

# Physikalisch- Technische Bundesanstalt



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<b>Guideline</b>	<b>Application of Coordinate</b>
<b>DKD-R 4-5</b>	<b>Measuring Machines (CMMs)</b>

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## Deutscher Kalibrierdienst (DKD) – German Calibration Service

Since its foundation in 1977, the German Calibration Service has brought together calibration laboratories of industrial enterprises, research institutes, technical authorities, inspection and testing institutes. On 3rd May 2011, the German Calibration Service was reestablished as a *technical body* of PTB and accredited laboratories.

This body is known as *Deutscher Kalibrierdienst* (DKD for short) and is under the direction of PTB. The guidelines and guides developed by DKD represent the state of the art in the respective areas of technical expertise and can be used by the *Deutsche Akkreditierungsstelle GmbH* (the German accreditation body – DAkkS) for the accreditation of calibration laboratories.

The accredited calibration laboratories are now accredited and supervised by DAkkS as legal successor to the DKD. They carry out calibrations of measuring instruments and measuring standards for the measurands and measuring ranges defined during accreditation. The calibration certificates issued by these laboratories prove the traceability to national standards as required by the family of standards DIN EN ISO 9000 and DIN EN ISO/IEC 17025.

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## Foreword

DKD guidelines are application documents that meet the requirements of DIN EN ISO/IEC 17025. The guidelines contain a description of technical, process-related and organizational procedures used by accredited calibration laboratories as a model for defining internal processes and regulations. DKD guidelines may become an essential component of the quality management manuals of calibration laboratories. The implementation of the guidelines promotes equal treatment of the equipment to be calibrated in the various calibration laboratories and improves the continuity and verifiability of the work of the calibration laboratories. In addition, the implementation of the guidelines allows the state of the art in the respective field to be incorporated into laboratory practice.

The DKD guidelines should not impede the further development of calibration procedures and processes. Deviations from guidelines as well as new procedures are permitted in agreement with the accreditation body if there are technical reasons to support this action.

Calibrations by accredited laboratories provide the user with the security of reliable measuring results, increase the confidence of customers, enhance competitiveness in the national and international markets, and serve as metrological basis for the monitoring of measuring and test equipment within the framework of quality assurance measures.

The present guideline has been drawn up by the DKD Technical Committee *Length* and approved by the Board of the DKD.

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## 1. Purpose and scope of application

This guideline serves to implement the requirements of DIN EN ISO/IEC 17025 for the use of coordinate measuring machines (CMMs). Criteria are specified both for stationary measuring technology in so-called measuring rooms (cf. VDI/VDE 2627 Part 1) as well as for portable systems used at the customer's premises (indoors) or outdoors. The described good laboratory practice describes aims to ensure the determination of valid results.

The guideline is aimed at accredited calibration and testing laboratories as well as industrial users in need of QA measures due to the requirements of other standards and guidelines (e.g. DIN EN ISO 9001, IATF 16949).

This guideline describes the current status of technology.

The requirements are largely based on requirements defined in the relevant standards and guidelines, in particular the series of standards VDI/VDE 2617, VDI/VDE 2630, VDI/VDE 2634 and DIN EN ISO 10360 for measurement and testing of coordinate measuring machines (CMMs) as well as the series of standards DIN EN ISO 14253, DIN ISO/TS 15530, ISO/TS 23165, ISO/TS 17865 and relevant standards on form and positional tolerances used among other things for defining a competent measurement strategy. Moreover, the requirements for climatic conditions in the measuring rooms (criteria, verification, and monitoring) are described in the VDI/VDE 2627 series of guidelines.

## 2. Content of the quality policy statement

The commitment to "good professional practice" entails the following obligation for users:

Continuous adaptation of the procedures in accordance with the ongoing development of technology, the continued development and revision of standards and guidelines as well as changes to applicable legal provisions. After publication of the respective standard sheets, users must adapt their procedures to the amended status within a planned period, preferably within two years.

### Scope of laboratory activities

For the users, a statement regarding the services offered also includes a list of the CMMs used within the scope of accreditation or the range of services. Information on the manufacturer, type, measurement software used, measurement volume, limit values of the specified performance features (limit values in accordance with the applicable VDI/VDE or ISO regulations) as well as examples of the best measurement capabilities must be documented.

The scope of accreditation or range of services must be suitably formulated by the service provider and made available to customers and interested parties. The location where the service is provided (fixed installations, on-site or in mobile laboratories) must also be documented. For calibration laboratories, for instance, the scope would be "application of coordinate measuring machines". For testing laboratories and industrial users, the scope must be clearly described, for example:

- determination of dimensional deviations and form deviations of manufactured products using tactile and optical 3D coordinate measuring machines (CMMs),
- carrying out and documenting dimensional initial sample inspections on homogeneous workpieces using computer tomography (CT),
- carrying out geometric measurements on components using tactile and optical 3D measuring systems.

