Calibrating measurement gauges – expense and findings

Dipl.-Ing. Paul Simons[1], Dipl.-Ing. Stefanie Rolfsmeier[2],
Dipl.-Phys. Francisco Pujiula[3]

1, 2, 3 BlowerDoor GmbH
Zum Energie- und Umweltzentrum 1
31832 Springe, Germany
info@blowerdoor.de

KEYWORDS

Minneapolis BlowerDoor; calibration; gauge; accuracy; traceability to national standards

ABSTRACT

This presentation will explain what exactly calibration should mean. It will also look into the hierarchy of and the differences between the calibration labs of national standards, accredited labs (like DAkkS, a national government-appointed accreditation body in Germany, or Cofrac – Comité français d'accréditation – in France), and manufacturer's calibration labs. Even the labs themselves must have their own measuring devices checked in order to guarantee what is known as traceability to national standards, and to determine the measurement uncertainty of their testing devices. This is necessary if you want to make a clear statement on adherence to the accuracy, which is known as a statement of compliance or declaration of conformity. Another topic covers the measuring range and the accuracy of pressure gauges and measuring fans, as well as their calibration process, by looking at the example of the Minneapolis BlowerDoor.

INTRODUCTION

In order to achieve the most precise, reproducible and therefore comparable measurement results possible when measuring the airtightness of buildings, gauges are required that can measure flow rates and building pressure differentials with a defined level of precision. The user can check the gauges' accuracy in calibration labs. But what exactly does calibration mean, how precise are the gauges, what level of quality can be expected from a calibration certificate, and are there differences between the calibration labs? These questions will be addressed below and illustrated using a Minneapolis BlowerDoor.

ACCURACY

Every gauge is assigned an accuracy level by the manufacturer. With this information, the user can estimate the extent to which the measured value shown (calculated) may deviate from the real value to be measured. If, for example, a thermometer with an accuracy level of ±2°C shows a reading of 21°C, the real temperature can fall within 19°C to 23°C. The more accurate it is, the closer the reading will reflect the actual value.

CALIBRATION

Calibration simply refers to comparing the readings of a device to be calibrated (DG-700) with those of a reference standard. The calibration laboratory records the readings of both the device and the reference standard (see Figure 2) and calculates the deviations (absolute and/or in percent). The customer can then compare these with the specifications of their gauge in order to judge its effectiveness. The calibration shows the accuracy of the calibrated device at the time of calibration; it is a snapshot in time and does not provide information on the device's long-term stability.

In the following example (Figure 1), the reference standard shows a measurement of 12 Pa while the device being tested shows 13 Pa. The deviation between device and reference is +1 Pa. The device's accuracy (for example, as provided by the manufacturer) is given as ±4 Pa. The deviation is therefore within the specification of the range between -4 Pa and +4 Pa. The device fulfills its requirements in this aspect.

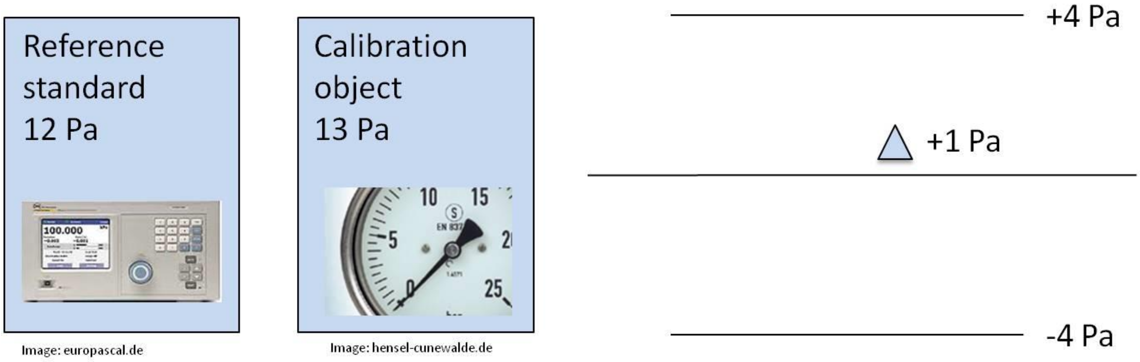


Figure 1: Measurements displayed by reference standard and by calibrated device, showing a deviation that lies within specifications.

