Calibration Certificate

Invar rod (type, No.):
GPCL3 79918

ISO-Classification:
ISO 12858-1 - 3 B A

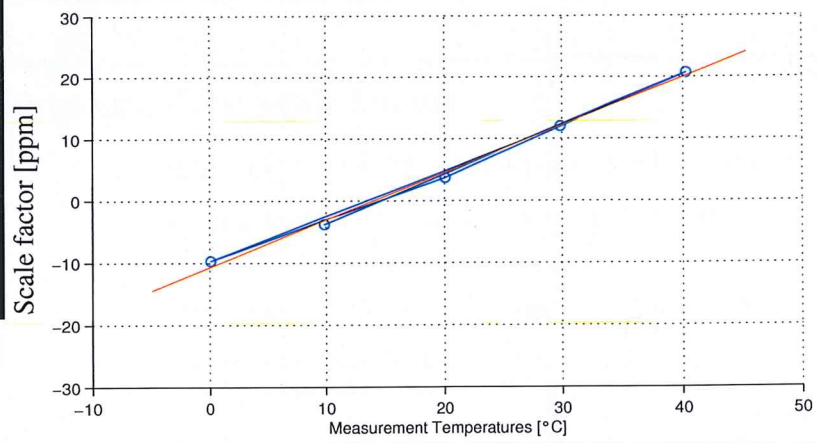
No. of graduations measured:
5 - 345

Contract:
21-445-2076384

Date :
16.03.2021

Determination of the coefficient of expansion
Horizontal calibration position

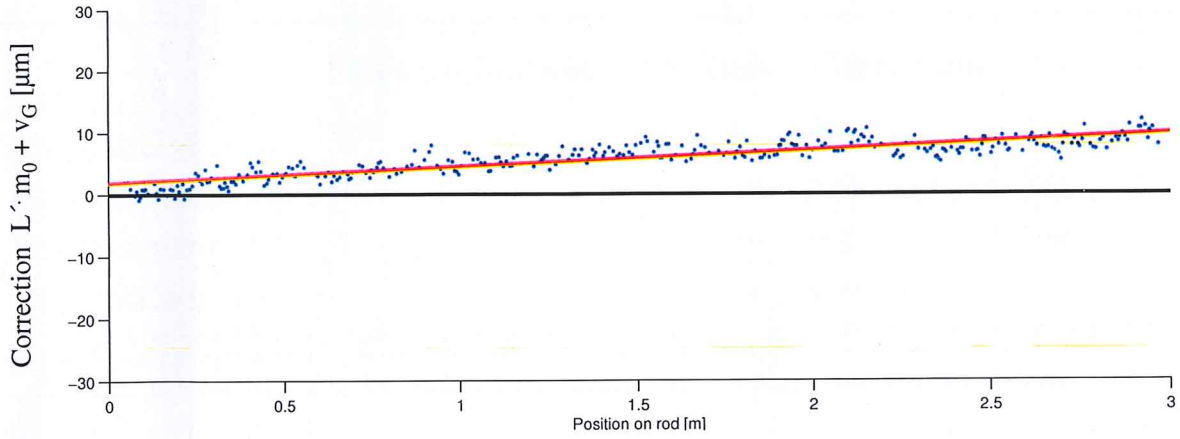
Measurement cycle: 30 → 0 → 20 → 40 → 10 [°C]



Coefficient of expansion:

α_T = 0.77 ± 0.03 *ppm/ °C*

Determination of the scale factor **Vertical calibration position, middle 16 mm of scale**



Scale factor: m_0 = 2.66 ± 1.15 *ppm* at T_0 = 19.7 °C

Length adjustment from the vertical calibration (position of use)

$L = l^0 + L'[1 + (m_0 + \alpha_T(T - T_0)) \cdot 10^{-6}] + v_G$

$l^0 = l_K^0 + v_K$

L'[m] = observed rod length
T[°C] = temperature
l^0 [m] = index correction (l_K^0[m] = index correction of reference bar, v_K[m] = reference bar correction)
v_G [m] = graduation correction

l^0 = -0.014 ± 0.002 mm
v_G = +0.002 mm

l_K^0 = -0.006 ± 0.002 mm
v_K = -0.008 mm

Technical specialist: Schreyer
Laboratory director:

Munich, 16.03.2021
Institute director:

Geodätisches Prüflabor am Lehrstuhl für Geodäsie der TU München
Arcisstraße 21, 80290 München, Tel.: 089/289-22850, Fax: 089 /289-23967

Calibration of Invar Rods

Invar rods for precise levelling are examined on the comparators at the Geodetic Laboratory of the Chair of Geodesy at the Technical University of Munich. The distances between the code edges on the invar tape are measured using a CCD camera and laser interferometer system in a fully automated process.

