Guideline

DKD-R 6-1

Edition 03/2014

Calibration of Pressure Gauges

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"I AM NIMT"

สถาบันมาตรวิทยาแห่งชาติ

National Institute of Metrology (Thailand)

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ความแตกต่างของ DKD-R 6-1 ระหว่าง Version 2003 และ 2014

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Symbols and designations

2003

M1 ... M6	Measurement series
max. load	Highest value (of calibration range)
Y	Output quantity
X	Value-determining input quantity
δX	Unknown measurement deviation
K	Correction factor

2014

M1 ... M6	Measurement series
EW	Highest value (of the calibration range)
Y	Output quantity of the model of measurement [VIM 2.51]
X	Input quantity of the model of measurement [VIM 2.50]
δX	Influence quantity [VIM 2.52]
K	Correction factor

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2003

x	Estimate of input quantity
y	Estimate of output quantity
c	Sensitivity coefficient
k	Expansion factor
a	Half-width of a distribution
P	Probability

2014

x	Best estimate of the input quantity
y	Best estimate of the output quantity
c	Sensitivity coefficient
k	Expansion factor [VIM 2.38]
a	Half-width of a distribution
$g_{X_i}(\xi_i)$	Probability

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2003

δp	Unknown measurement deviation of the quantity of pressure
S	Transmission coefficient (of pressure transducer)
ΔS	Systematic deviation of transmission coefficient from single-number rating ($\Delta S = S - S^{*}$)
V	Voltage
G	Amplification factor
h	Difference of pressure reference levels of reference instrument and the instrument tobe calibrated

* ซ้ำกับ hysteresis

2014

δp	Influence quantity in the dimension of pressure
S	Transmission coefficient (of the pressure transducer)
ΔS	Systematic deviation of the transmission coefficient from the single-figure indication
$U....$	Voltage with different indices (Sections 8.5.1 and 8.5.2)
G	Amplification factor
Δh	Height difference between the reference planes

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Indices

2003

Supply	Supply voltage
j	Number of measurement point
m	Number of measurement series
n	Number of measurement cycles
ref	Reference conditions
cond. of use	Conditions of use

2014

Sp	Supply voltage
j	Number of the measurement point
m	Number of the measurement series
n	Number of measurement cycles
Std	Standard conditions
appl	Conditions of use

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2003

3. Reference and working standards

...

The reference standards used are pressure gauges of long-time stability such as pressure balances and liquid-level manometers. They are calibrated **at the PTB** at regular intervals and a calibration certificate is issued for them stating the expanded uncertainty under reference conditions (standard acceleration due to gravity, 20°C).

2014

3. Reference and working standards

...

The reference standards used are pressure gauges of long-time stability as, for example, pressure balances and liquid-level manometers**, or less long-term stable electrical pressure gauges (see Annex F, p.49).** They are calibrated at regular intervals and provided with a calibration certificate stating the expanded measurement uncertainty under standard conditions (among other things, standard or local acceleration due to gravity, 20°C, 1 bar). **The reference standard is subject to surveillance and documentation by the accreditation body.**

2003

When a calibration is carried out outside the reference conditions, corrections are to be applied to the pressure calculation. The measurement uncertainties to be attributed to these corrections due to influence quantities are to be taken into account as further contributions in the uncertainty budget.

2014

If the calibration does not take place under standard conditions, corrections are to be applied to the pressure calculation. The measurement uncertainties to be attributed to these corrections due to influence quantities are to be taken into account as further contributions in the uncertainty budget.

★★★ **When calculating the measurement uncertainty of the standards used, all relevant influence quantities are to be taken into account. In case of indicating pressure gauges that are used as standards, the resolution has to be considered a second time when calculating the measurement uncertainty.**

2003

The working standards documented in the quality manual of the **DKD** laboratory are calibrated in an accredited laboratory and a calibration certificate is issued for them stating the expanded uncertainty under reference conditions. The working standard is subject to approval by the **PTB**. The working standards can be different as regards their type.

2014

The working standards documented in the quality manual of the laboratory are calibrated in an accredited laboratory and provided with a calibration certificate stating the expanded uncertainty at the time of calibration. The working standard is subject to surveillance by the **accreditation body**. Depending on their type, the working standards may vary considerably.

