Calibration procedure for digital thermometers

Version 1 - 2022

1 Calibration procedure for digiSubject calibration

Calibration method with covers on calibration digital thermometers, range calibration (-40 until + 200)° C or digital thermometers - measuring chains temperature - calibrated in place measurement, range calibration (-40 until +180)°C.

2 Related regulations

TNI 01 0115	International metrological dictionary - Basic and general concepts and associated terms (VIM)
ČSN 25 8005	Nomenclature of field measurement temperature
EA 4/02	Expression uncertainty measurement at calibrations
ČSN EN ISO/IEC 17025	Assessment matches - General requirements on eligibility test and calibration laboratories
TPM 0051- 93	Determination uncertainty at measurements

3 Qualifications workers implementers calibration

Worker performing calibration must be trained and must have certificate for implementation calibration digital thermometers issued by a recognized authority.

4 Nomenclature and definitions

Nomenclature and definition they are occupied in relevant documents:

- TNI 01 0115,
- ČSN 25 8005,
- EA 4/02

5 gauges, machines and aids needed for calibration

5.1 STANDARDS

Benchmark thermometer:

- digital thermometer
- resistive sensor temperatures, Pt100

Machines must be established on national benchmarks and they have to have valid calibration, uncertainty better than 0.07 °C.

5.2 HELPFUL GAUGES

Measurement temperature Surroundings:

- thermometer - apparatus must have valid calibration blade, uncertainty better than 0.5 °C

Measurement time:

- stopwatch - Apparatus must have valid calibration, uncertainty better than 1 with.

5.3 MACHINES AND TOOLS

Source trial temperatures:

- liquid bath, liquid technical alcohol for range temperature (-40 until +40) °C
- liquid bath, liquid silicone oil for range temperature (30 until 200) °C

- thermal chamber for range temperature (-40 until +180) °C

Next machines and gadgets:

- homogeneous environment, e.g. container with liquid
- stands and holders
- cleaning means

6 Conditions calibration

Temperature Surroundings at calibration must be (22±3) °C.

7 Own method

7.1 EXTERNAL VISITATION

At recipient thermometer to calibration with primarily checks:

- functionality of the thermometer - whether the measured temperature is the temperature measured in the immediate vicinity, the functionality of the control elements,
- state battery - at any suspicion on discharged battery Yippee necessarily her exchange,
- functionality power supply resources (if necessary to operation thermometer),
- state display - whether you can of display safely read all needed data,
- whether housing temperature sensor and its interconnector knowledge (thermometer with sensor outside housing of the thermometer), the thermometer case, the display are not obviously mechanically damaged.

AT measuring chains temperature with further finds out:

- Properties working environment tested thermometer having influence on calibration,
- possibility use resources limiting undesirable influence working environment on calibration,
- state of the measuring chain and method of protection against unwanted states affecting the measurement; the measuring chain must be secured against unwanted manipulation,
- way evaluation measured values and their imaging; to tested temperature sensors must be unequivocally assigned them measured value, device must enable display immediately measured values or unambiguously assign a measurement time to the measured value, the method of evaluating the measured value must be secured against unwanted manipulation.

7.2 DETERMINATION MISTAKES

Error values measured examined thermometer with finds out by comparison this one values with value measured by the standard and it at same temperature.

7.2.1 Calibration in liquid baths

Thermometers with to spa places so, that thermal sensor tested thermometer and thermal sensor benchmark were as close as possible to to myself and in areas the best stability. At evaluation uncertainty measurement Yippee necessary evaluate depth the immersion of the standard as well as the distribution of the temperature field and the stability of the bath. If not from technical documentation, the minimum immersion depth of the temperature sensor of the tested thermometer is known, the immersion depth is chosen so that the measurement result is not substantially affected levy heat stem sensors. If would it could milk to damage temperature sensors when the temperature sensor is immersed in the liquid in the bath, the sensor is placed in a protective cover. This adjustment of the sensor must be taken into account when evaluating the measurement uncertainty.

