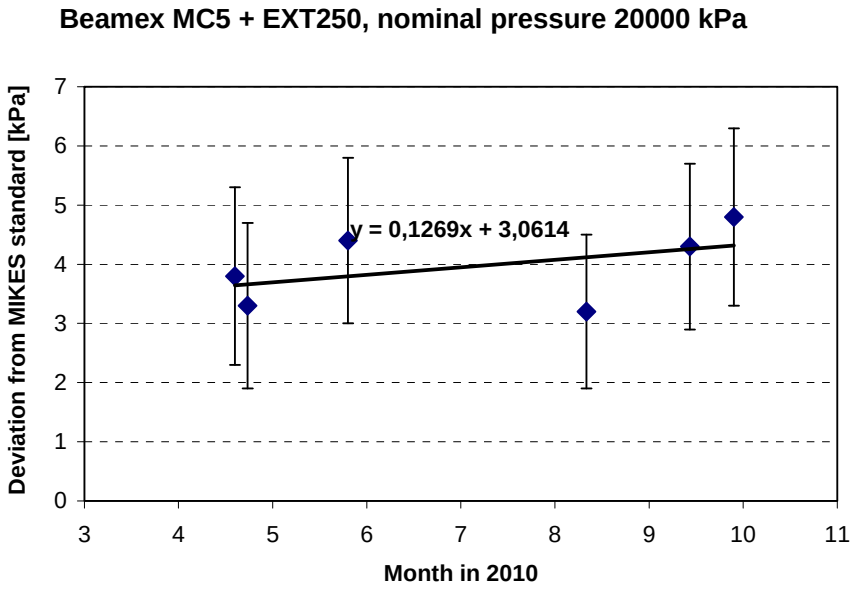

Figure 1. MIKES results at nominal pressure 20000 kPa and the fitted line.

Table 1. Calculation of reference values (t = time in months in 2010).

Nominal pressure MPa	Formula for calculating the deviation at the time of measurements	Uncertainty (k=2) kPa
5	0,079 kPa + t · 0,099 kPa/month	1,205
10	1,347 kPa + t · 0,073 kPa/month	1,251
15	2,188 kPa + t · 0,130 kPa/month	1,336
20	3,061 kPa + t · 0,127 kPa/month	1,452
25	3,284 kPa + t · 0,285 kPa/month	1,586

7 Results

A summary of the results delivered by the participating laboratories is shown in Table 2 and Figures 2 to 6. According to a common comparison practise the laboratories were given letter codes, and each laboratory knows only its own code.

Most of the laboratories sent their results within a few days of making their measurements measurements. As the results received from laboratory H (result set H1) clearly deviated from the results obtained at MIKES, the laboratory was asked to check their data. Subsequently the measurements at laboratory H were carried out again and a revised calibration certificate was delivered (result set H2).

The uncertainties estimated at each laboratory are also illustrated in Figures 2 to 6. The resolution of the transfer standard, 1 kPa, is a dominating factor in determining the minimum value for the uncertainty of the results. The resolution affects both zeroing the instrument and reading pressures.

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

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

where
$p_{transfer}$ is 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.

The E_n-values calculated for all the results are also shown in Table 2. A summary of the E_n-values are presented in Table 3.

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. In this case all E_n-values for all the results from all the laboratories are well within the limits -1 and +1, if the replaced first result set H1 is not taken into account.

Table 2. Summary of results.