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2003

5. Calibratability

…

Note:

If repair or adjustment work has to be carried out to ensure calibratability, this work has to be agreed upon between customer and calibration laboratory.

2014

5. Calibration capability

…

Note:

If repair work or adjustments are required to ensure the calibration capability, this work has to be agreed upon between customer and calibration laboratory. **Relevant device parameters are to be documented, as far as possible, before and after the adjustments.**

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2003

6. Ambient conditions

The calibration is to be carried out after temperature equalization between calibration item and environment. A period for warming up the calibration item or potential warming-up of the calibration item due to the supply voltage is to be taken into account.

2014

★★★

6. Ambient conditions

The calibration is to be carried out after a temperature equalisation between calibration item and environment **within the permissible temperature range (18 °C to 28 °C).** A warm-up time of the calibration item or a possible warming of the calibration item by the supply voltage must be considered. **The warm-up period depends on personal experience or specifications provided by the manufacturer.**

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2003

6. Ambient conditions (cont.)

…

The calibration is to be performed at an ambient temperature stable to within ±1 K; this temperature must lie between 18°C and 28°C and is to be recorded.

2014

6. Ambient conditions (cont.)

…

The calibration is to be carried out at a steady ambient temperature. The recommended temperature variation during calibration is limited to ±1 K. **It might be necessary to consider an additional uncertainty contribution when exploiting the maximum tolerance limits**; this temperature must lie between 18 °C and 28 °C and has to be recorded.

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2003

6. Ambient conditions (cont.)

…

Note:

If the air density has an effect on the calibration result, not only the ambient temperature but also the atmospheric pressure and the relative humidity are to be recorded.

2014

6. Ambient conditions (cont.)

…

Note:

When using piston pressure gauges (pressure balances), the air density may have a significant impact on the calibration result (air buoyancy mass and hydrostatic pressure); therefore, apart from the ambient temperature, also the atmospheric pressure and the relative humidity must be recorded and taken into account. This information must be stated in the calibration certificate (see DAkkS-DKD 5).

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2003

7. Calibration methods

…

- If the behavior of the calibration item as regards the influence of the torque during mounting is not sufficiently known, the calibration item has to be clamped once again to determine the reproducibility. In this case, the torque is to be measured and documented.

2014

7. Calibration methods

…

- If the calibration item's behavior regarding the influence of the torque is not sufficiently known during mounting, the reproducibility must be determined by an additional clamping. In this case, the value of the torque is to be documented.

- The difference in altitude between the reference altitudes of the standard and the calibration item is to be minimized or the correction is to be calculated.

2003

7. Calibration methods (cont.)

Note:

For the calibration of items with a range of measurement greater than 2500 bar, calibration sequence A is in principle to be used. If clamping effects are observed, the calibration is to be repeated clamping the calibration item anew.

2014

7. Calibration methods (cont.)

Note:

The calibration of items with a measurement range greater than 2500 bar basically requires the application of calibration sequence A. If clamping effects are observed, the calibration is to be repeated with a second clamping. **Calibration items that are calibrated with positive and negative gauge pressure should at least be calibrated at two points in the negative range (e.g. at -1 bar and -0.5 bar); the remaining measurement points should be calibrated in the positive range.**

If several references are required to carry out a calibration, the pressure at the calibration item must be kept constant when changing the reference. If this is not practicable (e.g. change of the mounting position, second clamping), a complete new calibration sequence has to be carried out.

8. Measurement uncertainty

2003

8.2.3 Product/quotient model

$$Y = X \cdot \prod_{i=1}^{N} K_i$$

Y	output quantity
X	value-determining input quantity/quantities
$K_i = (1 + \delta X_i)$	correction factor(s)
δX_i	unknown deviation(s)

2014

8.2.3 Product/quotient model

$$Y = X \cdot \prod_{i=1}^{N} K_i$$

Y	Output quantity
X	Input quantity (quantities)
$K_i = \left(1 + \frac{\delta X_i}{\lvert X_i \rvert}\right)$	Correction factor(s)
δX_i	Influence quantity (quantities)

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2003

8.2.5 Potential influence quantities, example

…

Note:

The measurement uncertainties which are attributed to the values of the standard, the adapter and the output unit are taken from calibration certificates (generally normally distributed, $k = 2$).

