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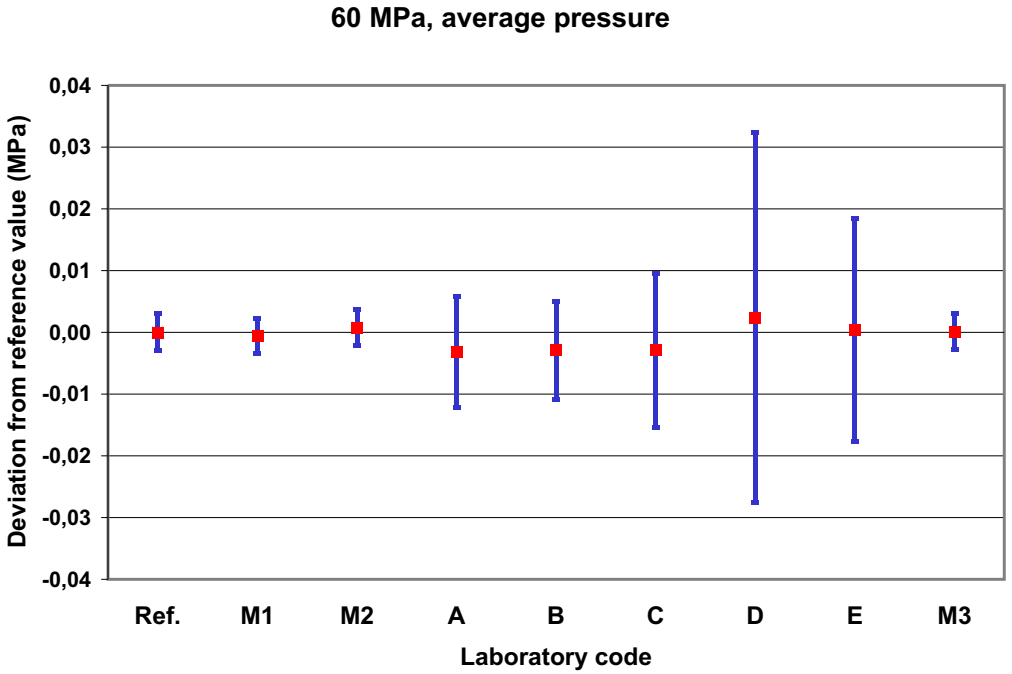
J3/2003



Intercomparison in gauge pressure range 0 ... 60 MPa

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Helsinki 2003

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ABSTRACT

An intercomparison P14 in the gauge pressure range 0 … 60 MPa was arranged in 2003 by the Centre for Metrology and Accreditation (MIKES). Five pressure calibration laboratories participated in the comparison, four laboratories from Finland and one from Sweden).

The transfer standard was a Beamex MC5 pressure calibrator equipped with an external 60 MPa sensor. The participants were advised to use their routine methods and existing procedures in calibrating the transfer standard. So it was possible to compare not only pressure results but also the measurement methods and the contents of the calibration certificates.

All the pressure results were in a good agreement with the results of MIKES.

TIIVISTELMÄ

Mittatekniikan keskus (MIKES) järjesti vuonna 2003 vertailumittauksen P14 ylipainealueella 0 … 60 MPa. Vertailumittaukseen osallistui neljä kalibrointilaboratorioa Suomesta ja yksi Ruotsista.

Kiertävä vertailulaite oli Beamex MC5 painekalibraattori varustettuna ulkoisella anturilla. Mittausohjeissa kehotettiin osanottajia tekemään mittaukset omien rutiinimenettelyjensä mukaisesti. Näin voitiin varsinaisten paineen mittaustulosten lisäksi vertailla mittausmenetelmiä ja kalibrointitodistusten sisältöä.

Kaikki paineen mittaustulokset olivat mittausepävarmuuksien puitteissa samoja kuin MIKESin tulokset.

CONTENTS

INTERCOMPARISON IN GAUGE PRESSURE RANGE 0 … 60 MPa

1 INTRODUCTION

An intercomparison P14 was arranged in 2003 by the Centre for Metrology and Accreditation (MIKES) in the gauge pressure range 0 … 60 MPa.

The aim of the comparison was to compare not only the results of pressure measurements but also the methods in making the measurements and the expression of the results and uncertainties in a routine calibration job. The transfer standard used in the comparison was an instrument familiar to all of the participants. No detailed instructions were given to the laboratories but they were advised to use their routine methods.

Four accredited pressure calibration laboratories from Finland and one from Sweden participated in the comparison.

