AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF MINING SURVEYING
AND ENVIRONMENTAL ENGINEERING
DEPARTMENT OF GEOMATICS

The Optimum Procedures of Determining the Coefficient of Linear Thermal Expansion and Calibration of Precise Leveling Rods (5854)

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Geodetic Metrology Laboratory

Laboratory studies of precise leveling rods

Geodetic Metrology Laboratory
AGH University of Science and Technology in Krakow

Coefficient of linear thermal expansion (CLTE)

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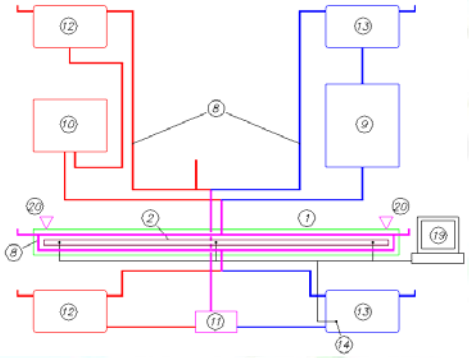
CLTE

Modernization of the stant for determination CLTE

1998 r. – first thermal stand

2003 – 2004 – modernization



Scheme of the thermal chamber

General view of the thermal chamber

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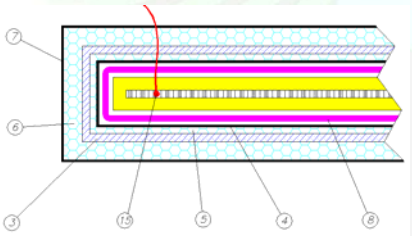
CLTE

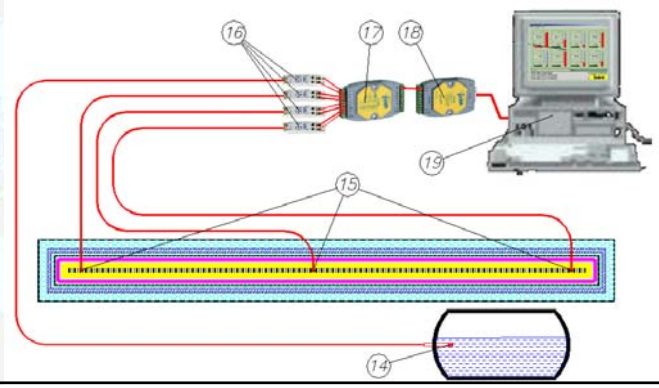
Thermal chamber

Obtained temp.: –10 C do +50 C

Error of Invar band temp.: 0.05 C

Error of lenght changes: 0.8 m





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CLTE

Procedure of determining the CLTE

Time: about 12 – 16 hours

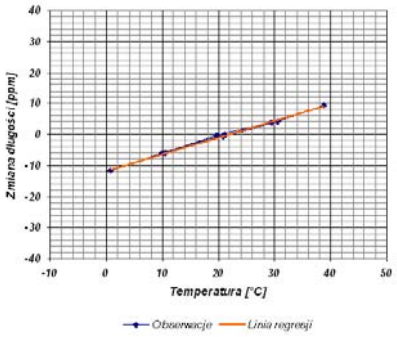
Cycle: 20→10→0→10→20→30→40→30→20 [˚C]

Measured values:

Changes of Invar band temperature t_i and Invar band lenght l_i

$$v_i = a_0 + a_1 \cdot \Delta t_i - l_i$$

Error of CLTE: 0.01÷0.05 ppm/ C



Result of CLTE

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CLTE

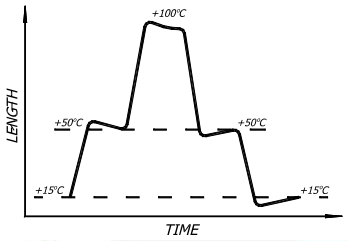
Thermal anomalies of Invar and temperature histeresis