To illustrate the range of services or the respective field of expertise, a presentation providing some minimum information – as shown in the example below – is required for all users.

CMM	Measuring range	Specification	Examples of expanded measurement uncertainty	Remarks
CMM tactile	Measurement volume: $X = 700 \text{ mm}$ $Y = 1200 \text{ mm}$ $Z = 1000 \text{ mm}$	$E_{0,MPE} = 1,7 \mu\text{m} + 2,3 \cdot 10^{-6} \cdot l$ according to DIN EN ISO 10360-2:2010 $P_{\text{Form.Sph.1} \times 25:\text{SS:Tact}} = 2,2 \mu\text{m}$ according to DIN EN ISO 10360-5:2020 $L_{\text{Dia.Sph.5} \times 25:\text{j:Tact}} = 2,9 \mu\text{m}$ according to DIN EN ISO 10360-5:2020	$l = 20 \text{ mm}$ : $U = 1,2 \mu\text{m}$ $l = 1100 \text{ mm}$ : $U = 7,4 \mu\text{m}$ Gauge block made of steel	$l = \text{measured length}$
CMM with optical image processing	Measurement volume: $X = 400 \text{ mm}$ $Y = 200 \text{ mm}$ $Z = 200 \text{ mm}$	$E_{B,MPE} = 2,2 \mu\text{m} + 4 \cdot 10^{-6} \cdot l$ according to DIN EN ISO 10360-7:2011 $P_{F2D} = 2,5 \mu\text{m}$ according to DIN EN ISO 10360-7:2011 $P_{FV2D} = 1,8 \mu\text{m}$ according to DIN EN ISO 10360-7:2011	$l = 20 \text{ mm}$ : $U = 1,9 \mu\text{m}$ $l = 500 \text{ mm}$ : $U = 7,4 \mu\text{m}$ Glass scale made of float glass	$l = \text{measured length}$
Laser tracker	Range 25 m	$E_{\text{Avg:L:LT,MPE}} = 15 \mu\text{m} + 6 \cdot 10^{-6} \cdot l$ according to ISO 10360-10:2021 $P_{\text{Form.Sph.1} \times 25:\text{SMR:LT,MPE}} = 15 \mu\text{m}$ according to ISO 10360-10:2021 $P_{\text{Size.Sph.1} \times 25:\text{SMR:LT,MPE}} = 15 \mu\text{m}$ according to ISO 10360-10:2021	2,3 m ball bar at 2 m distance: $U = 50 \mu\text{m}$ at 20 m distance: $U = 100 \mu\text{m}$	Use of probing styli $l = \text{measured length}$
Optical 3D CMM	Measurement volume: $X = 1000 \text{ mm}$ $Y = 750 \text{ mm}$ $Z = 750 \text{ mm}$	$E_{\text{Vol:CMV.MV:O3D,MPE}} = 63 \mu\text{m}$ according to ISO 10360-13:2021 $P_{\text{Form.Sph.95 \%:SMV.SV:O3D,MPEol:CMV.MV:O3D,MPE}} = 15 \mu\text{m}$ according to ISO 10360-10:2021 $P_{\text{Size.Sph.95 \%:SMV.SV:O3D,MPEol:CMV.MV:O3D,MPE}} = 25 \mu\text{m}$ according to ISO 10360-10:2021	$l = 20 \text{ mm}$ : $U = 35 \mu\text{m}$ $l = 1000 \text{ mm}$ : $U = 55 \mu\text{m}$ Ball bar made of CFRP	Surface treatment $l = \text{measured length}$

