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REPORT

A comparison of low differential pressure standards in the range 3 Pa to 1000 Pa

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NPL National Physical Laboratory

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ABSTRACT

This report summarises the calibrations carried out by eleven laboratories during the period October 1993 to October 1995 in a comparison of low differential pressures under contract to the Programme for Applied Metrology and Chemical Analysis (BCR)[1]. The differential pressure range was 3 Pa to 1000 Pa superimposed upon a line pressure of nominally 100 kPa. The transfer standard used was a Furness Controls FRS4.

[1] Now DGXII Unit C5: Standards, Measurement and Testing Programme

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1 INTRODUCTION

The measurement of low differential pressures frequently forms an essential part of the measurement of the flow of gases, particularly air. Examples of applications are in heating and ventilating engineering, aircraft instrumentation, aerodynamic research and the leak testing of enclosures for protecting delicate equipment or containing hazardous materials. Many thousands of instruments for measuring low differential pressures are calibrated each year within the European Community. The main objective of this comparison exercise was the harmonisation of European primary and reference standards for the measurement of low differential pressures.

The comparison was carried out in two phases, with a check being made on the transfer standard between each phase by the pilot laboratory, NPL.

The laboratories which took part are listed below in order of participation together with the nature of their differential pressure measurement standards.

Phase 1	Standard
National Physical Laboratory (NPL), UK	Oil manometer
Furness Controls Ltd, UK	FRS4
Physikalisch-Technische Bundesanstalt (PTB), Germany	Diving bell manometer
Technical University of Delft (TUD), Netherlands	Inclined pressure balance
Chell Instruments, UK	Capacitance manometer
National Engineering Laboratory (NEL), UK	Capacitance manometer
National Physical Laboratory (NPL), UK	Oil manometer

Phase 2	Standard
Aeronautical Research Institute (FFA), Sweden	Capacitance manometer
Centre for Metrology and Accreditation (CMA), Finland	Capacitance manometer and pressure balance
Danish Technological Institute (DTI), Denmark	Micromanometer
Laboratoire National d'Essais (LNE), France	Capacitance manometers
C.N.R.-Istituto di Metrologia "G. Colonnetti" (IMGC), Italy	Mercury manometer
National Physical Laboratory (NPL), UK	Oil manometer

2 THE TRANSFER STANDARD

2.1 DESCRIPTION

The transfer standard used in the comparison was a Furness Controls FRS4, consisting of a piston-cylinder assembly mounted above an electronic balance with digital readout. It is shown schematically in Figure 1 (excluding the piston suspension) and in a photograph in Figure 2. To generate differential pressures, gas from a pressure supply unit flows through an orifice near the top of the wall of the cylinder into the gap between the piston and the cylinder. Initially, part of the gas flows upwards into a chamber with a pressure port above the piston; the remainder flows downwards to the bottom of the piston and then escapes through a low impedance path to atmosphere. The pressure in the chamber above the piston builds up until the entry of further gas is opposed and all the gas then flows downwards. The pressure difference established between the ends of the piston forces it downwards; this force is opposed and measured by the electronic balance.

The span of the electronic balance is set by suspending a known mass below it. For the purposes of this comparison the mass chosen was approximately equal to that appropriate to standard gravity, that is 9.80665 ms^{-2}. Thus all FRS4 indications had to be multiplied by the ratio of standard gravity to local gravity.

The temperature of the FRS4 was measured by an internally mounted PT100 platinum resistance thermometer (PRT).

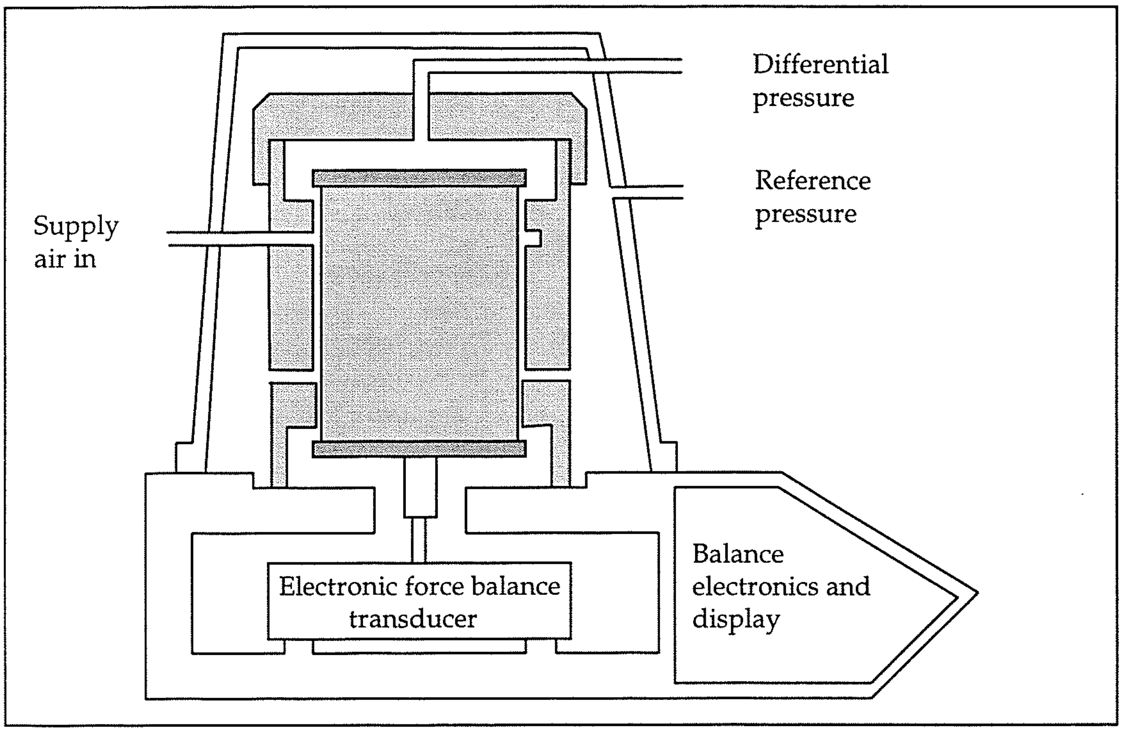

Figure 1 Schematic diagram of Furness Controls FRS4

2.2 ACCEPTANCE TESTING

Prior to the comparison, the FRS4 was calibrated at the NPL at pressures of 10 Pa, 100 Pa, 300 Pa and 1000 Pa in the same manner as was to be used in the comparison. It was then prepared for transportation and taken by car for approximately 100 km before being recalibrated.

The results of these calibrations gave an overall standard deviation for the corrections of less than 0.025 Pa at each pressure, showing a repeatability well within the required value of ± (0.1 Pa + 0.01% of reading). The FRS4 was therefore accepted for use as the transfer standard.

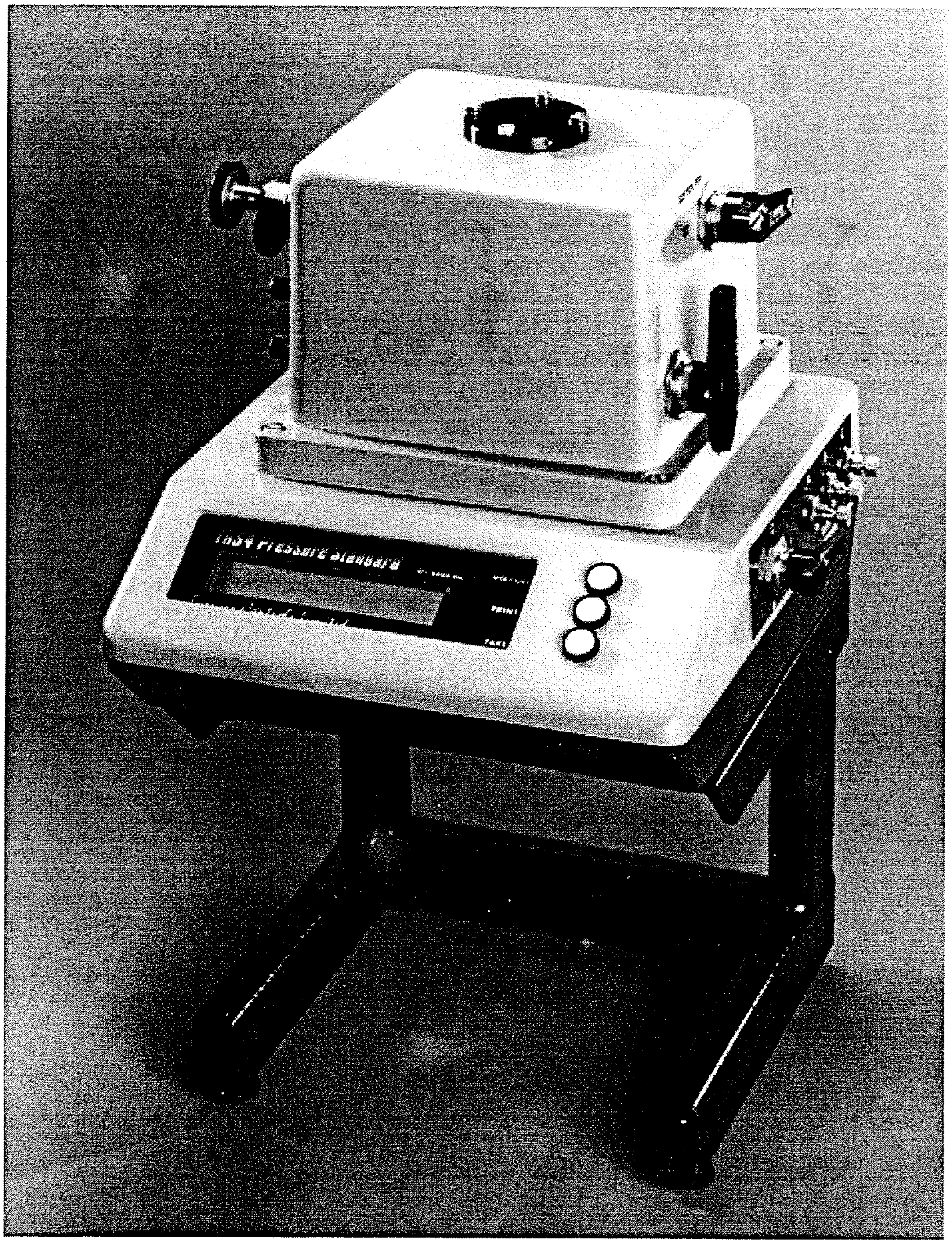

Figure 2 Furness Controls FRS4

3 DESCRIPTION OF PARTICIPANTS' MEASUREMENT STANDARDS

3.1 NATIONAL PHYSICAL LABORATORY

The NPL standard is an oil-manometer consisting of two glass tubes, 100 mm in diameter, clamped between a stainless steel base plate and circular lids. A hole through the base plate connects the tubes together. The oil surfaces are sensed interferometrically using cat's-eye optics, with servo-focused lenses mounted outside the pressure system. The measurement beams pass through gas of differing refractive index and iterative corrections to optical path length are calculated. The main assembly is mounted in a temperature controlled water bath. The differential pressure, P, is given by

$$P = \rho . g . h$$

where ρ = oil density
g = local acceleration due to gravity
h = height difference

3.2 FURNESS CONTROLS LTD

The standard employed by Furness Controls is an FRS4, similar to that used as the transfer standard in the comparison and described in section 2.

3.3 PHYSIKALISCH-TECHNISCHE BUNDESANSTALT

The PTB standard is a bell manometer in which a bell-jar is suspended within a vessel containing liquid nonan (C_9H_{20}). As the pressure within the bell is altered, a corresponding vertical force is created. The bell-jar is supported by a mass-balance and the force due to the applied pressure is equalised by the application of compensation masses. The force, F, is then given by

$$F = g . m . (1 - \frac{\rho_{air}}{\rho_m})$$

where g = local acceleration due to gravity
m = compensation mass
ρ_{air} = density of air
ρ_m = density of mass m

The pressure, P, is then given by

$$P = \frac{F}{A}$$

where A = effective area of the bell-jar

3.4 TECHNICAL UNIVERSITY OF DELFT

The TUD standard is an inclined pressure balance. It consists of a rotating cylinder within which there is an air-lubricated piston. In order to eliminate piston rotation and oscillation the hollow piston is loaded with a small internal mass. Inclining the cylinder creates an axial component of gravitational force. Gauge blocks are used to make initial settings, final adjustment being achieved by means of a micrometer screw gauge.

The axial component of gravimetric force, F, is given by

$$F = m.\sin\alpha.g$$

where m = mass of the piston
α = angle between piston-cylinder and horizontal
g = local acceleration due to gravity

The force F is in equilibrium with the forces due to the applied differential pressure P beneath the piston, and so

$$P = \frac{F}{A}$$

where A = effective area of the piston-cylinder

3.5 DANISH TECHNOLOGICAL INSTITUTE

The DTI standard is a Combustion Instruments U-tube micromanometer of the Prandl type. A movable reservoir attached to a digital height gauge forms one side of the manometer, with an inclined tube forming the other. The fluid within the manometer is DC200 silicone oil. The differential pressure, P, is given by

$$P = \rho.g.h$$

where ρ = oil density
g = local acceleration due to gravity
h = height difference

3.6 ISTITUTO DI METROLOGIA "G COLONNETTI"

The IMGC standard is a mercury manometer constructed from stainless steel which uses an interferometric method to measure the heights of the mercury columns. The laser beams in the interferometer are reflected directly from the mercury surfaces through focusing cat's-eye lenses in floats. The two columns, which are of 60 mm diameter and 120 mm length, are bored from a single piece of stainless steel, with a horizontal channel connecting them at their base. A platinum resistance thermometer (PRT) is fitted coaxially along the channel. The differential pressure, P, is given by

$$P = \rho . g . h$$

where ρ = mercury density
g = local acceleration due to gravity
h = height difference

3.7 AERONAUTICAL RESEARCH INSTITUTE

The standards employed by FFA are capacitance manometers (see description at 3.10).

3.8 CHELL INSTRUMENTS

The standards employed by Chell are capacitance manometers (see description at 3.10).

3.9 LABORATOIRE NATIONAL D'ESSAIS

LNE employs two standards, both of which are capacitance manometers (see description at 3.10). The first is used for pressures up to 100 Pa and the second up to 1000 Pa. The sensitivity of both is determined by comparison with two pressure balances.

3.10 NATIONAL ENGINEERING LABORATORY

The standards employed by laboratories 3.7 to 3.10 are electronic capacitance manometers. These devices contain a chamber divided into two parts by a thin tensioned diaphragm. One side of the diaphragm is connected to the reference pressure and the other to the test pressure. Changes in pressure cause slight movements of the diaphragm which are detected as a change in capacitance between the diaphragm and a fixed plate (or plates) within the chamber.

3.11 CENTRE FOR METROLOGY AND ACCREDITATION

CMA employs two types of standards: capacitance manometers (see description at 3.10), for pressures below 300 Pa, and a digital pressure balance for the higher pressures. In the digital pressure balance, the pressure to be measured is applied to a piston-cylinder combination of known effective area. This generates a force which is measured by a dynamometer that has been previously calibrated using known masses. The pressure, P, is therefore given by

$$P = \frac{F}{A}$$

where F = force acting on piston
A = effective area of piston-cylinder assembly

4 CALIBRATION PROCEDURE

The calibrations were performed at differential pressures of 3 Pa, 10 Pa, 30 Pa, 100 Pa, 300 Pa and 1000 Pa. Four sets of measurements were taken, two rising series and two falling series. Within each series ten measurements were taken at each pressure. The instrument's zero differential pressure indication was noted before and after each set of ten measurements.

Each participant was required to complete, for each pressure in each series of measurements, a results sheet containing the following information:

- atmospheric pressure at the time of the measurement;
- the initial FRS4 indication with zero differential pressure and the time at which it was taken;
- the initial PRT indication (in ohms) and the time at which it was taken;
- the FRS4 indication, the measured differential pressure (from the participant's standard) and the time for each of the ten readings;
- the final FRS4 indication with zero differential pressure and the time at which it was taken;
- the final PRT indication and the time at which it was taken.

The local value of acceleration due to gravity was also recorded.

5 TREATMENT OF DATA

Interpolated values for the FRS4 zero differential pressure[2] and PRT indications[3] were calculated by NPL for each of the ten readings at each pressure, assuming linear drift with time, between initial and final values. From the interpolated PRT indications, values for the temperature were determined assuming the PRT to conform with BS 1904:1984 Class A.

From these data, the mean correction to each FRS4 reading was determined using the equation

$$\overline{C} = \frac{\sum_{i=1}^{10}\left(P_i - \left[(R_i - z_i)(1 - a \times (T_i - 20))\left(\frac{g_s}{g_l}\right)\right]\right)}{10}$$

where $\overline{C}$ = Mean FRS4 correction
P_i = differential pressure measured by the participant's standard
R_i = FRS4 indication
z_i = interpolated drift in FRS4 zero differential pressure reading
T_i = temperature in °C
g_l = local value of acceleration due to gravity
g_s = standard gravity = 9.80665 ms^{-2}
a = coefficient of thermal expansion of the piston-cylinder, taken to be 3.2×10^{-5} °C^{-1}

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[2] CMA, DTI and IMGC measured the FRS4 zero indication before each reading, so interpolation was not necessary

[3] TUD, NEL and DTI supplied temperature values rather than resistance values.