2014

8.2.5 Potential influence quantities, example

…

Note:

The measurement uncertainties which are attributed to the values of the standard, the adapter and the output unit are taken from calibration certificates (generally normally distributed, $k = 2$). **When using electrical pressure gauges, their long-term stability, resolution and temperature dependence are to be assessed as a contribution to the measurement uncertainty and, if necessary, must be taken into account.**

2003

8.6.2 Zero deviation f_0

The zero point can be set prior to every measurement cycle consisting of an increasing and a decreasing series and must be recorded prior to and after every measurement cycle. The reading is to be made with the instrument being completely relieved.

2014

8.6.2 Zero deviation f_0

The zero point (unloaded pressure gauge usually at atmospheric pressure) can be set prior to each measurement cycle consisting of an increasing and a decreasing series; it has to be recorded prior to and after each measurement cycle. The reading is to be carried out with the instrument being completely relieved.

In the case of pressure gauges for excess pressure whose initial measuring range is different from the atmospheric pressure (e.g. -1 bar to 9 bar), the drift has to be determined at the zero point.

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2003

8.6.5 Hysteresis h

When mean values are stated, the hysteresis is determined from the difference of the zero point-corrected measurement values of the increasing and decreasing series as follows:

$$h_{\text{mean, j}} = \frac{1}{n} \cdot \left\{ \left| \left(x_{2,j} - x_{1,0}\right) - \left(x_{1,j} - x_{1,0}\right) \right| + \left| \left(x_{4,j} - x_{3,0}\right) - \left(x_{3,j} - x_{3,0}\right) \right| + \left| \left(x_{6,j} - x_{5,0}\right) - \left(x_{5,j} - x_{5,0}\right) \right| \right\} \quad (27)$$

For index j, see above. The variable n stands for the number of the complete measurement cycles.

2014

8.6.5 Hysteresis *h*

When stating mean values, the hysteresis is determined from the difference of the zero point-corrected measurement values of the increasing and decreasing series as follows:

$$h_{mean,j} = \frac{1}{n} \cdot \left\{ \begin{array}{l} \left| \left(x_{2,j} - x_{1,0}\right) - \left(x_{1,j} - x_{1,0}\right) \right| + \left| \left(x_{4,j} - x_{3,0}\right) - \left(x_{3,j} - x_{3,0}\right) \right| + \\ \left| \left(x_{6,j} - x_{5,0}\right) - \left(x_{5,j} - x_{5,0}\right) \right| \end{array} \right\} \quad (27)$$

For index *j*, see above. The variable *n* stands for the number of the complete measurement cycles (consisting of an increasing and decreasing series).

2003

Table 8: Measurement values

Pressure $p_{standard}$	Calibration	
	Calibration seque	
	Calibration sequence C	
	M1 (up)	M2 (down)
bar, Pascal, ...		
min.	min.	min.
↓	↓	↑
max.	max.	max.

2014

Table 8: Measurement values

Pressure at the height of the reference plane of the calibration item	Calibration s	
	Calibration sequenc	
	Calibration sequence C	
p	M1 (up)	M2 (down)
bar, Pascal, ...		b
min.	min.	min.
↓	↓	↑
max.	max.	max.

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9.1.1 Mean values $\overline{x}$

The mean values $\overline{x_{i,j}}$ with i = up/down, mean are calculated as follows:

$$\overline{x_{up,J}} = \frac{1}{l} \cdot \sum_m (x_{m,j} - x_{m,0}) \qquad \text{for m = 1,3,5}$$

$$\overline{x_{down,J}} = \frac{1}{l} \cdot \sum_m (x_{m,j} - x_{(m-l),0}) \qquad \text{for m = 2,4,6}$$

$$\overline{x_{mean,J}} = \frac{\overline{x_{up,J}} + \overline{x_{down,J}}}{2} \qquad (28)$$

where variable *l* indicates the number of measurement series.