Determination of the index correction

The distance between the reference edge of the graduation and the setup point of the rod is measured in the axis of the invar tape guidance and is compared to the nominal value. On the calibration certificate one can find

- the **index correction of the reference bar** l_K^0 which is the (single) bar defined for index error definition
- the **reference bar correction** v_K which is the correction of the reference bar due to its thickness error. It's a correction value which describes the difference between the reference bar and the reference bar's edge which is used for adjusting the index error
- the combined **index correction of the rod** l^0 which is the sum of the corrections above. This is the final value which has to be added to the rod reading.

For analogue rods with two graduation scales, the graduation offset k^0 is also determined.

DIN ISO 12858-1 allows an index error up to 50 µm.

Determination of the scale factor

The position of all graduation bars is observed in two measurement transits (the rod passing the camera up and down). The nominal and measured positions of each bar get compared and the results are related to a linear regression. The gradient of this regression is the **mean rode scale factor** m_0 at the **measurement temperature** T_0. The code pattern quality is rather defined by the linearity than by the scale factor; i.e. a graduation with a scale factor close to 0 and big deviations from linearity usually is worse than a linear graduation with a bigger scale factor.

DIN ISO 12858-1 classifies the scale as a combination of linear and non-linear effects, while class A rods usually have a scale factor < 10 ppm and scale factors > 50 ppm lead to a classification decline.

For rods with two line graduations, a scale factor for both graduations is determined individually.

A tabulation of the residuals of each graduation bar is supplied on the certificate. For analogue rods, these values may be added to the reading depending on the bar element observed; for digital rods a combined correction value v_G is specified which is a mean correction of the scale's non-linearity.

Determination of the coefficient of thermal expansion

Levelling rods consist of a graduation tape which is moveable in its housing. Under thermal expansion conditions, usually the housing's deformation is much bigger than the tape's elongation. To determine the coefficient of thermal expansion, the graduation's scale factor is determined at five different temperatures from 0°C to 40°C. Usually the scale factor values are linear to the measurement temperature, and the regression gradient is the **thermal coefficient of expansion** α_T. To ensure that friction between the tape and the housing as well as malfunctions of the tension module aren't systematically increasing during the measurements, a temperature cycle of 30°C → 0°C → 20°C → 40°C → 10°C is performed.

DIN ISO 12858-1 classifies a coefficient of thermal expansion up to 1.5 ppm/°C, while all standard invar tapes used are classified as B.

An explanation on how to read the calibration certificate and how to use the calibration results provided can be found on the reverse side.

Geodetic Laboratory at the Chair of Geodesy
Technical University of Munich, Arcisstraße 21, 80333 München
Phone: ++49 89 289 22850 Fax: ++49 89 289 22967 calibration@bv.tum.de

Calibration Certificate

Invar rod (type, No.):
LD13 12345

ISO-Classification:
ISO 12858-1 - 3 B A

Rod quality classification according to ISO standard.