IN if the temperature sensor is not permanently connected to the evaluation unit (replaceable temperature sensors), performs with calibration for the whole lineup "thermal sensor + evaluative unit". IN case that has thermometer more input channels and customer does not require otherwise, performs with calibration for all combination input channels and temperature sensors separately.

If customer does not require otherwise, performs with measurement least in three temperature points - on beginning in the middle and at the end measuring range. It contains if span 0 °C, is performed measurement also at this temperature. The order of temperature points is chosen sequentially from the lowest to the highest temperature.

Deduction values measured examined thermometer and benchmark with performs at constant or equally with increasing bath temperature. The rate of temperature change can be no more than 0.2 °C/min.

When recording values in at least 3 series of readings from individual thermometers are performed at one temperature point according to the following scheme:

$$i.e_{\_}, t_{of1}, t_{of2}, \dots, t_{zm-1}, t_{zm}, t_{zm}, t_{zm-1}, \dots, t_{of2}, t_{of1}, i.e_{\_} \qquad (1)$$

t_e value measured benchmark

t_z value measured examined thermometer

m number suddenly tested thermometers

7.2.2 Calibration in thermal chamber

The thermometers are placed in the chamber so that the temperature sensor of the tested thermometer and the temperature sensor of the standard are as close as possible to each other and in the region of best stability.

IN if the temperature sensor is not permanently connected to the evaluation unit (replaceable temperature sensors), performs with calibration for the whole lineup "thermal sensor + evaluative unit". IN case that has thermometer more input channels and customer does not require otherwise, performs with calibration for all combination input channels and temperature sensors separately.

If customer does not require otherwise, performs with measurement least in three temperature points - on beginning in the middle and at the end measuring range. It contains if span 0 °C, is performed measurement also at this temperature. The order of temperature points is chosen sequentially from the lowest to the highest temperature.

Deduction values measured examined thermometer and benchmark with performs at constant temperature in chamber.

When recording values at each temperature point, at least 3 series of readings from individual thermometers are performed according to the same scheme as in the temperature bath.

7.2.3 Calibration measuring chains temperature

Comparison values measured examined thermometer with value measured benchmark with performs in working environment tested thermometer.

Thermal sensor benchmark and tested thermometer with will insert together to homogeneous environment - e.g. container with suitable liquid, whereas container must have before calibration temperature working environment. Container must be placed freely in a space where there are no sudden changes in temperature.

If containers cannot be used, then the temperature sensor of the standard and the tested thermometer are attached to each other, and is placed freely in such a place in the work space where there are no sudden changes in temperature. Neither the standard nor the tested sensor must touch walls or other constructions or equipment in the work area.

In order to correctly evaluate the uncertainty of the measurement, it is necessary to determine the homogeneity and stability of the temperature field of the working environment, which we can determine using two test known temperature sensors, when we determine the difference in the temperatures measured by them. We place these sensors in the space where the tested thermometer is located. The distance of the sensors is chosen according to the location of the tested thermometer in the working environment, the method of arrangement and the dimensions of the working environment. That is, in such a way that the possible difference and fluctuations in temperature at the point of measurement are captured by the tested thermometer and benchmark. At use containers we insert trial sensors to containers what farthest from myself and container we place it in the space where the tested thermometer is located. We perform these measurements in such an operating mode of the work environment that will be similar to the one used during the calibration itself.

The reading of the values measured by the tested thermometer and standard is carried out after proper stabilization and equalization of the temperature of the tested sensor and standard with the temperature of the working environment.

In devices that allow this and the customer does not request otherwise, measurements are made at at least three temperature points - at the beginning in the middle and on the end of the measuring range of the tested thermometer. Otherwise performs measurement at one temperature - the temperature of the working environment.

Number readings and length interval between individual readings with chooses with regard on progress changes temperature working environment, but the number of readings is always at least 11.