CMM	Measuring range	Specification	Examples of expanded measurement uncertainty	Remarks
Computed tomography scanner (CT)	Maximum radiographic penetration length: 125 mm Acceleration voltage: 130 kV	$E_{(TS),MPE} = 5 \mu\text{m} + 20 \cdot 10^{-6} \cdot l$ according to VDI/VDE 2617 Part 13:2011 $P_{F(TS),MPE} = 4 \mu\text{m}$ according to VDI/VDE 2617 Part 13:2011 $P_{S(TS),MPE} = 6 \mu\text{m}$ according to VDI/VDE 2617 Part 13:2011	$l = 10 \text{ mm}:$ $U = 4,5 \mu\text{m}$ $l = 85 \text{ mm}:$ $U = 6,5 \mu\text{m}$ Ball bar made of CFRP	Permissibility of multi-material components $l =$ measured length
Photogram-metric measurement system	Measurement volume: $X = 2000 \text{ mm}$ $Y = 2000 \text{ mm}$ $Z = 1500 \text{ mm}$	$E_{MPE} = 35 \mu\text{m}$ according to VDI/VDE 2634 Part 1:2002	$l = 20 \text{ mm}:$ $U = 25 \mu\text{m}$ $l = 2200 \text{ mm}:$ $U = 30 \mu\text{m}$ Scale made of CFRP	On-site $l =$ measured length
Articulated arm	Measuring range 3500 mm	$E_{\text{Uni:0:Tact.AArm,MPE}} = 45 \mu\text{m}$ according to DIN EN ISO 10360-12:2018 $P_{\text{Form.Sph.1}\times 25::\text{Tact.AArm,MPE}} = 25 \mu\text{m}$ according to DIN EN ISO 10360-12:2018 $P_{\text{Size.Sph.1}\times 25::\text{Tact.AArm,MPE}} = 30 \mu\text{m}$ according to DIN EN ISO 10360-12:2018	$l = 20 \text{ mm}:$ $U = 45 \mu\text{m}$ $l = 2350 \text{ mm}:$ $U = 55 \mu\text{m}$ Beam with cone elements made of silicon carbide	In a mobile laboratory $l =$ measured length


**Table 1:** Examples of specifications for the use of CMMs

The expanded measurement uncertainties **with a coverage probability of approximately 95 %** should be specified for at least two lengths. At least one length measurement task with a length  $\geq 66 \%$  of the available spatial diagonal of the specified measurement volume should be listed.

For easily reproducible examples (measurement task and material), the measurement uncertainty (not the length measurement deviation) is to be determined as the smallest possible for the typical temperature range at the place where the service is provided [e.g.  $(20 \pm 2) \text{ }^\circ\text{C}$ ]. Optionally, a number of specifications can be made for further typical examples. The specifications given must always be made on the basis of documented calculations. For calibration laboratories, extended requirements regarding the specification of the expanded measurement uncertainty or CMC may apply.

Should the measurements not be carried out on the premises of the service provider, this must be entered under "Remarks".



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## Review of requests, tenders and contracts

Should a measurement task specified by the customer not correspond to technical practice or should a high measurement uncertainty be expected in relation to given tolerances, the customer must be informed accordingly. To maintain the integrity of the service provider, a conscientious evaluation of the measurement task is essential.

In particular, the technical review of requests must cover the following points:

- technical feasibility of the specified features,
- implementation of the drawings (e.g. form and positional tolerances) into a suitable measurement and evaluation strategy (creation of suitable compensation elements and references) and, if necessary, coordination of the measurement strategy with the customer,
- if necessary, determination of the conformity statement and the decision rules used,
- clarification as to whether the work to be carried out is within or outside the accredited area.

The aforementioned review of requests is a complex process. The persons in charge must have the appropriate technical expertise (e.g. knowledge of form and positional tolerances, determination of measurement uncertainty, capabilities of applicable measuring systems).

## 3. Technical requirements

### 3.1 Laboratory personnel

A head of laboratory is to be appointed.


#### Requirements to be met by the head of the laboratory:

- qualified basic technical training (e.g. qualified advanced training (Germany: Meister) or engineering education)
- adequate professional experience as a CMM user
- detailed knowledge of form and positional tolerances and the corresponding indication of tolerances (inscription in drawings)
- detailed knowledge of the measuring methods used, including detailed knowledge of the relevant standards and guidelines
- detailed knowledge regarding measurement uncertainties and their determination
- knowledge of the test value uncertainty of test and calibration procedures of the measurement technology used
- knowledge regarding conformity decisions and decision rules

#### Requirements to be met by the measurement technician in charge:

- basic technical knowledge
- knowledge of form and positional tolerances (geometric dimensioning and tolerancing) and the corresponding indication of tolerances (inscription in drawings)
- sufficient knowledge for the application of the measurement technology used
- knowledge of the measuring methods used
- sufficient practical experience to perform the measurement task
- knowledge of the main influence quantities on the measurement uncertainty

The qualifications of the employees must be suitably documented (e.g. technical CVs with corresponding training certificates). Apart from indicating the topic of the training, training certificates should also contain summarised information on the training content. In addition, employees' authorisations must be assigned and documented.

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### 3.2 Facilities and environmental conditions

The requirements regarding the facilities (premises) and environmental conditions on site are specified in a suitable manner, e.g. in accordance with VDI/VDE 2627, Part 1. It is recommended that this standard be used as a basis for the construction of new air-conditioned measuring rooms or when equipping existing ones.