Lab code	Nominal pressure MPa	Laboratory result kPa	Laboratory uncertainty kPa	Reference value kPa	Uncertainty of ref.value kPa	Deviation from ref.value kPa	E(n)
A	5	0,5	1,3	0,64	1,205	-0,14	-0,08
	10	2,1	1,8	1,76	1,251	0,34	0,16
	15	2,9	2,7	2,93	1,336	-0,03	-0,01
	20	4,1	3,3	3,78	1,452	0,32	0,09
	25	5,0	3,9	4,90	1,586	0,10	0,02
B	5	0,7	0,88	0,86	1,205	-0,16	-0,11
	10	2,2	0,94	1,92	1,251	0,28	0,18
	15	3,6	1,07	3,22	1,336	0,38	0,22
	20	4,5	1,19	4,07	1,452	0,43	0,23
	25	5,7	1,35	5,54	1,586	0,16	0,08
C	5	1,0	1,5	0,92	1,205	0,08	0,04
	10	2,1	2,4	1,97	1,251	0,13	0,05
	15	3,3	3,4	3,30	1,336	0,00	0,00
	20	4,0	4,4	4,15	1,452	-0,15	-0,03
	25	5,1	5,4	5,73	1,586	-0,63	-0,11
D	5	0,6	1,3	0,97	1,205	-0,37	-0,21
	10	1,7	1,4	2,01	1,251	-0,31	-0,17
	15	2,7	1,7	3,36	1,336	-0,66	-0,31
	20	3,7	2,2	4,21	1,452	-0,51	-0,19
	25	4,7	2,5	5,86	1,586	-1,19	-0,39
E	5	0,7	1,2	0,61	1,205	0,09	0,05
	10	1,4	1,4	1,74	1,251	-0,34	-0,18
	15	2,8	1,8	2,88	1,336	-0,08	-0,04
	20	4,1	2,0	3,74	1,452	0,36	0,15
	25	5,4	2,3	4,80	1,586	0,60	0,21
F	5	1,91	1,8	0,58	1,205	1,33	0,61
	10	2,90	2,7	1,72	1,251	1,18	0,40
	15	4,55	3,8	2,85	1,336	1,70	0,42
	20	5,08	4,9	3,71	1,452	1,37	0,27
	25	6,09	6,0	4,74	1,586	1,35	0,22
G	5	0,9	0,79	0,77	1,205	0,13	0,09
	10	2,2	1,2	1,86	1,251	0,34	0,20
	15	3,8	1,8	3,10	1,336	0,70	0,31
	20	4,1	2,1	3,95	1,452	0,15	0,06
	25	4,4	2,3	5,29	1,586	-0,89	-0,32
H1	5	6	4	0,94	1,205	5,06	***1,21***
(results	10	14	5	1,98	1,251	12,02	***2,33***
drawn	15	22	6	3,32	1,336	18,68	***3,04***
out)	20	28	7	4,17	1,452	23,83	***3,33***
	25	36	8	5,77	1,586	30,23	***3,71***
H2	5	1	4	0,95	1,205	1,55	0,37
(new	10	4	5	1,99	1,251	4,51	0,88
results)	15	6	6	3,34	1,336	3,66	0,60
	20	7	7	4,19	1,452	3,81	0,53
	25	9	8	5,81	1,586	3,69	0,45
I	5	0,7	1,2	1,03	1,205	-0,33	-0,19
	10	2,5	1,3	2,05	1,251	0,45	0,25
	15	3,4	1,4	3,45	1,336	-0,05	-0,03
	20	5,4	1,9	4,29	1,452	1,11	0,46
	25	6,3	1,7	6,04	1,586	0,26	0,11

Table 3. Summary of normalised error values E_n.

Lab. code	Nominal pressure 5 MPa	10 MPa	15 MPa	20 MPa	25 MPa	Range
A	-0,08	0,16	-0,01	0,09	0,02	-0,08 … +0,16
B	-0,11	0,18	0,22	0,23	0,08	-0,11 … +0,23
C	0,04	0,05	0,00	-0,03	-0,11	-0,11 … +0,05
D	-0,21	-0,17	-0,31	-0,19	-0,39	-0,39 … -0,17
E	0,05	-0,18	-0,04	0,15	0,21	-0,18 … +0,21
F	0,61	0,40	0,42	0,27	0,22	+0,22 … +0,61
G	0,09	0,20	0,31	0,06	-0,32	-0,32 … +0,31
H1	***1,21***	***2,33***	***3,04***	***3,33***	***3,71***	***+1,21 … +3,71***
H2	0,37	0,88	0,60	0,53	0,45	+0,37 … +0,88
I	-0,19	0,25	-0,03	0,46	0,11	-0,19 … +0,46