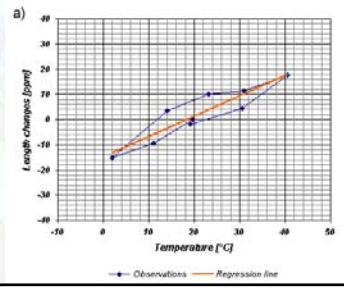
- rate of temp. changes
- choise of the moment of obser.
- temperature stability

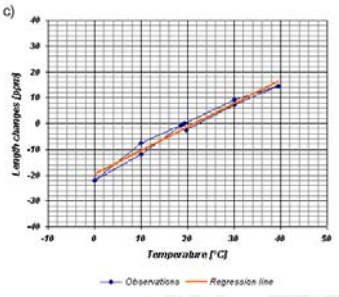
Change of CLTE: 0.5 ppm/ C

Elimination: better insolation

better stabilization







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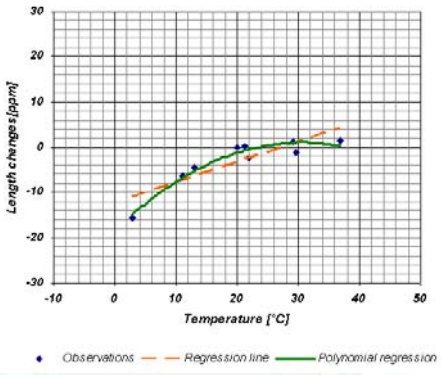
CLTE

Nonlinear changes in the lenght of Invar



Nonlinear changes in the length
(rod: Topcon 16408)

Three models:

-Linear regression (90%)

-Polynomial regression of 2-nd degree (10%)

-Polynomial regression of 3-rd degree (0%)

For 10% rods it was required to apply polynomial thermal correction

Differences in the value of thermal corection: 0.5 mm/km

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Calibration

Modernization of vertical comparator

1998 – first concept of comparator

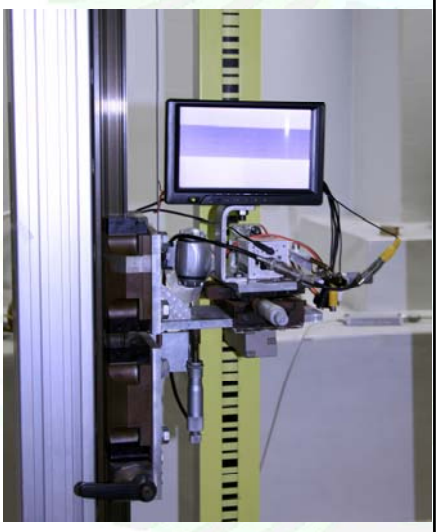
2004 – 2006 – modernization

since 2010 – image analysis

HP Laser Interferometer

Two-axis measurement

CCD camera



Part of the vertical comparator

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Calibration

The procedure of calibration

60 – 75 „meas. points”

- atmosphere reductions for all interf. records

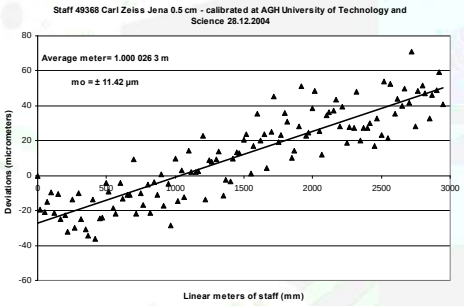
- thermal influences

- corrections of the measurement system

- graduation corrections r_D

$$v = a_0 + a_1 D + (D + r_D)$$

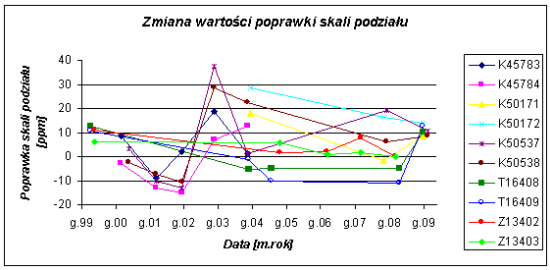
„Measurement points”