For pressure gauges, where the zero point is not included in the calibration range (e.g. 800 mbar abs to 1200 mbar abs), the zero point correction is omitted when calculating the mean values.

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2003

9.1.3 Conformity

If the error span and the transmission coefficients with attributed measurement uncertainty lie within the error limit stated by the manufacturer, the conformity according to DKD-5 can be confirmed. The range for which it is valid is also to be stated.

2014

9.1.3 Conformity

If the error spans and the transmission coefficients with attributed measurement uncertainty lie within the indicated specification limits, the conformity according to DAkkS-DKD-5 [12] can be confirmed. Their range of validity has to be indicated. **When assessing the compliance with the required specification limits, their origin has to be indicated, e.g. manufacturer-specific specifications according to data sheet, customer demands, inter alia.**

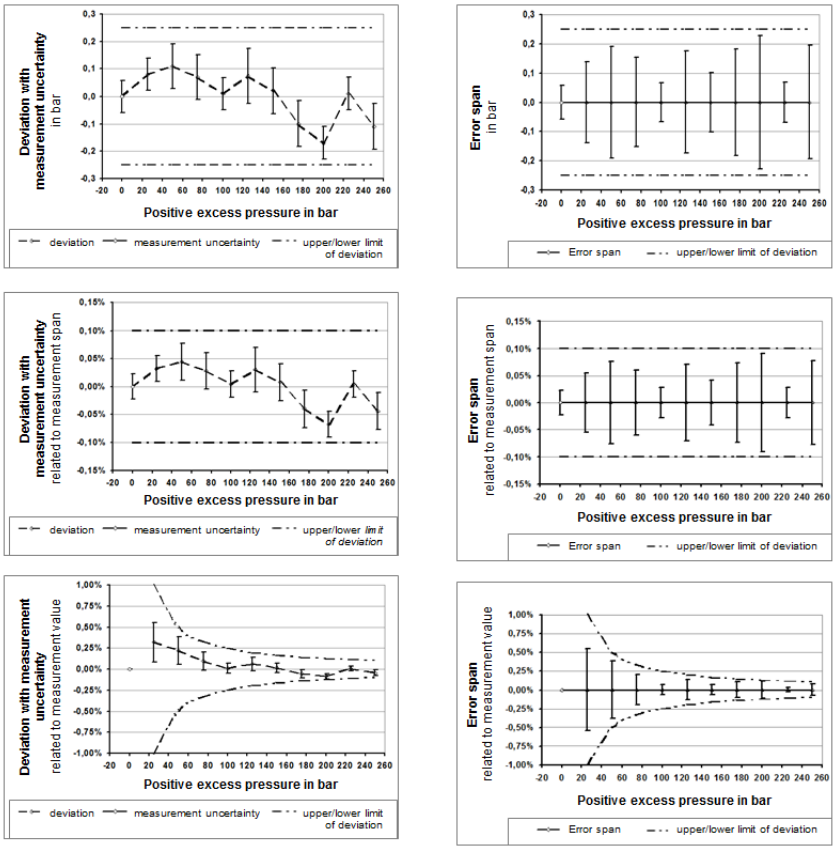
9.2 Visualisation of the calibration result