The limit values to be observed with regard to temperature, temperature gradients and relative humidity (if applicable, among other things) are specified in a procedural instruction. At least the following aspects must be taken into account:

- manufacturer specifications regarding the CMMs
- desired measurement uncertainty of the method

Other influences on the results, such as vibrations, solar radiation, environmental light, contamination (e.g. oil mist, dust), may also have to be taken into account.

The following steps must be observed and documented:

#### 1. Defining limit values:

Based on these requirements, the laboratory must define limit values for parameters influencing the measurement results or measurement uncertainty at the installation site or in any other relevant rooms (e.g. sample storage). These parameters are, for example, deviation of the environmental temperature from the standard reference temperature as well as the time-related and spatial gradients of the environmental temperature.

#### 2. Proof and continuous monitoring:

Continuous monitoring ensures that the limit values are adhered to. Documentation is provided for the relevant periods.

The number, distribution, and suitability of the sensors for monitoring must be adapted to the requirements. For a numerical correction of the linear expansion, a temperature measurement of the object is necessary depending on the measurement uncertainty.

The procedure for continuous monitoring of the parameters must be described. Regular and timely monitoring of the parameters must be carried out. The monitoring data must be stored and analysed appropriately. For example, suitable mechanisms and warning thresholds must be in place so that measurement operations can be stopped, or other appropriate measures taken should these thresholds be exceeded.


Monitoring of the parameters should be carried out by means of visualisation in order to enable a rapid response to changes and to raise employee awareness.

### 3.3 Measurement procedures and their validation

#### 3.3.1 Procedures not specified in normative documents

As a rule, there are no procedures to be found in normative documents describing how to carry out measurements with CMMs. It is up to the laboratory to describe the procedure in a suitable form. It must be ensured that consistent application of the laboratory activities and the validity of the results are guaranteed.

Often, a comprehensive description of the procedures (i.e. with the greatest level of detail for each possible case) is difficult to achieve. However, the general procedure for each step of the measurement process with a relevant influence on the validity of the results must be defined.

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Critical parameters (e.g. probe parameters, calibration of several stylus positions when using a rotary/swivel unit, analogue parameters for other measuring systems) must be checked and documented before the start of each measurement or series of measurements.

The description, including further applicable documents, should enable new employees to become familiar with the method (suitability of the description for training purposes). In other words, the description should be understandable for a reader with technical background (for instance, abbreviations used should be explained; technical set-ups should, if possible, be documented with photographs or sketches).

### 3.3.2 Additional requirements for portable systems or mobile laboratories for on-site use

If applicable, the process descriptions must also cover on-site use. In particular, the work process in the run-up to on-site use must be described; in particular, an intermediate check must be carried out and recorded. Furthermore, details must be specified, e.g. packing lists/checklists, preparation and packaging of the measuring equipment, confidentiality, and protection of information, for instance with regard to on-site electronic data processing.

The measuring systems and standards used must comply with defined specifications for mobile use. These specifications are defined upon acceptance of the measuring system by the manufacturer or during subsequent use by the laboratory. If specifications according to current standards and guidelines do not exist for the measuring system, then the laboratory must define derived specifications.

### 3.3.3 Validation of procedures

The procedures not described in normative documents must be validated in a suitable and comprehensible manner. Possible instruments include measurements of known objects (reference standards and calibrated master parts; typical measurement task if possible), comparisons between laboratories and comparisons with previously validated methods. The  $E_n$  score (DIN ISO 13528 and DIN EN ISO/IEC 17043) is recommended for evaluating the validation. Other evaluation criteria must be justified.

The validation must be repeated if significant components of the procedure have changed.

Proof of validation including the corresponding results must be recorded.


A procedure may only be used if it has been approved by an authorised employee of the laboratory. Such approval must follow a regulated procedure. Method and software used must be clearly identifiable.

### 3.3.4 Determination of the measurement uncertainty

For laboratories, it is necessary to describe and apply a general procedure for the determination of measurement uncertainties.

The following methods can be used to determine the measurement uncertainty:

- All methods that calculate measurement uncertainties based on rules in accordance with JCGM 100 (GUM), EA-4/02 M and DKD-L 13-1.
- Determination of measurement uncertainty using a calibrated workpiece according to the method in DIN EN ISO 15530-3, which is also dealt with and explained in VDI/VDE 2617 Part 8.
- Determination of measurement uncertainties in accordance with VDI/VDE 2617 Part 11

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- Determination of measurement uncertainty by simulation in accordance with JCGM 101 (GUM Supplement 1) and ISO/TS 15530-4 which is also dealt with and explained in VDI/VDE 2617 Part 7, e.g. virtual coordinate measuring machine VCMM

### 3.3.5 Intermediate checks

Intermediate checks and testing of specified parameters must be defined in accordance with the described methods (e.g. DIN EN ISO 10360, VDI/VDE guideline series 2617, 2630, 2634) for all measuring systems or measuring procedures used. These tests must be carried out on a regular basis. At the beginning, the intervals for intermediate checks must be short. Later it will be possible to adjust the intervals (shortened or extended) depending on the results achieved, based on a risk assessment.

