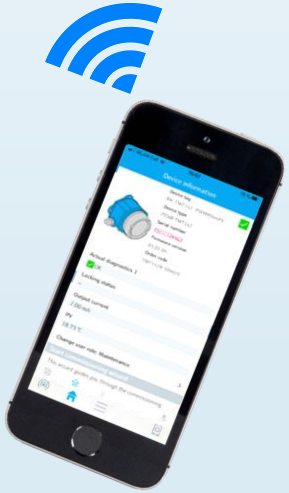
Beyond RTDs vs Thermocouples

Understanding the New I&C Temperature Choices



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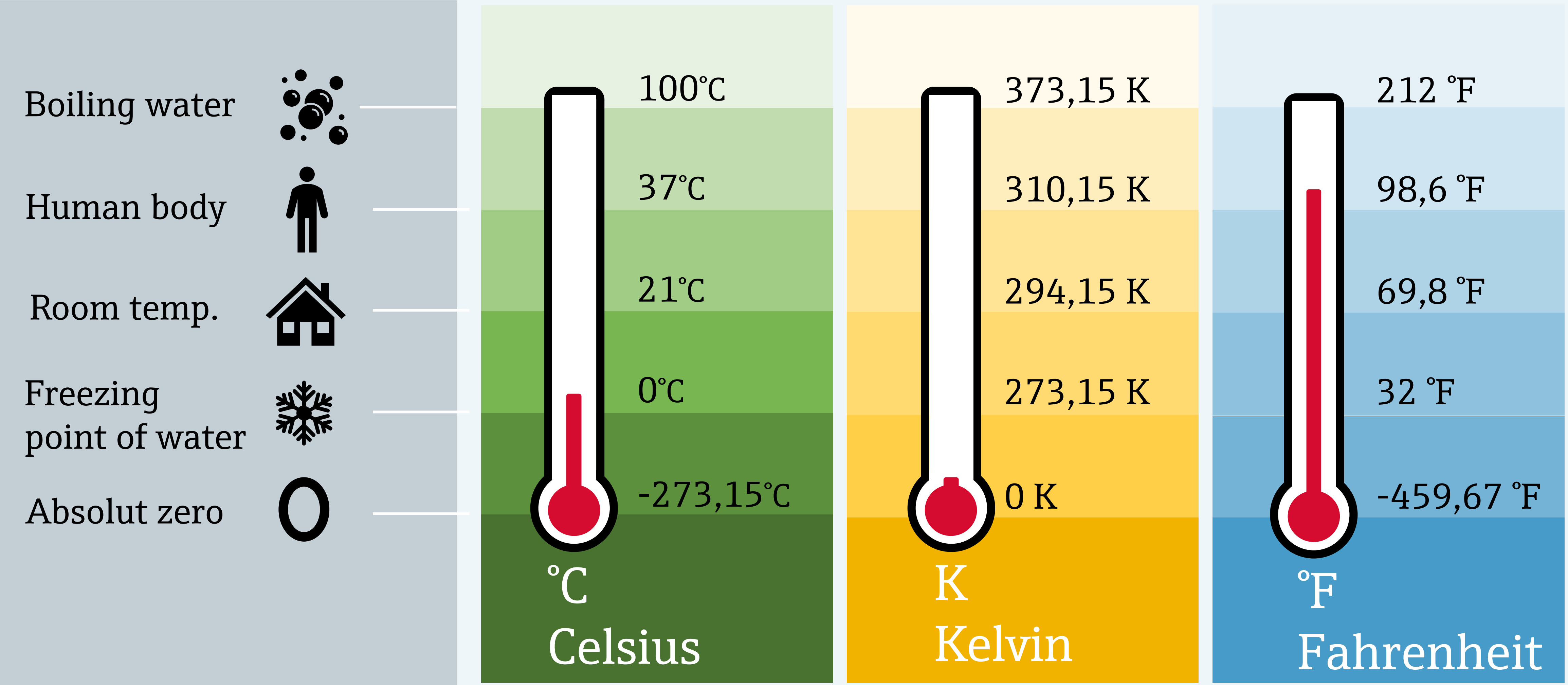
Temperature scales