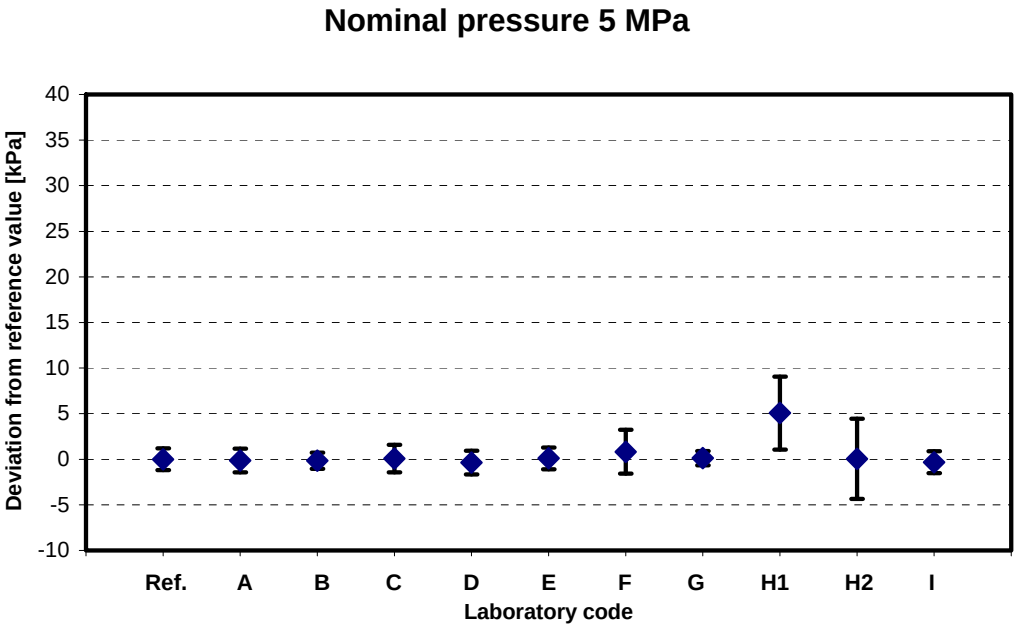

Figure 2. Results at 5 MPa.

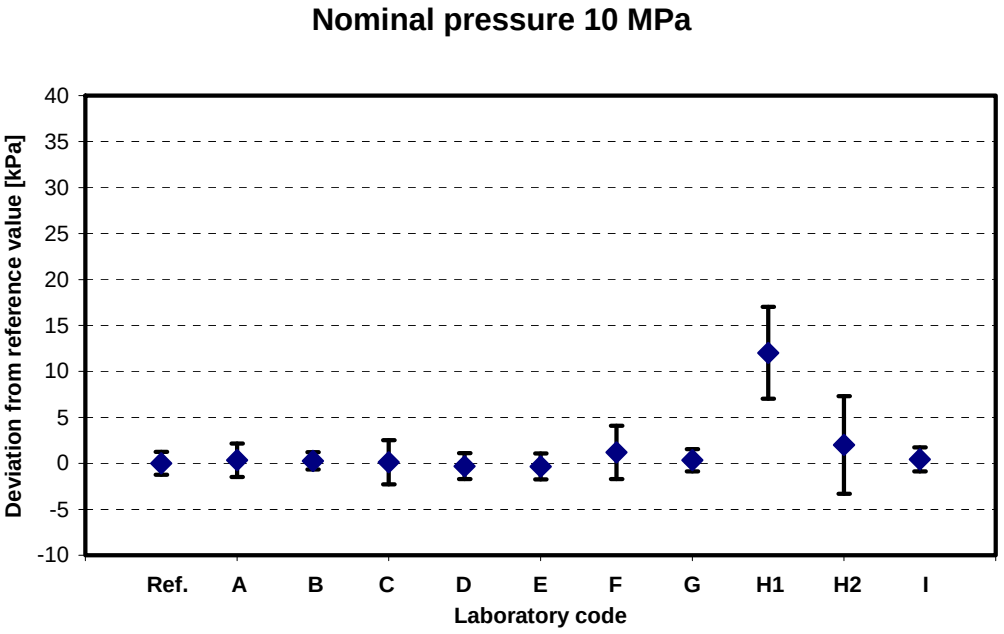

Figure 3. Results at 10 MPa.