Adherence to specified parameters for the system components used (e.g. multiple probes, rotary/swivel measuring head system, zoom levels, interchangeable lenses, rotary table, etc.) must be confirmed during the intermediate checks. The specified parameters must be defined in accordance with the limit values of the manufacturer or according to those set by the laboratory. Self-defined limit values must be substantiated by empirical values and results from intermediate checks. These limits must be defined such as to confirm the uncertainty contribution from the measurement system for the intended use.

It must be ensured that the influence of the devices under test on the results of the intermediate check is sufficiently small. Valid metrological traceability for the devices used in the intermediate check is recommended but not mandatory.

Depending on the specified parameters, it may be necessary to position the device under test at different points in the measurement volume used.

The procedures for intermediate checks must be described, including considerations on the appropriateness of the measures, the devices under test to be used (e.g. test ball, gauge blocks, setting ring, master part, etc.), the frequency and the intervention limits. The results must be suitably analysed and presented, and a graphical representation to determine drift or the like must be provided (history).

Generally, mobile measuring systems are used at different sites under widely varying environmental conditions. This can lead to geometric changes in the systems. Vibrations and widely varying temperatures during transport, for example, may reduce the metrological performance. Therefore, suitable intermediate testing must be carried out after a change of location.


In case of unforeseen events which may affect the performance of the CMM (e.g. serious collision, failure of the air conditioning system, release change of relevant software), an unscheduled intermediate check should be carried out to secure the results.

## 3.4 Metrological traceability

Valid metrological traceability must be provided for all coordinate measuring machines and relevant equipment used. This calibration must be carried out by means of an acceptance inspection in accordance with the currently valid standards and guidelines (transition periods within a planned period, preferably within two years, are permissible).

ILAC-P10 also allows for internal calibration of the coordinate measuring machine by the laboratory itself. The internal calibration must be carried out in accordance with the currently valid standards. Particular attention must be paid to the calibration procedure, metrological traceability, measurement uncertainty and, if necessary, validation.

Calibration of the coordinate measuring machine by a non-accredited service provider, e.g. the manufacturer, is permissible in principle in accordance with ILAC-P10, taking into account the

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applicable standards and guidelines. However, the requirements of DIN EN ISO/IEC 17025 for calibration certificates and the valid metrological traceability of the standards used must be complied with and verified. This procedure is only permissible under this guideline if there is no National Metrology Institute (NMI) or accredited calibration laboratory offering this calibration service.

The same applies in particular to the calibration of external environmental sensors.

These calibrations must be carried out on a regular basis. At the beginning, the recalibration interval must be short and can then be adjusted (shortened or extended) depending on the results achieved (e.g. drift, deviations detected during calibration), based on a risk assessment.

### 3.5 Ensuring the validity of results

"Good professional practice" already offers various options for ensuring the validity of results. They are routinely used in practical work. Suitable documentation must be kept for verification purposes. This could be the measurement protocol of a repeat measurement or handwritten notes on correlations, for example.

Options for ensuring validity are, for example:

- measurements with alternative measuring systems (e.g. other CMMs, 1D length measuring systems),
- repeating a measurement on the same object,
- measurements on a similar object known from previous measurements,
- checking the correlation of results for different characteristics of an object (e.g. similar form deviations of different characteristics, similar diameter deviations of different diameters)

All users must regularly participate in suitable proficiency tests or interlaboratory comparisons (see 71 SD 0 010 or EA-4/18 and ILAC-P9).


In addition, "intermediate checks" are carried out on a regular basis to ensure validity (see chapter 3.3.5).

### 3.6 Results reports

The requirements for reports from DIN EN ISO/IEC 17025 apply. The essential requirements (minimum requirements) are in particular the following.