8 A dvantage _ _ _

Record measured values and others reality important ones for calibration and evaluation measurement is performed by MS Excel software.

8.1 EXTERNAL VISITATION

If they are not fulfilled all requirements listed in the chapter 7.1, in next calibration with does not continue. The reason for the interruption of the calibration is recorded.

8.2 DETERMINATION MISTAKES

8.2.1 Value measured benchmark

According to chapters 7.2 we get in once by temperature point for standard *n* readings, of which we will find out the real one temperature -
conventionally the right one value:

$$\sum^{n} t_{ei}$$

$$i.e_{-} = \frac{\sum_{i=1}}{n} \quad (2)$$

t_e	arithmetic diameter values measured benchmark in once by temperature point-real temperature - conventionally right value
t_{ei}	i -th deduction values measured benchmark in once temperature point
n	number readings in once by temperature point

8.2.2 Value measured examined thermometer

According to chapters 7.2 we get in once by temperature point for each tested thermometer *n* readings, of which we calculate the arithmetic mean:

$$t_z = \frac{\sum_{i=1}^{n} t_{zi}}{n} \qquad (3)$$

t_z arithmetic diameter values measured examined thermometer in once by temperature point
t_{zi} i -th deduction values measured examined thermometer in once by temperature point
n count readings in once by temperature point

8.2.3 Uncertainty measurement

Enhanced uncertainty measurement Yippee given relation: (4)

$$AT = to \times at$$

U extended uncertainty measurement
k coefficient extension
at standard uncertainty

$$u = \sqrt{u_A^2 + u_B^2} \qquad (5)$$

u_A standard uncertainty type AND
at_B standard uncertainty type B

$$at_A = \sqrt{\frac{1}{n(n-1)} \times \sum_{i=1}^{n} (t_{zi} - t_z)^2} \qquad (6)$$

t_z arithmetic diameter values measured examined thermometer in once by temperature point
t_{zi} i -th deduction values measured examined thermometer in once by temperature point
n count readings in once by temperature point

$$at_B = \sqrt{\sum_{j=1}^{m} (u_{Bj} \times c_j)^2} \qquad (7)$$

u_{Bj} uncertainty j- th resources uncertainty type B
m count resources uncertainty type B
c_j sensitive coefficient j- th resources uncertainty type B

$$at_{Bj} = \frac{\Delta\, of_{\max}}{\chi}$$

(8)

Δz_{max} estimate maxim j- th resources uncertainty

χ type layout probabilities j- th resources uncertainty

Considered resources uncertainty type B:

j	source uncertainty	estimate limits ; Δz_{max}	division ; χ	coef.citl .; C

1	benchmark : enhanced uncertainty *AT* benchmark detected of calibration sheet ; [° C]	$\Delta\ of_{\max} = AT$	normal $\chi = 2$	1
2	tested thermometer : resolution ; [° C]	$\Delta\ of_{\max} = \frac{d}{2}$ *d* value the last one valid digit	equally $\chi = \sqrt{3}$	1
3	liquid bath : layout temperature field *t* $_{tp}$, (stability , homogeneity) is determined by averaging possibly from technical documentation ; [° C]	$\Delta\ of_{\max} = t_{tp}$	equally $\chi = \sqrt{3}$	1
4	thermal chamber layout temperature field *t* $_{tp}$, (stability , homogeneity) is determined by averaging possibly from technical documentation ; [° C]	$\Delta\ of_{\max} = t_{tp}$	equally $\chi = \sqrt{3}$	1
5	spatial temperature field: layout temperature field *t* $_{pp}$, in place measurement (stability , homogeneity) is determined experimentally , [° C]	$\Delta\ of_{\max} = {}_{pp}$ —	equally $\chi = 3\sqrt{}$	1