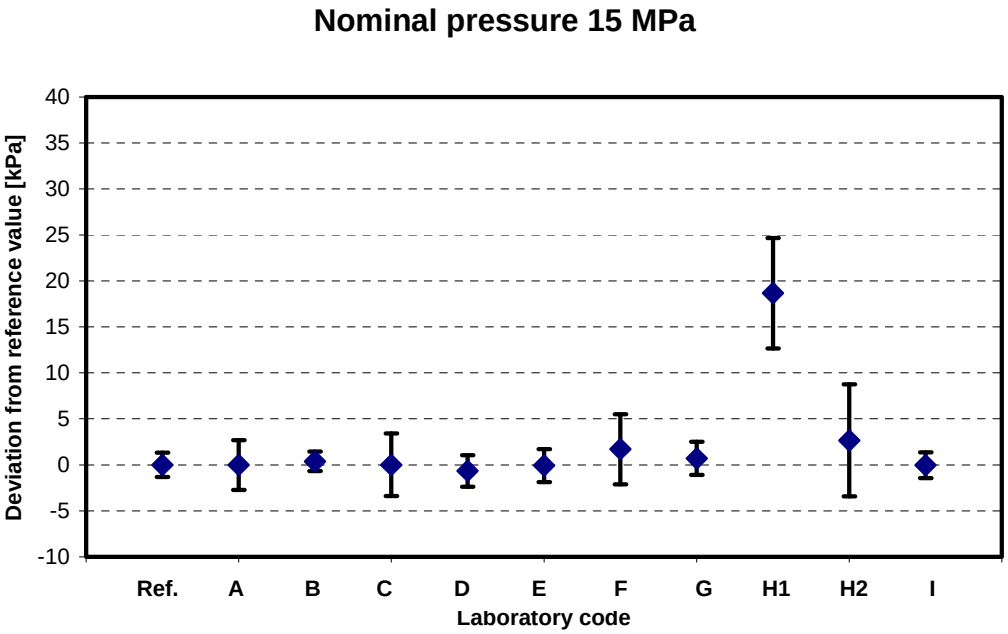

Figure 4. Results at 15 MPa.

