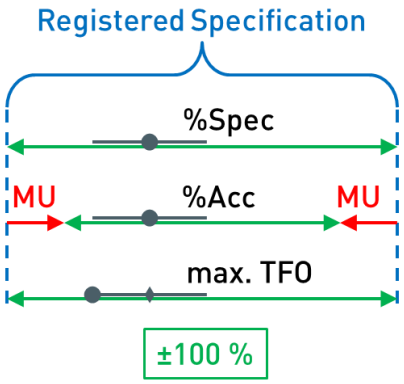
esz Calibration Certificate[1]

Explanation of Terms and Legend

Glossary

- **%TOL:** The following types of Occupied Tolerance Calculation are possible; the results are given in relative terms in %:
  - **Percentage of specification interval (%Spec):** Position of the deviation relative to the registered **specification** (standard calculation method).
  - **Percentage of acceptance interval (%Acc):** Position of the deviation relative to the registered **specification** minus the reported **measurement uncertainty**.
  - **Maximum tolerance field occupation (max. TFO):** Maximum position of the deviation plus or minus the reported **measurement uncertainty** relative to the registered **specification**.



- **%Spec:** Only for the Occupied Tolerance Calculation **maximum tolerance field occupation**, an additional column in the measurement blocks is indicating the position of the deviation relative to the registered **specification**.
- **Adjustment:** Intervention on the device under test intended to minimise the **deviation**.
- **Deviation:** Difference between measured value and nominal value. The deviation is not reported as soon as the calibration value and the measured value are known to be the same. **Rounding** may affect the representation.

[1] Report of a calibration laboratory in the terms of DIN EN ISO/IEC 17025:2018, section 7.8.1.2.

- **Deviation type:** The following formats can be used to indicate the **deviation**:
  - **A:** Absolute (measurement unit)
  - **D:** In decibels (dB)
  - **R:** Relative (%, 10^{-6}, 10^{-9}, ...)
- **Issue date:** Shown in the footer of the calibration certificate, this date represents the creation date of this revision of the report.
- **Rem.:** Indication per measurement; six results are possible for the column "Remark"[2]:
  - **Pass** - without remarks

    >95% probability of being within specification (ILAC-G8:09/2019 Fig. 5, Pass)
  - **!**

    Intervention threshold exceeded, >95% probability of being within specification
  - **Conditional Pass** - ?

    with a probability of >50% to 95% of being within the specification, taking into account the measurement uncertainty (MU) (ILAC-G8:09/2019 Fig. 5, Conditional Pass)
  - **?!**

    over the intervention threshold exceeded but with a probability of >50% to 95% of being within the specification, taking into account the MU
  - **Conditional Fail** - X?

    with a probability of >50% to 95% of being outside the specification, taking into account the MU (ILAC-G8:09/2019 Fig. 5, Conditional Fail)
  - **Fail** - X

    >95% probability of being outside the specification (ILAC-G8:09/2019 Fig. 5, Fail)
- **DAkkS: D**eutsche **Akk**reditierungs**s**telle (German Accreditation Body)
- **DGUV:** Tested according to DIN EN 50678 (VDE 0701) or DIN EN 50699 (VDE 0702) in accordance with DGUV Vorschrift 3
- **Intervention/warning threshold:** Set to 80% of specification per default and adaptable to customer requirements
- **Incoming Test/Outgoing Test:** Identification of a calibration before (incoming test) and after (outgoing test) an intervention on the device under test (e.g. an adjustment or repair) that has an influence on the measurement results or conformity assessment.

