Innovative approaches to improving the accuracy of thermal energy measurement by simulating and analysing the installation points

JUMO

19th September 2024 | Seeon

EMATEM

European Metrology Association for Thermal Energy Measurement

Dipl.-Ing. Daniel Bott
Market Segment Manager
Temperature Probes
for Heat Meter

Often underestimated: The Heat Conduction Error

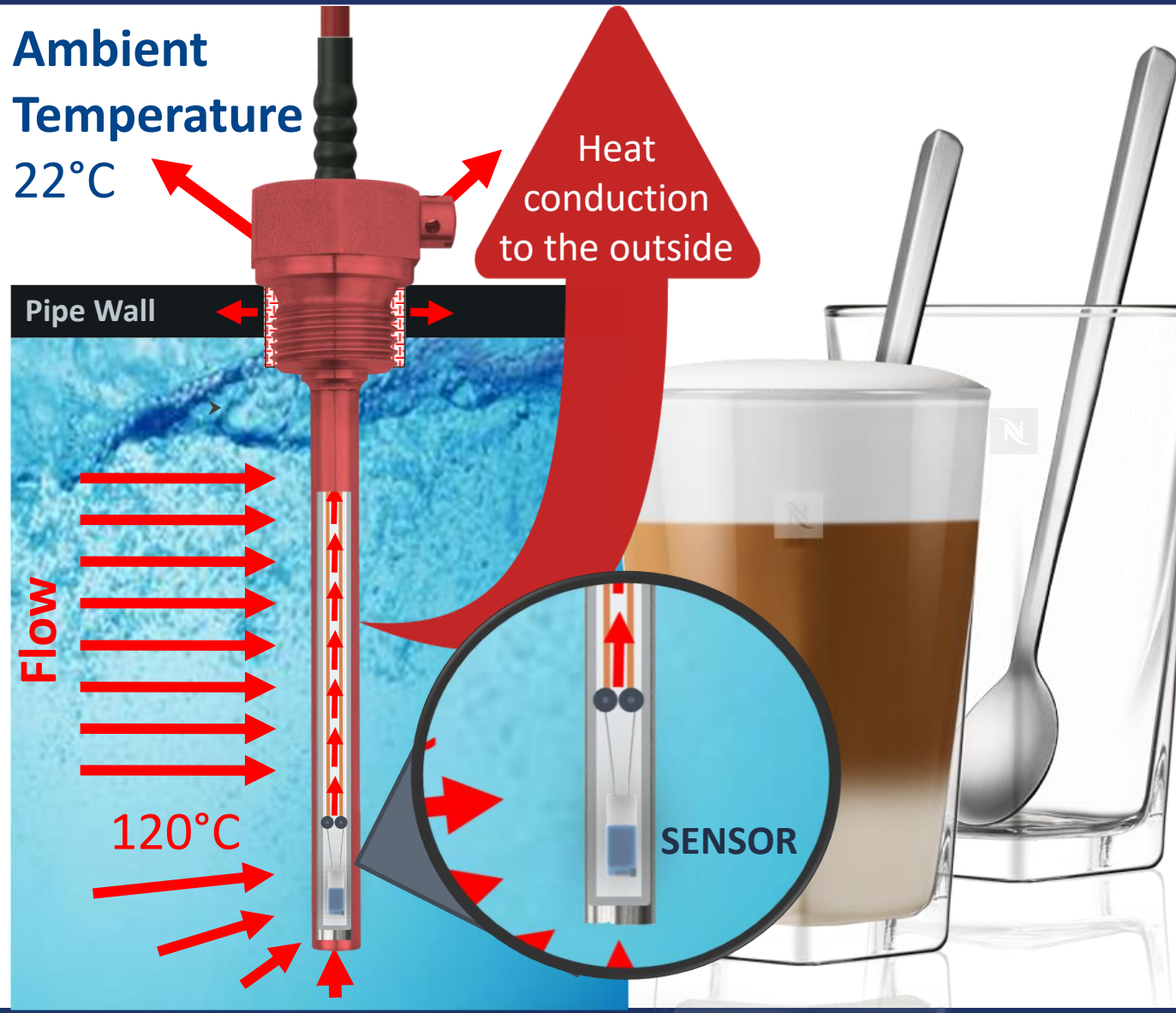
- **The temperature sensor always measures a Temperatur**
  → only the question is whether it is the right one

- **Generally not used at ambient temperature**
  - Generally not used at ambient temperature

- **Temperaturgefälle innerhalb des Temperaturfühlers**
  - This creates a heat flow
  - Sensor element is cooled or heated

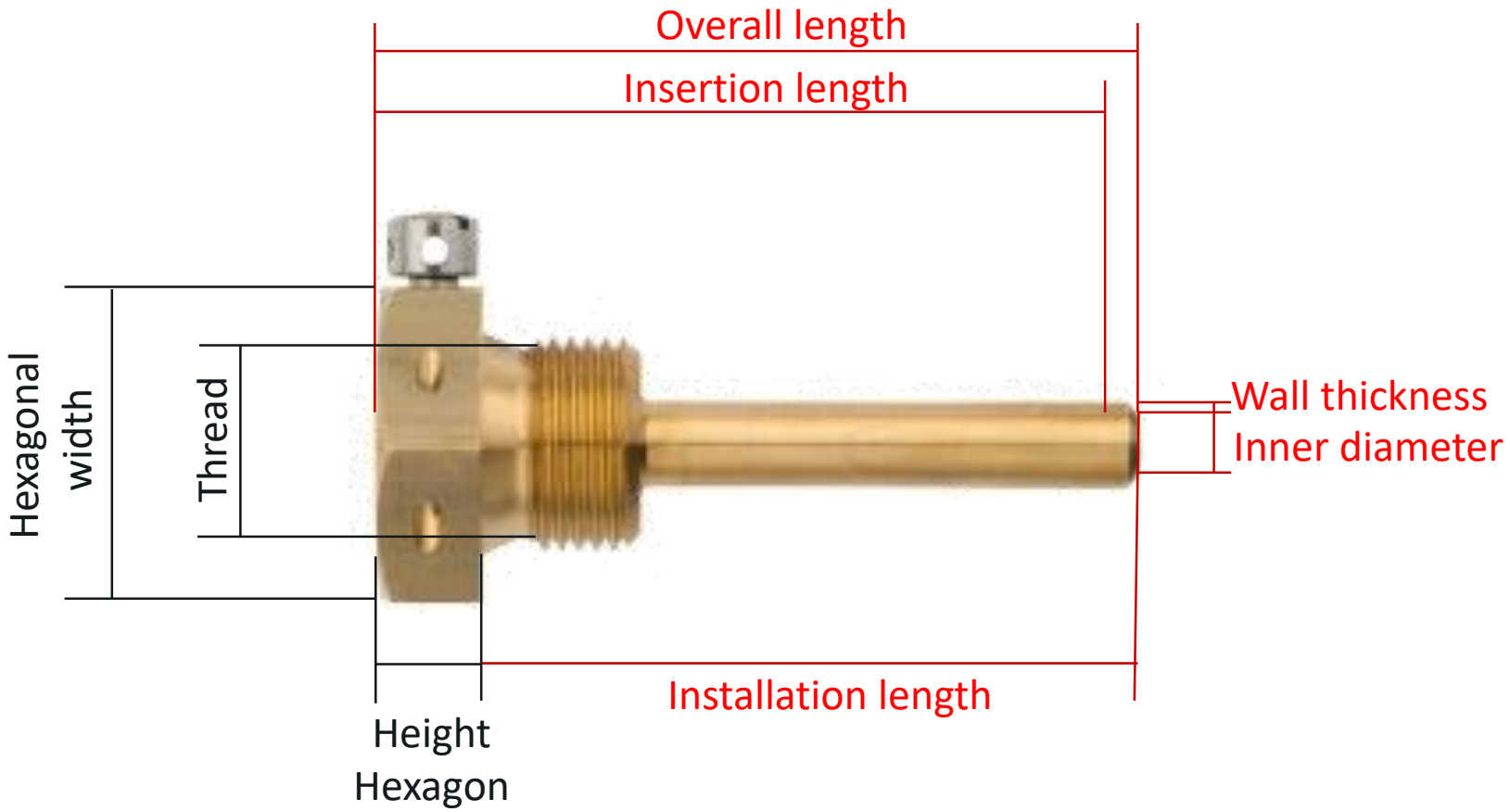
The result: **faulty display / faulty measured value**

Additional influence due to pockets
→ Especially with short pockets !!!



Influencing factors for an Pocket

- **There are various factors influencing the heat dissipation error for thermowells**
- **Some influencing variables have a large share, some have a smaller one**