8.2.4 Error of the tested thermometer

Calibration in liquid spa:

$$\Delta t_z = t_z - i.e_{\_} + \Delta t_r + \Delta t_l \qquad (9a)$$

Measuring string temperatures:

$$\Delta t_z = t_z - i.e_{\_} + \Delta t_r + \Delta t_{Mr} \qquad (9b)$$

Δt_z	error tested thermometer
t_z	arithmetic diameter values measured examined thermometer, see equation (3)
t_e	conventionally right value, see equation (2)
Δt_r	correction on distinction tested thermometer
Δt_l	correction on layout temperature field liquid spa

Δt_p correction on influence spatial temperature field

8.2.5 Evaluation matches with specifications

In all of them temperature points with error tested thermometer will compare with biggest holiday by mistake:

a) in case that in all of them temperature points apply:

$$|\Delta t_z| + AT < \Delta_{max} \qquad (10)$$

Δt_z error tested of the
thermometer U extended
measurement uncertainty Δ_{max}
the largest permissible error
tested thermometer he complied required specification.

b) in case that at least in once by temperature point apply:

$$|\Delta t_z| - AT \; \Delta_{max} \qquad (11)$$

Δt_z error tested of the
thermometer U extended
measurement uncertainty Δ_{max}
the largest permissible error
tested thermometer did not comply required specification.

c) in others cases can't decide, whether tested thermometer he complied whose did not comply required specification.

9 Calibration center _ _ _

Result calibration and more information with in the necessary scope they record to calibration sheet. Calibration sheet it is created in accordance with EN ISO/IEC 17025 and its model is given in Annex 1.

10 Example calculation uncertainty

Example calculation uncertainty Yippee carried out for case calibration in liquid baths for temperature 50 °C and in in accordance with document EA 4/02.

10.1 INPUT DATA

Tried thermometer:

injectable electronic thermometer	
measuring range	(-50 until +150) °C
resolution	0.1 °C
biggest holiday error	1 °C

Standard:

digital thermometer + resistive sensor temperature Pt100
enhanced uncertainty measurement at 50 °C Yippee according to calibration sheet 0.037 °C for k=2

Liquid bath:

bath stuffed silicone oil
worst measured value homogeneity and stability Yippee ±0.05 °C

Conditions at calibration:
temperature Surroundings during whole times measurement (23±1) °C

10.2 MEASURED VALUES

C. I will read	t e ; standard [° C]	t of ; tested [° C]
1	50.25	50.4
2	50.25	50.4
3	50.26	50.4
4	50.25	50.4

10.3 EVALUATION

Error tested thermometer:

$$\Delta t_z = t_z - i.e_{\_} + \Delta t_r + \Delta t_l \quad (12)$$

Δt_z error tested thermometer
t_z arithmetic diameter values measured examined thermometer
t_e conventionally right value, detail benchmark
Δt_r correction on distinction tested thermometer
Δt_l correction on layout temperature field liquid spa

t of ; arithmetic diameter values measured examined thermometer

$$t_{of} = 50.4\ ° C$$

selective authoritative deviation - standard uncertainty type AND:

$$at_{AND} = 0.00\ ° C$$

t e ; conventionally right value - arithmetic diameter values measured benchmark

$$i.e_{\_} = 50.25\ ° C$$

standard uncertainty:

$$at_{you} = \frac{0.037}{2} = 0.019\ ° C$$

Δt r ; correction on distinction tested thermometer

$$\Delta t_r = 0.00\ ° C \pm 0.1\ ° C$$

standard uncertainty:

$$at_{\Delta tr} = \frac{0,1}{2 \times \sqrt{3}} = 0.029\ ° C$$

Δt l ; correction on layout temperature field liquid spa

$$\Delta t_l = 0.00\ ° C \pm 0.05\ ° C$$

standard uncertainty:

$$at_{\Delta\, thic\, kness} = \frac{0{,}05}{\sqrt{3}} = 0.029\ {}^{\circ}C$$

Overview uncertainty

magnitude	estimate	standard uncertainty	type distribution	coefficient sensitivity	contribution to uncertainty

i.e _	50.25 °C	0.019 °C	normal	1	0.019 °C
t z	50.4 °C	0.00 °C	normal	1	0.00 °C
Δt r	0.0 °C	0.029 °C	equally	1	0.029 °C
Δt l	0.0 °C	0.012 °C	equally	1	0.029 °C
Δt z	0.15 °C				0.045 °C