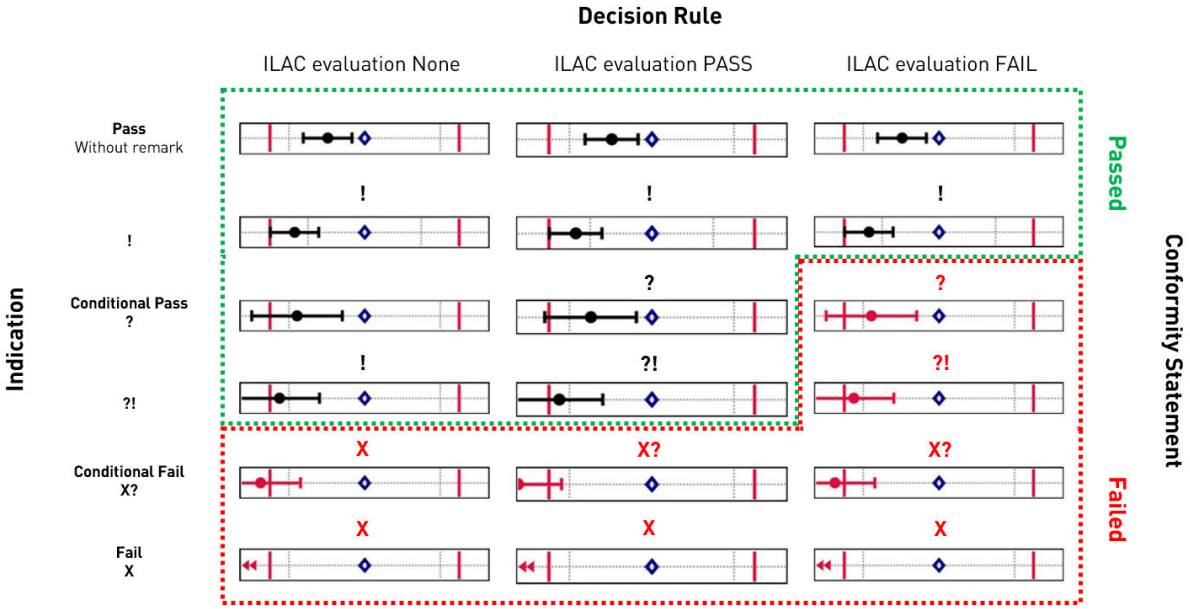
  In accordance with the specific requirements for calibration certificates in section 7.8.4.1 d) of

[2] The basis of the identification is a non-binary conformity statement with a guard band as described in ILAC-G8:09/2019, section 4.2.3. The guard band corresponds to the applied measurement uncertainty.

DIN EN ISO/IEC 17025:2018, results must be documented before and after an intervention. The incoming test is a key element of quality assurance, trackability and risk assessment. It enables the current state of the device under test to be assessed before an intervention. This is essential for analysing past measurement data of the device under test and deciding on necessary corrective actions.

The outgoing test documents the result of the adjustment or repair.

- **Approval date:** Date of confirmation of the calibration results and the conformity assessment by the authorized person
- **ILAC: I**nternational **L**aboratory **A**ccreditation **C**ooperation
- **ILAC evaluation:** Applied / defined (binary) decision rule for the conformity statement; the values appear in accordance (black) or not in accordance (marked **red**) with the specifications



- **PASS:** Standard decision rule according to the QM system of esz AG. Measurement results according to ILAC-G8:09/2019 Fig. 5, Pass and Conditional Pass are assessed as conforming to the specifications. Cases according to ILAC-G8:09/2019 Fig. 5, Conditional Fail and Fail are not considered to comply with the specifications.
- **None:** Decision rule according to ILAC evaluation "PASS" but without risk marking, i.e. question marks do not show during calibration and in the calibration certificate.

- **FAIL:** Decision rule according to DIN EN ISO 14253-1:2018-5.2 (on customer request). Measurement results according to ILAC-G8:09/2019 Fig. 5, Pass are assessed as conforming to the specifications. Cases according to ILAC-G8:09/2019 Fig. 5, Conditional Pass, Conditional Fail and Fail are not considered to comply with the specifications.