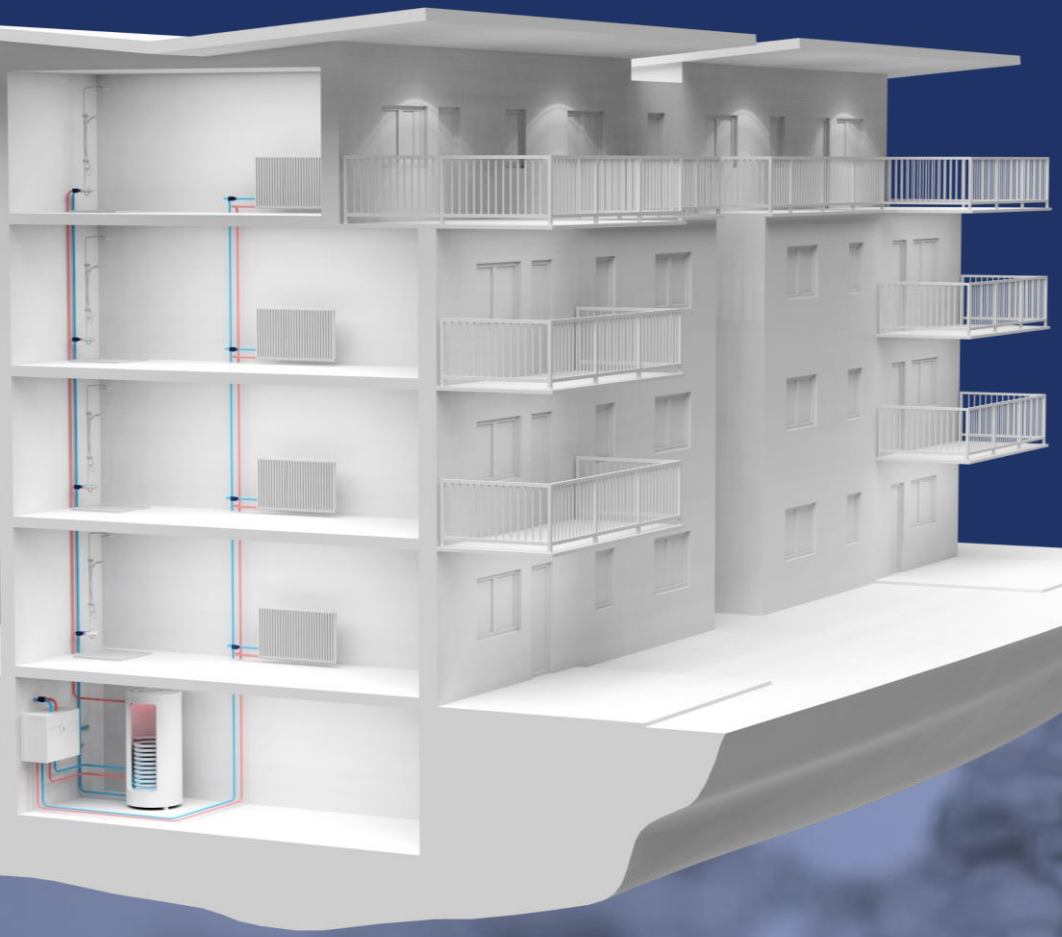
Large influence:

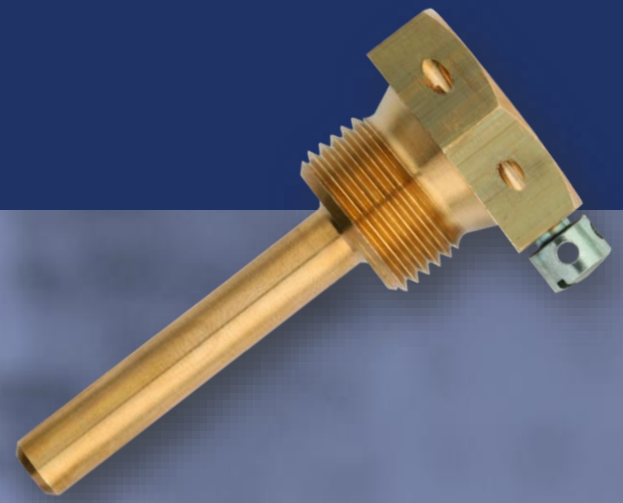
- **Length**
- **Inner diameter & wall thickness**

Small influence:

- **Thread**
- **Hexagon**

Pockets in Germany …





Pocket-Cluster in Germany

Cold Meter

Only long pockets

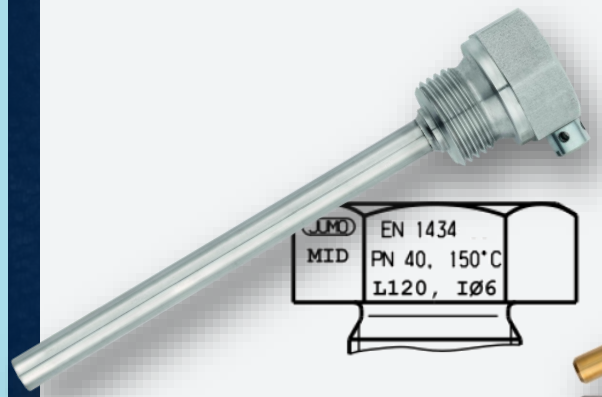
Temperature probes should always be installed directly in refrigeration applications.

For larger nominal diameters and flow velocities, however, it may be necessary to use pockets (in JUMO type examination certificate from 85 mm installation length)

Heat Meter

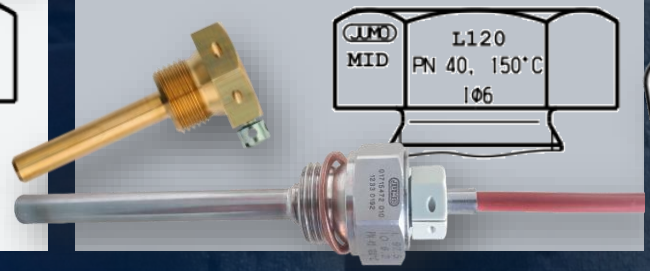
Long standardised EN1434 stainless steel pockets

The standardised pockets have a special fit (H11), so the thermal contact is very good.



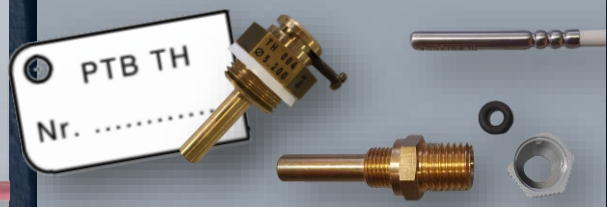
Long MID pockets made of stainless steel and brass

Although the pockets do not comply with the standardised EN1434 pockets, they still meet the requirements of this standard. The pockets are specified in the approvals.



Temporary tolerated, short pockets

Pocket versions that are no longer installed, but of which there is still a large number (~2 million) in use. Tolerated by a PTB notice until 2006 → extended to 2016 → 2026



What is regulated by the PTB Notice?

- **Pockets with lengths longer than 60 mm**
  - ... are considered tolerated if they comply with the fit tolerances (internal tolerance) of EN 1434-2 and thus have a low heat transfer error in connection with the immersion depth
  - When using MID-marked temperature probe in the field, dimensional testing shall be carried out with a gauge based on EN 1434-6, Annex C, as a sufficient criterion for checking suitability
  - Some pockets in the field have a larger inner diameter than defined in EN1434

    → therefore also require a toleration or metrological investigation

- **Pockets with lengths of 60 mm or smaller**
  - ... must first be examined for metrological suitability together with the temperature probes
  - For this purpose, the test required in EN 1434-4, clause 7.4.4.4 must be carried out at PTB as an example with new samples of the type under consideration.
  - The acceptance criterion of the aptitude test is 0.5 MPE, corresponding to about 1.6 times the acceptance criterion after the standard identification

Toleration only applies up to a medium temp. of 110°C

Distinguishing the pockets by their length

EN1434-4 → 7.4.4.4 and Appendix A (informative)

7.4.4.4 Testing of the influence of pockets

The manufacturer shall deliver a special temperature sensor pair with pockets, described as follows:

— one sensor (the dedicated inlet temperature sensor) with pocket, selected or manufactured that the gap between pocket and sensor is the maximum gap according to the manufacturer's specification;

Temperature probe flow

— one sensor (the dedicated outlet temperature sensor) with pocket, selected or manufactured that the gap between pocket and sensor is the minimum gap according to the manufacturer's specification.

Temperature probe return

Only the shortest pocket length in a family shall be tested, provided that thread, material, etc. are identical for all pockets in the family.

The test is carried out in two stages as follows:

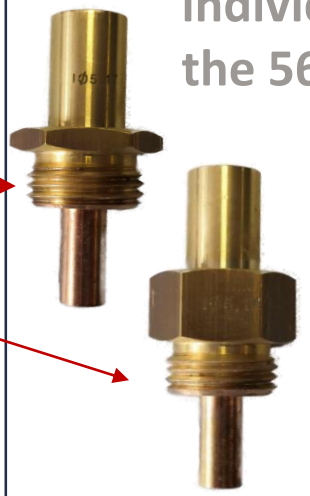
a) the two temperature sensors are tested without pockets according to 7.4.4.3;

b) the two temperature sensors are then mounted in the pockets as described above and retested according to 7.4.4.3.

The calculated difference between the results obtained with and without pockets shall be within 1/2 of the limits stated in EN 1434-1:2022, 9.2.2.2.

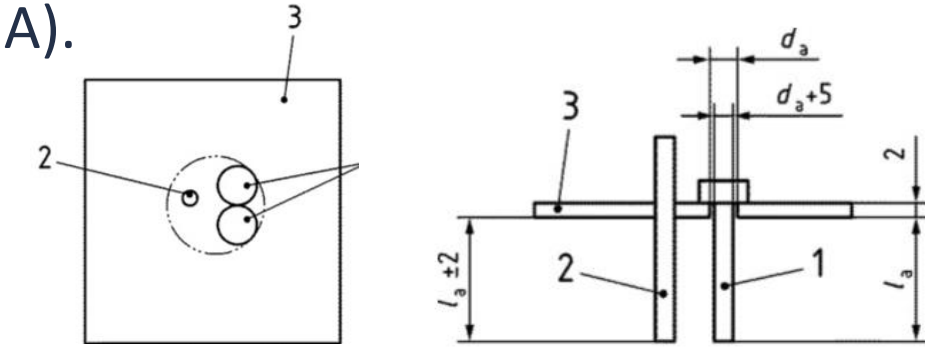
To get the best reproducibility it is strongly recommended that the tests with and without pockets are both carried out following the procedure in Annex A.

- **Boundary pockets for in total 56 pockets in the "German Toleration List"**
  - It is not economically possible to build up and measure all individual samples for each of the 56 tolerated pockets
  - Therefore, boundary pockets for this investigation were defined together with PTB
  - These are available with 2 different hexagon heights



Checking the Metrological Suitability

- Influence during the investigation
  - Since the influence of the pocket is to be determined, the immersion depth must be the same for direct measurement and the immersion depth with the pocket. The immersion depth is specified in EN1434-4 (Annex A).