General requirements:

1. title (e.g. "test report" or "calibration certificate")
2. name and address of the user
3. operation site of the CMM
4. clear labelling so that all parts are recognised as part of a complete report, e.g. page number and total page number
5. name and contact details of the customer
6. Reference regarding the method used, including date of issue
7. clear labelling of the test or calibration item
8. date of realisation of the activity
9. date of report
10. results, including indication of units
11. name of the person responsible for releasing the report, e.g. the employee in charge

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Special requirements for test reports:

In addition to the above requirements, test reports must contain the following information:

1. information regarding environmental conditions (temperature)
2. if necessary, conformity statement including specifications and applied decision rule
3. if applicable, indication of the measurement uncertainty in the same unit as that of the measurand or by a designation referring to the measurand (e.g. per cent), if:
  - a. they are relevant to the validity or application of the test results,
  - b. required by the customer; or
  - c. the measurement uncertainty affects conformity at given specification limits due to the decision rule,
4. specification of the CMM according to the examples in Table 1 unless a measurement uncertainty is specified for all results.

Special requirements for calibration certificates

1. measurement uncertainty of the measurement result in the same unit as that of the measurand or by a designation referring to the measurand (e.g. per cent)
2. conditions influencing the measurement result, e.g. environmental temperature, information regarding the measurement strategy, coordinate system of the calibration item, evaluation criteria, material properties, clamping under which the calibrations have been carried out
3. indication regarding the metrological traceability of the CMM used
4. if necessary, conformity statement including specifications and applied decision rule

If a temperature compensation has been performed, the linear coefficient of thermal expansion as well as its source must be indicated.

#### 4. Relevant guidelines and standards

- VDI/VDE 2617 Blatt 2.1, 2014-03, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Leitfaden zur Anwendung von DIN EN ISO 10360-2 zur Prüfung von Längenmaßen
- VDI/VDE 2617 Blatt 2.2, 2018-07, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Formmessung mit Koordinatenmessgeräten
- VDI/VDE 2617 Blatt 2.4, 2022-08 (Entwurf), Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Zwischenprüfung für Koordinatenmesssysteme mit Prüfkörpern
- VDI/VDE 2617 Blatt 4, 2006-05, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Leitfaden zur Anwendung von DIN EN ISO 10360-3 für Koordinatenmessgeräte mit zusätzlichen Drehachsen
- VDI/VDE 2617 Blatt 5, 2010-12, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Überwachung durch Prüfkörper
- VDI/VDE 2617 Blatt 5.1, 2011-01, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Überwachung mit Kugelplatten
- VDI/VDE 2617 Blatt 6.1, 2021-11, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Koordinatenmessgeräte mit optischer Antastung - Leitfaden zur Anwendung von DIN EN ISO 10360 für Koordinatenmessgeräte mit optischen Sensoren für laterale Strukturen
- VDI/VDE 2617 Blatt 6.2, 2021-02, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Leitfaden zur Anwendung von DIN EN ISO 10360 für Koordinatenmessgeräte mit optischen Abstandssensoren
- VDI/VDE 2617 Blatt 7, 2008-09, Genauigkeit von Koordinationsmessgeräten - Kenngrößen und deren Prüfung - Ermittlung der Unsicherheit von Messungen auf Koordinatenmessgeräten durch Simulation
- VDI/VDE 2617 Blatt 8, 2018-10, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung, Prüfprozesseignung von Messungen mit Koordinatenmessgeräten
- VDI/VDE 2617 Blatt 9, 2009-06, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Annahme und Bestätigungsprüfung von Gelenkarm-Koordinatenmessgeräten
- VDI/VDE 2617 Blatt 10, 2011-01, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Annahme und Bestätigungsprüfung von Lasertrackern
- VDI/VDE 2617 Blatt 10.1, 2014-05, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Annahme und Bestätigungsprüfung von Lasertrackern mit Multisensorik
- VDI/VDE 2617 Blatt 11, 2011-03, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Ermittlung der Unsicherheit von Messungen auf Koordinatenmessgeräten durch Messunsicherheitsbilanzen
- VDI/VDE 2617 Blatt 12.1, 2011-03, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Annahme und Bestätigungsprüfung für Koordinatenmessgeräte zum taktilen Messen von Mikrogeometrien
- VDI/VDE 2617 Blatt 12.2, 2023-02, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung - Annahme und Bestätigungsprüfung für Koordinatenmessgeräte zum optischen Messen von Mikrogeometrien
- VDI/VDE 2617 Blatt 13, 2011-12, Genauigkeit von Koordinatenmessgeräten - Kenngrößen und deren Prüfung; Leitfaden zur Anwendung von DIN EN ISO 10360 für Koordinatenmessgeräte mit CT-Sensoren - VDI/VDE 2630 Blatt 1.3: Computertomografie in der dimensionellen Messtechnik; Leitfaden zur Anwendung von DIN EN ISO 10360 für Koordinatenmessgeräte mit CT-Sensoren