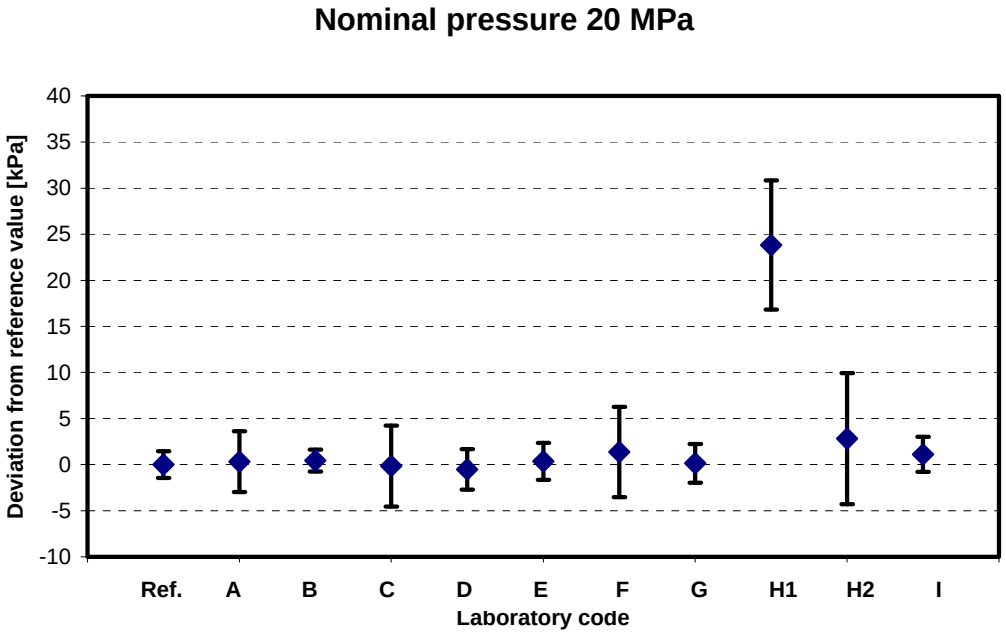

Figure 5. Results at 20 MPa.

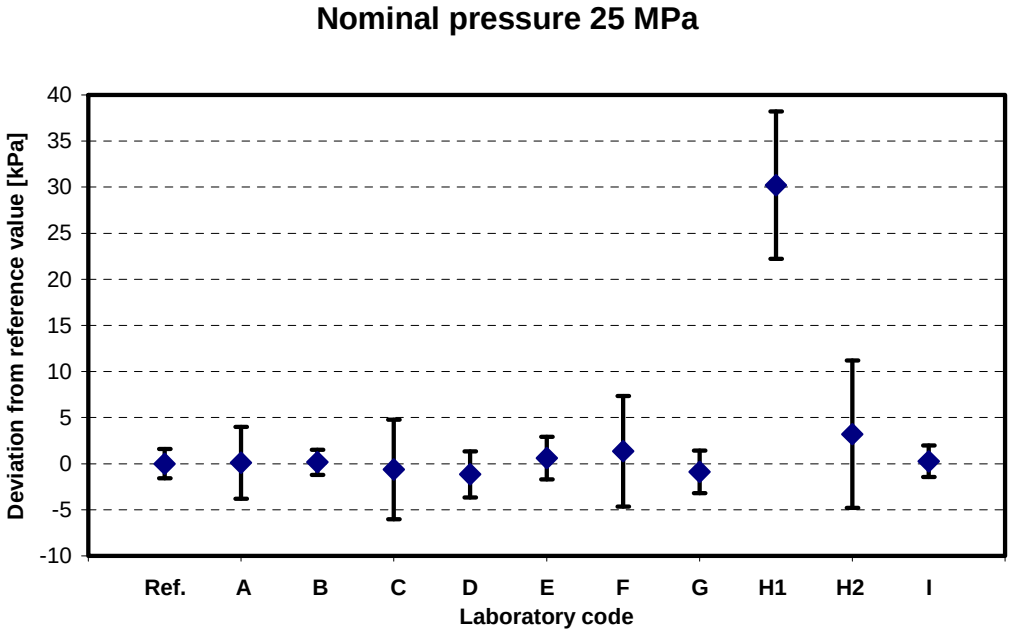

Figure 6. Results at 25 MPa.

8 Conclusions

Nine accredited pressure calibration laboratories participated in an inter-comparison in the gauge pressure range from 0 MPa to 25 MPa from may to September 2010 All results from the participating laboratories were in a good agreement with the reference values from MIKES. However, the results from one of the laboratories agreed only after corrective actions were taken.

The transfer standard, a Beamex MC5 multifunction calibrator equipped with an external transducer EXT250 , was found to be suitable for an inter-comparison at this level.

9 Acknowledgement

The authors wish to thank Mr. Pasi Kauppila of Beamex Oy Ab for providing the transfer standard.