Key

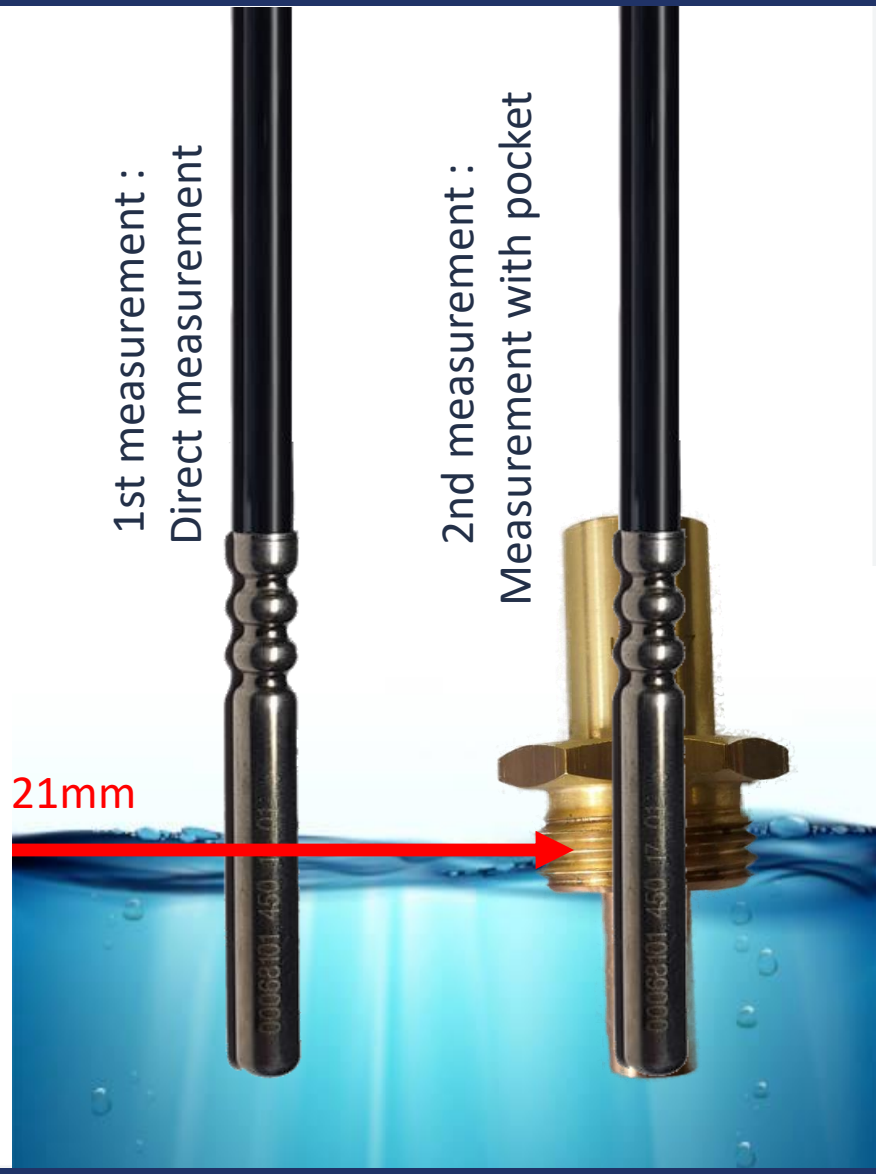
1 sensor pair / pockets under test (50 % of the pocket thread shall be over the metal lid)

2 reference sensor

3 metal lid (thickness 2 mm, stainless steel) not in thermal contact with the body of the bath (e.g. point fixing by plastic parts; no metal contact between the lid and the bath housing); but the bottom side of the lid shall be in contact with the liquid

Figure A.1 — Details of temperature bath

No thermal insulation shall be used over the metal lid.



What is the content of the „German Toleration List“?

Liste der ausgesprochenen Duldung der Bestandstauchhülsen

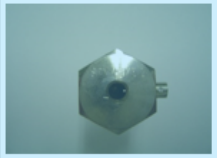
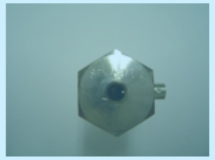
im Feld identifizierbar

zusätzlich Merkmale

Status: 15.03.2023

Ansprechpartner: Herr Dr. Sebastian Baack (sebastian.baack@ptb.de, +49 30 3481 7729) oder Frau Gerlinde Eichhorn (gerlinde.eichhorn@ptb.de, +49 30 3481 7270)

Baumusterprüfbescheinigungsnr

lfd. Nr.	Duldungs-kennzeichen TH XXX	Bautyp [A, B, C, sonstig]	Bild	signifikantes Merkmal im eingebauten Zustand	identifizierbares Kennzeichen (Beschriftung)	Tauchhülsen-innen-durchmesser di [mm]	Toleranzen Innendurch-messer [mm]	Baulänge [mm]	Einschub-länge [mm] ab Oberkante = Baulänge abzgl. Bodenstärke	Einbaulänge [mm]	Wandstärke [mm]	Gewindemaß [Angabe in " oder mm]	Schlüssel-weite	Höhe des Sechskants [mm]	max. Einsatz-temperatur tmax=105°C oder Angabe von tmax	Stückzahl im Feld (D)
1	TH 001	Spanner-Pollux Invensys Sensus Brunata			SPX/50/5,2 (oder SPX/150/5.2)	5,2	H11: +0,075 -0,000	43	42	32,8	0,5	1/2	SW24	6	150	>> 100000
2	TH 002	Spanner-Pollux Invensys Sensus			SPX/50/5,2 (oder SPX/150/5.2)	5,2	H11: +0,075 -0,000	43	42	32,8	0,5	3/8	SW24	6	150	>> 100000
3	TH 003	Spanner-Pollux Invensys Sensus		 Sechskant-Überwurfmutter zur Fühler-Fixierung		5,2	-	57	56	44,3	0,85	1/2	SW24 (SW22)	9	150	> 40000
4	TH 004	Spanner-Pollux, Sensus Invensys Brunata		 Umlaufende Nut für Plombierdraht oberhalb Sechskant		5,2	-	54	53	33,3	1,1	1/2	SW24 (SW22)	9	150	>> 100000

Examples in the list of “German Toleration List” (as of 15.03.2023 → 56 pockets)

What is the content of the „German Toleration List“?

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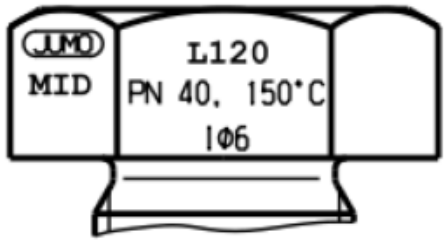
Baumusterprüfbescheinigungsnr. der MID - konformitätsuntersuchten Wärmezähler / Temperaturfühler