2 TRANSFER STANDARD

The transfer standard was a Beamex MC5 pressure calibrator s/n 24512824 equipped with an external sensor Beamex EXT 600 s/n 20854, made available by Oy Beamex Ab. According to the manufacturer, the sensor is intended to be used in the horisontal position. Any non-corrosive gas or liquid can be used. For the instrument as a standard product the maximum error is defined as 0,04% of reading + 0,015% of full scale.

Before the circulation, the Beamex laboratory adjusted a small pressure dependent error in the transfer standard. However, the output was within the specifications.

3 REFERENCE LABORATORY

For the oil pressure range 0,5 MPa … 500 MPa the reference standard of MIKES is a Desgranges & Huot 5306 pressure balance. This pressure range is covered by four piston-cylinder units. The effective areas are traceable to Laboratoire National d'Essais (BNM-LNE), Paris. The masses of the ring weights were determined by the mass laboratory of MIKES.

4 PARTICIPANTS

The following laboratories participated in the comparison:

Finnair Oy Test Equipment Calibration, Vantaa
Finnish Air Force, Air Materiel Command, Calibration Laboratory, Tampere
Inspecta Oy Measuring Technology, Helsinki
Oy Beamex Ab, Calibration Laboratory, Pietarsaari
SAAB AB, Linköping, Sweden

5 CALCULATION OF THE REFERENCE VALUES

The transfer standard was calibrated three times at the reference laboratory MIKES. The first calibration was made at beginning of May and the last at the end of June in 2003.

Figure1 1 shows all the result points of MIKES calibrations. The stability of the transfer standard was very good, and drift during the circulation was negligible.

The reference values were calculated as the averages of the MIKES results for each nominal pressure in two ways. The first way was to calculate the reference values separately for increasing and decreasing pressures, and the second to calculate only one reference value for each nominal pressure. In the latter case the uncertainties are higher due to the hysteresis effects.

The major uncertainty components taken into account were

- uncertainty in setting the zero of the transfer standard
- resolution of the transfer standard
- scatter of the results
- hysteresis (not for the separate values for increasing and decreasing pressures)
- uncertainty of the measurement standard.

According to the manufacturer the effects of calibration temperature can be neglected in a typical laboratory environment.

6 MEASUREMENT INSTRUCTIONS

The measurement instructions were short and straightforward: The participants were asked to calibrate the transfer standard using their own procedures. However, the participants were advised to select MPa for the pressure unit, and the use of the nominal pressures 5 MPa, 10 MPa, 20 MPa, 30 MPa, 40 MPa, 50 MPa and 60 MPa was recommended.

Finally, the participants were asked to send their results as calibration certificates to MIKES within two weeks after the measurements.

7 RESULTS

All the laboratories presented their results as calibration certificates, and indicated that the uncertainty of calibration was estimated using the document EA-4/02 and a coverage factor k = 2.

Following the EA intercomparison practice all laboratories were given letter codes. Each laboratory knows only its own code.

A summary of all the result is shown in Appendix 1. The figures 2 to 6 show results at nominal pressures 5 MPa up, 5 MPa down, 30 MPa up, 30 MPa average and 60 MPa.

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 E_n-values of all the results are shown in Appendix 1.

A summary of the E_n-values is in the following:

Laboratory	range of E_n-values
A	-0,34 … 0,80
B	-0,77 …-0,16
C	-0,27 … 0,21
D	-0,01 … 0,43
E	0,02 … 0,53

The result in an interlaboratory 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 the E_n-values for all the results from all the laboratories are between -1 and +1.

The absolute E_n-values above 0,5 seem to be more frequent at lower nominal pressures. The reason may be the underestimation or neglecting the uncertainty in setting the transfer standard zero.

8
MEASUREMENT PROCEDURES AND CONTENTS OF CERTIFICATES

As the measurement procedure was not specified, there was variation in the methods used by the participants. A comparison of the calibration methods and the certificate contents is shown in Table 1.

The question marks in the Table 1 mean that the information is not directly shown in the certificate. References to internal laboratory procedures may contain more information but it does not immediately help the reader.

Generally speaking the certificates of all the participating laboratories were in accordance with the requirements of ISO/IEC 17025. However, a remark can be made on the ISO/IEC 17025 point 5.10.4.1 a. This point states that calibration certificates should include *the conditions under which the calibrations were made that have influence on the measurement results.* The position of the pressure sensor, and the procedures applied in pre-pressurising and in setting the zero are potential influence factors in pressure calibrations. Including this information in the certificate is highly recommended.

9
CONCLUSIONS

Five pressure calibration laboratories participated in an intercomparison in the gauge pressure range 0 to 60 MPa between April and June 2003.

All the results from all the participating laboratories were in a good agreement with the reference values from MIKES. However, there was some variation in the measurement methods and in the contents of the calibration certificates.

The transfer standard, a Beamex MC5 calibrator with an external pressure sensor EXT600, was found to be very stable and its resolution was good enough for an intercomparison at this level.