6 RESULTS

Table 1 gives the FRS4 corrections obtained by each participant from their measurements at each of the nominal differential pressures carried out under rising pressure conditions, in order of participation. Similarly, Table 2 gives the corrections obtained under falling pressure conditions. The results for LNE show extra measurements at 100 Pa as they used two standards at this pressure, whilst dashes within the tables indicate that no measurement was taken by a participant in that series. The corrections are expressed to one more decimal place than the FRS4 display. Table 3 shows the mean correction obtained by each of the participants at each of the nominal differential pressures and Table 4 the standard deviations of the mean corrections. Table 5 shows the mean correction and standard deviation from all participants' data, and Table 6 shows the uncertainty claimed by each participant at each of the nominal differential pressures, expressed in pascals at the 2σ uncertainty level. NEL were unable to provide uncertainty figures as, subsequent to their measurements, they discovered that there had been a fault with the capacitance manometer used as their standard.

The results of the comparison are presented graphically in the Figures. Summary graphs are shown in Figure 3 to Figure 6, showing the differences between each participants' mean corrections and the overall mean corrections from the NPL, PTB and IMGC data. These three laboratories provided the most generally consistent results and their overall mean values were thus taken to be the datum value against which individual results were compared. Figure 3 compares the NPL, PTB IMGC and Furness Controls results against the datum values. Figure 4 compares all other results with the datum values at the same correction scale sensitivity as Figure 3. Figure 5 repeats Figure 4 but with reduced correction scale sensitivity. Figure 6 repeats Figure 3 but including differential pressures up to 100 Pa only, and with increased correction scale sensitivity. Because these are mean values, and also to aid clarity, no error bars are shown in Figure 3 to Figure 6.

Figure 7 to Figure 18 show the full calibration results obtained by each of the participants as calculated FRS4 correction against nominal pressure. For clarity, corrections at the same nominal pressure have been slightly offset horizontally. The error bars represent the $\pm 2\sigma$ uncertainty figures provided by each participant. NPL data is presented in both Figure 7 and Figure 8; Figure 7 shows all data and Figure 8 is expanded to show data only up to 100 Pa but with increased correction scale sensitivity. Because NPL took three full sets of results, there is more data on Figure 7 and Figure 8 than in the remaining figures. Also, a number of participants took fewer measurements. Note that the sensitivity of the correction scale differs between figures.

The dashed lines in Figure 7 show the defined reproducibility requirement for the transfer standard of $\pm$ (0.1 Pa + 0.01% of reading) superimposed upon the mean NPL results. It can be seen that this performance was bettered throughout the period of the comparison. The standard deviations of the transfer standard's corrections were less than 0.04 Pa over the entire range.

Figure 19 to Figure 30 show the calculated corrections at each nominal pressure in both the rising and falling series for every participant, again in order of participation. Each participant is represented in each figure by a letter identified in the key in Table 7 which also shows the date on which each participants' measurements were taken. Again, the results are presented as corrections with the error bars showing the participants' quoted $\pm 2\sigma$ uncertainty. Where there is no result for a particular participant it is because that participant did not take a measurement in that series.

Figure 31 to Figure 36 show the standard deviations of all corrections obtained by each participant. Generally, the repeatability of each participants' measurements was poorest at 1000 Pa, as were the differences between participants' mean values. Thus Figure 37 shows the mean corrections and standard deviations from all data obtained by each participant at 1000 Pa, with the dotted lines representing intervals of 1 standard deviation. Figure 38 shows Figure 37 data recalculated omitting the three laboratories whose mean correction was outside the ±1 standard deviation lines. Note that the standard deviation calculated for Figure 37 is 0.56 Pa but in Figure 38 it is 0.13 Pa.

7 DISCUSSION

The aim of the exercise was to compare the differential pressure standards of European laboratories using a transfer standard with a reproducibility of better than ± (0.1 Pa + 0.01% of reading). From the results of the pilot laboratory (Figure 7) it can be seen that this performance was bettered throughout the period of the comparison. However, there is some evidence of a shift in the performance of the transfer standard between the NPL1/2 and NPL 3/4 calibrations of approximately 0.06 Pa at 1000 Pa. As the time at which this shift took place is not known, and no significant evidence of drift was subsequently observed, it was not possible to correct any participants' results for its effect.

Some participants reported problems with obtaining stable readings whilst using the FRS4. This was probably caused by atmospheric turbulence; because of the need to make measurements within a relatively short period it was not always possible to wait for calm weather.

The results show that whilst most agree within the quoted uncertainties, there were differences between some participants that exceeded the maximum likely difference expected from the values of quoted measurement uncertainties and the repeatability of the transfer standard. This suggests that some uncertainty claims are optimistic. The performance of the large-bore liquid-filled instruments was generally better than that of the other instruments.

Little evidence of hysteresis was observed, either in the performance of the transfer standard or in the participants' standards.

After the results had been circulated, LNE reported that re-calibration of their reference standard used in the pressure range 100 Pa to 1000 Pa, and undertaken shortly after participation in the comparison, showed significant and unusual changes in its characteristics. When using the calibration coefficients from the new data all corrections at pressures of 100 Pa, 300 Pa and 1000 Pa were within 0.2 Pa.

8 CONCLUSION

This comparison has shown that, when taking into account the often large uncertainties, many of the differential pressure measurements made by the participants are consistent between laboratories. This is not exclusively so, however, and some participants may wish to re-examine their uncertainties.

Nominal Differential Pressure Pa	Participating Laboratory												
	NPL	Furness	PTB	TUD	Chell	NEL	NPL	FFA	CMA	DTI	LNE	IMGC	NPL
	Correction / Pa												
3	-0.007 +0.001	-0.001 +0.004	-0.007 -0.002	+0.022 +0.037	+0.010 0.000	- -	+0.003 +0.005	-0.029 -	-0.004 -0.025	-0.057 -	+0.014 -0.006	-0.002 +0.005	+0.006 +0.003
10	-0.001 -0.003	0.000 -0.001	+0.006 +0.001	+0.014 +0.048	+0.031 -0.006	+0.110 -0.020	-0.001 +0.004	+0.017 -	+0.008 +0.007	-0.098 -0.108	+0.018 -0.006	-0.010 -0.011	0.000 +0.005
30	+0.007 0.000	-0.004 -0.003	+0.007 +0.009	-0.024 +0.091	+0.039 +0.051	+0.127 -0.048	+0.010 +0.009	-0.012 -	+0.052 +0.044	-0.086 -	+0.052 +0.026	+0.005 +0.002	+0.006 +0.009
100	+0.021 +0.014	+0.003 +0.004	+0.032 +0.029	+0.033 +0.063	+0.124 +0.065	+0.419 -0.180	+0.032 +0.030	-0.115 -	+0.070 +0.204	+0.015 -0.071	+0.081 +0.058 +0.021 +0.040	+0.010 +0.001	+0.026 +0.033
300	+0.068 +0.072	+0.014 +0.005	+0.081 +0.086	+0.042 +0.020	+0.281 +0.285	-0.568 -0.562	+0.088 +0.094	-0.206 -	+0.196 +0.175	+0.012 -	+0.210 +0.234	+0.046 +0.053	+0.080 +0.088
1000	+0.207 +0.203	-0.007 +0.004	+0.177 +0.184	+0.223 +0.117	+0.357 +0.351	-1.353 -1.323	+0.270 +0.288	-0.427 -	+0.135 +0.235	-0.041 -	+1.142 +1.217	+0.200 +0.265	+0.254 +0.270

Table 1 Corrections obtained by each participant in rising series of pressures

Nominal Differential Pressure Pa	Participating Laboratory												
	NPL	Furness	PTB	TUD	Chell	NEL	NPL	FFA	CMA	DTI	LNE	IMGC	NPL
	Correction / Pa												
3	-0.012 -0.002	-0.001 -0.012	+0.009 -0.002	+0.017 +0.066	+0.009 +0.023	- -	+0.002 -0.003	-0.040 -	+0.001 -0.019	-0.053 -	+0.002 -0.010	+0.005 +0.006	+0.007 +0.008
10	-0.014 -0.005	-0.004 +0.003	+0.015 +0.002	-0.018 +0.064	+0.002 +0.054	-0.045 +0.029	+0.006 +0.007	-0.035 -	+0.005 -0.005	-0.088 -0.102	+0.013 +0.001	+0.005 +0.009	+0.009 +0.010
30	-0.002 -0.006	-0.001 +0.023	+0.016 +0.004	-0.039 +0.036	+0.048 +0.051	-0.080 +0.094	+0.012 +0.011	-0.076 -	+0.045 +0.034	-0.158 -	+0.034 +0.019	+0.009 +0.020	+0.015 +0.014
100	+0.006 +0.021	+0.014 +0.008	+0.028 +0.020	-0.057 +0.018	+0.082 +0.077	-0.195 -0.220	+0.033 +0.033	-0.123 -	+0.074 +0.152	+0.006 -0.033	+0.077 +0.054 -0.005 +0.033	+0.027 +0.040	+0.034 +0.041
300	+0.081 +0.056	+0.017 -0.001	+0.062 +0.054	-0.118 -0.054	+0.309 +0.261	-0.598 -0.575	+0.099 +0.091	-0.220 -	+0.132 +0.078	+0.025 -0.016	+0.209 +0.237	+0.068 +0.135	+0.088 +0.099
1000	+0.209 +0.217	-0.004 +0.001	+0.169 +0.153	-0.061 -0.081	+0.489 +0.235	-1.340 -1.328	+0.287 +0.262	-0.598 -	+0.145 +0.224	-0.099 -	+1.150 +1.226	+0.190 +0.214	+0.245 +0.277

Table 2 Corrections obtained by each participant in falling series of pressures

Nominal Differential Pressure Pa	Participating Laboratory												
	NPL	Furness	PTB	TUD	Chell	NEL	NPL	FFA	CMA	DTI	LNE	IMGC	NPL
	Correction / Pa												
3	-0.005	-0.003	0.000	+0.036	+0.011	-	+0.002	-0.035	-0.011	-0.055	0.000	+0.003	+0.006
10	-0.006	-0.001	+0.006	+0.027	+0.020	+0.019	+0.004	-0.009	+0.004	-0.099	+0.007	-0.002	+0.006
30	0.000	+0.004	+0.009	+0.016	+0.048	+0.023	+0.011	-0.044	+0.044	-0.122	+0.033	+0.009	+0.011
100	+0.015	+0.007	+0.027	+0.014	+0.087	-0.044	+0.032	-0.119	+0.125	-0.021	+0.045	+0.020	+0.034
300	+0.069	+0.009	+0.071	-0.027	+0.284	-0.576	+0.093	-0.213	+0.145	+0.008	+0.223	+0.076	+0.089
1000	+0.209	-0.001	+0.171	+0.049	+0.358	-1.336	+0.277	-0.512	+0.185	-0.070	+1.184	+0.217	+0.261

Table 3 Mean corrections obtained by each participant

Nominal Differential Pressure Pa	Participating Laboratory												
	NPL	Furness	PTB	TUD	Chell	NEL	NPL	FFA	CMA	DTI	LNE	IMGC	NPL
	Standard deviation / Pa												
3	0.011	0.007	0.007	0.023	0.012	-	0.004	0.037	0.020	0.040	0.010	0.007	0.003
10	0.009	0.005	0.007	0.037	0.029	0.061	0.004	0.054	0.018	0.028	0.011	0.011	0.005
30	0.009	0.012	0.006	0.055	0.017	0.091	0.002	0.051	0.020	0.049	0.013	0.011	0.004
100	0.012	0.006	0.006	0.053	0.030	0.271	0.004	0.091	0.073	0.054	0.013	0.017	0.006
300	0.011	0.010	0.014	0.068	0.045	0.030	0.005	0.085	0.163	0.062	0.014	0.068	0.009
1000	0.010	0.027	0.012	0.158	0.121	0.039	0.012	0.147	0.074	0.105	0.040	0.038	0.013

Table 4 Standard deviations of mean corrections obtained by each participant

Nominal Differential Pressure Pa	Mean Correction Pa	Standard Deviation Pa
3	-0.004	0.023
10	-0.002	0.031
30	+0.003	0.044
100	+0.019	0.060
300	+0.019	0.215
1000	+0.076	0.563

Table 5 Mean correction and standard deviation from all participants' data

Nominal Differential Pressure Pa	Participating Laboratory										
	NPL	Furness	PTB	TUD	Chell	NEL	FFA	CMA	DTI	LNE	IMGC
	claimed uncertainty / Pa (2σ)										
3	0.003	0.02	0.015	0.26	0.085	-	0.111	0.02	0.215	0.015	0.014
10	0.003	0.02	0.015	0.26	0.145	-	0.114	0.09	0.226	0.022	0.015
30	0.005	0.02	0.015	0.26	0.275	-	0.122	0.12	0.258	0.042	0.015
100	0.011	0.023	0.016	0.26	0.653	-	0.15	0.23	0.37	0.070	0.017
300	0.031	0.028	0.022	0.26	1.65	-	0.23	0.35	0.69	0.170	0.023
1000	0.103	0.048	0.055	0.26	4.32	-	0.51	0.35	1.81	0.520	0.044

Table 6 Claimed measurement uncertainties of each participant in pascals (2σ)

Label	Participant	Date of Calibration	Label	Participant	Date of Calibration
A	NPL 1	16/23.04.93	M	NPL 3	11.01.95
B	NPL 2	30.04/04.05.93	N	NPL 4	13.01.95
C	Furness 1	02.07.93	O	FFA	18.04.95
D	Furness 2	06.07.93	P	CMA 1	08-11.05.95
E	PTB 1	30.09.93	Q	CMA 2	09-12.05.95
F	PTB 2	04.10.93	R	DTI 1	07.06.95
G	TUD 1	18.11.93	S	DTI 2	08.06.95
H	TUD 2	22.11.93	T	LNE 1	27.07-01.08.95
I	Chell 1	9/10.02.94	U	LNE 2	02-03.08.95
J	Chell 2	11.02.94	V	IMGC 1	22.09.95
K	NEL 1	18.03.94	W	IMGC 2	26.09.95
L	NEL 2	18.03.94	X	NPL 5	16.10.95
-	-	-	Y	NPL 6	17.10.95