Schlüssel-weite	Höhe des Sechskants [mm]	max. Einsatz-temperatur tmax=105°C oder Angabe von tmax	Stückzahl im Feld (D)	Oberflächenfärbung	1	2	3	4	5	6	7	8	9	10
SW24	6	150	>> 100000	MS/Ni	Temperaturfühler A 0445/2112/2007 (Jumo GmbH & Co.KG) Duldung vom: 01.04.2011	Wärmezähler DE-07-MI004-PTB004, DE-07-MI004-PTB006, DE-07-MI004-PTB027, DE-07-MI004-PTB028 (Sensus GmbH), Duldung vom 17.06.2011	Wärmezähler DE-07-MI004-PTB001, DE-07-MI004-PTB025, DE-08-MI004-PTB005, DE-09-MI004-PTB018, DE-09-MI004-PTB012, jeweils für Temp.Fühlerpaar CS-5.2/CST-5.2 (Engelmann Sensor GmbH) Duldung vom 3.9.2011	Wärmezähler DE-11-MI004-PTB004, DE-11-MI004-PTB003, DE-06-MI004-PTB007 (Landis+Gyr GmbH) Duldung vom 24.9.2011	Wärmezähler DE-10-MI004-PTB013, DE-07-MI004-PTB030, DE-09-MI004-PTB001, DE-10-MI004-PTB004, (Diehl Metering GmbH) Duldung vom 22.3.2012	Wärmezähler DE-12-MI004-PTB009 (Qundis GmbH) Duldung vom 2.5.2012	Wärmezähler DE-12-MI004-PTB010 (Zenner International GmbH) Duldung vom 15.01.2013	Wärmezähler DE-13-MI004-PTB001 (Engelmann Sensor GmbH) Duldung vom 25.02.2013	Temperaturfühler DE-06-MI004-PTB009 (Engelmann Sensor GmbH) Duldung vom 24.06.2015	Wärmezähl DK-0200-MI0 (Kamstrup Duldung v 14.04.20
SW24	6	150	>> 100000	MS/Ni	Temperaturfühler A 0445/2112/2007 (Jumo GmbH & Co.KG) Duldung vom: 01.04.2011	Wärmezähler DE-07-MI004-PTB004, DE-07-MI004-PTB006, DE-07-MI004-PTB027, DE-07-MI004-PTB028 (Sensus GmbH), Duldung vom 17.06.2011	Wärmezähler DE-07-MI004-PTB001, DE-07-MI004-PTB025, DE-08-MI004-PTB005, DE-09-MI004-PTB018, DE-09-MI004-PTB012, jeweils für Temp.Fühlerpaar CS-5.2/CST-5.2 (Engelmann Sensor GmbH) Duldung vom 3.9.2011	Wärmezähler DE-11-MI004-PTB004, DE-11-MI004-PTB003, DE-06-MI004-PTB007 (Landis+Gyr GmbH) Duldung vom 24.9.2011	Wärmezähler DE-10-MI004-PTB013, DE-07-MI004-PTB030, DE-09-MI004-PTB001, DE-10-MI004-PTB004, (Diehl Metering GmbH) Duldung vom 22.3.2012	Wärmezähler DE-12-MI004-PTB009 (Qundis GmbH) Duldung vom 2.5.2012	Wärmezähler DE-12-MI004-PTB010 (Zenner International GmbH) Duldung vom 15.01.2013	Wärmezähler DE-13-MI004-PTB001 (Engelmann Sensor GmbH) Duldung vom 25.02.2013	Temperaturfühler DE-06-MI004-PTB009 (Engelmann Sensor GmbH) Duldung vom 24.06.2015	Wärmezähl DE-14-MI004- (Qundis Gm Duldung 04.04.20
SW24 (SW22)	9	150	> 40000	MS/Ni	Temperaturfühler A 0445/2112/2007 (Jumo GmbH & Co.KG) Duldung vom: 01.02.2012	Wärmezähler DE-11-MI004-PTB004, DE-11-MI004-PTB003, DE-06-MI004-PTB007 (Landis+Gyr GmbH) Duldung vom 2.3.2012	Wärmezähler DE-10-MI004-PTB013, DE-07-MI004-PTB030, DE-09-MI004-PTB001, DE-10-MI004-PTB004, (Diehl Metering GmbH) Duldung vom 22.3.2012	Wärmezähler DE-12-MI004-PTB009 (Qundis GmbH) Duldung vom 2.5.2012	Wärmezähler DE-07-MI004-PTB004, DE-07-MI004-PTB006, DE-07-MI004-PTB027, DE-07-MI004-PTB028 (Sensus GmbH), Duldung vom 23.05.2012	Wärmezähler DE-12-MI004-PTB010 (Zenner International GmbH) Duldung vom 15.01.2013	Wärmezähler DE-07-MI004-PTB001, DE-07-MI004-PTB025, DE-08-MI004-PTB005, DE-09-MI004-PTB012, DE-13-MI004-PTB001, (Engelmann Sensor GmbH) Duldung vom 01.09.2014	Temperaturfühler DE-06-MI004-PTB009 (Engelmann Sensor GmbH) Duldung vom 24.06.2015	Wärmezähler DE-14-MI004-PTB006 (Qundis GmbH) Duldung vom 04.04.2016	Wärmezähl DK-0200-MI0 (Kamstrup Duldung v 14.04.20
SW24 (SW22)	9	150	>> 100000	MS/Ni	Temperaturfühler A 0445/2112/2007 (Jumo GmbH & Co.KG) Duldung vom: 01.02.2012	Wärmezähler DE-11-MI004-PTB004, DE-11-MI004-PTB003, DE-06-MI004-PTB007 (Landis+Gyr GmbH) Duldung vom 20.2.2012	Wärmezähler DE-10-MI004-PTB013, DE-07-MI004-PTB030, DE-09-MI004-PTB001, DE-10-MI004-PTB004, (Diehl Metering GmbH) Duldung vom 22.3.2012	Wärmezähler DE-12-MI004-PTB009 (Qundis GmbH) Duldung vom 2.5.2012	Wärmezähler DE-07-MI004-PTB004, DE-07-MI004-PTB006, DE-07-MI004-PTB027, DE-07-MI004-PTB028 (Sensus GmbH), Duldung vom 23.05.2012	Wärmezähler DE-12-MI004-PTB010 (Zenner International GmbH) Duldung vom 15.01.2013	Wärmezähler DE-07-MI004-PTB001, DE-07-MI004-PTB025, DE-08-MI004-PTB005, DE-09-MI004-PTB012, DE-13-MI004-PTB001, (Engelmann Sensor	Temperaturfühler DE-06-MI004-PTB009 (Engelmann Sensor GmbH) Duldung vom	Wärmezähler DE-14-MI004-PTB006 (Qundis GmbH) Duldung vom 04.04.2016	Wärmezähl DK-0200-MI0 (Kamstrup Duldung v 14.04.20

MID/EN1434 – Pocket identification in the field

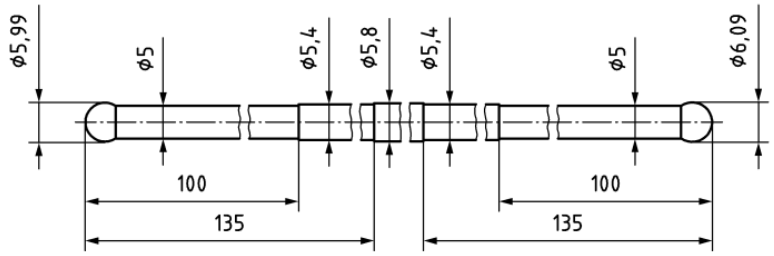
Inscription "MID" (not normatively specified)

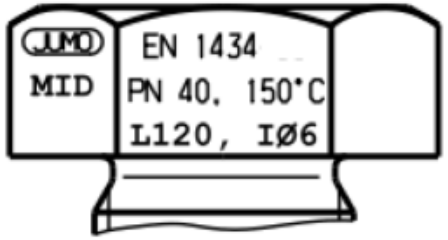
- No conformity can be declared for pockets with the inscription "MID" (therefore no CE mark
- It merely states that this pocket has been approved together with a temperature probe/pair in a type examination certificate
- Originally the metrological suitability test was carried out in accordance with EN 1434-4, clause 7.4.4.4 for the type examination certificate



Inscription "EN-1434" + "MID" (metrologically proven)

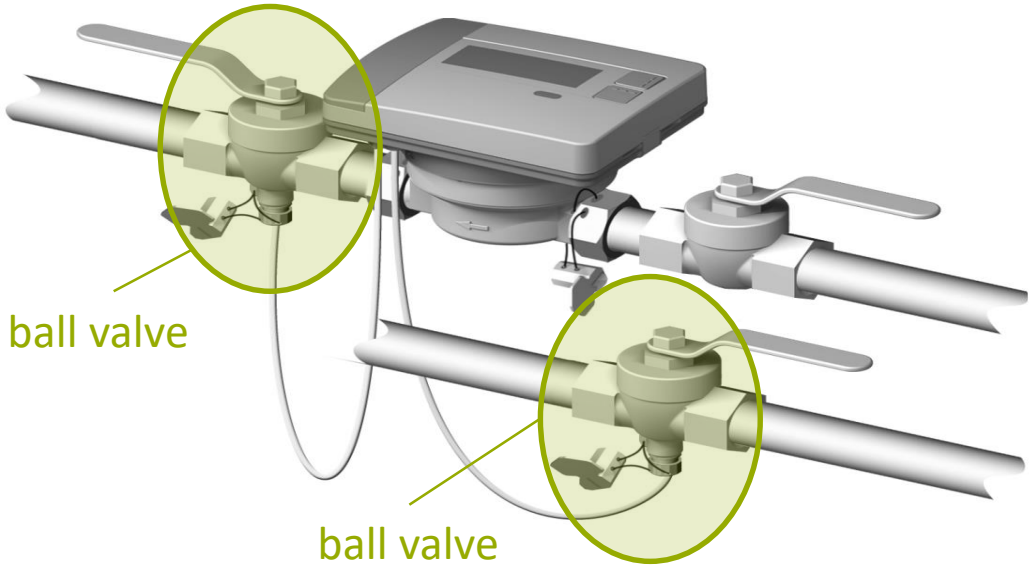
- Pockets comply with the fit tolerances (internal tolerance) according to EN 1434-2
- Proposed gauge for verification (EN1434-6)
  - One end of the tool must fit completely downwards into the bottom of the pocket.
  - The other end of the tool must not fit into the pocket.





Examples of marking on pockets

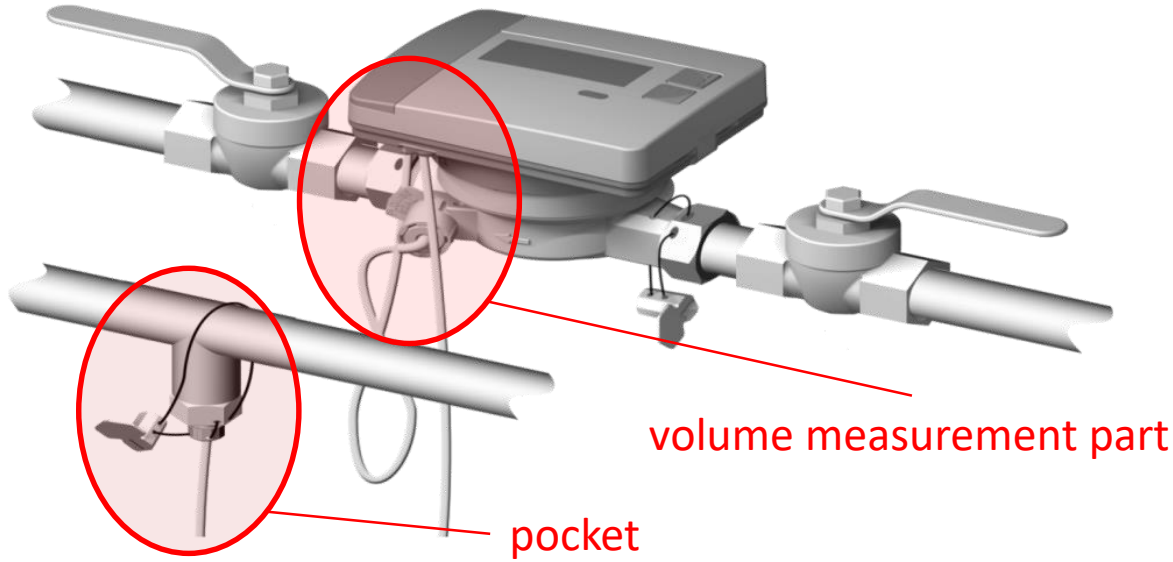
The “german toleration list regulation“applies only to symmetrical probe installation.