- **Date of Calibration:** Date or date range on which the calibration occurred.
- **Calibration Label:** Sticker attached to the device under test, providing an explicit reference to the calibration certificate
- **Calibration Certificate Number:** Located on the first page of the calibration certificate, this number is a unique identification for this calibration certificate.
- **Nominal value:**
  - **Calibration of sources (including gauges):** The value set or indicated on the device under test.
  - **Calibration of measurement devices:** The value set or indicated on the standard.
- **Calibration Mark:** Unique identification of the calibration. This mark consists of the calibration certificate number, an identifier of the laboratory ("D-K-15019" for accredited calibration certificates or "esz AG" for factory calibration certificates) and the (month-specific) calibration date. It is written in the header of the calibration certificate
  Examples: 405364-01-D-K-15019-2021-01 or 405364-02-esz AG-2021-01
- **Calibration Certificate:** Report according to the requirements of DIN EN ISO/IEC 17025:2018, Section 7.8. At esz AG calibration & metrology, this applies not only to accredited calibration certificates, but also in particular to the result reports of factory calibrations.
- **Statement of Conformity:** Statement whether given results meet specified requirements or not ("Passed" or "Failed")[3], meaning that measurements comply with specifications (successful conformity assessments per measurement step).
  The definition of the specifications according to the manufacturer's data or application requirements was agreed on at the time the order was placed.
  A calibration is assessed as **Passed** if a successful statement of conformity is available for all specified measurement steps. A calibration is assessed as **Failed** if there is no successful statement of conformity or a defect for at least one specified measurement step.
- **LWL:** Optical waveguide

[3] DIN EN ISO/IEC 17000:2004

- **Multiple Values:** Repeatedly obtained measured values and nominal values are reported in the calibration certificate as an arithmetic mean value and marked distinctly. Additionally, the number n of values is reported. The stated deviation corresponds to the difference between the respective mean values of the measured value and the nominal value. The standard deviation of the stated deviation is considered in the measurement uncertainty (MU). A possible statement of conformity is carried out exclusively based on the mean values.

Nominal Value	Measured Value	Specification	Deviation	%TOL	MU
Ø 100,0 °C (n=3)	Ø 99,9 °C (n=3)	±1,5 %; ±1 D	-0,1 K	7 %	0,57 K
Ø 199,9 °C (n=3)	Ø 198,9 °C (n=3)	±1,5 %; ±1 D	-1 K	31 %	0,99 K

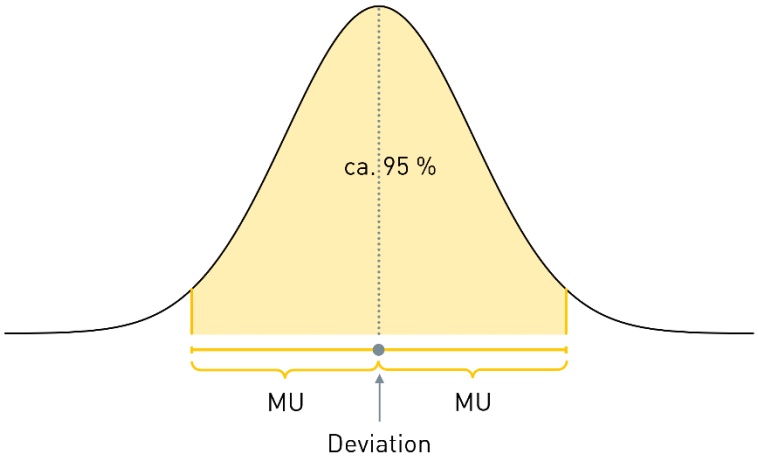
Optionally (at the customer's explicit request), the underlying multiple values can be stated for information purposes in addition to the mean value (their additionally stated measurement uncertainty does not include the present variation).

Nominal Value	Measured Value	Specification	Deviation	%TOL	MU
1,00000 V	*0,97948 V*		*-0,02052 V*		*0,0059 • 10^{-3} V*
1,00000 V	*1,01946 V*		*0,01946 V*		*0,0059 • 10^{-3} V*
1,00000 V	*0,99989 V*		*-0,00011 V*		*0,0059 • 10^{-3} V*
1,00000 V	*1,00381 V*		*0,00381 V*		*0,0059 • 10^{-3} V*
Ø 1,00000 V (n=4)	**Ø 1,00066 V (n=4)**	**±0,045 V**	**0,00066 V**	**1 %**	**0,016 V**