Standard		Channel A		% Difference
9,9	Pa	9,9	Pa	0,0%
25,7		25,7		0,0%
40,5		40,5		0,0%
50,0		50,0		0,0%
64,2		64,2		0,0%
91,6		91,6		0,0%

Figure 2: Excerpt from calibration log with measurements from reference standard (here referred to as "Standard") and from calibrated device (here referred to as "DG-700 Channel A") and the deviation in percent.

In Figure 3, the calibrated device shows a measurement of 6 Pa, significantly lower than the reference standard of 12 Pa. The deviation amounts to -6 Pa and is therefore outside the specification of ±4. The specs are not met.

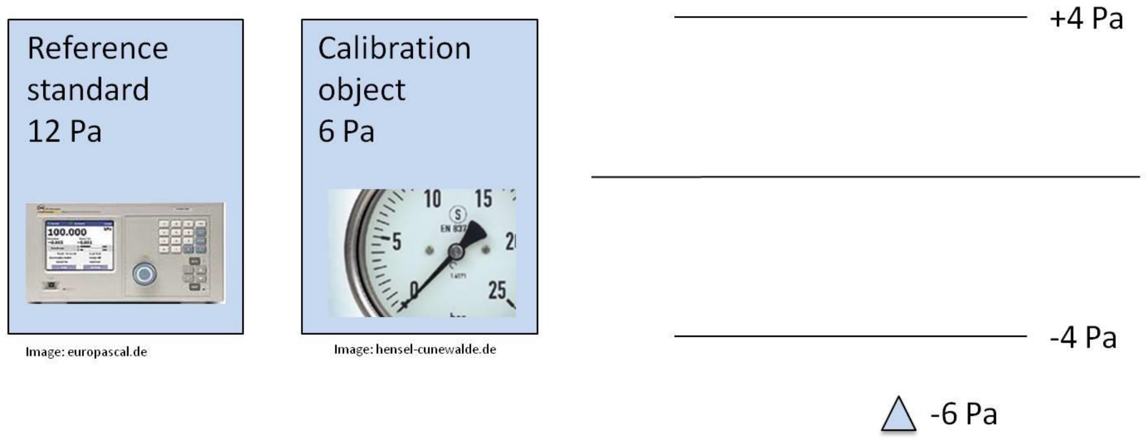


Figure 3: Measurements displayed by reference standard and by calibrated device, showing a deviation that lies outside of specifications.

The only way to achieve information on how the device performs over time is to perform repeated calibrations at certain intervals: the calibration intervals.

CALIBRATION INTERVALS

The user is responsible for regular calibration. Recommendations for calibration intervals are provided, for example, by manufacturers or can be found in standards or regulations. In the field of airtightness measurements, calibration intervals for gauges are provided in the standard DIN EN 13829 and the corresponding supplementary sheet from FLiB e. V. (Professional Association of Airtightness in Architecture) for Germany or the governmental ordinance GA P50-784_V2014 for France.

EVALUATING REFERENCES AND MEASUREMENT RESULTS

The calibration laboratories themselves also have their own reference standards regularly calibrated in order to identify any measurement uncertainty. This is necessary to be able to determine the accuracy of the calibration. This is also necessary for laboratories to be able to provide a declaration of conformity on compliance with accuracy as stipulated by, for example, regulations such as DIN EN 13829.

Inaccuracies in the reference standard influence measurement uncertainty, as do additional factors that can affect measurement results, such as the accuracy of temperature measurements and the long-term stability of the reference standard. When several years of observation demonstrate that the reference is reliably accurate, measurement uncertainty decreases.

The following figure/example shows a +1 deviation between the calibrated device and the measurement standard. The measurement uncertainty of this measurement is displayed as an error bar in the diagram. In DAkkS calibration logs, this area is provided – as agreed upon – in such a manner that the measurement value lies within the bar with a probability of 95%.