10
REFERENCES

EA-4/02: Expression of the Uncertainty of Measurement in Calibration

ISO/IEC 17025: General requirements for the testing and calibration laboratories.

Certificates of Calibration M-03P060, M-03P069 and M-03P084. Centre for Metrology and Accreditation

MR 25.9.2003

Fig. 1. Beamex EXT 600 stability

Calibrations at MIKES (all results)
Deviations from the straight line fitted to M1 results.

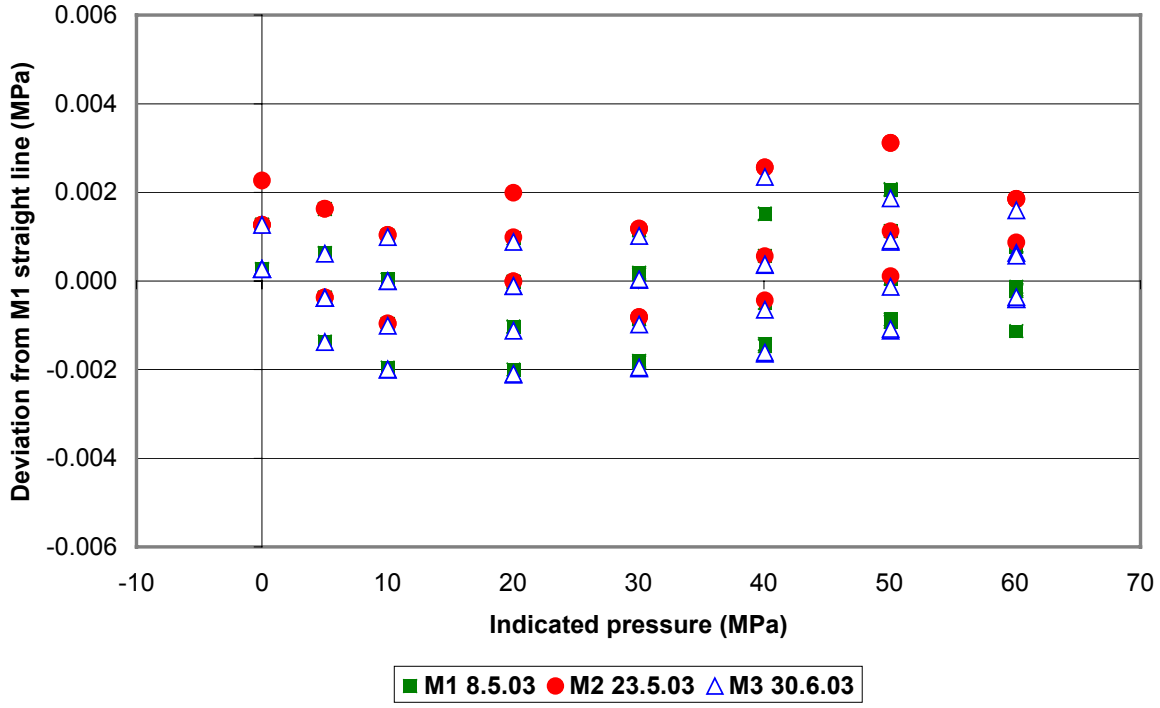

Fig. 2. 5 MPa, increasing pressure

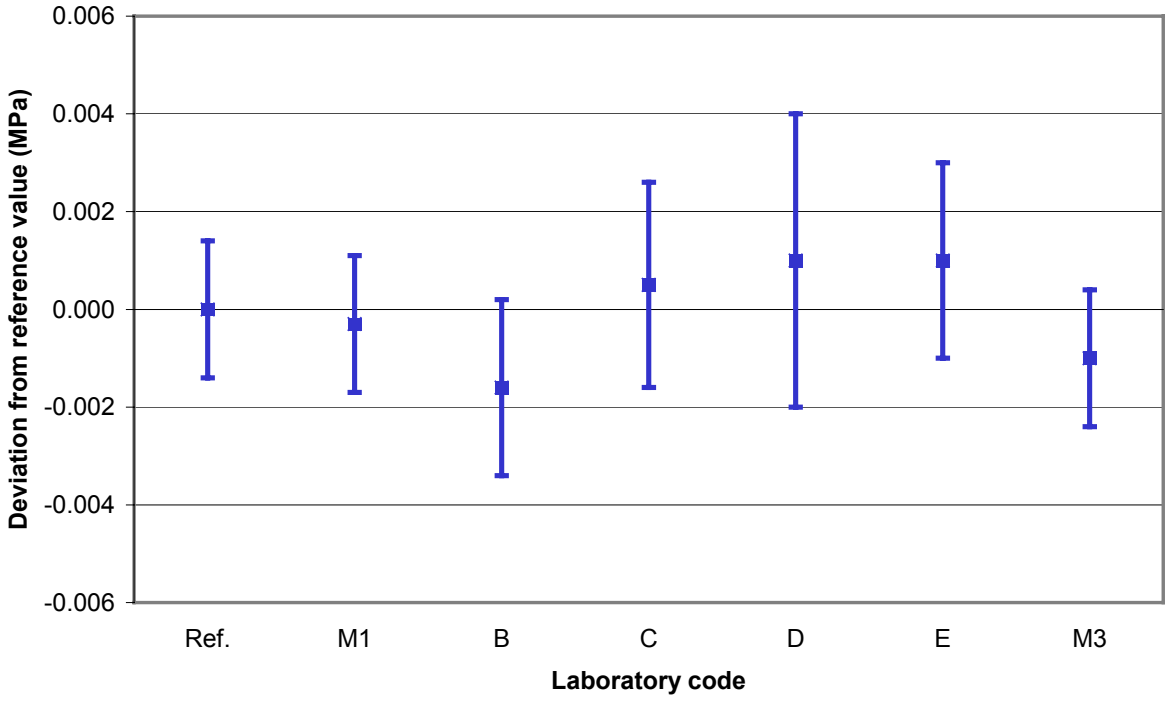