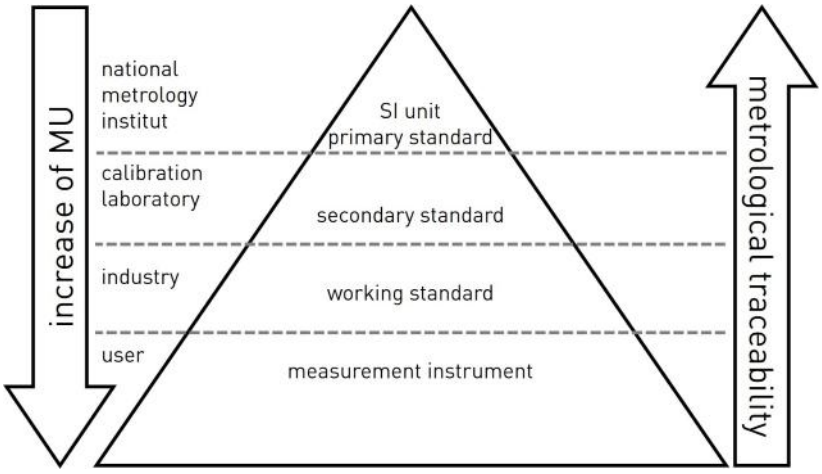
- **MU:** Measurement uncertainty

  The measurement uncertainty is a non-negative parameter that takes into account all relevant influence quantities of a measurement and their effects. The measurement uncertainty depends on the measurand and the measurement method.

  According to EA-4/02 M: 2022, the determination of the measurement uncertainty is based on a statistical approach, whereby each influence quantity is described by an appropriate probability density. A normal distribution (Gaussian) is assumed for the measurement result. A complete measurement result thus always requires the statement of a deviation (maximum of the normal distribution) and the associated measurement uncertainty (width of the normal distribution). The measurement uncertainty spans a symmetrical interval around the deviation in which the true value can be found with a probability of approx. 95 %.



Furthermore, the measurement uncertainty provides the basis for the metrological traceability. Metrological traceability to an SI unit or primary standard cannot be established without knowing the measurement uncertainty of each level within the metrological traceability pyramid. To establish metrological traceability to the next higher level, calibration with the higher-level (reference) standard is required.



- **MU (-) and MU (+):** In contrast to the symmetrical representation of the measurement uncertainty described above, an asymmetrical representation is chosen for certain measurands or parameters. The measurement uncertainty spans an asymmetrical interval around the deviation in which the true value can be found with a probability of approx. 95 %.

- **Measured value:**
  - **Calibration of sources (including gauges):** The value read on the standard.
  - **Calibration of measurement devices:** The value read on the device under test.
- **Next calibration:** Date for the next calibration agreed within the order placement. The definition and compliance to intervals for recalibrations lie within the user's responsibility
- **PTB: P**hysikalisch-**T**echnische **B**undesanstalt (the National Metrology Institute of Germany)
- **Relative** (%, 10^{-6}, 10^{-9}, ...)
  - **Deviation** refers to
    - the nominal value when calibrating **sources (including gauges)**
    - the nominal value when calibrating **measurement devices**
  - **Measurement Uncertainty** refers to
    - the measured value when calibrating **sources (including gauges)**
    - the nominal value when calibrating **measurement devices**
- **Rounding:** All calculations, including the statement of conformity, are based on numerical values with the maximum available digit precision. The resulting numerical values in the calibration certificate are rounded. Resolution and readability can influence the rounding digit.
  - **Rounding of the relative deviation:** The representation of the deviation for the deviation type relative (R) depends on how the number of significant digits of the deviation differs from the number of significant digits of the measurement uncertainty if the relative deviation were to be represented with the resolution and exponential notation of the MU.

    esz has defined a representation rule that distinguishes between three cases:
    - Case 1: Deviation (Dev.) smaller than the measurement uncertainty (|Dev.| < MU)
    - Case 2: Deviation greater than or equal to the measurement uncertainty (|Dev.| ⩾ MU)
    - Case 3: Deviation is much greater than the measurement uncertainty (|Dev.| >> MU) If the difference between the significant digits reaches 3 (or more), the deviation is considered to be "much greater".

    Implementation of the representation in the certificate to improve readability:
    - Case 1 (|Dev.| < MU): Representation of the deviation with two significant digits, rounding to the last resulting digit, including a switch from e.g. % to 10^{-6} or 10^{-9}
    - Case 2 (|Dev.| ⩾ MU): Representation of the deviation with the resolution of the relative measurement uncertainty, rounding to the last resulting digit

- Case 3 (|Dev.| >> MU): Representation of the deviation with two significant digits, rounding to the last resulting digit, including a switch from e.g. 10^{-9} to 10^{-6} or %.