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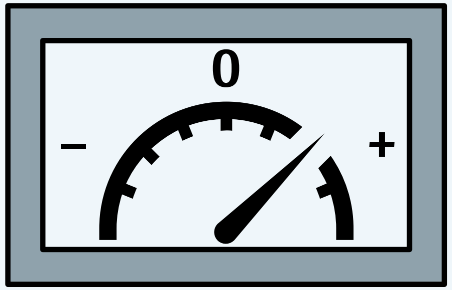
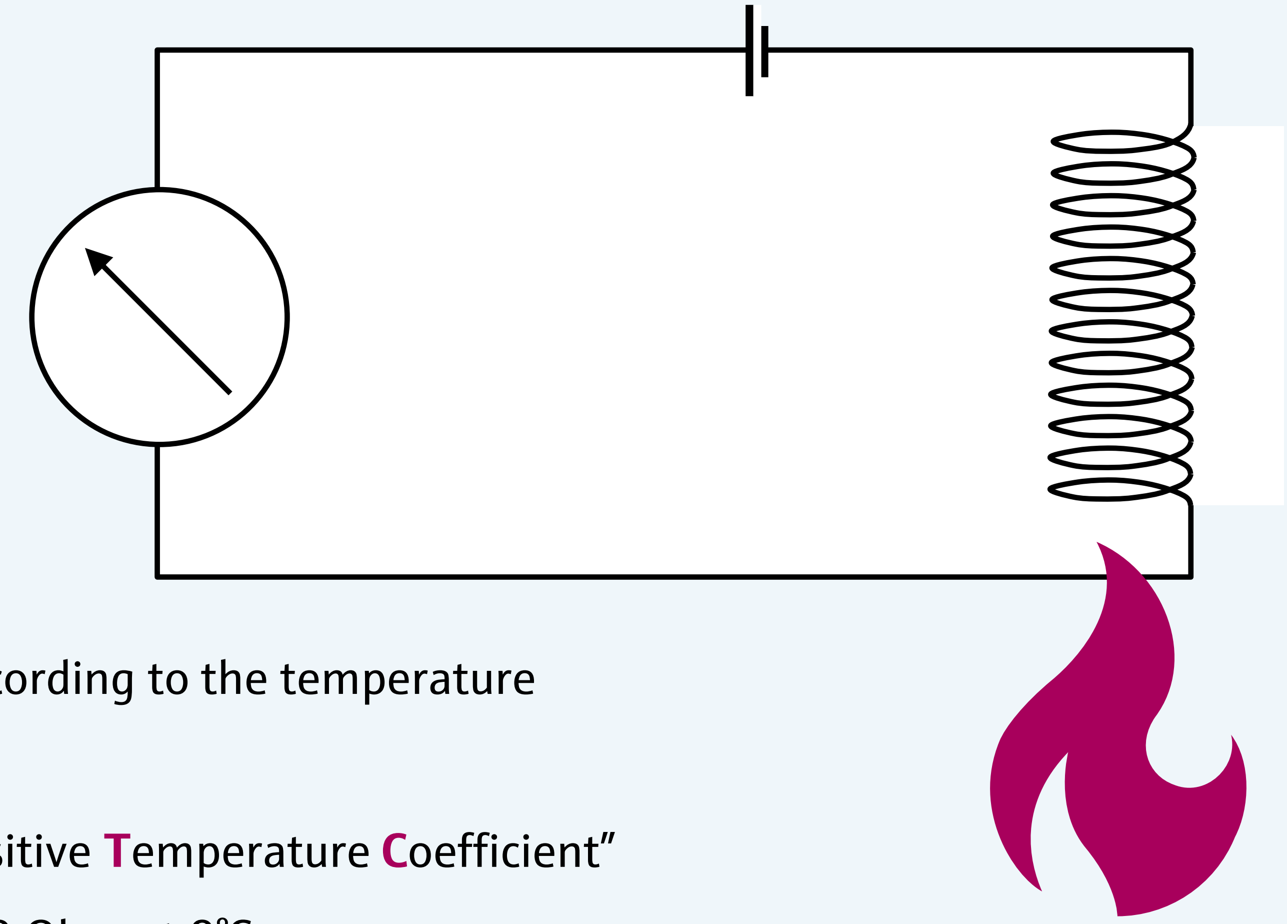
RTD - Resistance Temperature Detectors