Table 7 Key to Figures 19 to 30

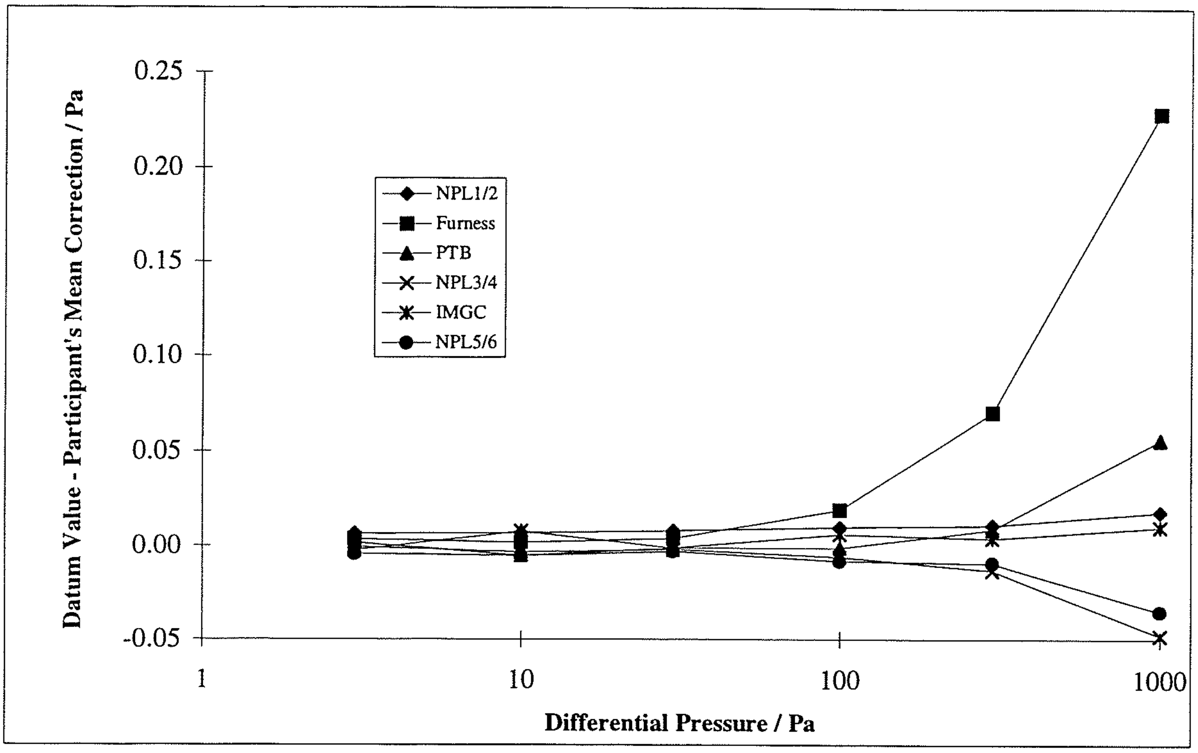

Figure 3 Summary: participants with generally lower claimed uncertainties

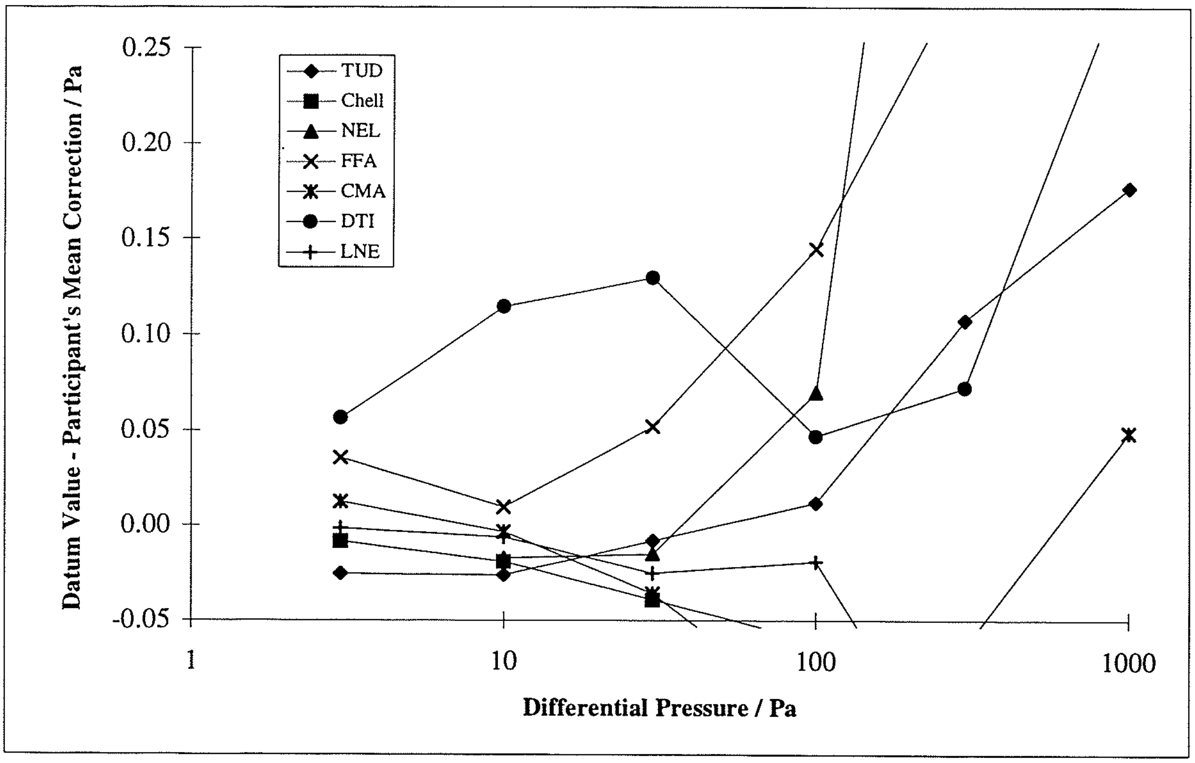

Figure 4 Summary: remaining participants (same scale as Figure 3)

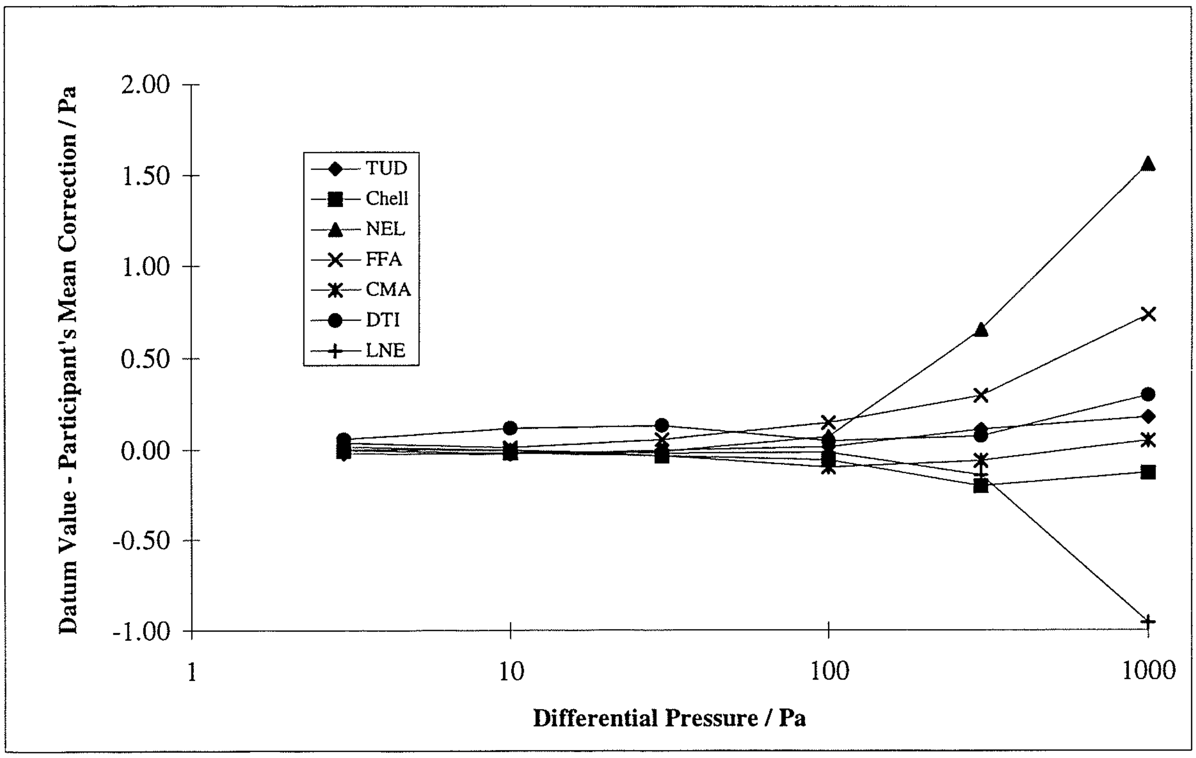

Figure 5 Summary: as Figure 4 but with reduced correction scale sensitivity

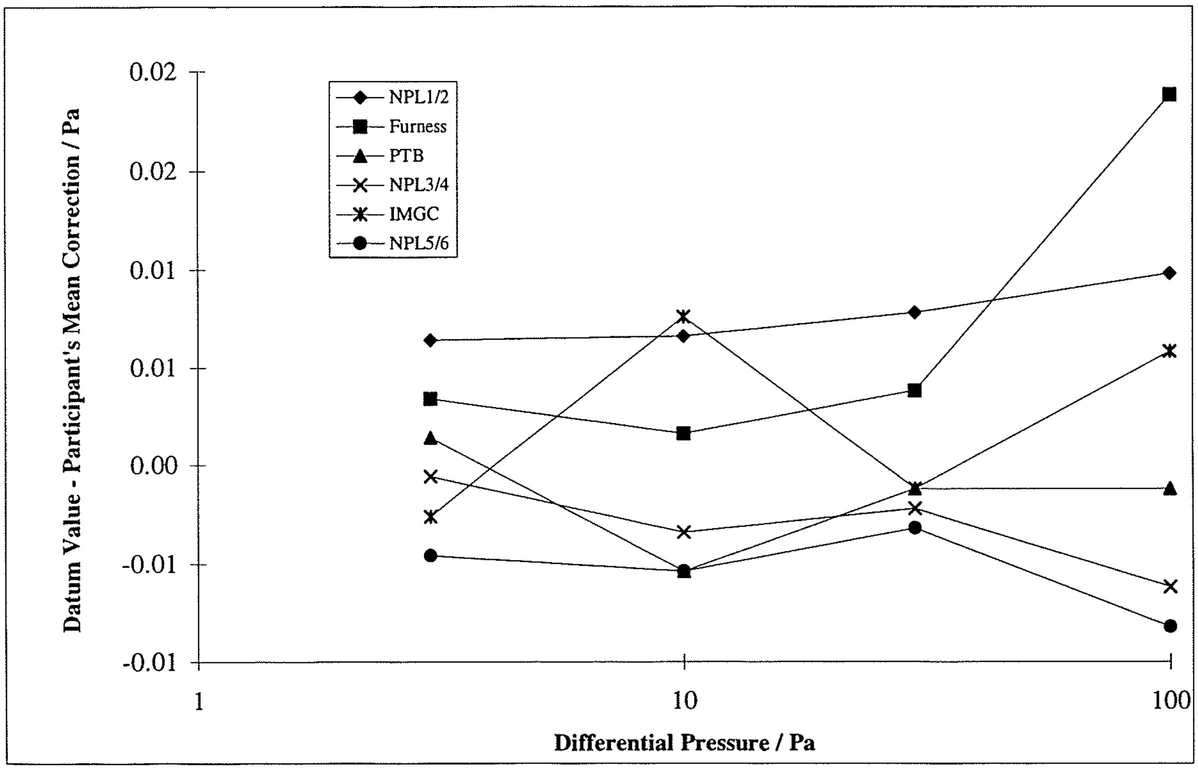

Figure 6 Summary: as Figure 3 but pressures up to 100 Pa only and with increased correction scale sensitivity

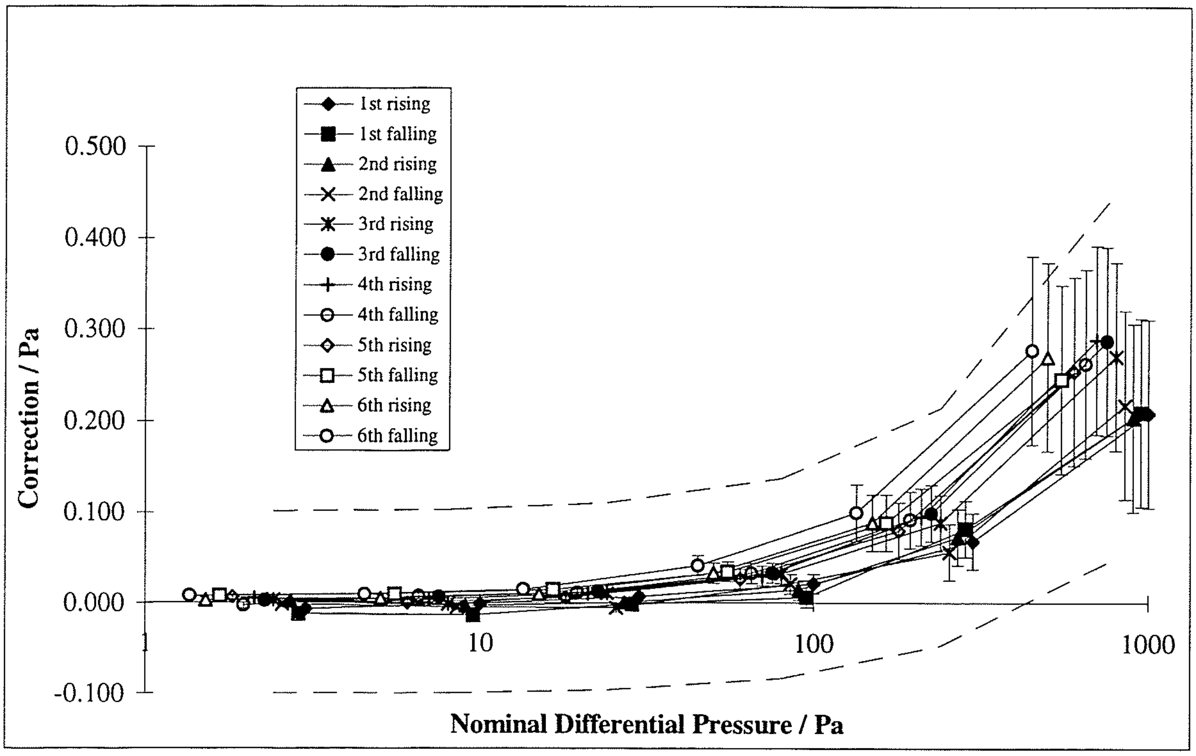

Figure 7 Calibration by NPL

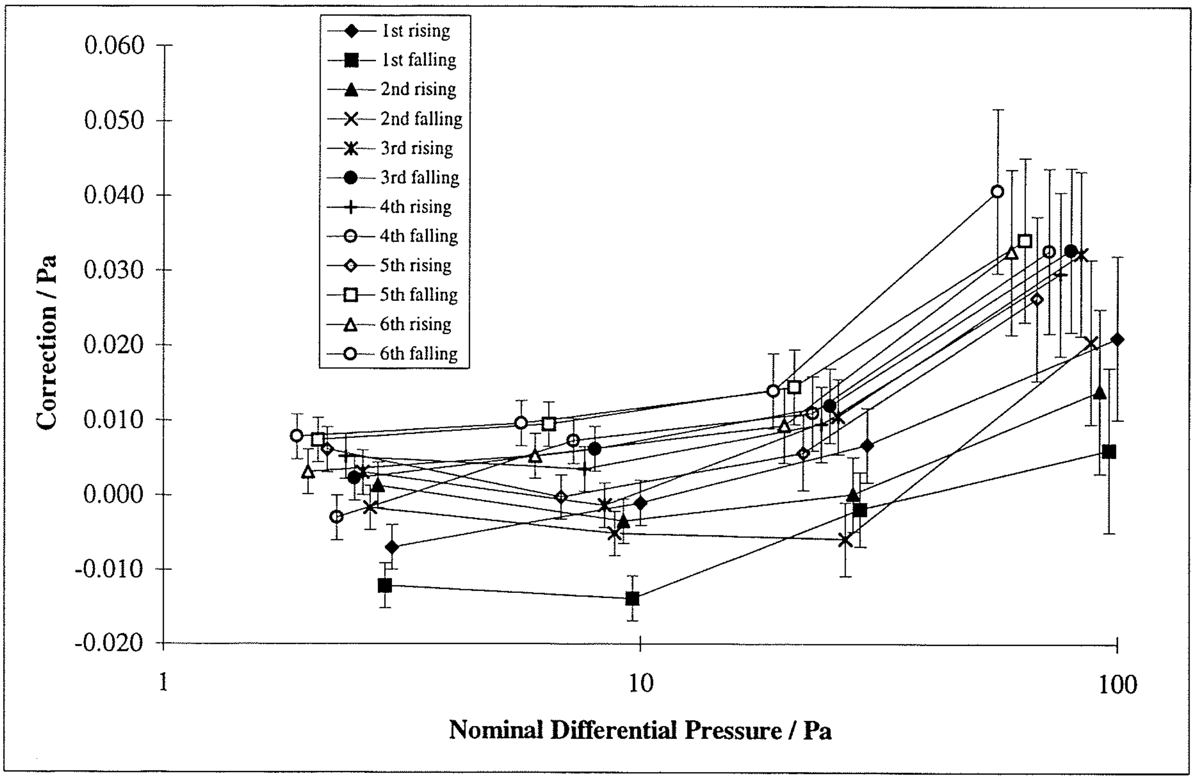

Figure 8 As Figure 7 but pressures up to 100 Pa only and with increased correction scale sensitivity