Symmetrical installation

= both sensors directly installed **(wet/wet)**

= both sensors installed in pockets of the same type **(dry/dry)**



Asymmetrical installation

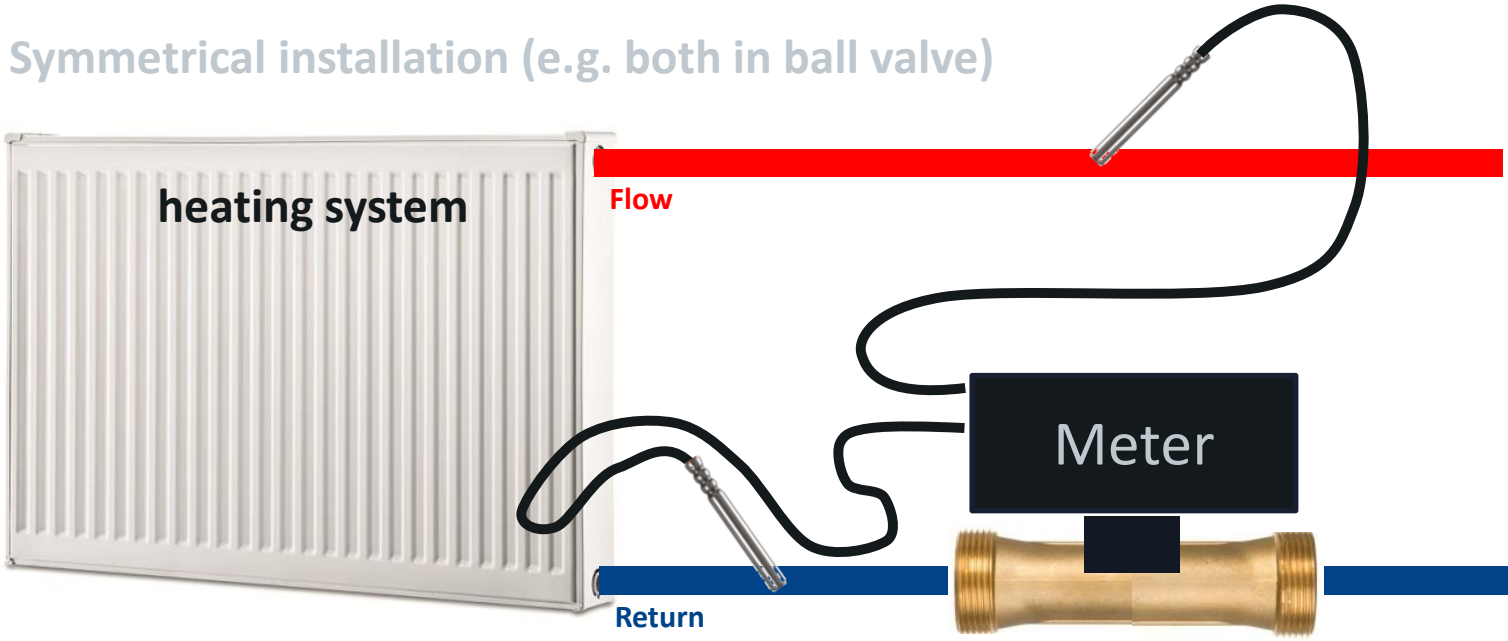
= Mix of direct **(wet)** installation and probe in pocket **(dry)**

Why is there so often asymmetrical installation?

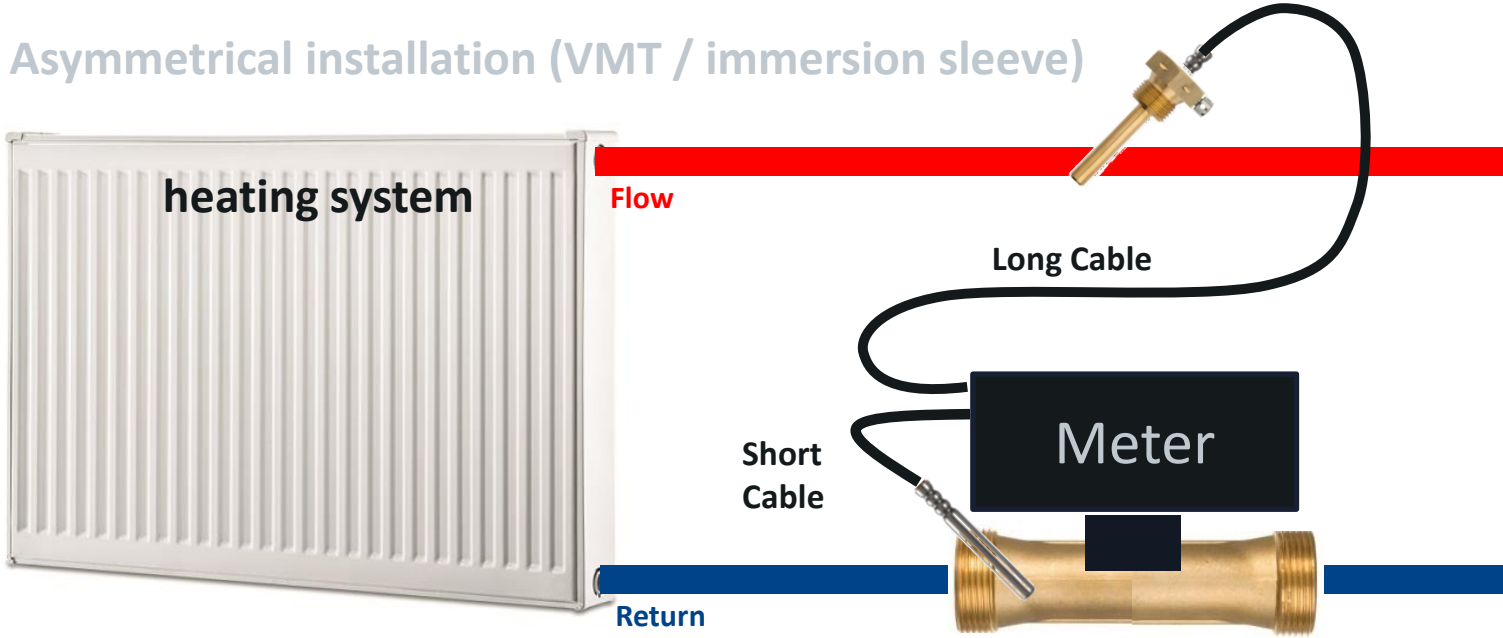
Saving one installation point

→ Installation in the volume measurement unit saves on the number of installation points and the probe is often already pre-installed.

Symmetrical installation (e.g. both in ball valve)



Asymmetrical installation (VMT / immersion sleeve)



Impact analysis during asymmetrical installation

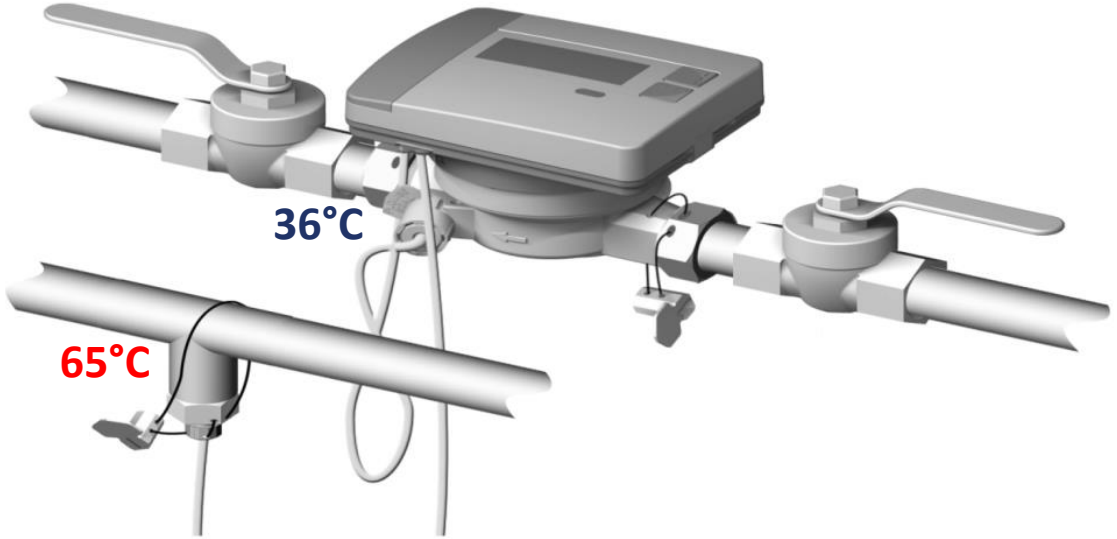
ATTENTION:

In the case of asymmetrical installation, the impact test differs from symmetrical installation.

Background:

- Between flow and return the temperature difference has an additional asymmetric error caused by the heat conduction
  error of the different installation site

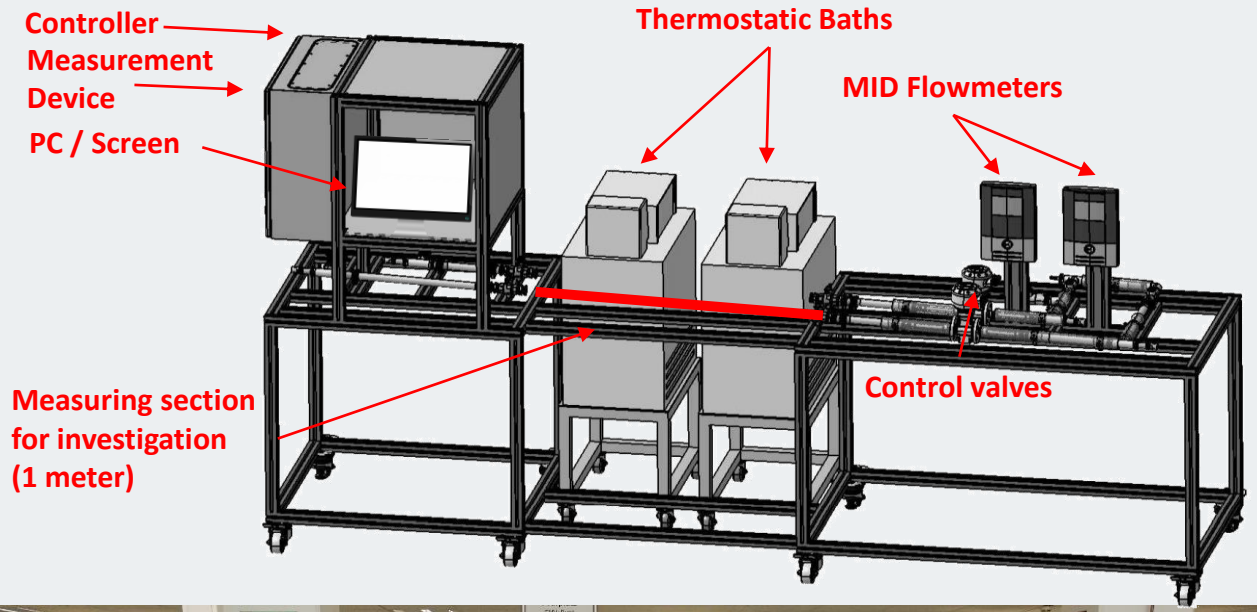
- The flow velocity can also be differ significantly (tapering of nominal diameter in the volumetric measuring section)