Fig. 3. 5 MPa, decreasing pressure

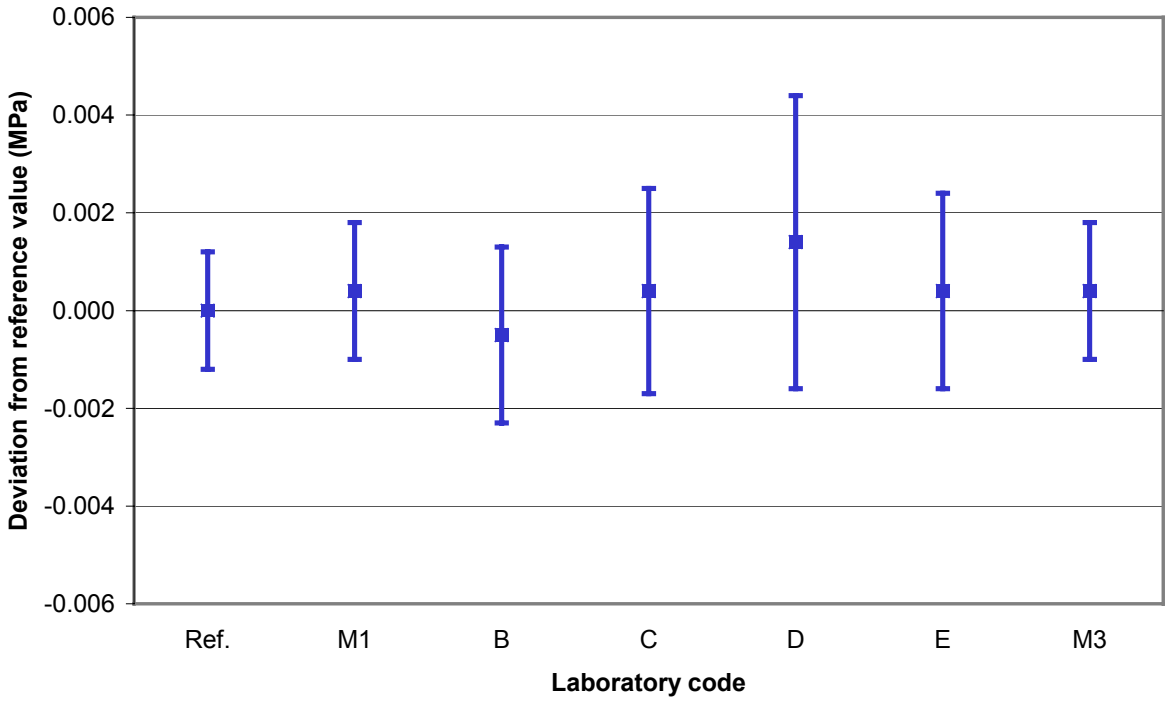

Fig. 4. 30 MPa, increasing pressure

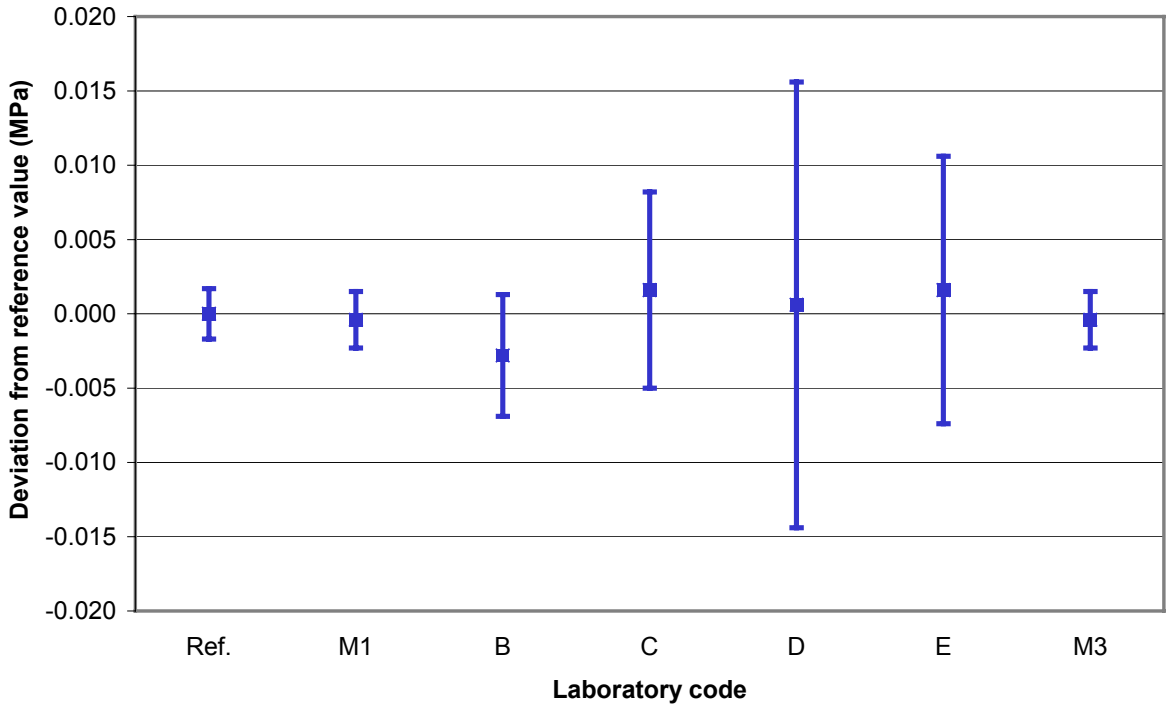

Fig. 5. 30 MPa, average pressure

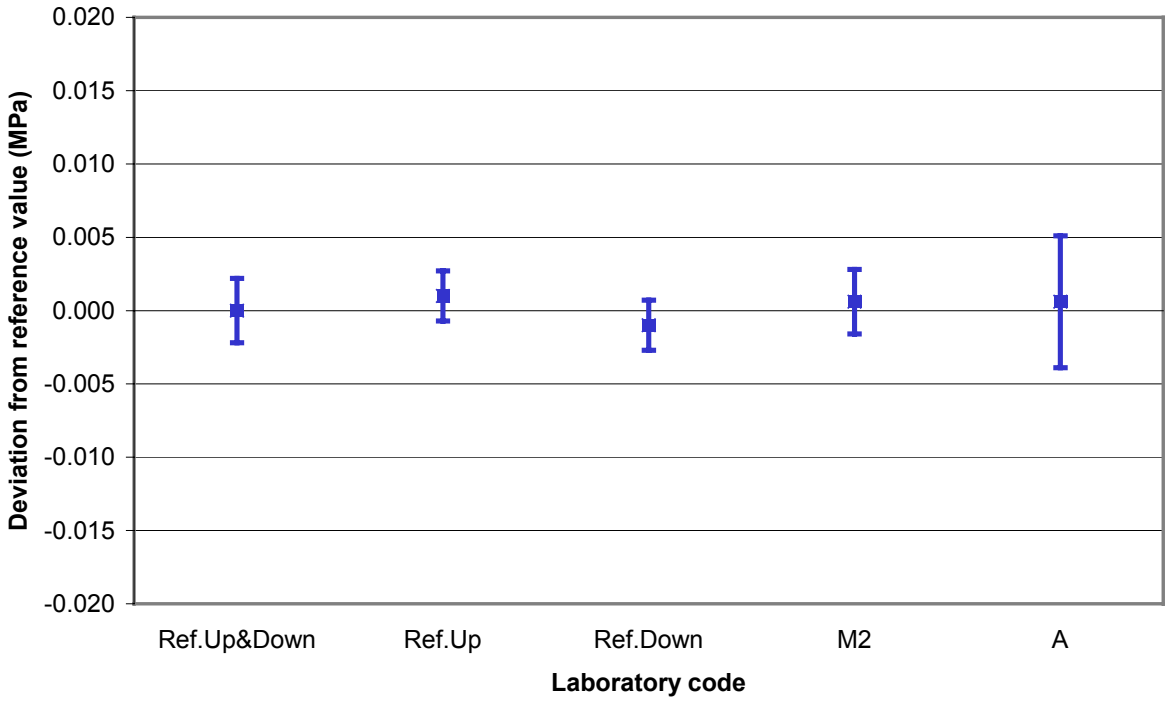

Fig. 6. 60 MPa, average pressure

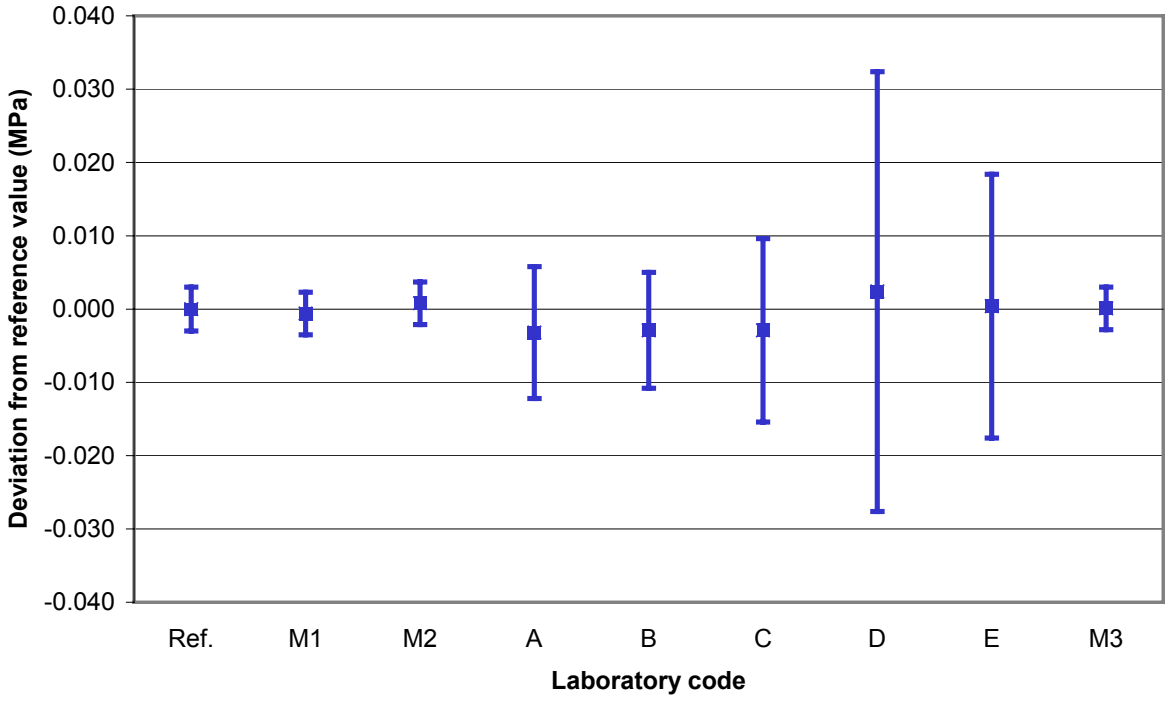

Table 1. Comparison of calibration methods and certificate contents

Laboratory code	A	B	C	D	E	M2	M3
Ambient temperature	21+/-0.5	23+/-1	23+/-2	23+/-2	21.5	22.4+/-1	23+/-1