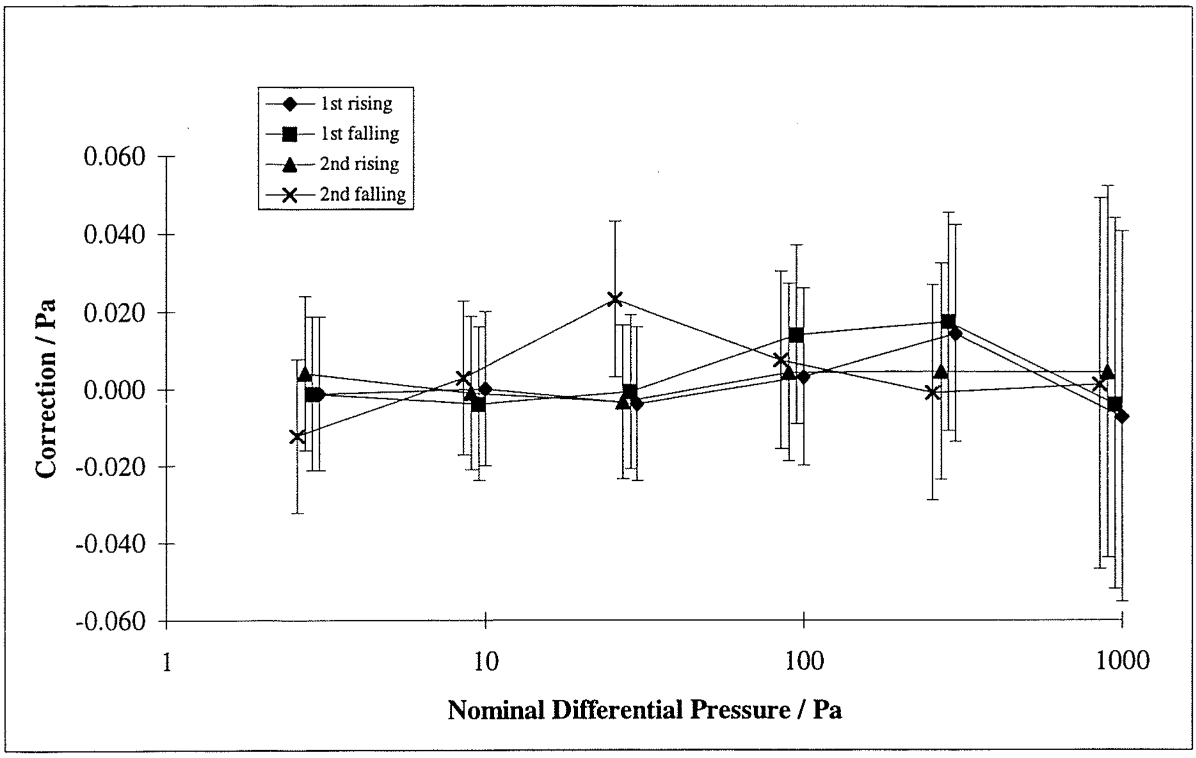

Figure 9 Calibration by Furness Controls

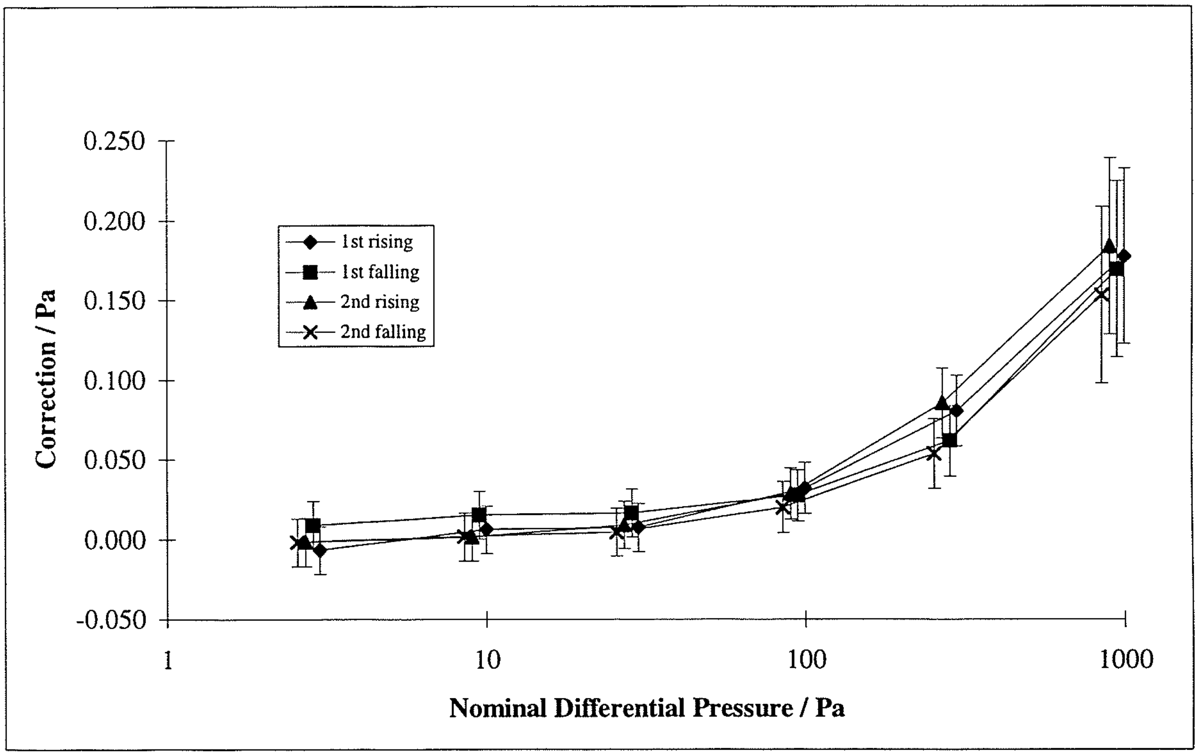

Figure 10 Calibration by PTB

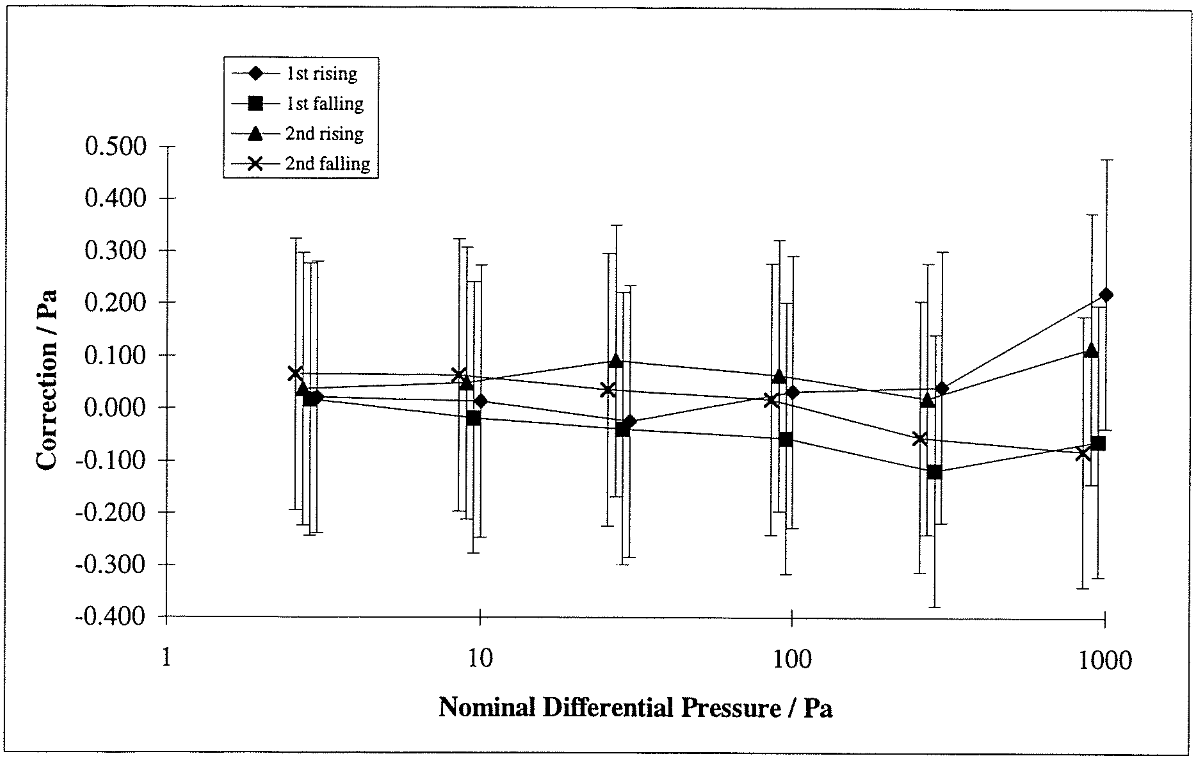

Figure 11 Calibration by TUD

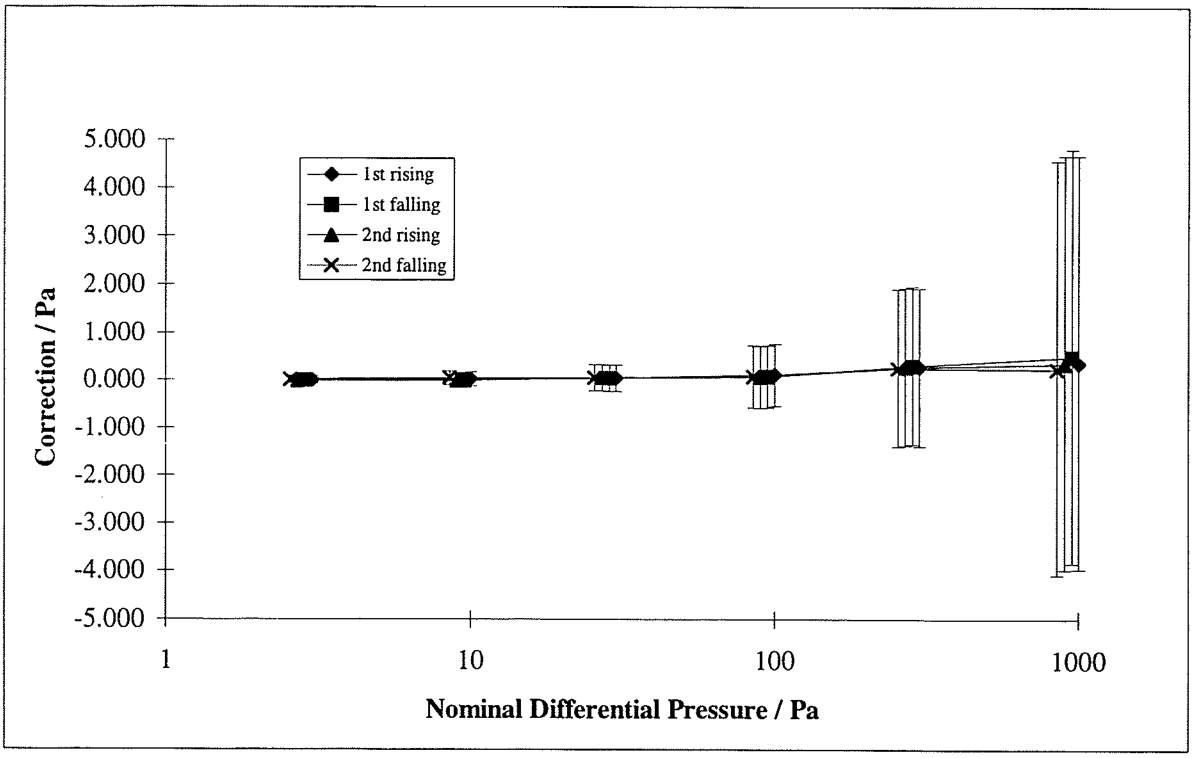

Figure 12 Calibration by Chell

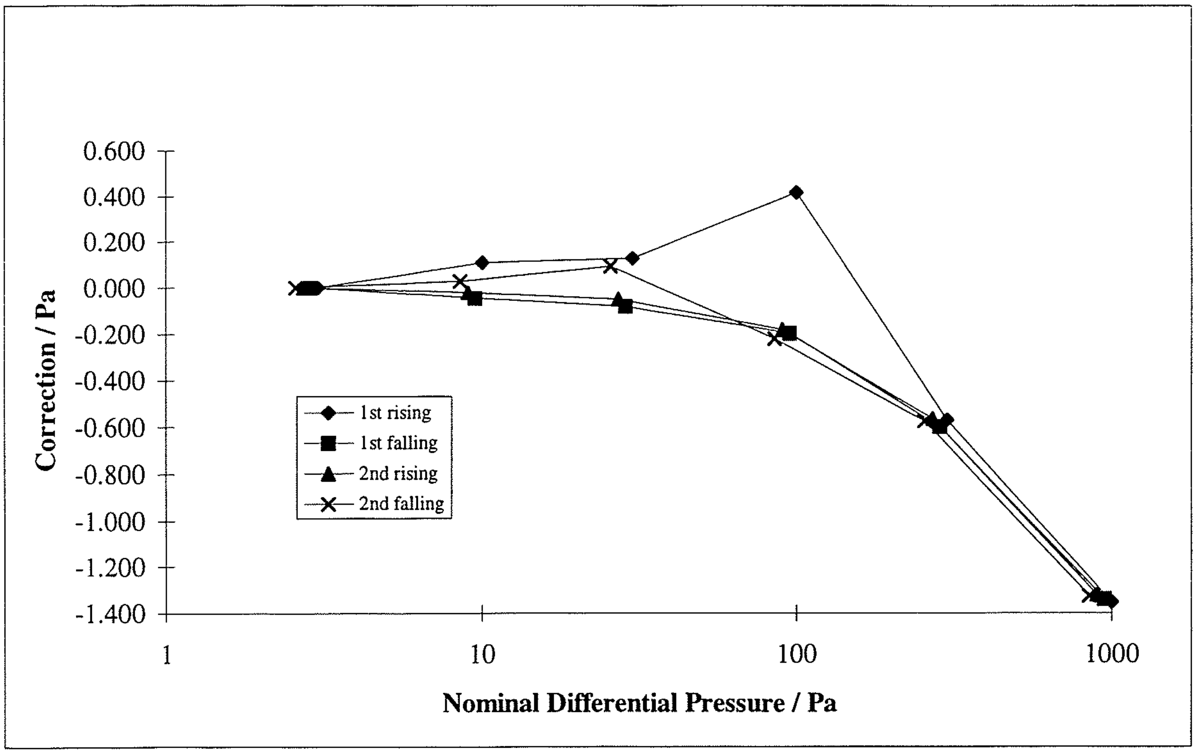

Figure 13 Calibration by NEL

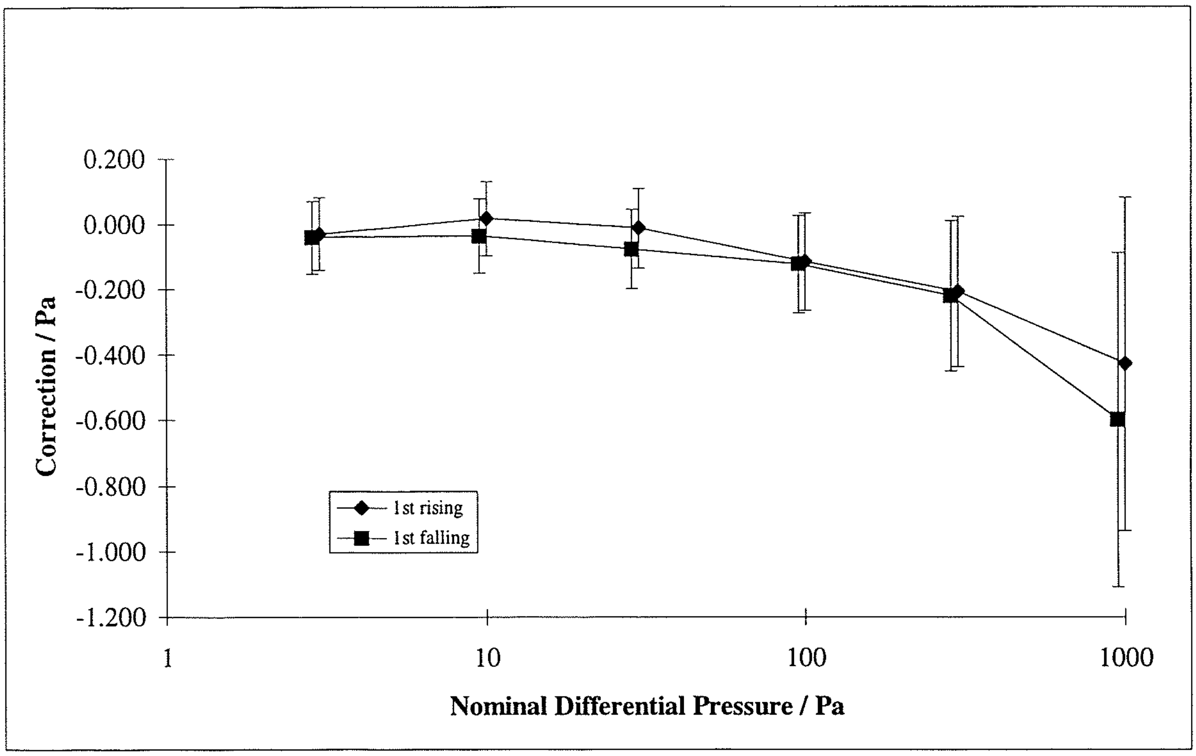

Figure 14 Calibration by FFA

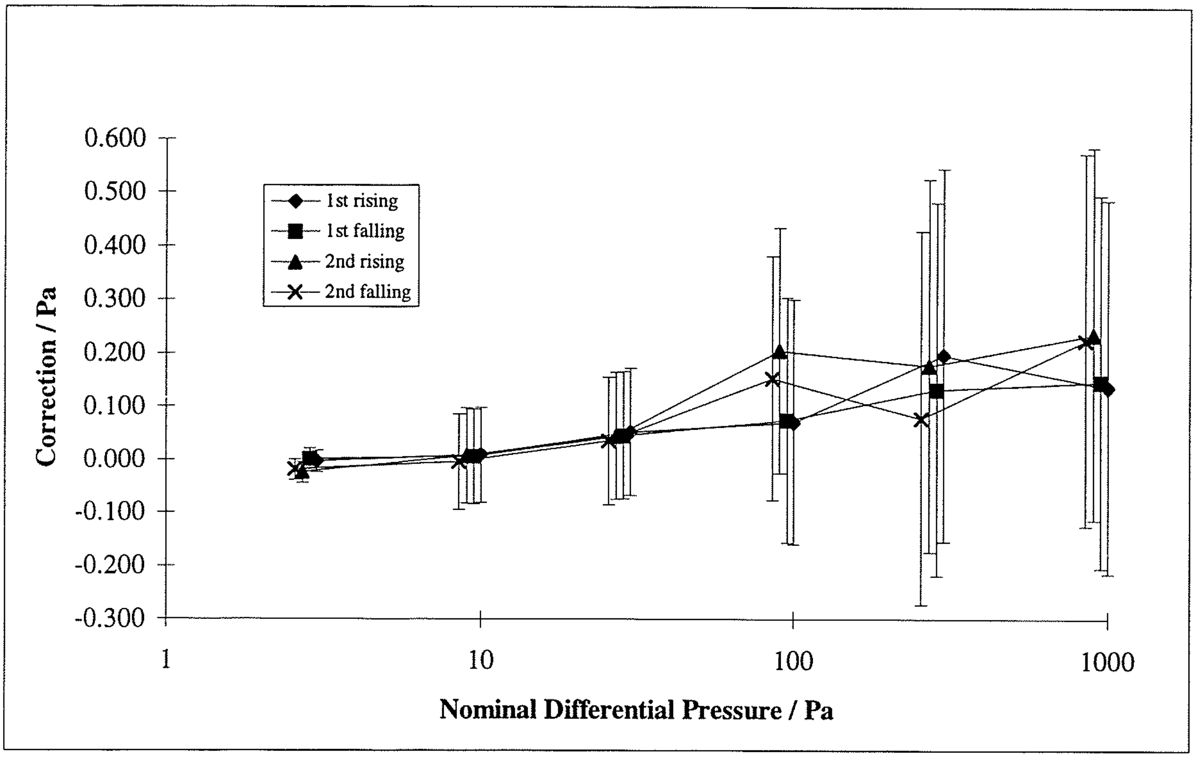

Figure 15 Calibration by CMA