- **Specification:** Documented limits around the **nominal value** used for the **statement of conformity**.

  In addition to the representation in the unit of the nominal value, the following notations are used in the calibration certificate:

  - **%:** percent (10^{-2}) of the nominal value
  - **%FS:** percent (10^{-2}) of the range
  - **ppm:** parts per million (10^{-6}) of the nominal value
  - **ppmFS:** parts per million (10^{-6}) of the range
  - **ppb:** parts per billion (10^{-9}) of the nominal value
  - **ppbFS:** parts per billion (10^{-9}) of the range
  - **D:** Digit (smallest displayable or settable decimal place of the device under test)
- **TUR: T**olerance **U**ncertainty **R**atio. Relationship between tolerance field and measurement uncertainty (also specification measurement uncertainty ratio)
- **Ambient Conditions:** The ambient conditions are documented by indicating the measured values for temperature, relative humidity and barometric pressure. The values are also given in the form of ranges of measured values. The respective measured values of the ambient conditions are taken and documented at the beginning and end of the calibration. Parameters that are not relevant for the calibration can be marked with "n.a.". In addition, the expanded measurement uncertainty (coverage probability of approx. 95 %) of the measured values is specified (e.g. ±1 K).

  3. Ambient Conditions
  Temperature (22,9 to 23,0) °C ±1 K
  Relative Humidity 50 % ±3 %
  Barometric Pressure 1000 mbar ±5 mbar

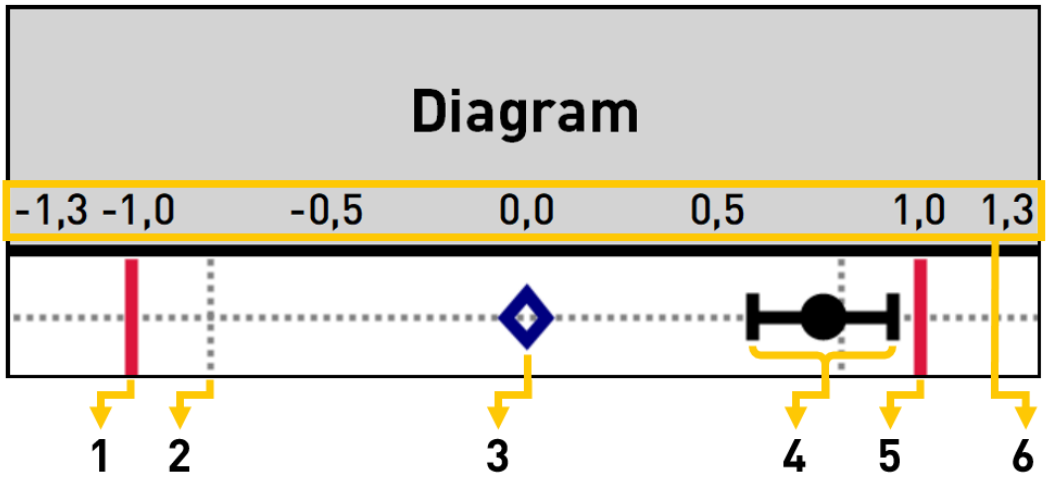
- **Calibration equipment and standards:** Documentation of the traceability of the present calibration by specifying the calibration standards used, including information on the calibration status of the standards and their traceability. If applicable, the traceability to national standards is included.

  This documentation fulfils the requirement of DIN EN ISO/IEC 17025:2018, section 7.8.4.1c) for indication of traceability and is mandatory in the case of a factory calibration certificate. For

an accredited calibration certificate, this may be omitted, since the accreditation of esz AG calibration & metrology by DAkkS already provides proof of traceable calibration.

- **Diagram:** Visualisation of results with a **Statement of Conformity**. The representation is normalized to the registered **Specification** or a multiple of the **Measurement Uncertainty**.

Legend Diagram



1: Lower specification limit

2: Intervention/warning threshold

3: Deviation of 0,0

4: Deviation incl. measurement uncertainty

5: Upper specification limit

6: Scale