Impact analysis for asymmetrical installation

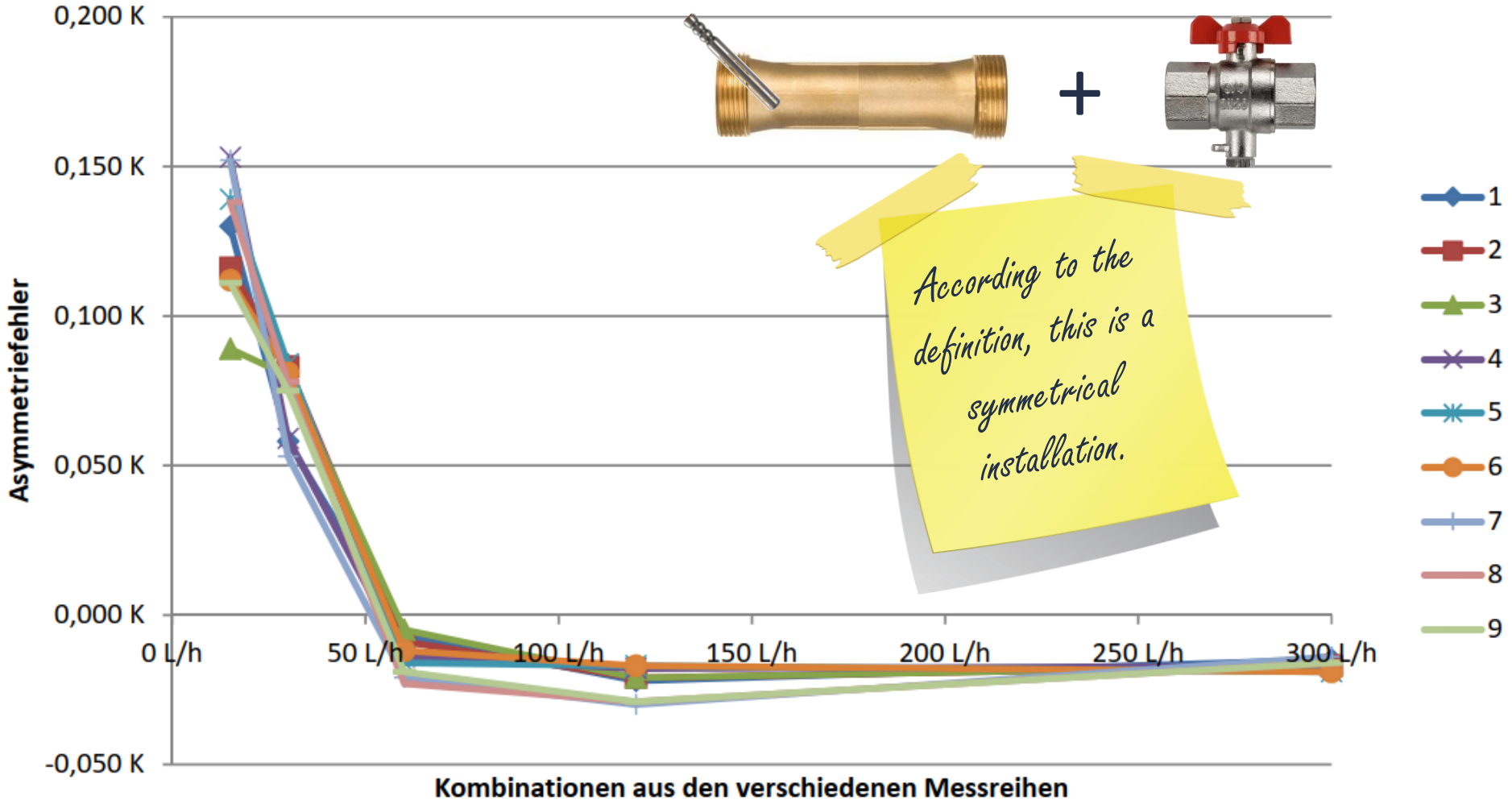
Procedure:

- 3 temperature probes and 3 installation points each (e.g. pocket, ball valve, volume measuring part, T-piece) must be examined
- Groups/boundary patterns can also be created for pockets
- Here, too, minimum and maximum gap dimensions must be considered
- All individual components are measured separately at 15l/h - 300l/h with the specially designed flow channel
- Then the asymmetry error is calculated (difference of the single measurements)



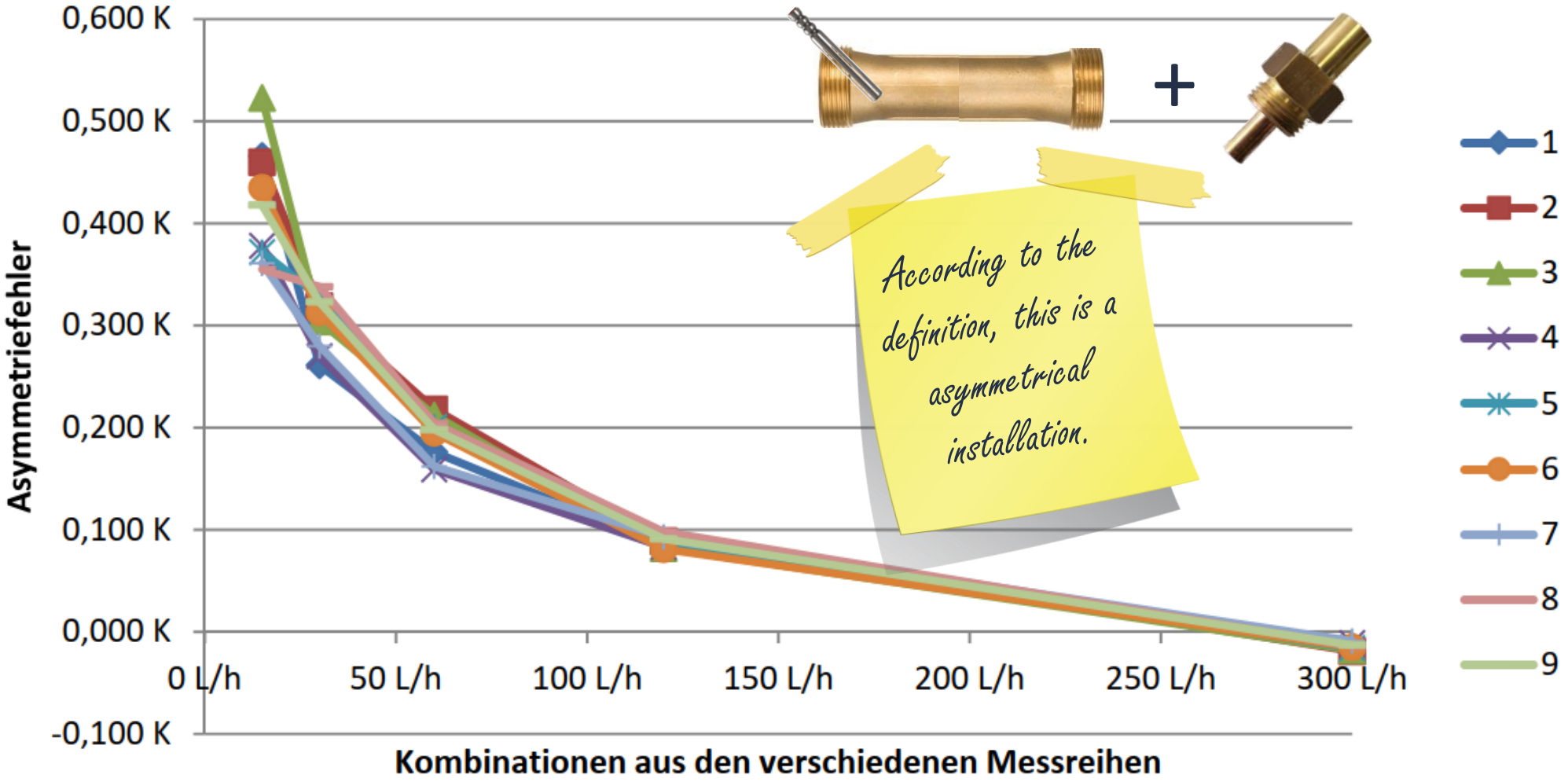
Examples of results of the investigation (graphical)

Additional error between volume measuring part and ¾" ball valve



Examples of results of the investigation (graphical)

Additional error between volume measuring part and 5.2mm boundary pocket



Example of regulation of asymmetrical installation by the manufacturer

- Screenshot: Operating instructions of a compact heat meter
- In this case the dT_{min} is limited to 5K
- See also the note that the pocket must be installed insulated

Asymmetric mounting (temperature sensor)

The meter can be mounted asymmetric, too. This means one temperature sensor is directly immersed in the volume measuring tube, whereas the other temperature sensor is mounted in a protection pocket. For the lower value of the temperature difference is then 5 K valid at the respective lower flow limit qi. For this kind of installation the mentioned protection pockets must be used. Furthermore the national regulations of the respective country have to be observed.