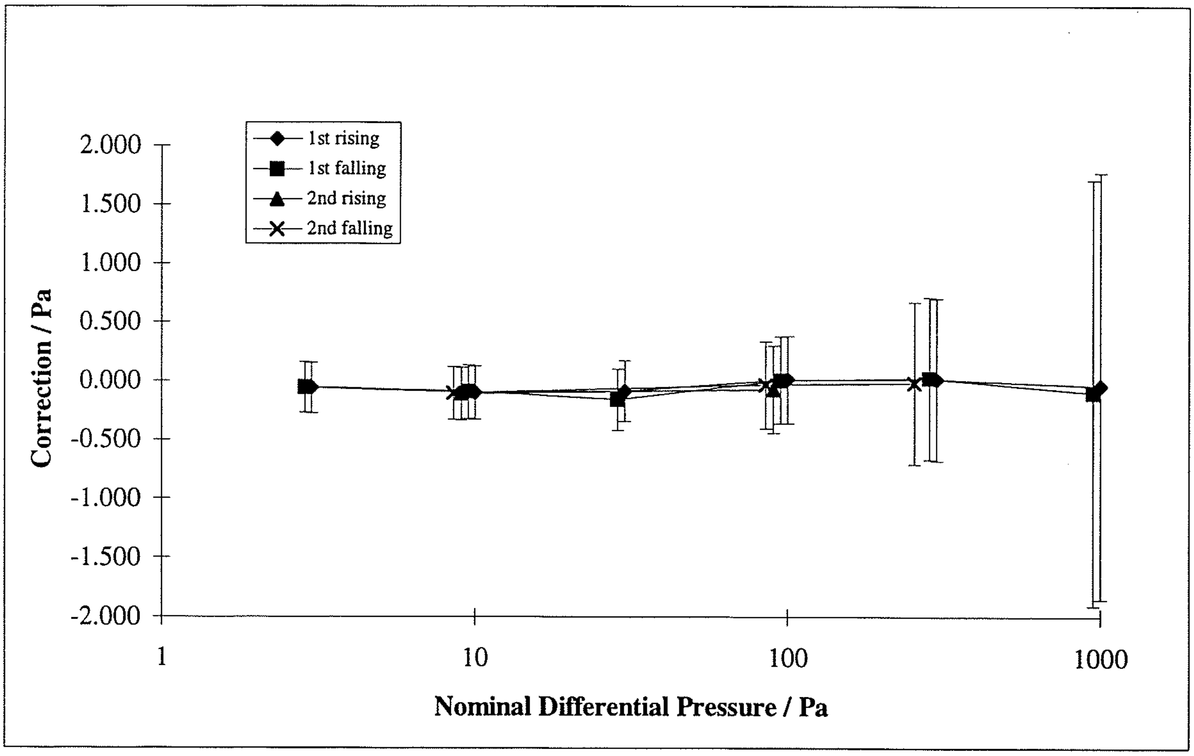

Figure 16 Calibration by DTI

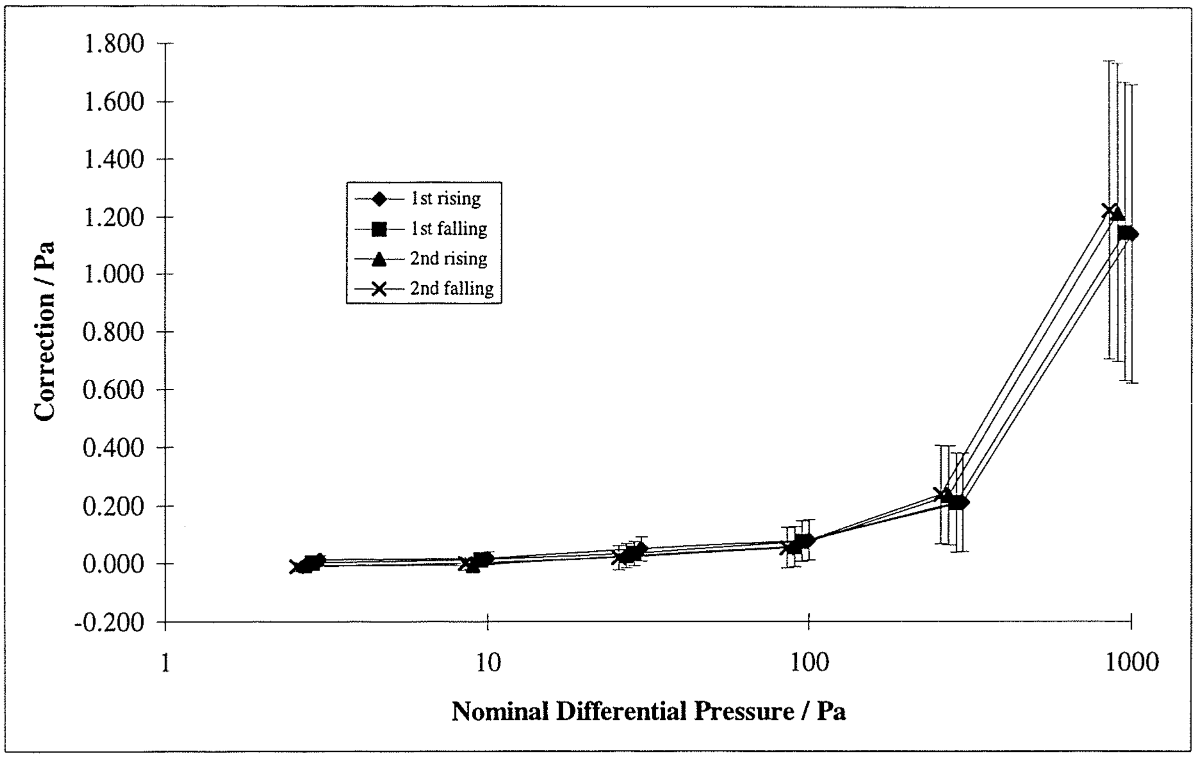

Figure 17 Calibration by LNE

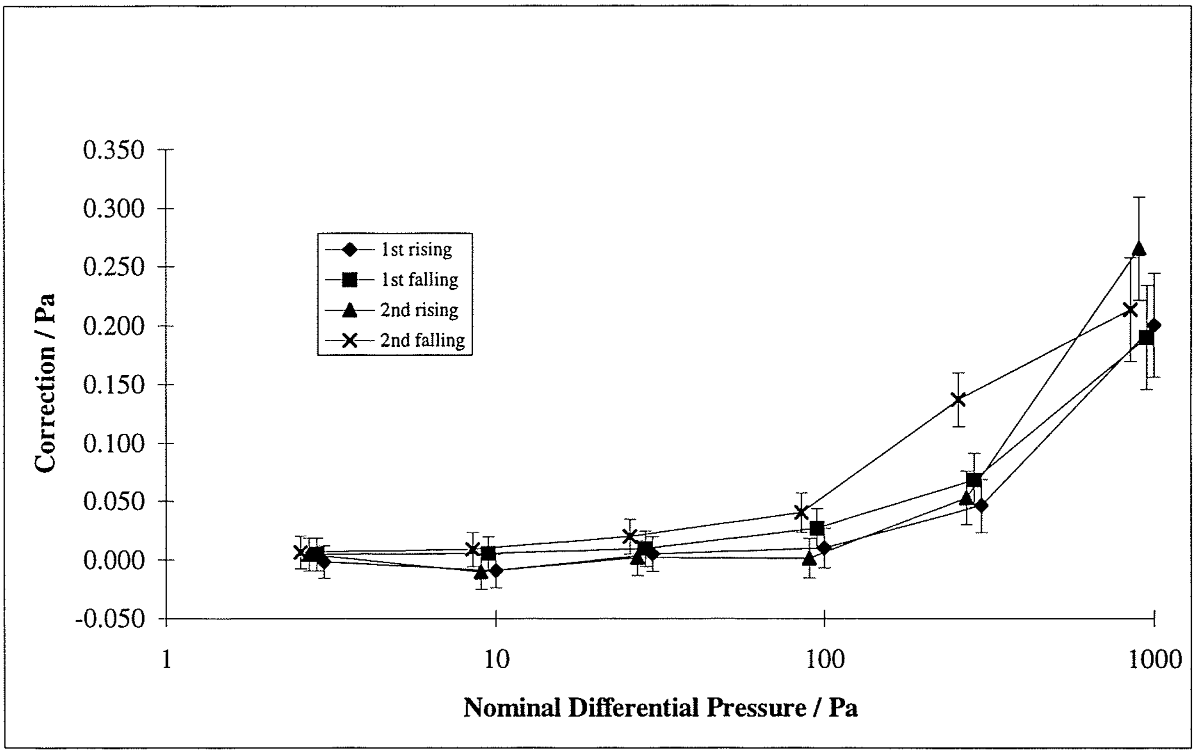

Figure 18 Calibration by IMGC

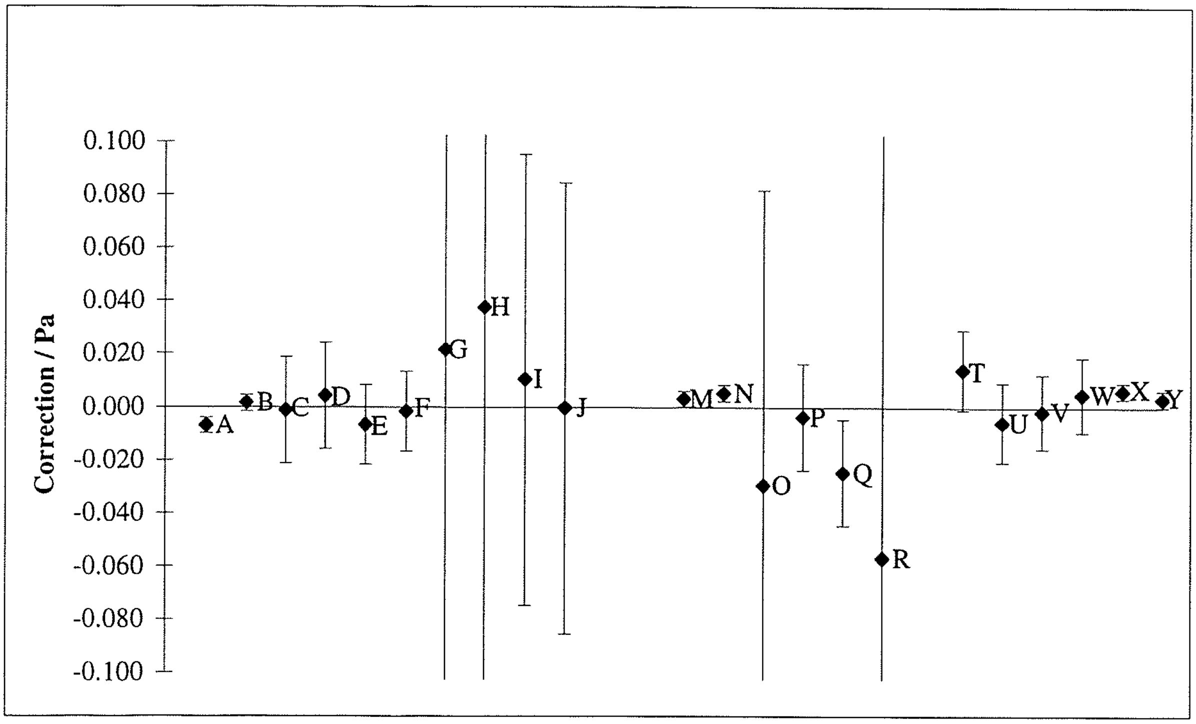

Figure 19 Rising-pressure corrections at 3 Pa

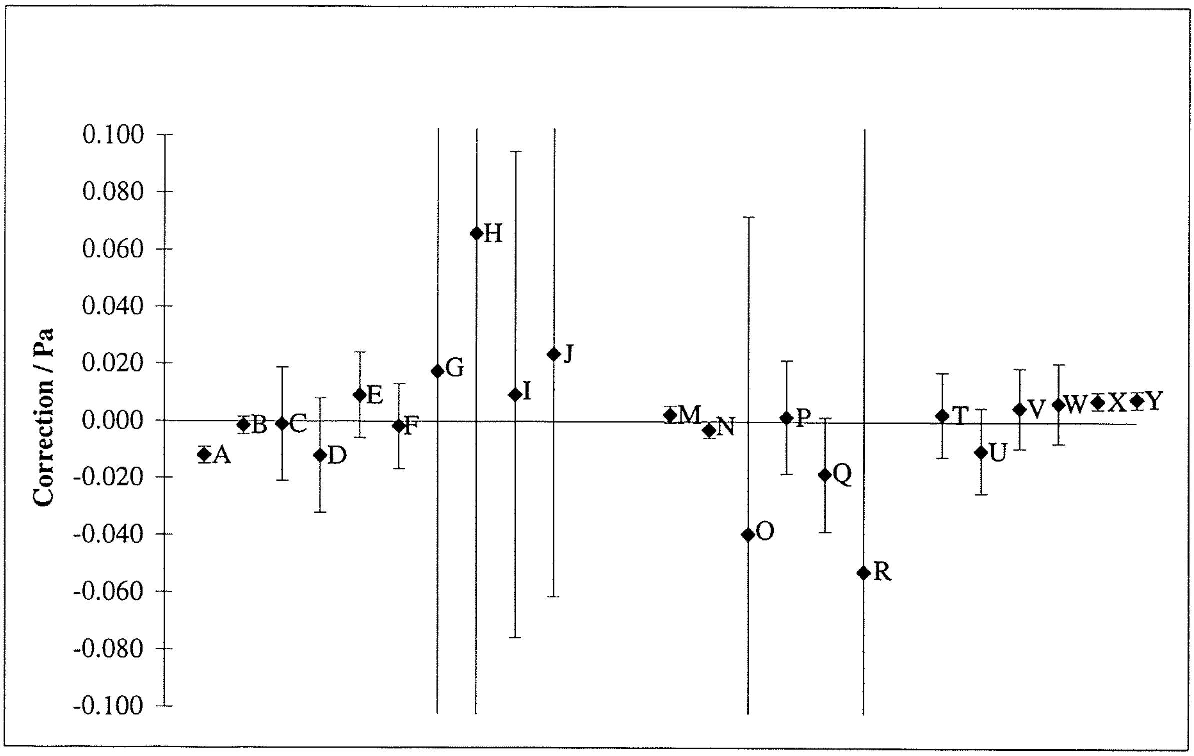

Figure 20 Falling-pressure corrections at 3 Pa

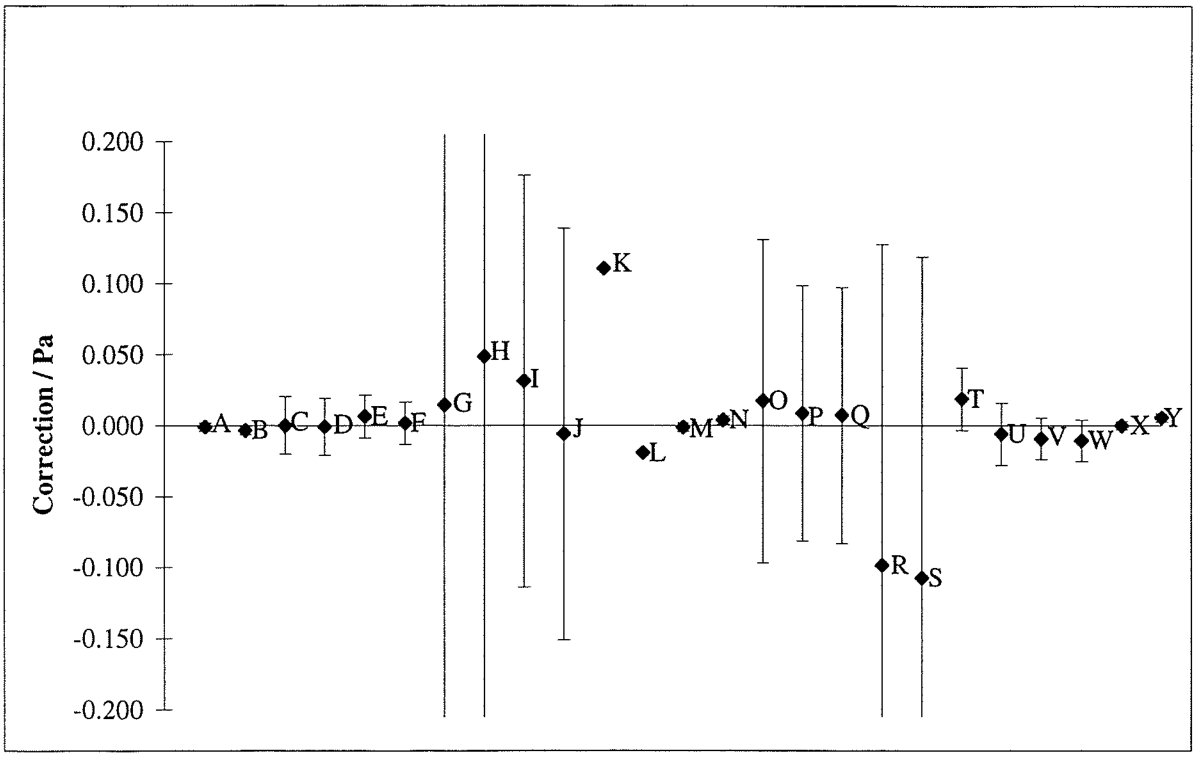

Figure 21 Rising-pressure corrections at 10 Pa

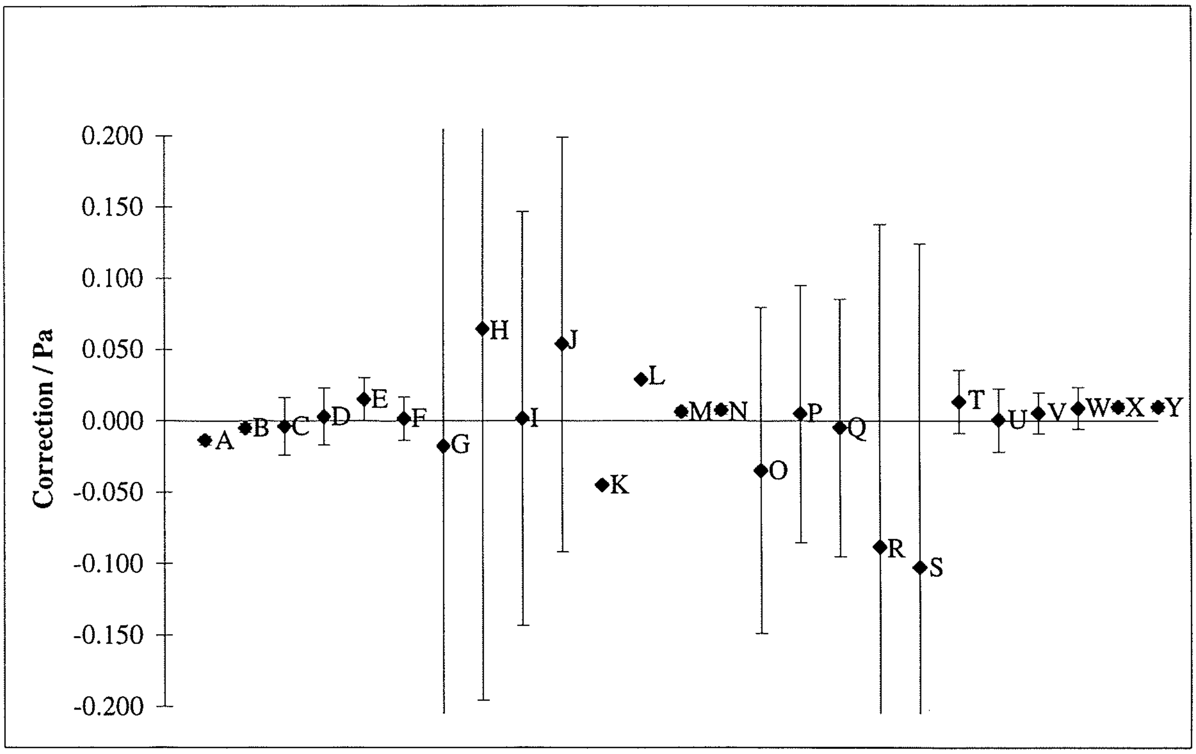