Sensor positition	Vertical, connection down	?	?	?	Vertical, connection up	Horizontal	Horizontal
Pressure medium	Oil	Oil	Distilled water	Oil	Oil	Oil	Oil
Pre-pressures	?	60 MPa twice	60 MPa 3 times	?	60 MPa once	60 MPa twice	60 MPa twice
Zero setting	Before each cycle	?	?	?	After pre-pressures	After pre-pressures	After pre-pressures
Unit of pressure	MPa	MPa	MPa	MPa	MPa	MPa	MPa
N:o of nominal pressures up	11	8	8	8	8	8	8
down	10	7	7	7	7	7	7
N:o of measurements at each level							
up	3	3	2	4	1	2	3
down	3	3	2	4	1	2	3
Total n:o of measurements	63	45	30	60	15	30	45
Result as error or correction	error	error	error	averages of ref. and obj.readings	error	error	error
Results up/down	average	yes	yes	yes	yes	average	yes
Results as graph	no	no	yes	no	no	yes	yes
Uncertainty components named	yes	yes	yes	no	yes	yes	yes
Values for components	no	no	yes	no	no	no	no
Uncertainty at 60 MPa (k=2), MPa	0.009	0.0079	0.0125	0.03	0.018	0.003	0.003
parts per million	150	132	208	500	300	50	50

APPENDIX 1.
Summary of results in pressure intercomparison P14

Page 1(3)