Type of protection pocket	Inside diameter [mm]	Rack length from upper edge [mm]	Thread size [mm]
[illegible]	5.2	42	½“
[illegible]	5.2	46	½“
[illegible]	5.2	46	½“
[illegible]	5.2	50	½“
[illegible]	5.2	50	½“
[illegible]	5.2	37	½“

*) The sensor pocket must be installed in isolation.

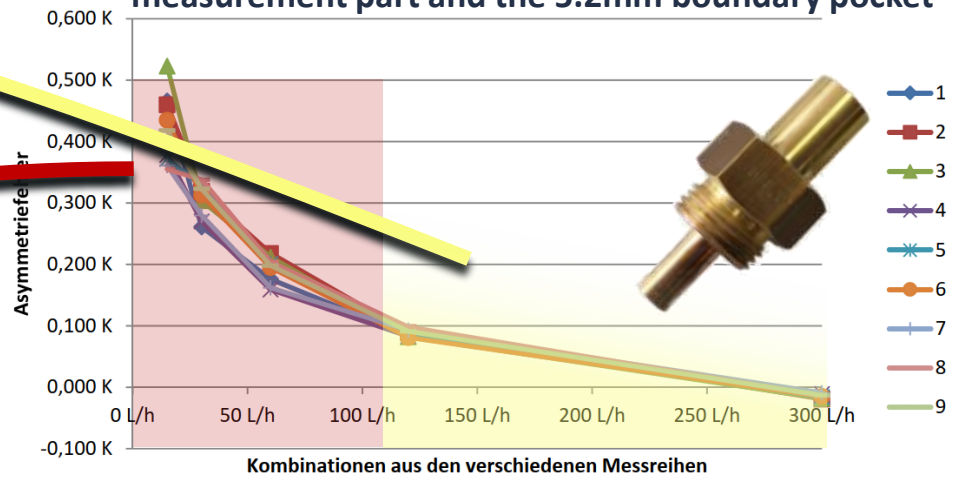
How to proceed with the „German Toleration List“ is currently under discussion

Ideas for handling the tolerated pockets in the field

Where is the limit?

Are there any restrictions on the operating range within which the tolerances apply?

Example of asymmetrical error between the volume measurement part and the 5.2mm boundary pocket



Radiators

The temperature difference for radiators is usually around 10-20 K. Flow rate: ~150 – 400L/h

Underfloor Heating

Temperature difference for underfloor heating is usually about 5-10 K. Flow rate: ~200 – 600L/h

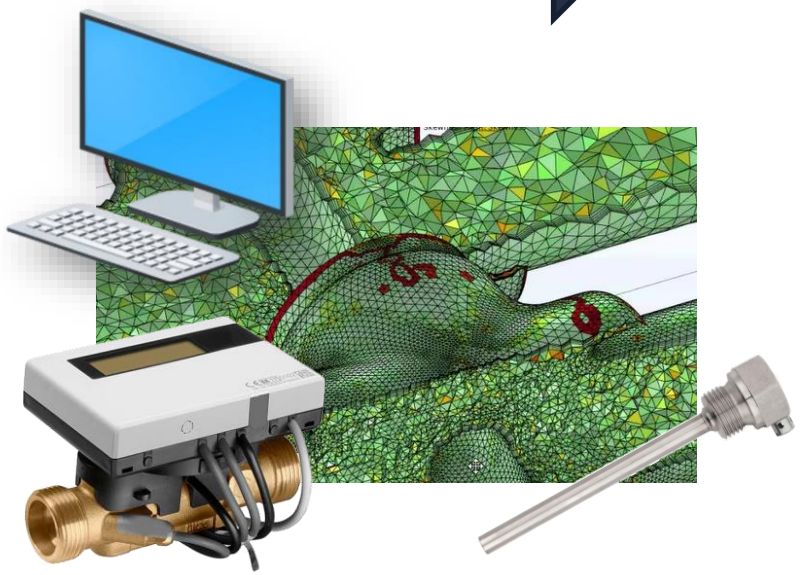
Ideas for handling the tolerated pockets in the field

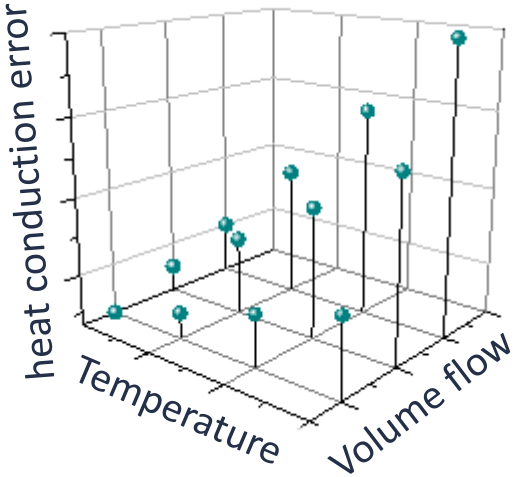
Dynamic correction of the heat conduction error for each installation point in the calculator during measurement

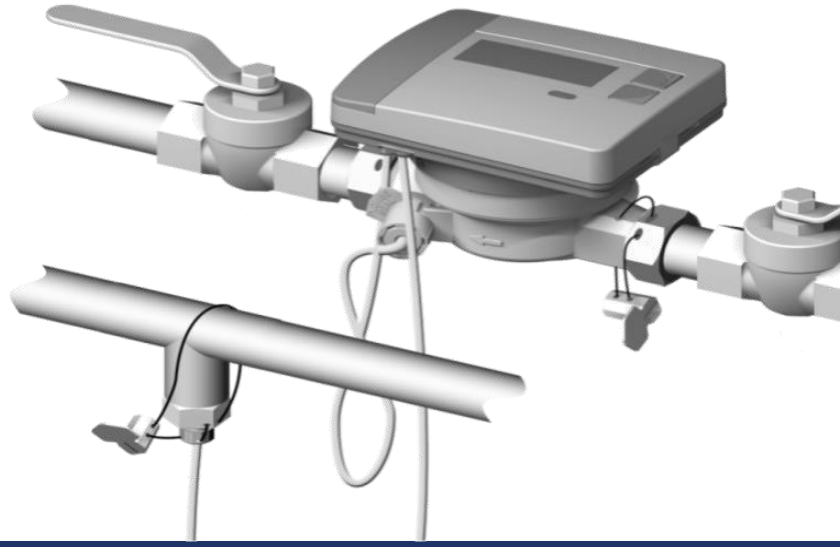
FEM simulation of the installation points (Volume measurement part, pocket, ball valve)

Calculate the characteristics for each installation point

The manufacturer or installer selects the respective installation points.







EMATEM + JUMO

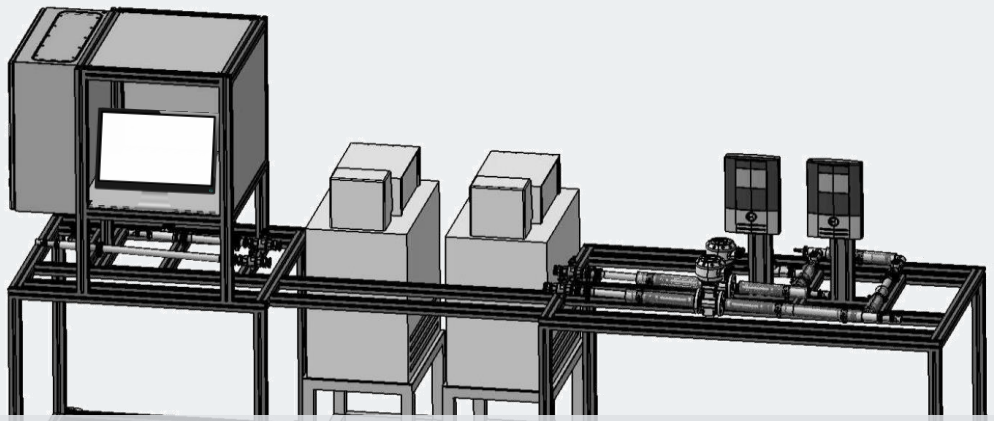
Research Project

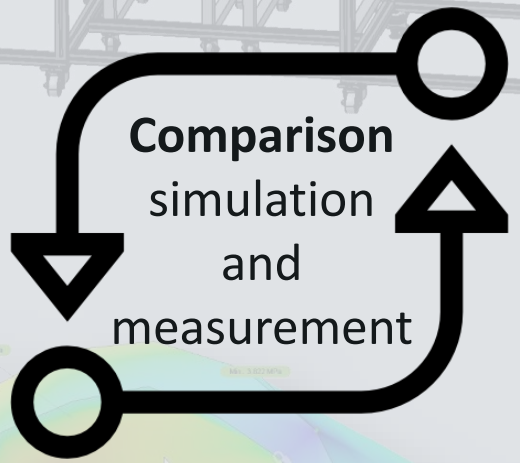
- The research project aims to develop and evaluate sustainable alternatives for measuring thermal energy in order to ensure accurate billing even after the temporary toleration of the pockets has expired.