Figure 22 Falling-pressure corrections at 10 Pa

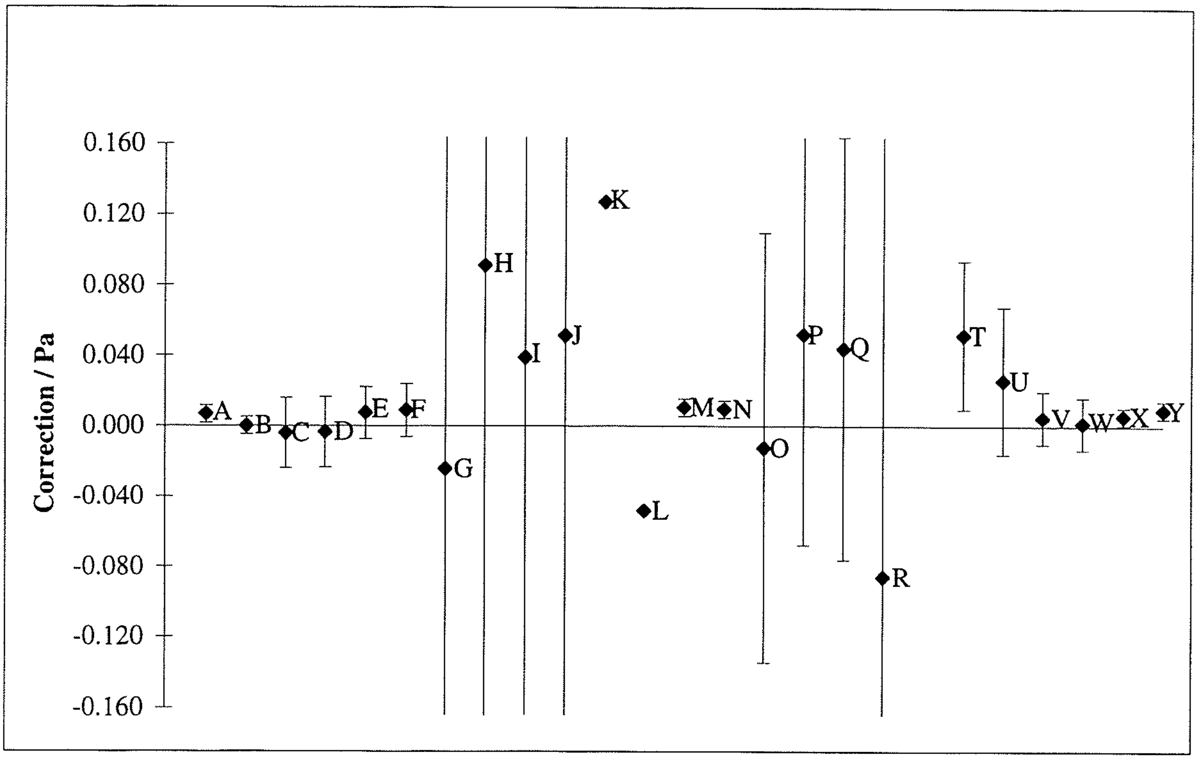

Figure 23   Rising-pressure corrections at 30 Pa

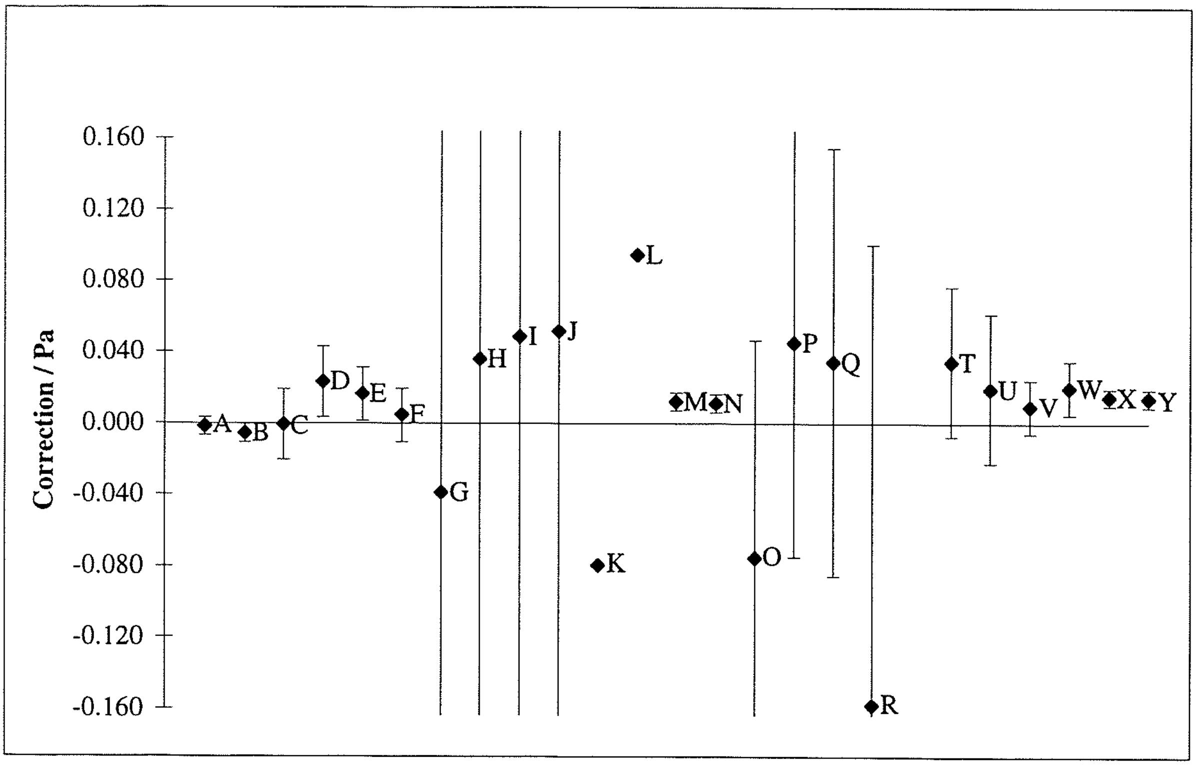

Figure 24   Falling-pressure corrections at 30 Pa

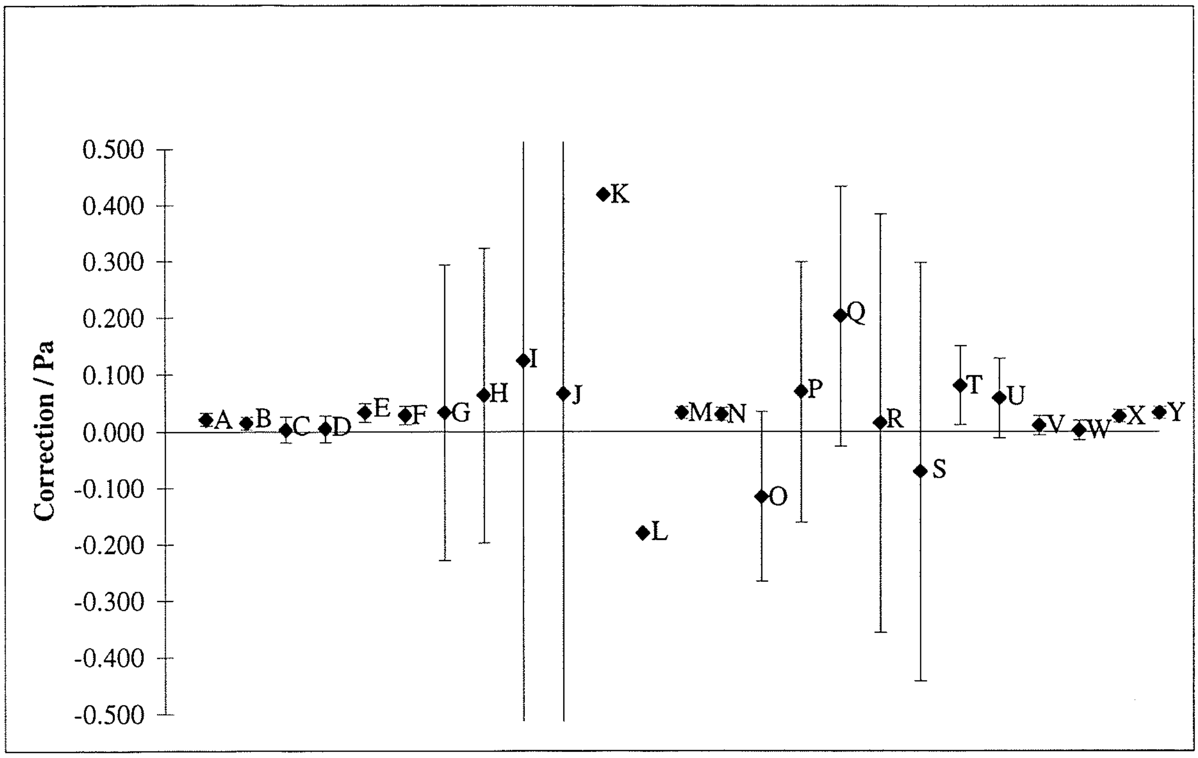

Figure 25 Rising-pressure corrections at 100 Pa

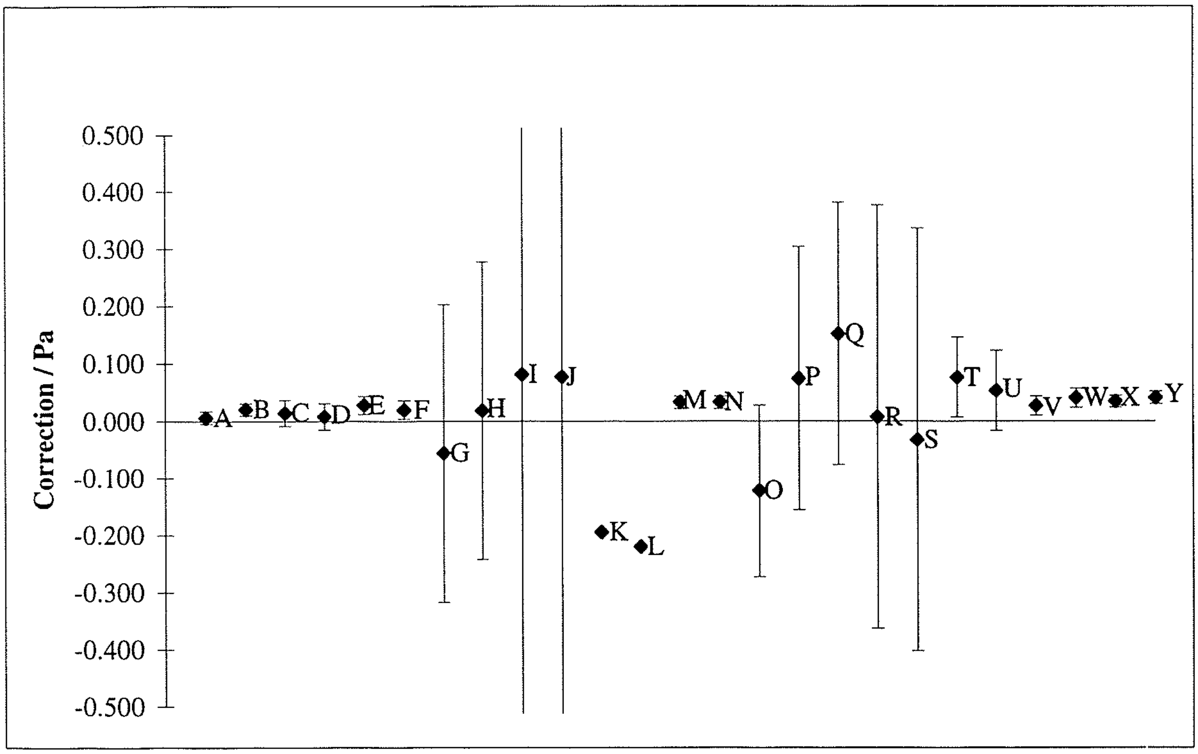

Figure 26 Falling-pressure corrections at 100 Pa

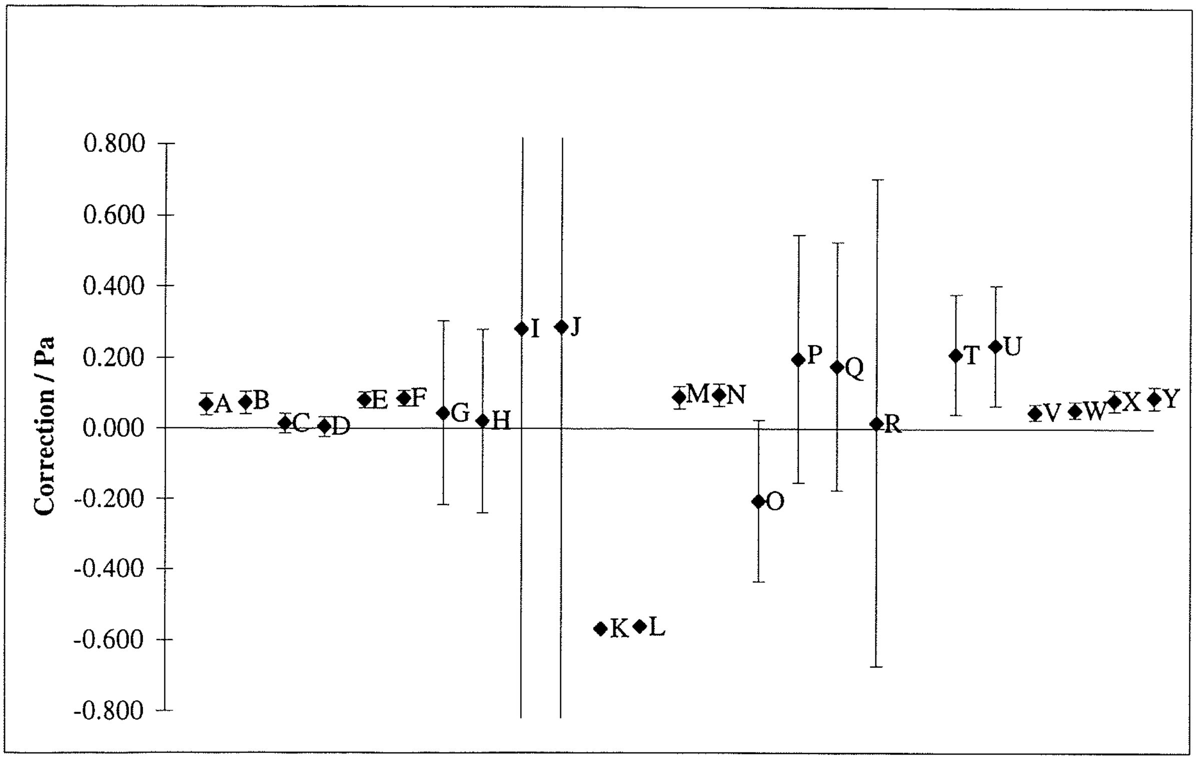

Figure 27 Rising-pressure corrections at 300 Pa