…

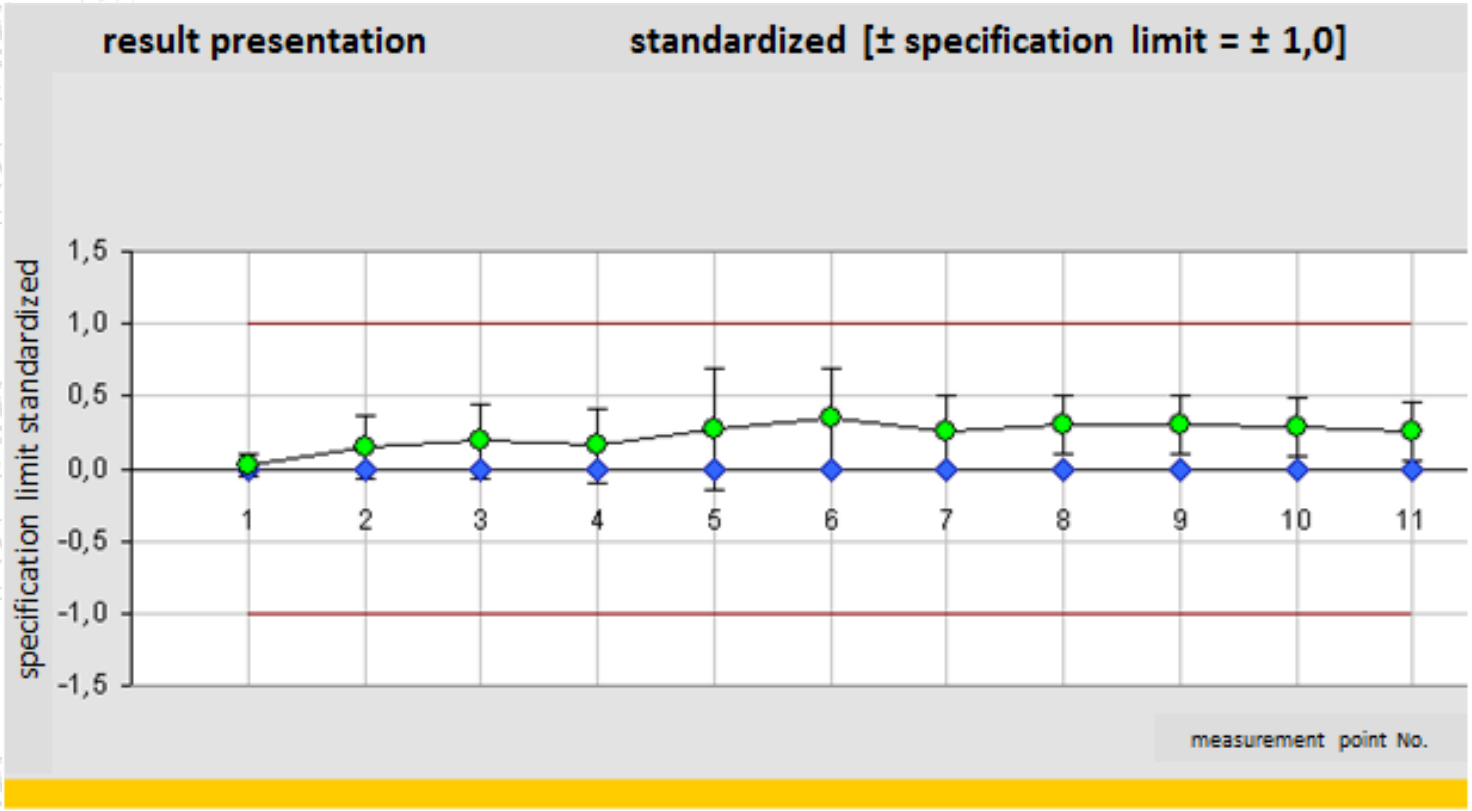
9.2.1 Bourdon tube pressure gauges, electrical pressure gauges:

…

Figure 4: Visualisation of the calibration result for a Bourdon tube pressure gauge or an electrical pressure gauge



To support a statement of conformity, the results can also be represented in standardized form (specification limit = 100%). The specification limit can either be specified by the customer, or the one provided by the manufacturer can be adopted.



legend:

- blue = standard (rectangle; measurement values N1↑ standardized)
- green = calibration item (circle; measurement values μ (KG) standardized)
- red = +- specification limits (standardized to ± 1,0)
- black = U expanded measurement uncertainty for k=2 (standardized)

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9.3 Limiting values for uncertainty statements

The measurement uncertainty and the error span are calculated according to Section 8. This is valid for all the calibration sequences (A, B, C).

Regardless of the result of the calibration, however, the measurement uncertainty is stated

for	cal. sequence B	not smaller than	0.04%	of measurement span
and for	cal. sequence C	not smaller than	0.30%	of measurement span.

For the indication of an error span in a conformity statement according to DAkkS-DKD-5, the value must be given

for	cal. sequence B	not smaller than	0.06%	of measurement span
and for	cal. sequence C	not smaller than	0.60%	of measurement span.

The measurement uncertainty and the error span for the calibration sequence A remain unaffected by these limiting values. They are indicated as actually calculated.