Calibration results

Calibration

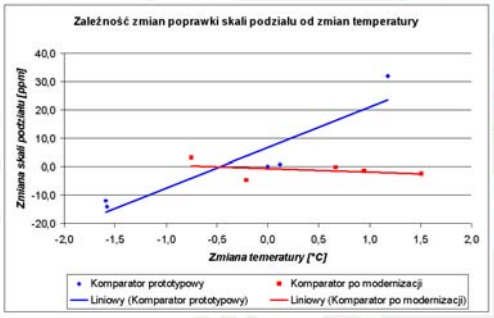
Changes of rod's scale



Changes of scale for various rods

Temperature influence on calibration results

Mean changes of scale and temperature



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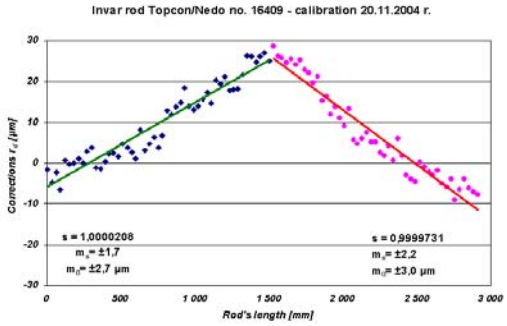
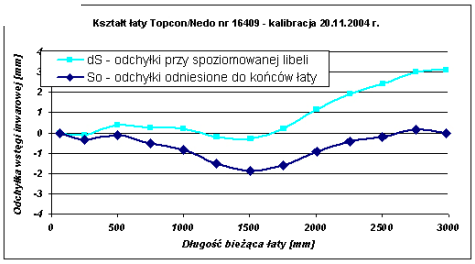
Calibration

Abnormal changes of graduation



Two different scale factors for graduation Invar rod no. 16409



Deformation of the aluminium body coused by fixing leveling support in the half of its lenght

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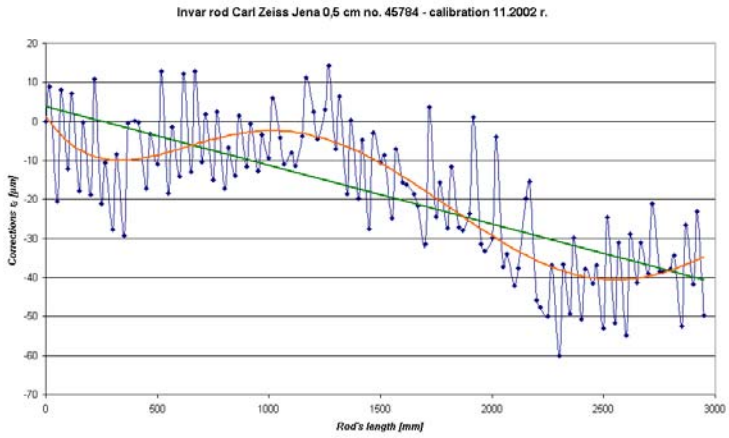
Calibration

Nonlinear changes in the graduation of leveling rod



Polynomial changes of classical graduation

Print screen method

- **lower precision of making**
- **using pattern of graduation**
- **repetitive errors**

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Conclusions

Owing to the modernization and detail procedures:

Mean error of CLTE was decreased by 0.02 ppm/ C

0.01÷0.05 ppm/ C – new rods

Mean error of scale of graduation was decreased by 1 ppm:

2.1 ppm – rods with barcode graduation

TUM ±2.0 ppm / TUG ±3.0 ppm

Proposed way of calculating calibration corrections:

- **using graduation corrections r_D**
- **approximation with a relevant polynomial**

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THANK YOU FOR YOUR ATTENTION

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