- VDI/VDE 2630 Blatt 1.1, 2016-11, Computertomografie in der dimensionellen Messtechnik - Grundlagen und Definitionen
- VDI/VDE 2630 Blatt 1.2, 2018-06, Computertomografie in der dimensionellen Messtechnik - Einflussgrößen auf das Messergebnis und Empfehlungen für dimensionelle Computertomografie-Messungen
- VDI/VDE 2630 Blatt 2.1, 2015-06, Computertomografie in der dimensionellen Messtechnik - Bestimmung der Messunsicherheit und der Prüfprozesseignung von Koordinatenmessgeräten mit CT-Sensoren
- VDI/VDE 2634 Blatt 1, 2002-05, Optische 3D-Messsysteme - Bildgebende Systeme mit punktförmiger Antastung
- VDI/VDE 2634 Blatt 2, 2012-08, Optische 3D-Messsysteme - Systeme mit flächenhafter Antastung
- VDI/VDE 2634 Blatt 3, 2008-12, Optische 3-D-Messsysteme - Bildgebende Systeme mit flächenhafter Antastung in mehreren Einzelansichten
- VDI/VDE 2627 Blatt 1, 2015-12, Messräume - Klassifizierung und Kenngrößen - Planung und Ausführung
- VDI/VDE 2627 Blatt 2, 2022-02, Messräume - Leitfaden zur Planung
- DIN EN ISO 1101, 2017-09, Geometrische Produktspezifikation (GPS) - Geometrische Tolerierung - Tolerierung von Form, Richtung, Ort und Lauf (ISO 1101:2017); German version EN ISO 1101:2017
- DIN EN ISO 9000:2015-11, Qualitätsmanagementsysteme - Grundlagen und Begriffe (ISO 9000:2015); German and English version EN ISO 9000:2015
- DIN EN ISO 9001:2015-11, Qualitätsmanagementsysteme - Anforderungen (ISO 9001:2015); German and English version EN ISO 9001:2015
- DIN EN ISO 10360-1, 2003-07, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 1: Begriffe (ISO 10360-1:2000 + Corr 1:2002) (contains correction Berichtigung AC:2002); German version EN ISO 10360-1:2000 + AC:2002
- DIN EN ISO 10360-2, 2010-06, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 2: KMG angewendet für Längenmessungen (ISO 10360-2:2009); German version EN ISO 10360-2:2009
- DIN EN ISO 10360-3, 2000-08, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 3: KMG mit der Achse eines Drehtisches als vierte Achse (ISO 10360-3:2000); German version EN ISO 10360-3:2000
- DIN EN ISO 10360-5, 2020-11, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 5: KMG mit berührendem Messkopfsystem im Einzelpunkt- und/oder Scanningmodus (ISO 10360-5:2020); German version EN ISO 10360-5:2020
- DIN EN ISO 10360-6, 2009-01, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 6: Abweichungsabschätzung beim Berechnen zugeordneter Geometrielemente nach Gauß (ISO 10360-6:2001+Cor. 1:2007); German version EN ISO 10360-6:2001+AC:2008
- DIN EN ISO 10360-7, 2011-09, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 7: KMG mit Bildverarbeitungssystemen (ISO 10360-7:2011); German version EN ISO 10360-7:2011
- DIN EN ISO 10360-8, 2014-03, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 8: KMG mit optischen Abstandssensoren (ISO 10360-8:2014); German version EN ISO 10360-8:2014