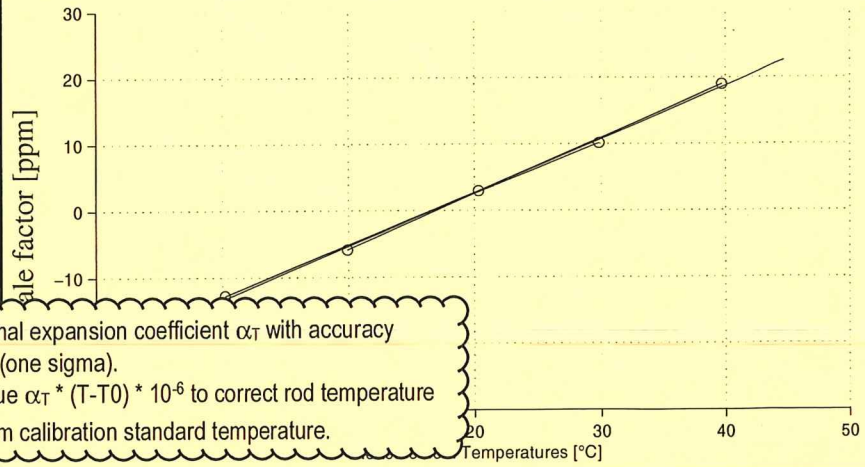
No. of graduations measured:
5 - 270

Contract:
18-410-12345678

Date :
04.10.2018

Determination of the coefficient of expansion
Horizontal calibration position

Measurement cycle: 30 → 0 → 20 → 40 → 10 [°C]

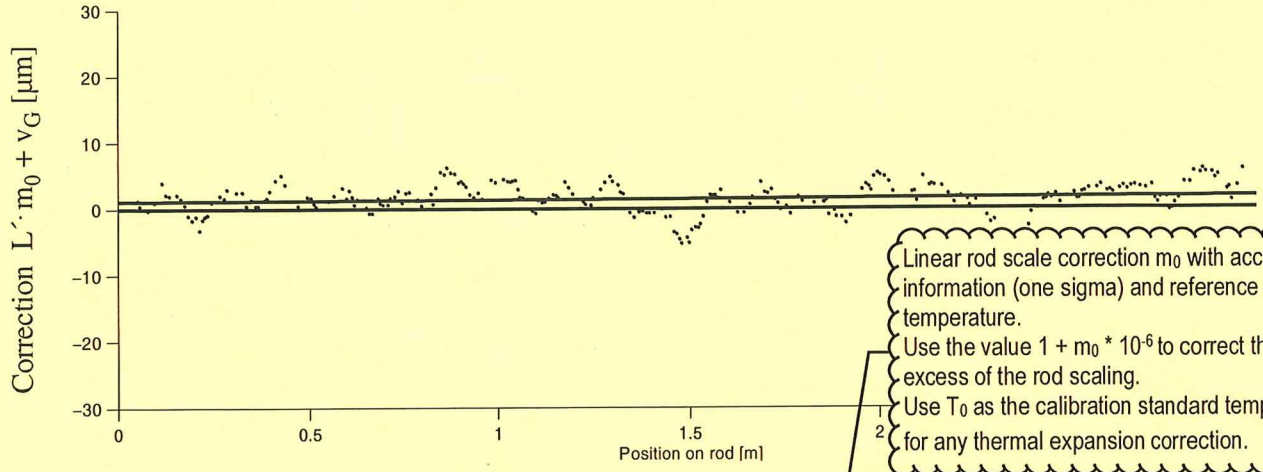


Coefficient of expansion:

$\alpha_T = 0.80 \pm 0.02$ *ppm/ °C*

Linear thermal expansion coefficient α_T with accuracy information (one sigma).
Use the value $\alpha_T * (T-T0) * 10^{-6}$ to correct rod temperature different from calibration standard temperature.

Determination of the scale factor **Vertical calibration position, middle 16 mm of scale**



Linear rod scale correction m_0 with accuracy information (one sigma) and reference temperature.
Use the value $1 + m_0 * 10^{-6}$ to correct the length excess of the rod scaling.
Use T_0 as the calibration standard temperature for any thermal expansion correction.

Scale factor: $m_0 = 0.22 \pm 1.16$ *ppm* at $T_0 = 20.0$ °C

Length adjustment from the vertical calibration (position of use)

$$L = l^0 + L'[1 + (m_0 + \alpha_T(T - T_0)) \cdot 10^{-6}] + v_G$$

Correction formula with respect to all corrective values being shown on the calibration reports.

$l^0 = +0.005 \pm 0.004$ mm
$v_G = +0.001$ mm

$l_K^0 = -0.003 \pm 0.004$ mm

v_G [m] = graduation correction

T [°C] = temperature

l^0 [m] = index correction (l_K^0 [m] = index correction

Zero index correction with accuracy information (one sigma) and graduation correction. Use this values as additive corrections.
l_0 is the zero index correction regarding the reference bar on the scaling and is subject to normative comparisons.
v_G is a calibration correction due to the non-linearity of the scale correction. It is usually very small (some µm) and may be neglected.

Technical specialist:

Laboratory director:

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