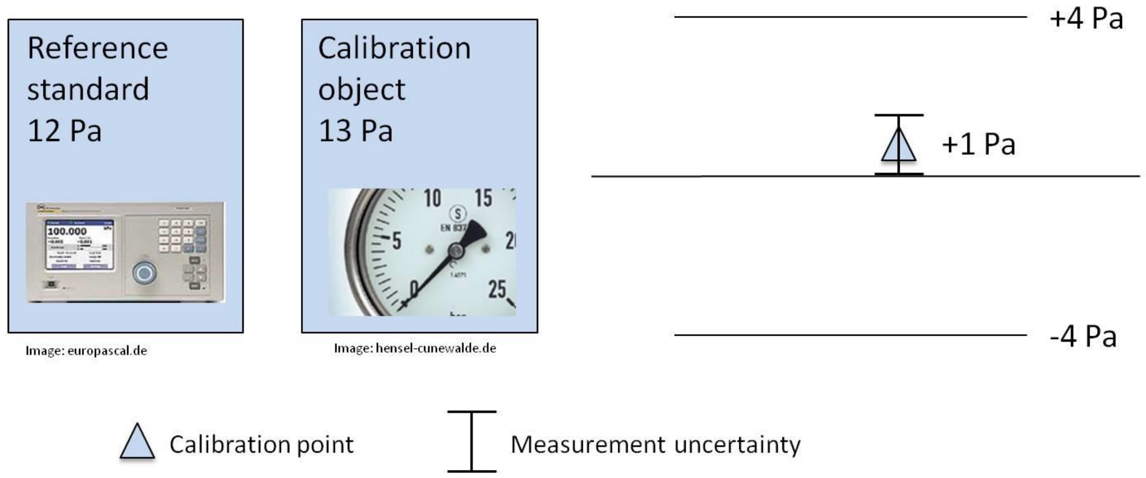


Figure 4

Measurement uncertainty can vary widely according to the reference standard used by the calibration laboratory. If it is clear that the reading provided by the reference standard lies within the determined tolerance zone, then both the difference and the sum of the reading and the measurement uncertainty must also lie within the specification limits applied. Specifications can be determined on the customer end, either taken directly from the manufacturer or from a standard, from national regulations, etc.

When all calibration points, including their measurement uncertainty levels, lie within specifications, conformity can be declared with, for example, corresponding norms or national regulations. Should these measurements, including their measurement uncertainty levels, lie outside error margins, then conformity cannot be declared.

In the following example (Figure 5), the calibrated device’s same deviation of +1 Pa can be seen. For the reference standard (left) with the low measurement uncertainty, conformity can be declared within the error margins. In the second case (right), the inaccuracy of the reference standard is so great that the error bar ends outside the error margins. Here, conformity cannot be confirmed.

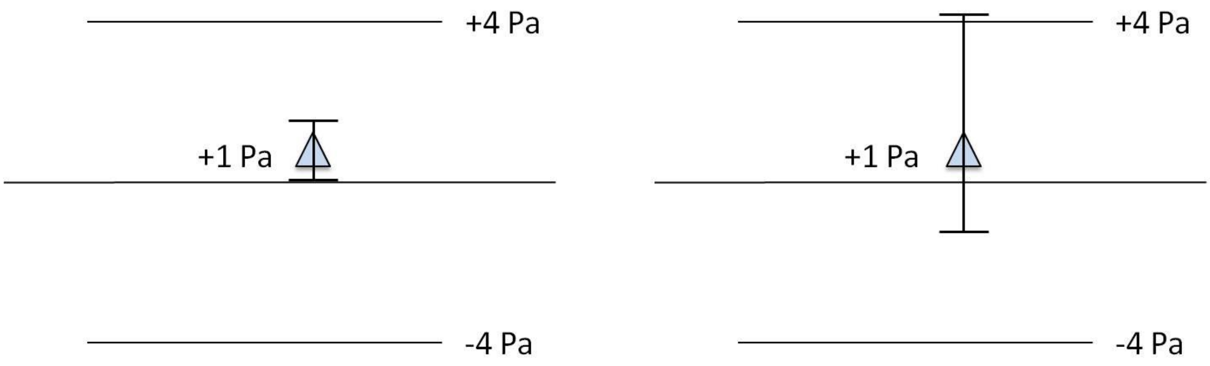


Figure 5: Relationship between measurements (deviation), measurement uncertainty and specification.