In case of measuring devices for which specifications of the measurement value or combined specifications are stated, the limiting values are to be applied using the specification limit at the upper limit of the measurement range.

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2003

EN 837 part 1

EN 837 part

DIN 16086

DIN 43790

EA-10/03

~~DKD-R 3-6~~

EA – 10/17

10. Additional rules and standards

2014

If appropriate, the following rules are to be taken into account for the calibration of pressure gauges. It may also be agreed to carry out the calibration in accordance with individual sections of some of these rules.

[1]	DIN EN 837 T1	Druckmessgeräte mit Rohrfedern Maße, Messtechnik, Anforderungen und Prüfung Edition February 1997 (English title: Pressure gauges - Part 1: Bourdon tube pressure gauges; dimensions, metrology, requirements and testing)
[2]	DIN EN 837 T3	Druckmessgeräte mit Platten- und Kapselfedern Maße, Messtechnik, Anforderungen und Prüfung Edition February 1997 (English title: Pressure gauges - Part 3: Diaphragm and capsule pressure gauges; dimensions, metrology, requirements and testing)
[3]	DIN 16086	Elektrische Druckmessgeräte Druckaufnehmer, Druckmessumformer, Druckmessgeräte Begriffe und Angaben in Datenblättern Edition January 2006 (English title: Electrical pressure measuring instruments - Pressure transmitters, pressure measuring instruments - Concepts, specifications on data sheets)
[4]	DIN 43790	Grundregeln für die Gestaltung von Strichskalen und Zeigern Edition January 1991 (English title: Basic principles for the design of line scales and pointers)
[5]	EURAMET cg-3	Calibration of Pressure Balances Version 1.0 (03/2011)
[6]	EURAMET cg-17	Guideline on the Calibration of Electromechanical Manometers Version 2.0 (03/2011)

2003

References

DIN:

DIN 1319-1:

DIN 1319-2:

DKD-5:

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General

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[8]	JCGM 200:2008	International vocabulary of metrology -- Basic and general concepts and associated terms (VIM) (identical with ISO/IEC Guide 99:2007) JCGM 200:2008 Corrigendum (2010) http://www.bipm.org/en/publications/guides/vim.html
[9]	DIN: 2010	Internationales Wörterbuch der Metrologie -- Grundlegende und allgemeine Begriffe und zugeordnete Benennungen (VIM) - German-English version ISO/IEC-Leitfaden 99:2007. Edition 2012. (English title: International vocabulary of metrology – Basic and general concepts and associated terms (VIM))
[10]	DIN 1319-1: 1996	Grundlagen der Messtechnik Teil 1: Grundbegriffe (English title: Fundamentals of metrology - Part 1: Basic terminology)
[11]	DIN 1319-2: 1999	Grundlagen der Messtechnik Teil 2: Begriffe für die Anwendung von Messgeräten (English title: Fundamentals of metrology - Part 2: Terminology related to measuring equipment)
[12]	DAkkS-DKD-5: 2010	Anleitung zum Erstellen eines Kalibrierscheins

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2003

~~**ISO:**~~

EA-4/02:

~~**EA-10/03:**~~

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Measurement uncertainty

[13] JCGM 100:2008	Evaluation of measurement data -- Guide to the Expression of Uncertainty in Measurement (GUM) (identical with ISO/IEC Guide 98-3:2008) http://www.bipm.org/en/publications/guides/gum.html
[14] JCGM 101:2008	Evaluation of measurement data -- Supplement 1 to the "Guide to the expression of uncertainty in measurement" -- Propagation of distributions using a Monte Carlo method (identical with ISO/IEC Guide 98-3:2008/Suppl 1:2008) http://www.bipm.org/en/publications/guides/gum.html
[15] JCGM 104:2009	Evaluation of measurement data -- An introduction to the "Guide to the expression of uncertainty in measurement" and related documents (identical with ISO/IEC Guide 98-1:2009) http://www.bipm.org/en/publications/guides/gum.html
[16] EA-4/02:1999	Expression of the Uncertainty of Measurement in Calibration -- including supplement 1 and 2 European co-operation for Accreditation http://www.european-accreditation.org/content/publications/pub.htm