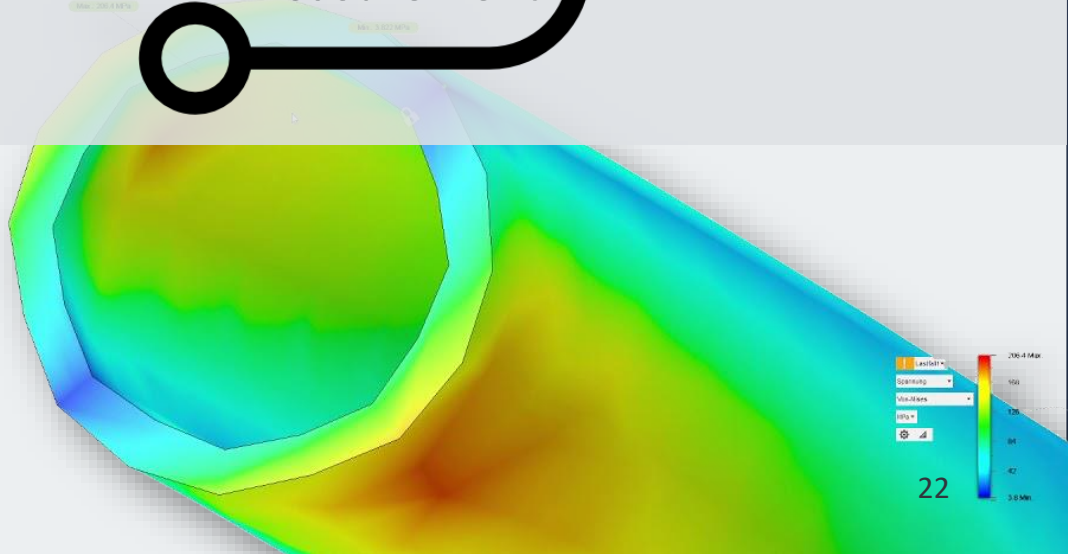
- **The project involves a feasibility study:** calculation of the physical behaviour of the existing pockets using the finite element method (FEM) and comparison with practical measurements in the flow channel.

- Project duration: 48 weeks / €37,800 Start September 2024

Thank you for the support from EMATEM e.V.







Scope of the research project

TH004 pocket (out of tolerated list) together with temperature probe (Direct Short - 5.2mm protective tube)

½“ T-Piece

Scope of the research project

Temperature probe (Direct Short - 5.2mm protective tube) in direct installation (T-piece/ball valve)

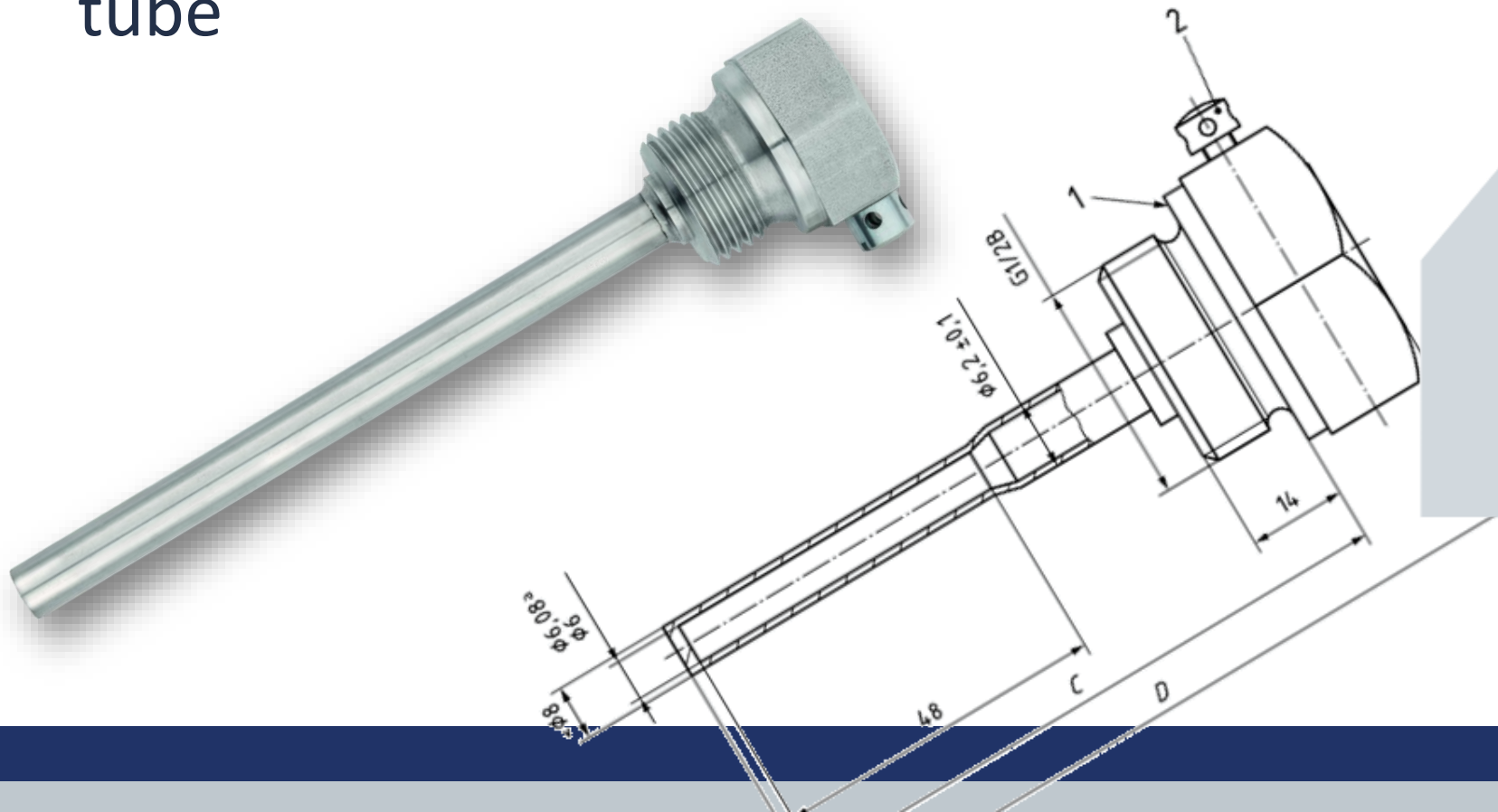
Scope of the research project

SPX pocket with 92.5mm length and temperature probe with 6.0mm protective tube (this pocket has a larger gap size than an EN1434 pocket)

3

Scope of the research project

EN1434 pocket with 85mm length and temperature probe with 6.0mm protective tube



Scope of the research project

The following parameters are included in each case:

- Flow rate of 15 l/h, 30 l/h, 60 l/h, 100 l/h and 300 l/h
- Medium temperature 23°C (ambient temperature), 35°C, 50°C, 65°C and 80°C

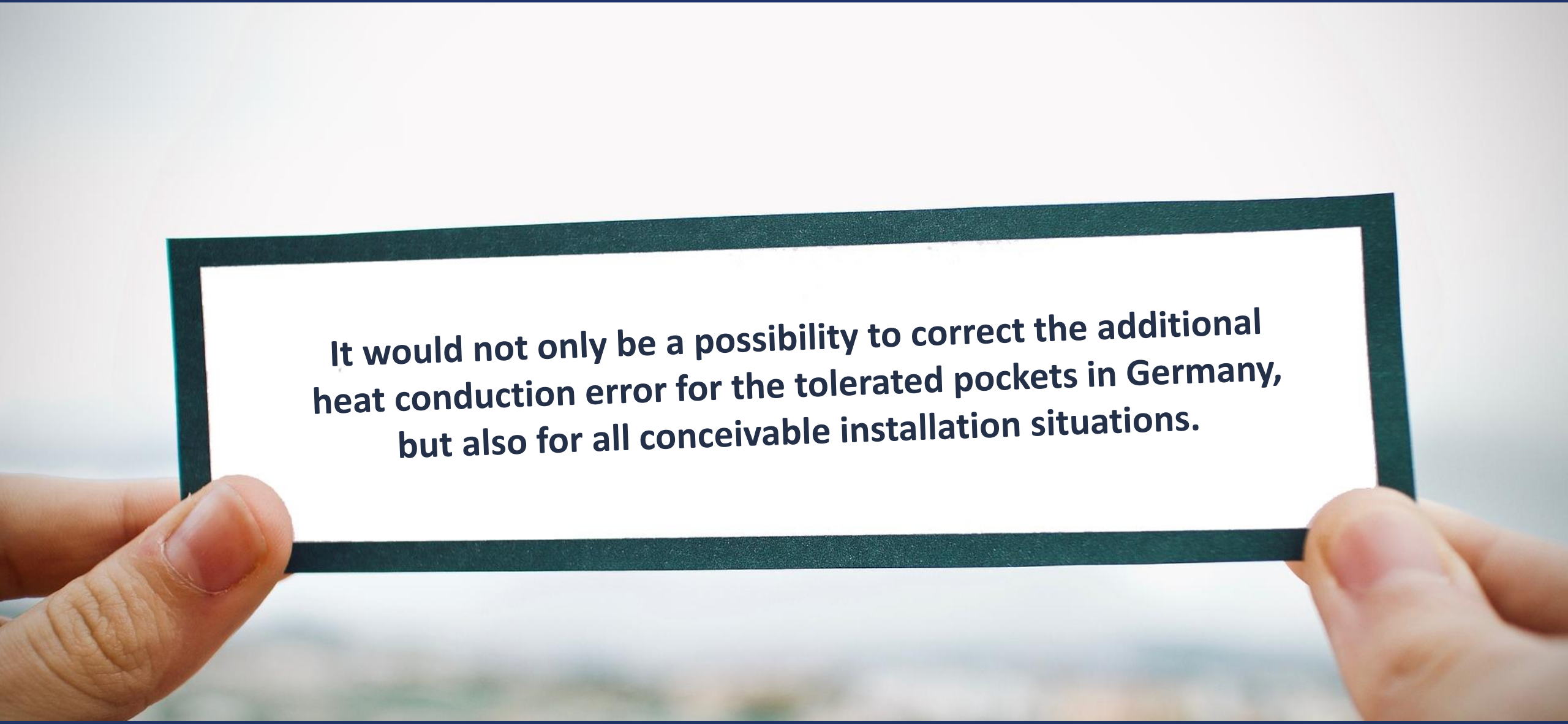
Info: Temperatures higher than 80°C cannot be realised in the practical measurement at the flow channel

- Stable ambient temperature 23°C
- Pipes and installation points insulated (19mm ArmaFlex)

→ Depending on the installation situation, there are 40 simulations with the influencing parameters (number of flow rates * number of medium temperatures * number of gap dimensions of the immersion sleeve).

→ For the four installation situations shown before, **there are thus 160 individual simulation tasks.**

What if it is feasible?



THANKS FOR WATCHING

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