10 References

[1] EA-4/02: Expression of the Uncertainty of Measurement in Calibration
[2] Certificates of Calibration M-10P058, M-10P059, M-10P070, M-10P080, M-10P092 and M-10P096. Centre for Metrology and Accreditation

1 Appendix 1: Measurement Instructions

Oil pressure comparison in the range 0 – 25 MPa gauge

Measurement protocol, MR 26.4.2010

1. Introduction

Centre for Metrology and Accreditation (MIKES) is arranging in 2010 an inter-laboratory comparison in the range 0 - 25 MPa primarily for accredited pressure calibration laboratories, using a digital pressure gauge as a travelling standard. The participating laboratories are expected to perform a calibration at six points using their own routine methods. However, some additional requirements should be taken into account.

2. Reference laboratory

MIKES is the national metrology institute of Finland. In this comparison MIKES is responsible for preparing the measurement instructions, determining the reference values and their uncertainties and reporting the results.

3. Transfer standard

Beamex MC5 multifunction calibrator, s/n 25516865, equipped with an external pressure transducer EXT250 s/n 40795 for the nominal range 0 MPa … 25 MPa, operating on oil. A battery charger for 100 V … 240 V input is included. The resolution of the display is 1 kPa and the estimated uncertainty of reference values is less than 2,0 kPa at all nominal pressures.

The transfer standard was made available by the manufacturer Oy Beamex Ab, Pietarsaari, Finland.

4. Transportation

For transportation the instrument is packed in an aluminium case. Hand-carrying to the next participant is not necessary. A courier service or post can be used for transportation.

Please unpack the case immediately after the delivery and inform both coordinators at MIKES about the arrival and the condition of the instrument by E-mail markku.rantanen@mikes.fi and sari.saxholm@mikes.fi. The coordinators will then give the name and address of the next participant.

Each participant is responsible for the costs of sending the instrument to the next laboratory.

5. Measurements

Preparation of the transfer standard

Plug in the battery charger and the external transducer. Switch the instrument on by pressing the red key. Press ***Continue.*** The pressure reading from the transducer is now shown in Window 2. Selecting ***MENU*** and ***Window 2*** allows you to reselect ***kPa*** and ***Pressure type (gauge)*** if other unit and type are in use. The resolution of the display is 1 kPa when kPa is selected. Close the ***MENU***.

Wait for at least 3 hours or preferably overnight before starting the measurement.

Measurements

1. Connect the external transducer to your laboratory standard. Place the transducer in a horizontal position, the serial number up.
2. Select ***MENU*** and ***Window 2*** Press ***Zero Pressure Module***. Close the ***MENU***.
3. Pre-pressurise two or three times to 25000 kPa.
4. Wait for 3 to 5 minutes and zero the pressure module again at atmospheric pressure.
5. Calibrate the instrument using the routine method of your laboratory at nominal pressure 0 kPa, 5000 kPa 10000 kPa, 15000 kPa, 20000 kPa and 25000 kPa.

Do not make any other adjustments on the device before or after your measurements.

6. Reporting by the participants

The results must be reported to the coordinators at MIKES within two weeks of completing the measurements. At a minimum, the participants report must include the following components:

- a hard copy of a calibration certificate
- a summary of the results in the following table:

	Nominal pressure kPa	Pressure supplied to travelling standard kPa	Calibration point	Deviation kPa	Uncertainty of deviation (k=2) kPa
1	0				
2	5000				
3	10000				
4	15000				
5	20000				
6	25000				

Deviation = Displayed pressure – Supplied pressure

7. Comparison schedule

Eight laboratories have joined in the comparison, four in Finland and four in other countries. Each laboratory should send the transfer standard again to the next participant within one week after receiving it. One day is certainly enough for the actual measurement and reporting. The comparison schedule will be decided later.

8. Confidentiality

The results of the inter-comparison are treated confidentially using letter codes. Each laboratory will get only its own code. At MIKES, only the two coordinators will know all the codes. Each participating laboratory can decide if its results or name are included in the draft or final reports.

9. Participation fee

The participation fee is 600 EUR (+ VAT) per participating laboratory. Further, each participating laboratory is responsible for the costs of sending the instrument to the next participant. The name and address of the next participant will be informed by the coordinators of the comparison.

10. Coordinators

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ISBN 978-952-5610-65-9
ISSN 1235-2704

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