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DIN V ENV 13005	[17] DIN V ENV 13005:1999	Leitfaden zur Angabe der Unsicherheit beim Messen Beuth Verlag Berlin (English title: Guide to the expression of uncertainty in measurement)
DKD-3:	[18] DAkkS-DKD-3:2010	Angabe der Messunsicherheit bei Kalibrierungen 1. Neuauflage, Deutsche Akkreditierungsstelle GmbH http://www.dakks.de/doc_kalibrier
DKD-3-E1: Supplement 1	[19] DAkkS-DKD-3-E1:2010	Angabe der Messunsicherheit bei Kalibrierungen, Ergänzung 1, Beispiele, 1. Neuauflage, Deutsche Akkreditierungsstelle GmbH http://www.dakks.de/doc_kalibrier
	[20] DAkkS-DKD-3-E2:2010	Angabe der Messunsicherheit bei Kalibrierungen, Ergänzung 2, Beispiele, 1. Neuauflage, Deutsche Akkreditierungsstelle GmbH http://www.dakks.de/doc_kalibrier
DIN 1319-3:	[21] DIN 1319-3:1996	Grundlagen der Messtechnik Teil 3: Auswertung von Messungen einer einzelnen Messgröße, Messunsicherheit Beuth Verlag Berlin (English title: Fundamentals of metrology - Part 3: Evaluation of measurements of a single measurand, measurement uncertainty)
DIN 1319-4:	[22] DIN 1319-4:1999	Grundlagen der Messtechnik Teil 4: Auswertung von Messungen, Messunsicherheit Beuth Verlag Berlin (English title: Fundamentals of metrology - Part 4: Evaluation of measurements; uncertainty of measurement)

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[24] Adunka, F.: Messunsicherheiten – Theorie und Praxis, Vulkan-Verlag Essen, 2007, ISBN 978-3-8027-2205-9

[25] Special edition from issues 3 and 4 of the PTB-Mitteilungen 111 (2001)

[26] VDI-Berichte (VDI reports)1805, 1867, 1947 u. Tagungsband 2008 (conference proceedings): Messunsicherheit praxisgerecht bestimmen, VDI/VDE-Gesellschaft für Mess- und Automatisierungstechnik,
Conferences:
20.-21.11.2003 und 30.11.-01.12.2004 in Oberhof/Thüringen
14.11.-15.11.2006 und 12.-13.11.2008 in Erfurt
VDI Verlag GmbH, Düsseldorf 2003/2004/2006 und VDI Wissensforum 2008

[27] Themenhefte Messunsicherheit: tm Technisches Messen, 2/2004 und 5/2005
(Special publication series on the subject of measurement uncertainty)

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Annex F Period of validity (recommended)	
Pressure balances	5 years
Bourdon tube pressure gauges, class >0,6	2 years
Electrical pressure gauges > 0,5% of measurement span	2 years
Pressure transmitters with electrical output > 0,5% of measurement span	2 years
Bourdon tube pressure gauges, class ≤ 0,6	1 year
Electrical pressure gauges ≤ 0,5% of measurement span	1 year
Pressure transmitters with electrical output ≤ 0,5% of measurement span	1 year

2014

Annex F Recalibration intervals (recommendation)	
Piston pressure gauges	5 years
Bourdon tube pressure gauges, class > 0.6	2 years
Electrical pressure gauges > 0.5 % of measurement span	2 years
Pressure transmitters with electrical output > 0.5 % of measurement span	2 years
Bourdon tube pressure gauges, class ≤ 0.6	1 year
Electrical pressure gauges ≤ 0.5 % of measurement span	1 year
Pressure transmitters with electrical output ≤ 0.5 % of measurement span	1 year

สรุป

เนื้อหาเพิ่มเติมที่สำคัญ คือ

1. Reference and working standards

When calculating the measurement uncertainty of the standards used, all relevant influence quantities are to be taken into account. In case of indicating pressure gauges that are used as standards, the resolution has to be considered a second time when calculating the measurement uncertainty.

2. Ambient conditions

The calibration is to be carried out after a temperature equalisation between calibration item and environment within the permissible temperature range (18 °C to 28 °C).

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