TRACEABILITY TO NATIONAL STANDARDS

A basic requirement for ensuring comparability in BlowerDoor measurements is that the gauges are calibrated on a uniform basis. This uniform basis is provided by the respective national standards. In Germany, this is the National Metrology Institute of Germany, or

Physikalisch-Technische Bundesanstalt (PTB); in France, it is the National Laboratory of Metrology and Testing, or Laboratoire national de métrologie et d'essais (LNE); and in the United States, it is the National Institute of Standards and Technology (NIST). The PTB is at the tip of the calibration chain in Germany, followed by accredited laboratories and finally labs for in-house calibrations.

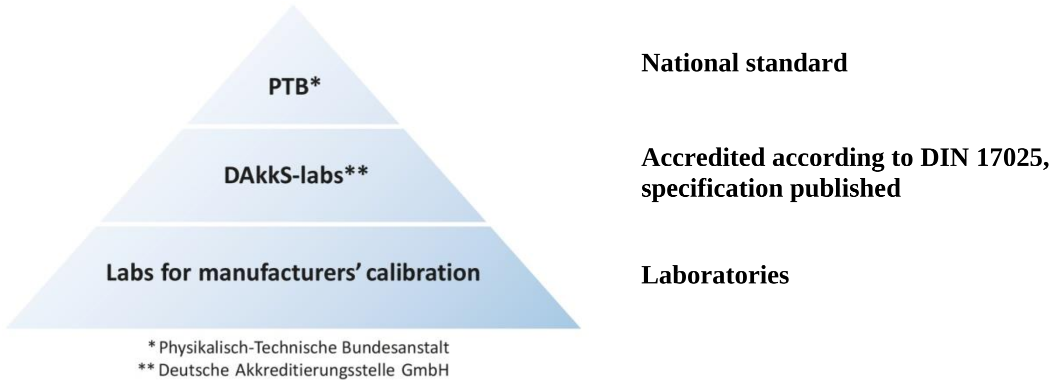


Figure 6: The hierarchy of calibration laboratories

Error analysis for the reference standard contains the calibration chain up to the national standard. The shorter the chain between the reference standard and the national standard, the more accurate the reference is.

In terms of maintaining their reference standards, calibration processes and internal organization, DAkkS labs are accredited according to DIN EN 17025. These laboratories are inspected regularly through an internal audit and by Germany's national accreditation body, Deutsche Akkreditierungsstelle GmbH (DAkkS). DAkkS determines the smallest measurement uncertainty that the laboratory is to claim. This enables customers to compare laboratories with the same measurement areas in terms of their performance. DAkkS calibrations can be most quickly and easily identified by the DAkkS logo on the calibration log.

Permanent laboratory

Measurement/ calibration object	Measurement range	Measurement conditions/process	Smallest measurement uncertainty possible [1)]	Notes
Pressure Positive and negative overpressure p_e	-2500 Pa to 2500 Pa	DKD-R 6-1: 2014 EURAMET cg-17 Version 2.0	$1{,}0 \cdot 10^{-4} \cdot p_e + 0{,}37$ Pa	Pressurizing medium: gaz

Figure 7: Specifications for the DAkkS-accredited laboratory of BlowerDoor GmbH

In-house calibration laboratories are not accredited and can work according to their own rules. The quality of the work performed by in-house calibration labs can certainly be very high.

CALIBRATION OF AIRTIGHTNESS GAUGES

For the field of airtightness measurement, the European Standard EN 13829 – which determines the air tightness of buildings – also requires regular calibration of gauges in addition to setting down requirements for their accuracy.

ACCURACY REQUIREMENTS AND CALIBRATION INTERVALS

DIN EN 13829-2000 requires the following accuracy levels for gauges:

- Pressure gauges for measuring building pressure differential of 0 to 60 Pa: ±2 Pa
- Flow rate meter (device for measuring air flow volume): ±7 % of measurement value
- Thermometer: ±1 K

Calibration should be performed regularly in accordance with manufacturers' recommendations or a standardized quality control system.