- DIN EN ISO 10360-9, 2014-04, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 9: KMG mit Multisensorik (ISO 10360-9:2014); German version EN ISO 10360-9:2014
- DIN EN ISO 10360-10, 2023-11, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 10: Lasertracker für Punkt-zu-Punkt-Messungen (ISO 10360-10:2021); German version EN ISO 10360-10:2021
- DIN EN ISO 10360-12, 2018-02, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 12: Gelenkarm-Koordinatenmessgeräte (KMG) (ISO 10360-12:2016); German version EN ISO 10360-12:2016
- DIN EN ISO 10360-13, 2023-11, Geometrische Produktspezifikation (GPS) - Annahmeprüfung und Bestätigungsprüfung für Koordinatenmessgeräte (KMG) - Teil 13: Optische 3D KMG (ISO 10360-13:2021); German version EN ISO 10360-13:2021
- DIN ISO 13528:2020-09, Statistische Verfahren für Eignungsprüfungen durch Ringversuche (ISO 13528:2015, corrected version 2016-10-15); text German and English
- DIN EN ISO 14253-1, 2018-07, Geometrische Produktspezifikationen (GPS) - Prüfung von Werkstücken und Messgeräten durch Messen - Teil 1: Entscheidungsregeln für den Nachweis von Konformität oder Nichtkonformität mit Spezifikationen (ISO 14253-1:2017); German version EN ISO 14253-1:2017
- DIN EN ISO 14253-2, 2018-09, Geometrische Produktspezifikationen (GPS) - Prüfung von Werkstücken und Messgeräten durch Messen - Teil 2: Anleitung zur Schätzung der Unsicherheit bei GPS-Messungen, bei der Kalibrierung von Messgeräten und bei der Produktprüfung (ISO 14253-2:2011); German version EN ISO 14253-2:2011
- DIN EN ISO 14253-3, 2011-10, Geometrische Produktspezifikation (GPS) - Prüfung von Werkstücken und Messgeräten durch Messen - Teil 3: Richtlinien für das Erzielen einer Einigung über Messunsicherheitsangaben (ISO 14253-3:2011); German version EN ISO 14253-3:2011
- DIN EN ISO 14253-5, 2016-12, Geometrische Produktspezifikation (GPS) - Prüfung von Werkstücken und Messgeräten durch Messen - Teil 5: Unsicherheit bei der Verifikationsprüfung von anzeigenden Messgeräten (ISO 14253-5:2015); German version EN ISO 14253-5:2015
- DIN CEN ISO/TS 15530-1, 2013-12, Geometrische Produktspezifikation und -prüfung (GPS) - Verfahren zur Ermittlung der Messunsicherheit von Koordinatenmessgeräten (KMG) - Teil 1: Übersicht und metrologische Merkmale (ISO/TS 15530-1:2013; German version CEN ISO/TS 15530- 1:2013
- DIN EN ISO 15530-3, 2018-09, Geometrische Produktspezifikation und -prüfung (GPS) - Verfahren zur Ermittlung der Messunsicherheit von Koordinatenmessgeräten (KMG) - Teil 3: Anwendung von kalibrierten Werkstücken oder Normalen (ISO 15530-3:2011); German version EN ISO 15530-3:2011
- DIN EN ISO 15530-4, 2008-06, Geometrische Produktspezifikationen (GPS) - Koordinatenmessmaschinen (CMM): Technik für die Bestimmung der Messunsicherheit - Teil 4: Auswertung von aufgabenspezifischen Messunsicherheiten mit Hilfe von Simulationen
- DIN EN ISO/IEC 17025:2018-03, Allgemeine Anforderungen an die Kompetenz von Prüf- und Kalibrierlaboratorien (ISO/IEC 17025:2017); German and English version EN ISO/IEC 17025:2017
- DIN EN ISO/IEC 17043:2023-10 Konformitätsbewertung - Allgemeine Anforderungen an die Kompetenz von Anbietern von Eignungsprüfungen (ISO/IEC 17043:2023); German and English version EN ISO/IEC 17043:2023

- ISO/TS 17865:2016-08, Geometrical product specifications (GPS) - Guidelines for the evaluation of coordinate measuring machine (CMM) test uncertainty for CMMs using single and multiple stylus contacting probing systems
- DIN ISO/TS 23165, 2008-08 (Vornorm), Geometrische Produktspezifikation (GPS) - Leitfaden zur Ermittlung der Testunsicherheit von Koordinatenmessgeräten (KMG) (ISO/TS 23165:2006)
- IATF 16949:2016-10, IATF 16949: Quality management system requirements for automotive production and relevant service parts organisations
- Leitfaden DKD-L 13-1, Praxisgerechte Ermittlung der Messunsicherheit, Ausgabe 02/2012, Revision 1 (2019), Physikalisch-Technische Bundesanstalt, Braunschweig und Berlin. DOI: 10.7795/550.20191105
- 71 SD 0 010 e Rev. 1.2 14. April 2016, Use of proficiency testing in accreditation, DAkkS
- EA-4/02 M: 2022, Ermittlung der Messunsicherheit bei Kalibrierungen (German translation of EA-4/02 M: 2022, DAkkS)
- EA-4/18 G: 2021, Guidance on the level and frequency of proficiency testing participation
- ILAC-P9:06/2014, ILAC Policy for Participation in Proficiency Testing Activities
- ILAC-P10:07/2020, ILAC Policy on Metrological Traceability of Measurement Results
- JCGM 100:2008, GUM 1995 with minor corrections, Evaluation of measurement data — Guide to the expression of uncertainty in measurement
- JCGM 101:2008, GUM 1995 with minor corrections, Evaluation of measurement data — Supplement 1 to the “Guide to the expression of uncertainty in measurement” — Propagation of distributions using a Monte Carlo method



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