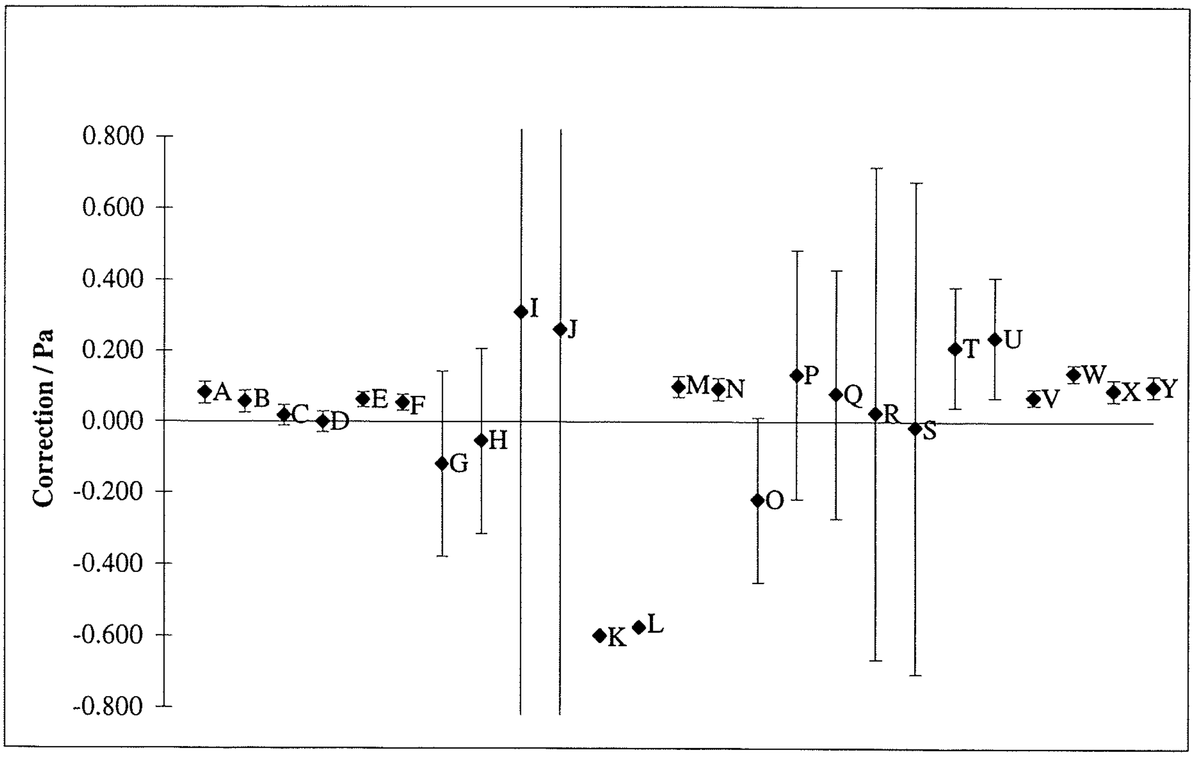

Figure 28 Falling-pressure corrections at 300 Pa

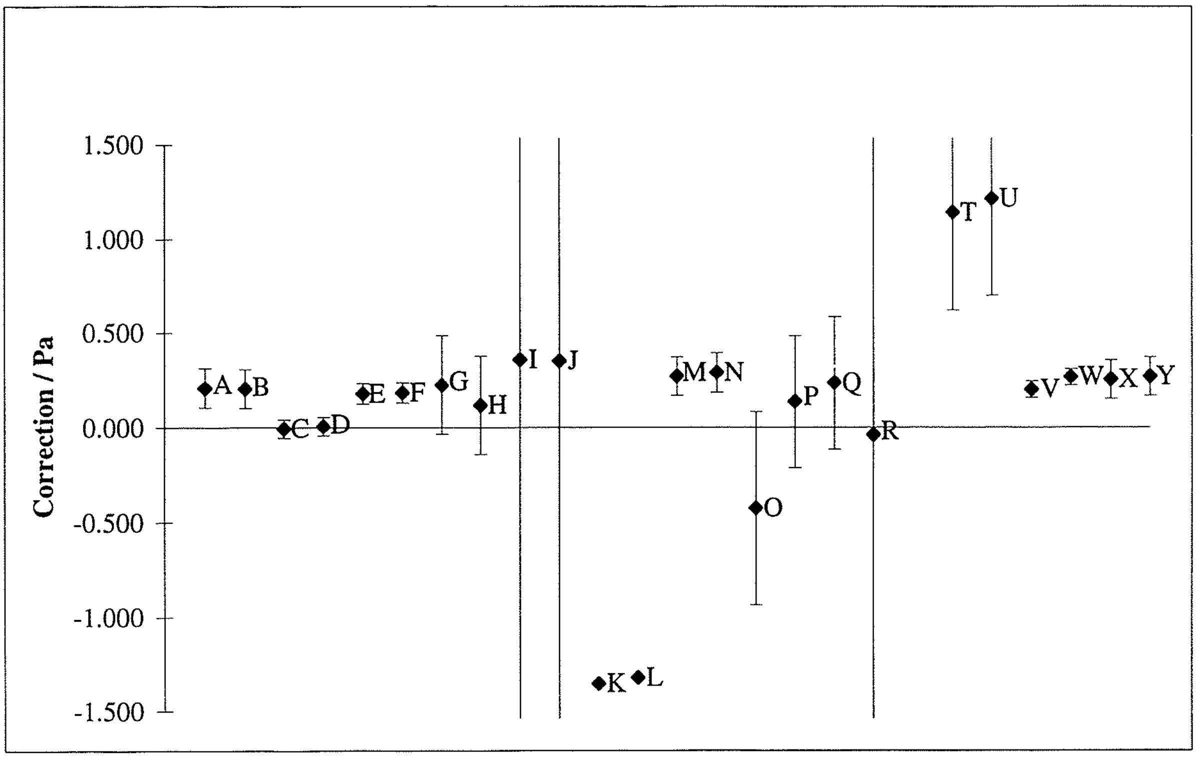

Figure 29 Rising-pressure corrections at 1000 Pa

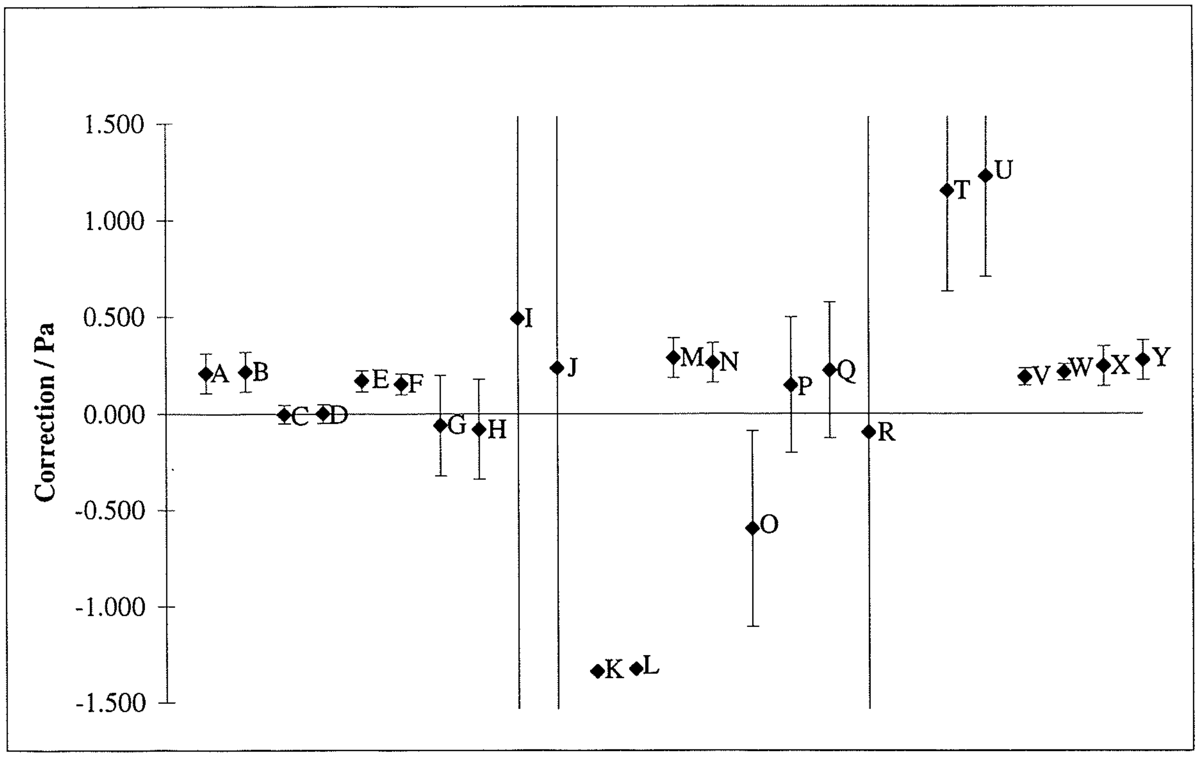

Figure 30 Falling-pressure corrections at 1000 Pa

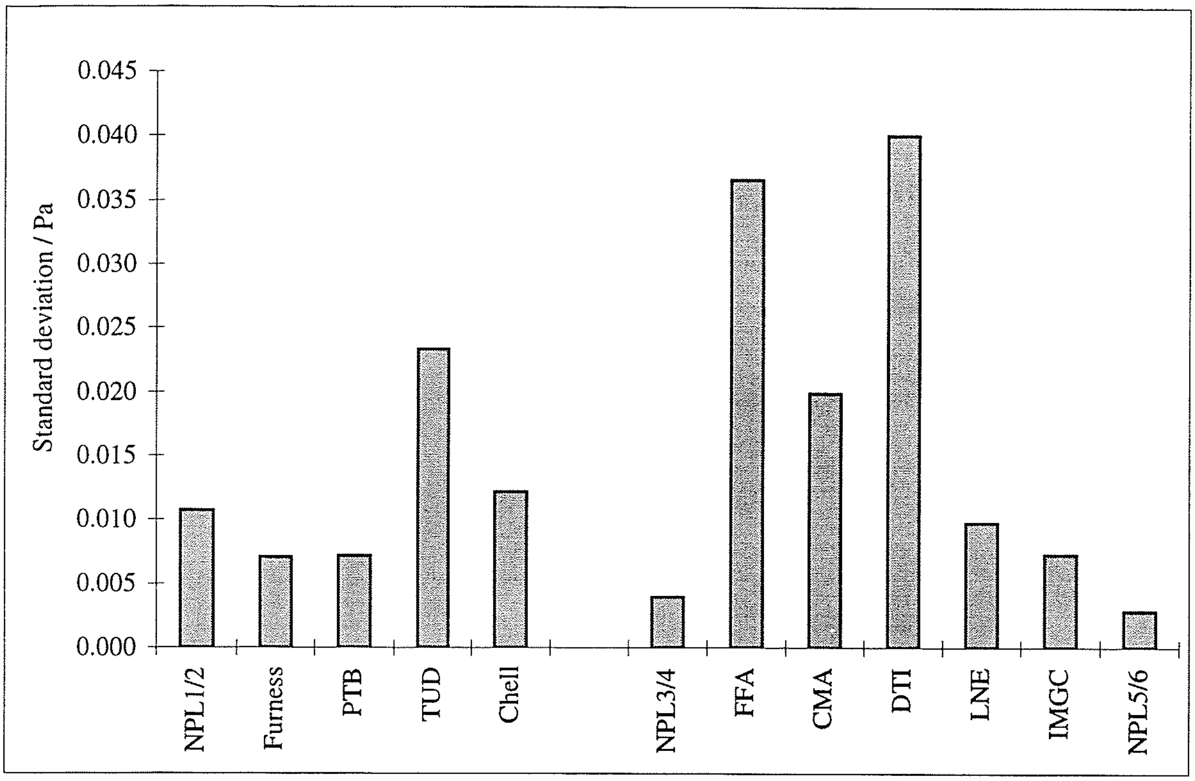

Figure 31 Standard deviation of all corrections obtained by each participant at 3 Pa

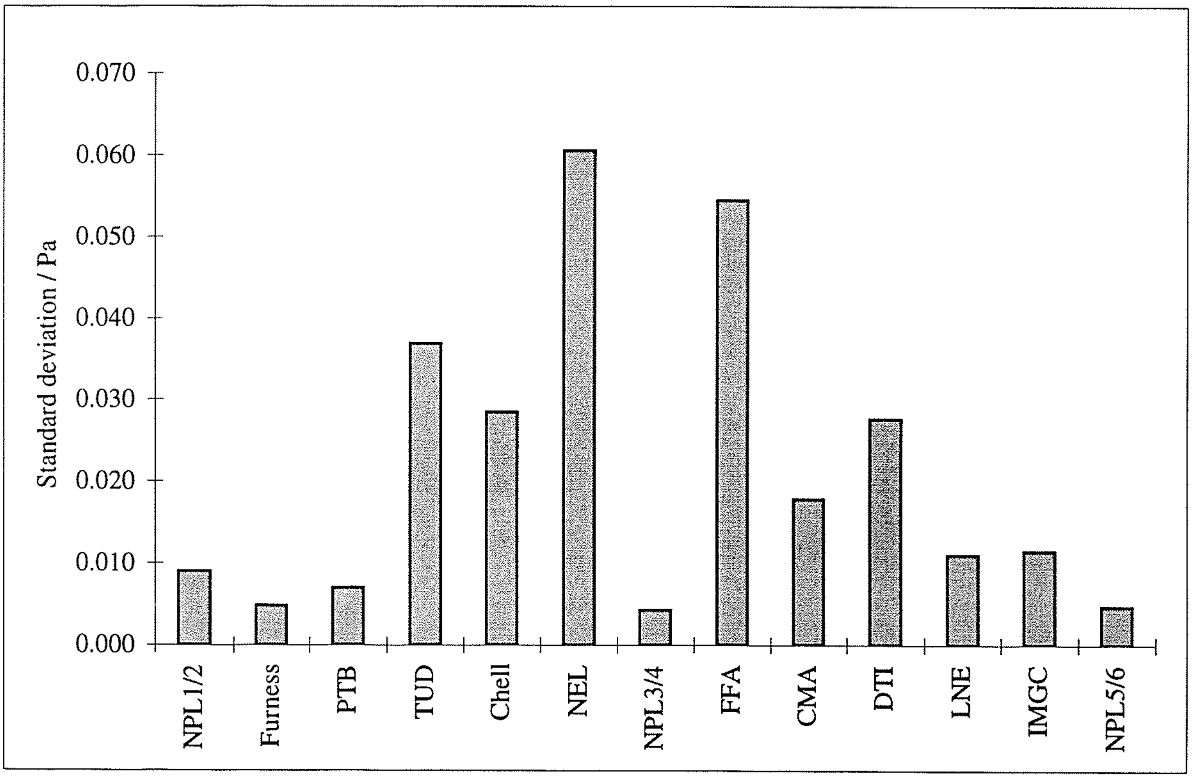

Figure 32 Standard deviation of all corrections obtained by each participant at 10 Pa