REQUIREMENTS IN GERMANY

In Germany, the Fachverband Luftdichtheit im Bauwesen, or FLiB e.V., is a professional body for airtightness in buildings that has provided additional information on calibration in a supplementary sheet to DIN EN 13829 from 2008 (a new edition is planned for 2015). According to this, inspection/calibration should take place every two years for pressure gauges and every four years for flow rate meters. Details on the form a meaningful inspection should take are not provided. A function check (to determine if, for example, a pressure gauge is defective) can be performed through comparison with the readings of a similar device. A rough estimation of flow rate can, for example, be conducted using an aperture plate. These measures do not replace a calibration, however.

REQUIREMENTS IN FRANCE

In addition to EN 13829, France has the regulation GAP50-784. This prescribes the following calibration rules:

- Pressure gauges for measuring building pressure differential of 0 to ±100 Pa: ±1 Pa or 1% of reading
- Gauge for determining flow rate from a pressure differential: ±1 Pa or 1% of reading
- Bellows gauge with three measuring points per configuration (plate): ±2 m³ or 5% of reading

The calibration interval for the pressure gauges is one year, and two years for the bellows gauge.

CALIBRATION BASICS FOR MINNEAPOLIS BLOWERDOOR INSTRUMENTS: PROCESS AND PHILOSOPHY

With the Minneapolis BlowerDoor measuring system, the bellows gauge and the pressure differential gauge are calibrated separately. The error level can be calculated using the accuracy of the pressure differential gauge and the bellows gauge along with the law of error propagation. The measuring system's philosophy is that the bellows gauge, the pressure differential gauge and the software can all be exchanged and combined as desired. This makes the system very flexible to use and reduces transfer errors. Components can be individually switched out as needed.

Calibration of the bellows gauge is conducted using the standard calibration parameters for every configuration (orifice plate). A change in the calibration parameters is not intended by the manufacturer, even if it would be possible for relatively extensive calibration work. If calibration shows that the bellows gauge's standard values are outside the accuracy levels stated by the manufacturer, then it is usually sufficient to undertake repairs followed by another calibration. The calibration of the pressure differential gauge takes place over the device's entire positive and negative measuring range.