Lab code	A					
Nominal pressure MPa	Result MPa	Uncert. MPa	Ref. value MPa	Ref. uncertainty MPa	Deviation from ref. MPa	E(n)
5	0.003	0.0014	0.0013	0.0016	0.0017	0.80
10	0.005	0.0017	0.0033	0.0017	0.0017	0.71
20	0.010	0.0030	0.0084	0.0019	0.0016	0.45
30	0.014	0.0045	0.0134	0.0022	0.0006	0.12
40	0.018	0.0060	0.0190	0.0026	-0.0010	-0.15
50	0.022	0.0075	0.0245	0.0029	-0.0025	-0.31
60	0.026	0.0090	0.0292	0.0030	-0.0032	-0.34

Lab code	B					
Nominal pressure MPa	Result MPa	Uncert. MPa	Ref. value MPa	Ref. uncertainty MPa	Deviation from ref. MPa	E(n)
5 up	0.0004	0.0018	0.002	0.0012	-0.0016	-0.74
10 up	0.0026	0.0022	0.0043	0.0012	-0.0017	-0.68
20 up	0.0068	0.0029	0.0093	0.0015	-0.0025	-0.77
30 up	0.0116	0.0041	0.0144	0.0017	-0.0028	-0.63
40 up	0.0170	0.0054	0.0202	0.0021	-0.0032	-0.55
50 up	0.0222	0.0067	0.0256	0.0025	-0.0034	-0.48
60 up	0.0267	0.0079	0.0296	0.0028	-0.0029	-0.35
50 down	0.0215	0.0067	0.0234	0.0025	-0.0019	-0.27
40 down	0.0164	0.0054	0.0178	0.0021	-0.0014	-0.24
30 down	0.0107	0.0041	0.0124	0.0017	-0.0017	-0.38
20 down	0.0061	0.0029	0.0076	0.0015	-0.0015	-0.46
10 down	0.0020	0.0022	0.0024	0.0012	-0.0004	-0.16
5 down	0.0001	0.0018	0.0006	0.0012	-0.0005	-0.23

Lab code	C					
Nominal pressure MPa	Result MPa	Uncert. MPa	Ref. value MPa	Ref. uncertainty MPa	Deviation from ref. MPa	E(n)
5 up	0.0025	0.0021	0.002	0.0012	0.0005	0.21
10 up	0.0042	0.0028	0.0043	0.0012	-0.0001	-0.03
20 up	0.0093	0.0046	0.0093	0.0015	0.0000	0.00
30 up	0.0128	0.0066	0.0144	0.0017	-0.0016	-0.23
40 up	0.0188	0.0085	0.0202	0.0021	-0.0014	-0.16
50 up	0.0227	0.0105	0.0256	0.0025	-0.0029	-0.27
60 up	0.0267	0.0125	0.0296	0.0028	-0.0029	-0.23
50 down	0.0217	0.0105	0.0234	0.0025	-0.0017	-0.16
40 down	0.0168	0.0085	0.0178	0.0021	-0.0010	-0.11
30 down	0.0109	0.0066	0.0124	0.0017	-0.0015	-0.22
20 down	0.0063	0.0046	0.0076	0.0015	-0.0013	-0.27
10 down	0.0017	0.0028	0.0024	0.0012	-0.0007	-0.23
5 down	0.0010	0.0021	0.0006	0.0012	0.0004	0.17

APPENDIX 1. continued:
Summary of results in pressure intercomparison P14

Page 2(3)

Lab code	D					
Nominal pressure MPa	Result MPa	Uncert. MPa	Ref. value MPa	Ref. uncertainty MPa	Deviation from ref. MPa	E(n)
5 up	0.003	0.003	0.0020	0.0012	0.001	0.31
10 up	0.005	0.005	0.0043	0.0012	0.0007	0.14
20 up	0.010	0.010	0.0093	0.0015	0.0007	0.07
30 up	0.015	0.015	0.0144	0.0017	0.0006	0.04
40 up	0.020	0.020	0.0202	0.0021	-0.0002	-0.01
50 up	0.026	0.025	0.0256	0.0025	0.0004	0.02
60 up	0.032	0.030	0.0296	0.0028	0.0024	0.08
50 down	0.024	0.025	0.0234	0.0025	0.0006	0.02
40 down	0.018	0.020	0.0178	0.0021	0.0002	0.01
30 down	0.013	0.050	0.0124	0.0017	0.0006	0.01
20 down	0.008	0.010	0.0076	0.0015	0.0004	0.04
10 down	0.003	0.005	0.0024	0.0012	0.0006	0.12
5 down	0.002	0.003	0.0006	0.0012	0.0014	0.43