Enhanced uncertainty measurement

$$AT = to \times u = \sqrt{0{,}019^2 + 0{,}00^2 + 0{,}029^2 + 0{,}029^2} = 2 \times 0.045 \; \} \; 0.09\,°\,C$$

$2x$ _

Said result

Error tested thermometer at nominal temperature 50 °C Yippee +0.15 °C ±0.09 °C.

Listed enhanced uncertainty measurement Yippee by product standard uncertainty measurement and coefficient extension k=2, which for normal distribution he answers probabilities coverage about 95 %. Standard uncertainty measurement she was determined in accordance with document EA 4/02.

11 Validation and care O calibration method

This calibration procedure for digital thermometers calibrated in thermal the spa was validated at interlaboratory comparison of tests organized by ČMI DMPZ-044-14 and the method of calibrating the temperature measuring chains was validated by the laboratory staff by comparing the measurement results with the results in the temperature bath and by systematically checking all factors affecting the measurement uncertainty.

Least once for year with checks timeliness calibration procedure.

12 Side dishes

Attachment C. 1 Pattern calibration sheet

KALIBRAČNÍ LIST
číslo : T-nnn-D/2020

Datum vystavení :	...dat.vystavení KL
Zadavatel :	Všeobecná fakultní nemocnice v Praze ...klinika ...adresa
Datum přijetí měřidla :	...dat.přijetí
Kalibrované měřidlo :	digitální elektronický teploměr
Výrobce :	...výrobce
Typ :	...typ
Identifikační označení / výr. č. :	...ozn. měřidla TD- / ...v.č.
Popis :	...popis
Kanál :	...označení kanálu
Nastavený rozsah :	...označení rozsahu
Rozlišení :	...rozlišení °C
Měřicí rozsah :	...měřicí rozsah (až) °C
Identifikační označení snímače :	...ozn. snímače
Podmínky kalibrace :	Měřidlo bylo kalibrováno porovnávací metodou. Naměřené hodnoty jsou vypočteny jako průměrné hodnoty z více odečtů.
Umístění etalonu :	Společně se zkoušeným přístrojem v kapalinové lázni.
Místo měření :	Všeobecná fakultní nemocnice v Praze oddělení metrologie Na Bojišti 1, Praha 2
Kalibrační postup :	KP-03-02
Použitý etalon :	... ...
Návaznost :	...
Teplota okolního prostředí :	(23±3) °C

Pokračování kalibračního listu č. T-nnn-D/2020

Tabulka naměřených a vypočtených hodnot :

Použitá označení :

t_e	konvenčně pravá hodnota teploty, údaj etalonu
t_z	hodnota naměřená zkoušeným teploměrem
Δt_z	chyba zkoušeného teploměru
U	rozšířená nejistota měření

kanál ...označení kanálu / rozsah ...označení rozsahu

t_e	t_z	Δt_z	U
°C	°C	°C	°C
...	...	...	...
...	...	...	...
...	...	...	...

Uvedená rozšířená nejistota měření je součinem standardní nejistoty měření a koeficientu rozšíření k=2, což pro normální rozdělení odpovídá pravděpodobnosti pokrytí asi 95 %. Standardní nejistota měření byla určena v souladu s dokumentem EA 4/02.

Poznámka : Naměřené hodnoty platí pro kanál ... .

Kalibroval : Ing. O. Kraus
technik metrolog

Dne : ...dat.kal.

Schválil : Ing. Jiří Pařík
vedoucí MS

----- konec kalibračního listu -----