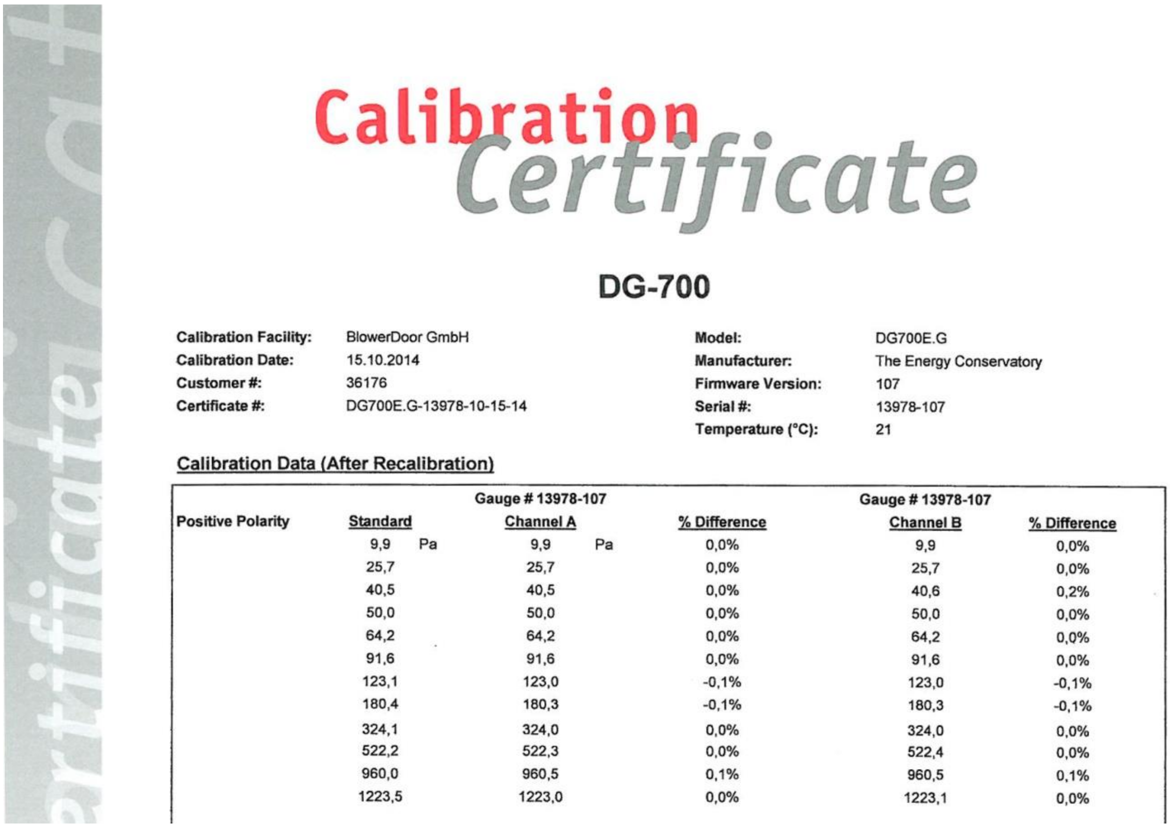
ACCURACY OF THE MINNEAPOLIS BLOWERDOOR

Afterwards, the measuring range and accuracy of pressure gauges and bellows gauges are presented, along with their calibration processes.

IN-HOUSE CALIBRATION OF PRESSURE GAUGES AT BLOWERDOOR GMBH

The pressure differential gauge DG-700 with two differential pressure channels are calibrated using a reference standard that reflects the national standard. In addition to its own calibration, the device undergoes the following standard process:

1. Update of firmware, if necessary.
2. Function check of device to be calibrated before calibration (inspection of buttons, activation of bellows gauge, etc.).
3. Initial calibration of device with documentation of reference standard and device measurements as well as current deviations. 12 measuring points are recorded each for both the positive and the negative ranges.
4. Adjustment of device being calibrated in order to achieve maximum accuracy.
5. End calibration after adjustment with documentation of reference standard and device measurements as well as new deviations. 12 measuring points are recorded each for both the positive and the negative ranges.



Calibration Certificate

DG-700

Calibration Facility:	BlowerDoor GmbH	Model:	DG700E.G
Calibration Date:	15.10.2014	Manufacturer:	The Energy Conservatory
Customer #:	36176	Firmware Version:	107
Certificate #:	DG700E.G-13978-10-15-14	Serial #:	13978-107
		Temperature (°C):	21

Calibration Data (After Recalibration)

		Gauge # 13978-107		Gauge # 13978-107	
Positive Polarity	Standard	Channel A	% Difference	Channel B	% Difference
	9,9 Pa	9,9 Pa	0,0%	9,9	0,0%
	25,7	25,7	0,0%	25,7	0,0%
	40,5	40,5	0,0%	40,6	0,2%
	50,0	50,0	0,0%	50,0	0,0%
	64,2	64,2	0,0%	64,2	0,0%
	91,6	91,6	0,0%	91,6	0,0%
	123,1	123,0	-0,1%	123,0	-0,1%
	180,4	180,3	-0,1%	180,3	-0,1%
	324,1	324,0	0,0%	324,0	0,0%
	522,2	522,3	0,0%	522,4	0,0%
	960,0	960,5	0,1%	960,5	0,1%
	1223,5	1223,0	0,0%	1223,1	0,0%

Figure 8: Excerpt from in-house calibration log for DG-700

DAKKS CALIBRATION OF PRESSURE GAUGES FROM BLOWERDOOR GMBH LABORATORY

For calibrations in a DAkkS-accredited laboratory, at least 9 points are calibrated in the range from -1250 to +1250 Pa, and the calibration cycle is repeated four times. If it is necessary to adjust the gauge, this should be done before the calibration. The example below (Figure 9) shows a DAkkS calibration log for the pressure differential gauge DG-700. M1 to M4 show the results of the calibration cycles.