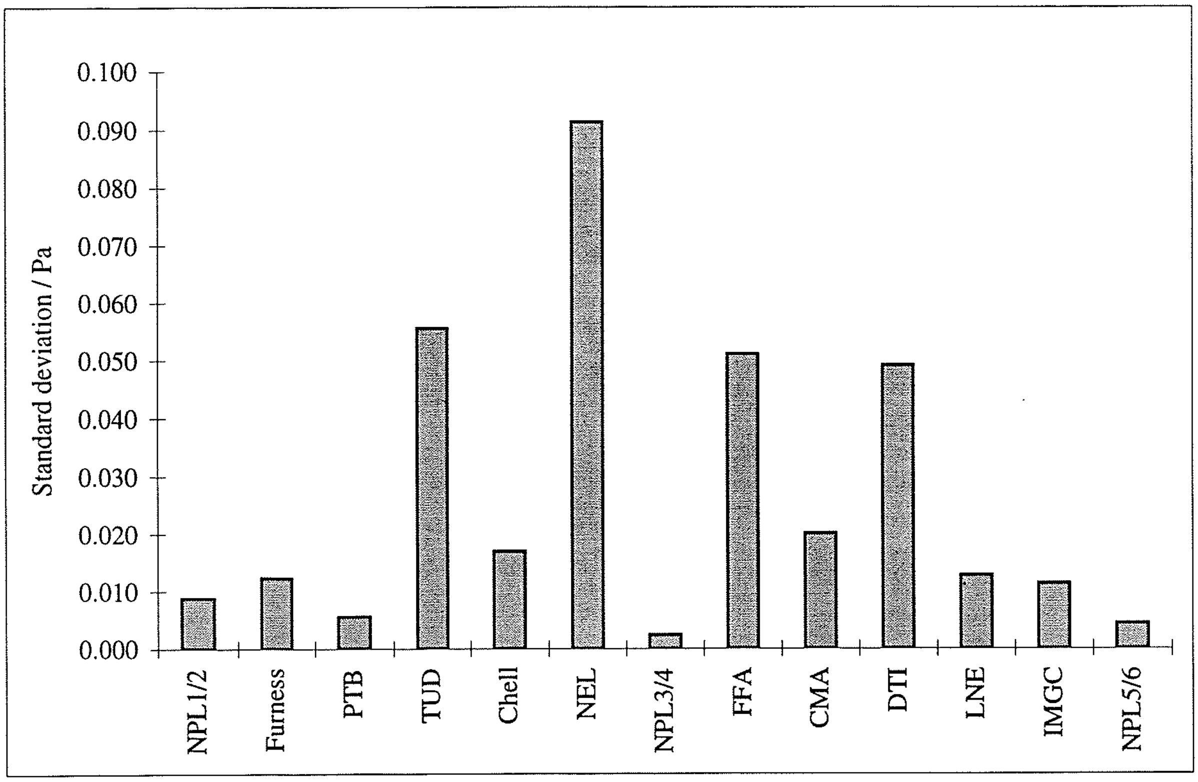

Figure 33 Standard deviation of all corrections obtained by each participant at 30 Pa

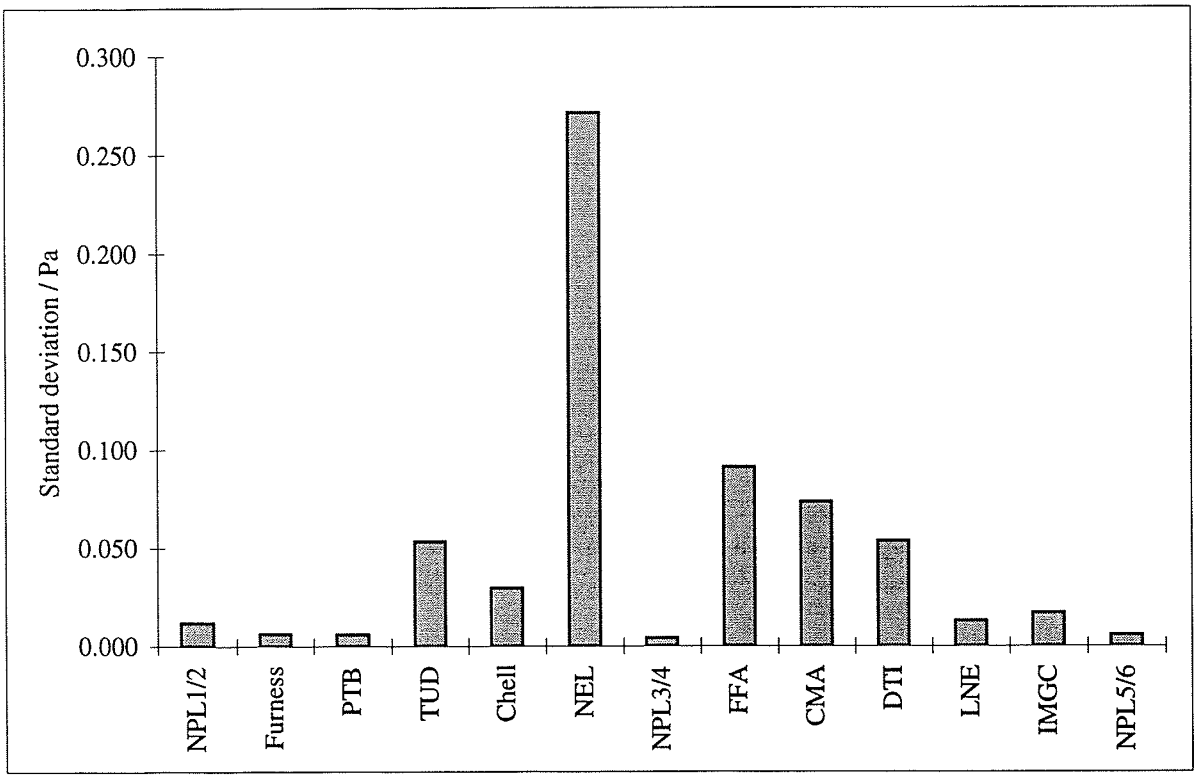

Figure 34 Standard deviation of all corrections obtained by each participant at 100 Pa

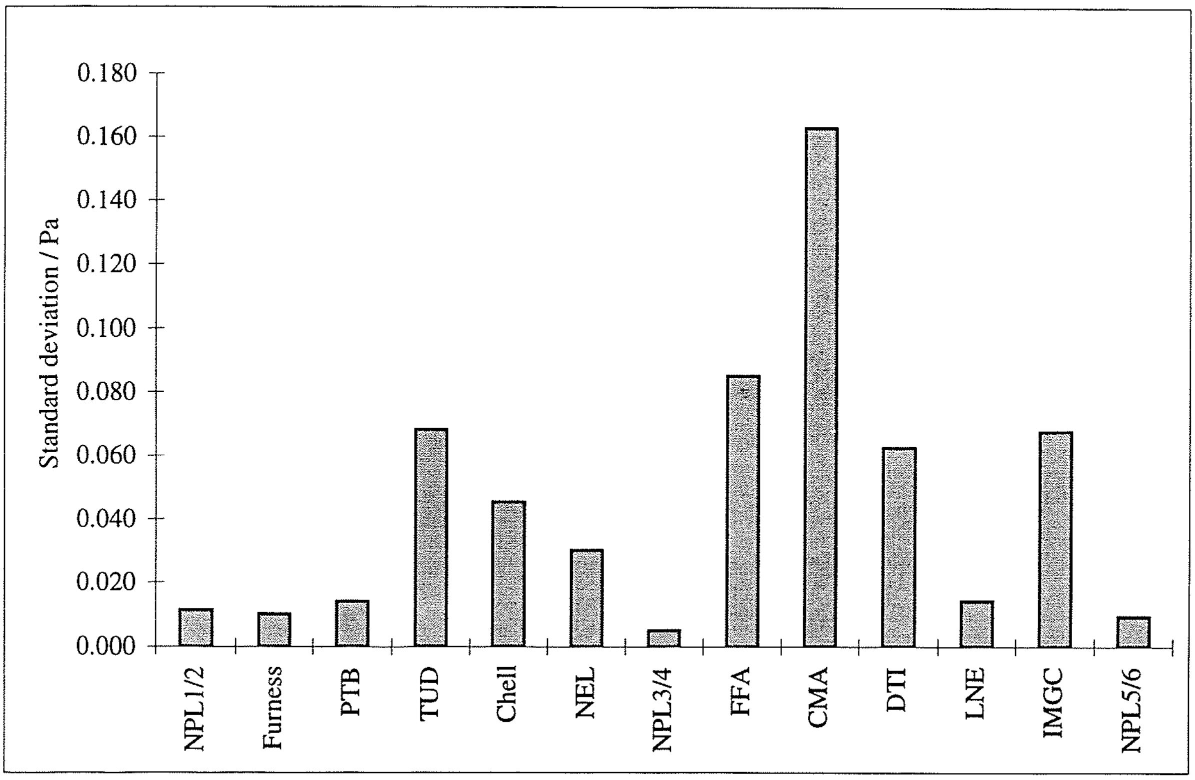

Figure 35 Standard deviation of all corrections obtained by each participant at 300 Pa

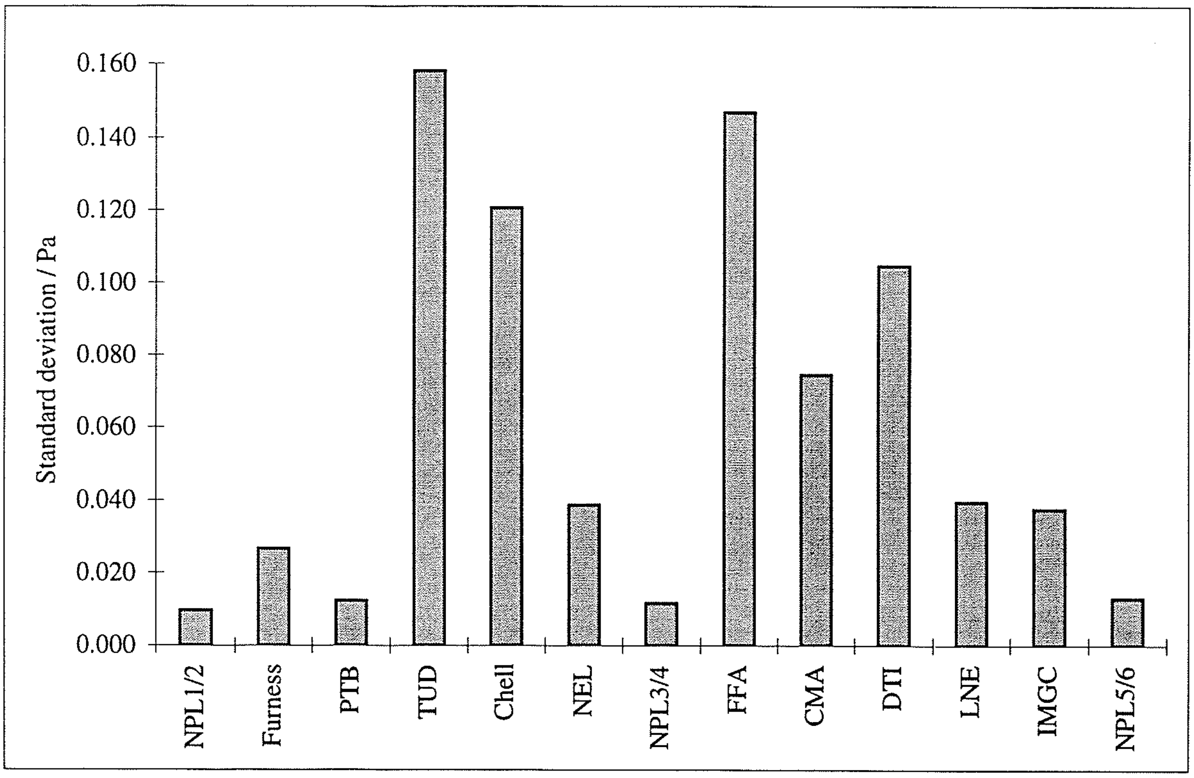

Figure 36 Standard deviation of all corrections obtained by each participant at 1000 Pa

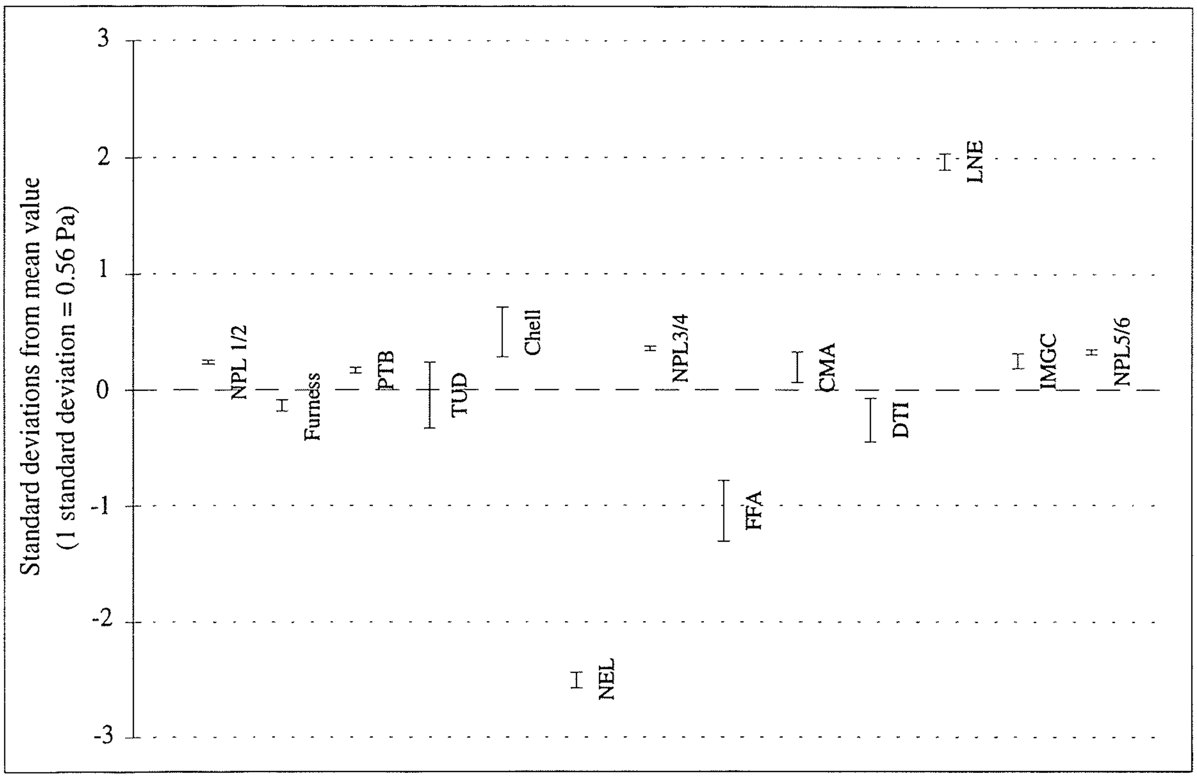

Figure 37 Mean correction and standard deviation from all data obtained by each participant at 1000 Pa: all participants

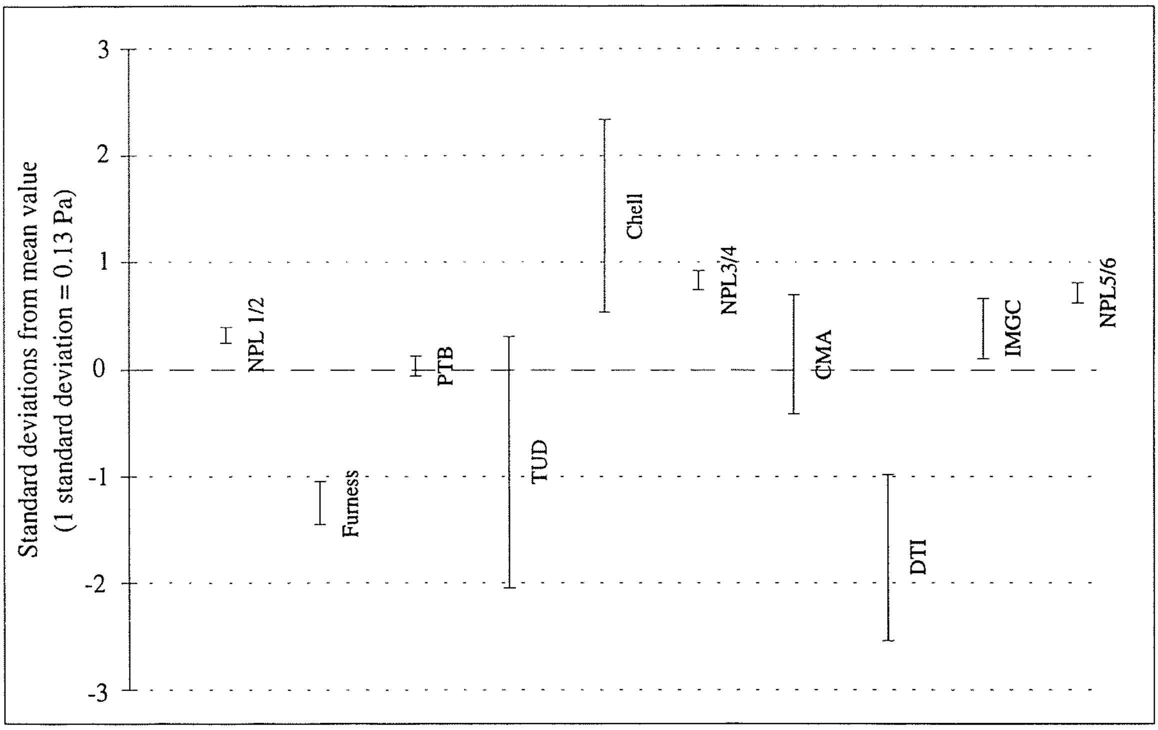

Figure 38 As Figure 37 but excluding NEL, LNE and FFA data