Lab code	E					
Nominal pressure MPa	Result MPa	Uncert. MPa	Ref. value MPa	Ref. uncertainty MPa	Deviation from ref. MPa	E(n)
5 up	0.003	0.002	0.0020	0.0012	0.0010	0.43
10 up	0.006	0.003	0.0043	0.0012	0.0017	0.53
20 up	0.011	0.006	0.0093	0.0015	0.0017	0.27
30 up	0.016	0.009	0.0144	0.0017	0.0016	0.17
40 up	0.021	0.012	0.0202	0.0021	0.0008	0.07
50 up	0.026	0.015	0.0256	0.0025	0.0004	0.03
60 up	0.030	0.018	0.0296	0.0028	0.0004	0.02
50 down	0.024	0.015	0.0234	0.0025	0.0006	0.04
40 down	0.019	0.012	0.0178	0.0021	0.0012	0.10
30 down	0.014	0.009	0.0124	0.0017	0.0016	0.17
20 down	0.008	0.006	0.0076	0.0015	0.0004	0.06
10 down	0.003	0.003	0.0024	0.0012	0.0006	0.19
5 down	0.001	0.002	0.0006	0.0012	0.0004	0.17

APPENDIX 1. continued:
Summary of results in pressure intercomparison P14

Page 3(3)

Lab code	MIKES 1					
Nominal pressure MPa	Result MPa	Uncert. MPa	Ref. value MPa	Ref. uncertainty MPa	Deviation from ref. MPa	E(n)
5 up	0.002	0.0014	0.002	0.0012	0.0000	0.00
10 up	0.004	0.0014	0.0043	0.0012	-0.0003	-0.16
20 up	0.009	0.0016	0.0093	0.0015	-0.0003	-0.14
30 up	0.014	0.0019	0.0144	0.0017	-0.0004	-0.16
40 up	0.020	0.0022	0.0202	0.0021	-0.0002	-0.07
50 up	0.025	0.0025	0.0256	0.0025	-0.0006	-0.17
60 up	0.029	0.0029	0.0296	0.0028	-0.0006	-0.15
60 down	0.028	0.0029	0.0289	0.0029	-0.0009	-0.22
50 down	0.023	0.0025	0.0234	0.0025	-0.0004	-0.11
40 down	0.018	0.0022	0.0178	0.0021	0.0002	0.07
30 down	0.012	0.0018	0.0124	0.0017	-0.0004	-0.16
20 down	0.007	0.0016	0.0076	0.0015	-0.0006	-0.27
10 down	0.002	0.0014	0.0024	0.0012	-0.0004	-0.22
5 down	0.001	0.0014	0.0006	0.0012	0.0004	0.22

Lab code	MIKES 2					
Nominal pressure MPa	Result MPa	Uncert. MPa	Ref. value MPa	Ref. uncertainty MPa	Deviation from ref. MPa	E(n)
5	0.002	0.0018	0.0013	0.0016	0.0007	0.29
10	0.004	0.0018	0.0033	0.0017	0.0007	0.28
20	0.009	0.0018	0.0084	0.0019	0.0006	0.23
30	0.014	0.0022	0.0134	0.0022	0.0006	0.19
40	0.020	0.0027	0.0190	0.0026	0.0010	0.27
50	0.026	0.0030	0.0245	0.0029	0.0015	0.36
60	0.030	0.0029	0.0292	0.0030	0.0008	0.19

Lab code	MIKES 3					
Nominal pressure MPa	Result MPa	Uncert. MPa	Ref. value MPa	Ref. uncertainty MPa	Deviation from ref. MPa	E(n)
5 up	0.001	0.0014	0.002	0.0012	-0.001	-0.54
10 up	0.004	0.0014	0.0043	0.0012	-0.0003	-0.16
20 up	0.009	0.0016	0.0093	0.0015	-0.0003	-0.14
30 up	0.014	0.0019	0.0144	0.0017	-0.0004	-0.16
40 up	0.020	0.0025	0.0202	0.0021	-0.0002	-0.06
50 up	0.025	0.0025	0.0256	0.0025	-0.0006	-0.17
60 up	0.030	0.0031	0.0296	0.0028	0.0004	0.10
60 down	0.029	0.0029	0.0289	0.0029	0.0001	0.02
50 down	0.023	0.0025	0.0234	0.0025	-0.0004	-0.11
40 down	0.018	0.0022	0.0178	0.0021	0.0002	0.07
30 down	0.012	0.0019	0.0124	0.0017	-0.0004	-0.16
20 down	0.007	0.0016	0.0076	0.0015	-0.0006	-0.27
10 down	0.002	0.0014	0.0024	0.0012	-0.0004	-0.22
5 down	0.001	0.0014	0.0006	0.0012	0.0004	0.22

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