Pressure at reference level UUT p_{Normal}	Reading UUT $p_{Display (Output)}$				Average M_{iw} = (M1+M2+M3+M4)/4	Deviation Δp $M_{iw} - p_e$	Repeatability b'_{mittel} = max(b'_{auf}, b'_{ab})	Hysteresis (|(M2-M10)-(M1-M10)|+|(M4-M30)-(M3-M30)|)/2	Extended uncertainty U
	M1	M2	M3	M4					
Pa	Pa	Pa	Pa	Pa	Pa	Pa	Pa	Pa	Pa
-1200,245	-1200,27	-1200,35	-1200,32	-1200,44	-1200,35	-0,10	0,14	0,06	0,68
-960,152	-960,94	-961,01	-961,02	-961,10	-961,02	-0,87	0,11	0,08	0,66
-720,078	-720,87	-720,96	-720,98	-721,05	-720,96	-0,89	0,08	0,08	0,64
-480,018	-480,42	-480,55	-480,57	-480,62	-480,54	-0,52	0,05	0,07	0,61
-239,979	-240,03	-240,18	-240,20	-240,28	-240,17	-0,19	0,02	0,04	0,59
0,000	-0,22	-0,36	-0,41	-0,48	-0,37	-0,37	0,00	0,05	0,57
240,099	239,78	239,64	239,57	239,51	239,63	-0,47	-0,01	0,06	0,59
480,119	479,89	479,77	479,67	479,62	479,74	-0,38	-0,03	0,07	0,61
720,130	719,94	719,84	719,70	719,65	719,78	-0,35	-0,05	0,08	0,63
960,134	959,82	959,75	959,55	959,52	959,66	-0,47	-0,08	0,11	0,66
1200,132	1199,50	1199,45	1199,20	1199,15	1199,33	-0,81	-0,11	0,11	0,68

Figure 9: Excerpt from a DAkkS calibration log for a pressure differential gauge DG-700.

The diagram below (Figure 10) illustrates the calibration results in graph form.

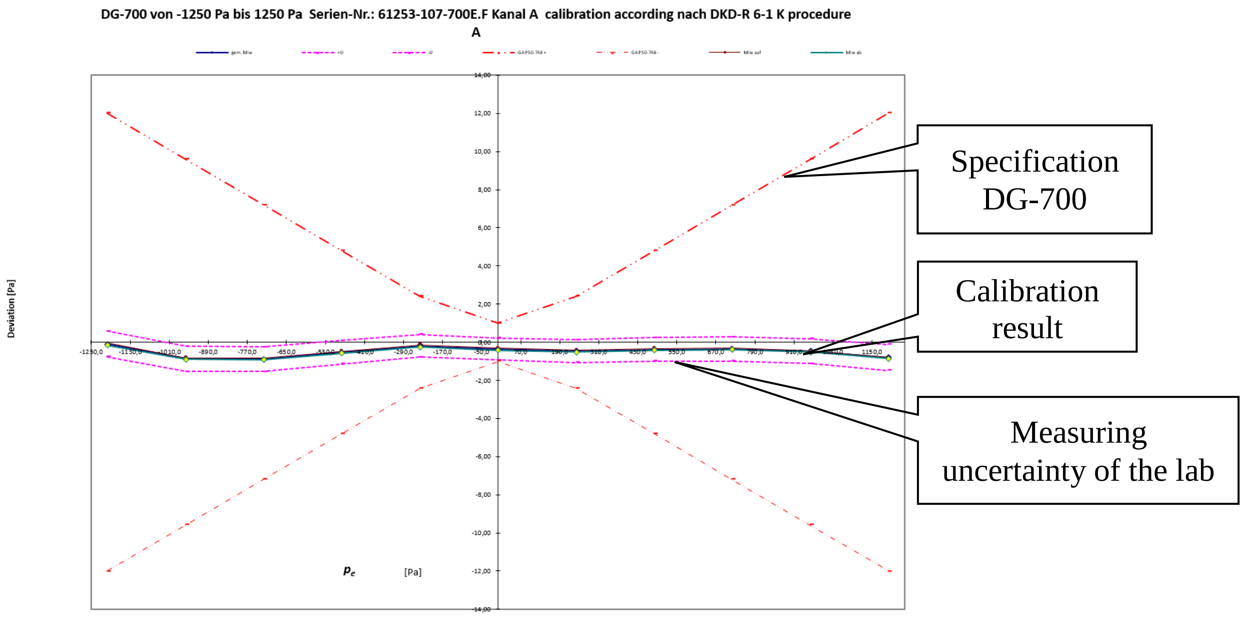


Figure 10: Results curve for the calibration in Figure 9.

The example log shows that the calibrated DG-700 is significantly more accurate than stated in the manufacturer's specification.

IN-HOUSE CALIBRATION OF BELLOWS GAUGES AT BLOWERDOOR GMBH

The calibration of a bellows gauge is presented using a Minneapolis BlowerDoor bellows model 4.1. The bellows gauge is calibrated with three measurement points for each of the six configurations (open bellows, plus five plates with various aperture sizes). The calibration points are found in the smallest, middle, and highest measurement ranges of each plate. That makes 18 total points per bellows. 50 Pascal is selected for the counterpressure (comparable with the building pressure during an airtightness measurement). For calibrations in France, 30 Pascal is the counterpressure setting.

Figure 11: Calibration station for measuring flow rates with a BlowerDoor bellows gauge.

Figure 12 shows the manufacturer's statement on measurement plate accuracy as a red line. The deviations from the calibration are visible as blue dots and the measurement uncertainty of the calibration station appears as an error bar.

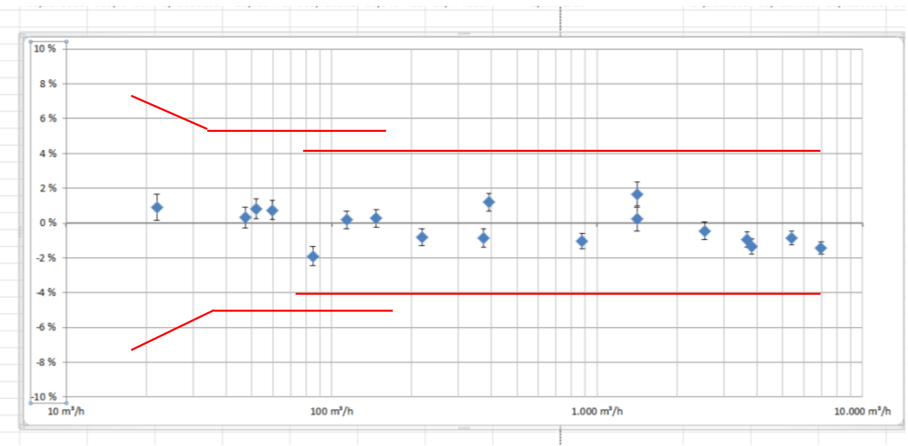


Figure 12: Calibration points of a bellows gauge [ ] with the measurement uncertainty of the chamber [ ] and the manufacturer's specifications [ ].

All measuring points, including measurement uncertainty of the testing chamber, are within specifications.

Calibration Certificate

page 2/2

Calibration parameters of fan

CE 3432	Offen	A	B	C	D	E
C	745,4	273,2	81,69	19,3	12,31	4,761
n	0,4848	0,4952	0,4968	0,5157	0,5032	0,5166

Measuring results

Ring	Chamber back pressure	Reference flow at ρ (UUT)	Fan flow	Deviation	Deviation	Uncertainty of meas. k=2
	Pa	m³/h	m³/h	m³/h	%	m³/h
Offen	49,5	7075,4	7013,2	-62,2	-0,89	± 25,6
Offen	49,9	5462,0	5313,9	-148,1	-2,79	± 21,1
Offen	50,1	3866,6	3798,3	-68,3	-1,80	± 16,6
A	49,6	3703,5	3650,2	-53,3	-1,46	± 16,2
A	49,8	2538,0	2507,2	-30,8	-1,23	± 12,9

Measurement uncertainty calculated according to GUM with a coverage factor k=2 and incudes the uncertainty of the process as well as of the device being tested (calibration object).

Figure 13: Excerpt from calibration log; here, 4 of 18 calibration points are pictured

Results - Declaration of conformity

	Offen	A	B	C	D	E
According to specification of manufacturer	X	X	X	X	X	X
Not according to specification of manufacturer						

Accuracy specification of manufacturer

Rings: Offen, A, B, C ± 4 % of reading

Rings: D, E ± 5 % of reading, but at least ± 1,7 m³/h

Figure 14: Example of a declaration of conformity for the bellows gauge

CONCLUSION

In order to achieve comparable results with airtightness measurements, gauges must be used that work within specific accuracy parameters. The user is responsible for ensuring that the devices fulfill the required accuracy specifications.