[Ω]



- The resistance of the sensor changes according to the temperature
- **R**esistance **T**emperature **D**etector = RTD
- A Pt100 is a "PTC" ; Resistance with "**P**ositive **T**emperature **C**oefficient"
- Pt stands for Platinum, "100" means 100 Ohm at 0℃

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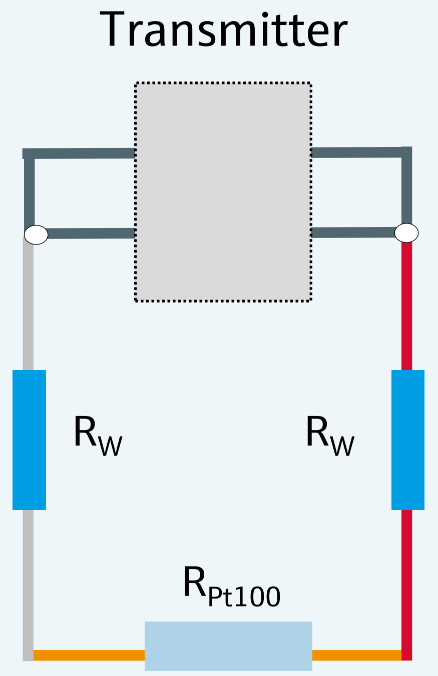
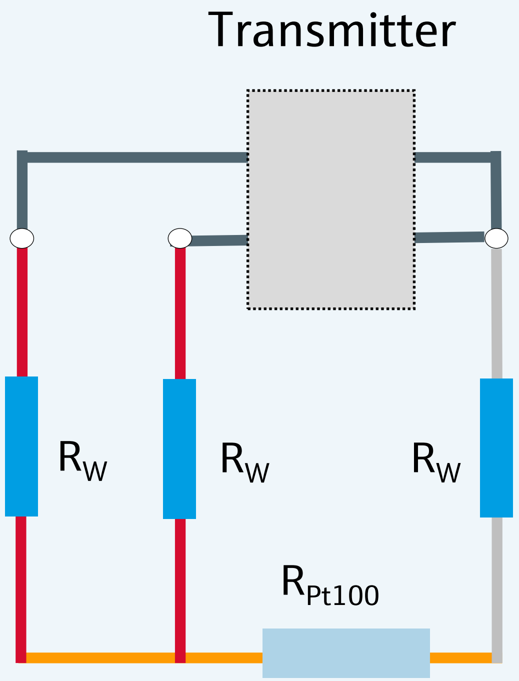
Wiring possibilities of RTD Sensors

2 wire connection



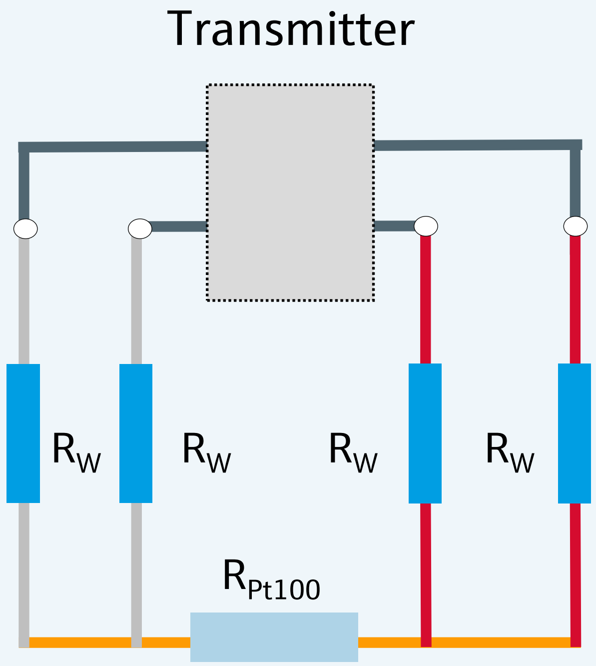
Error: 2 R_W

3 wire connection

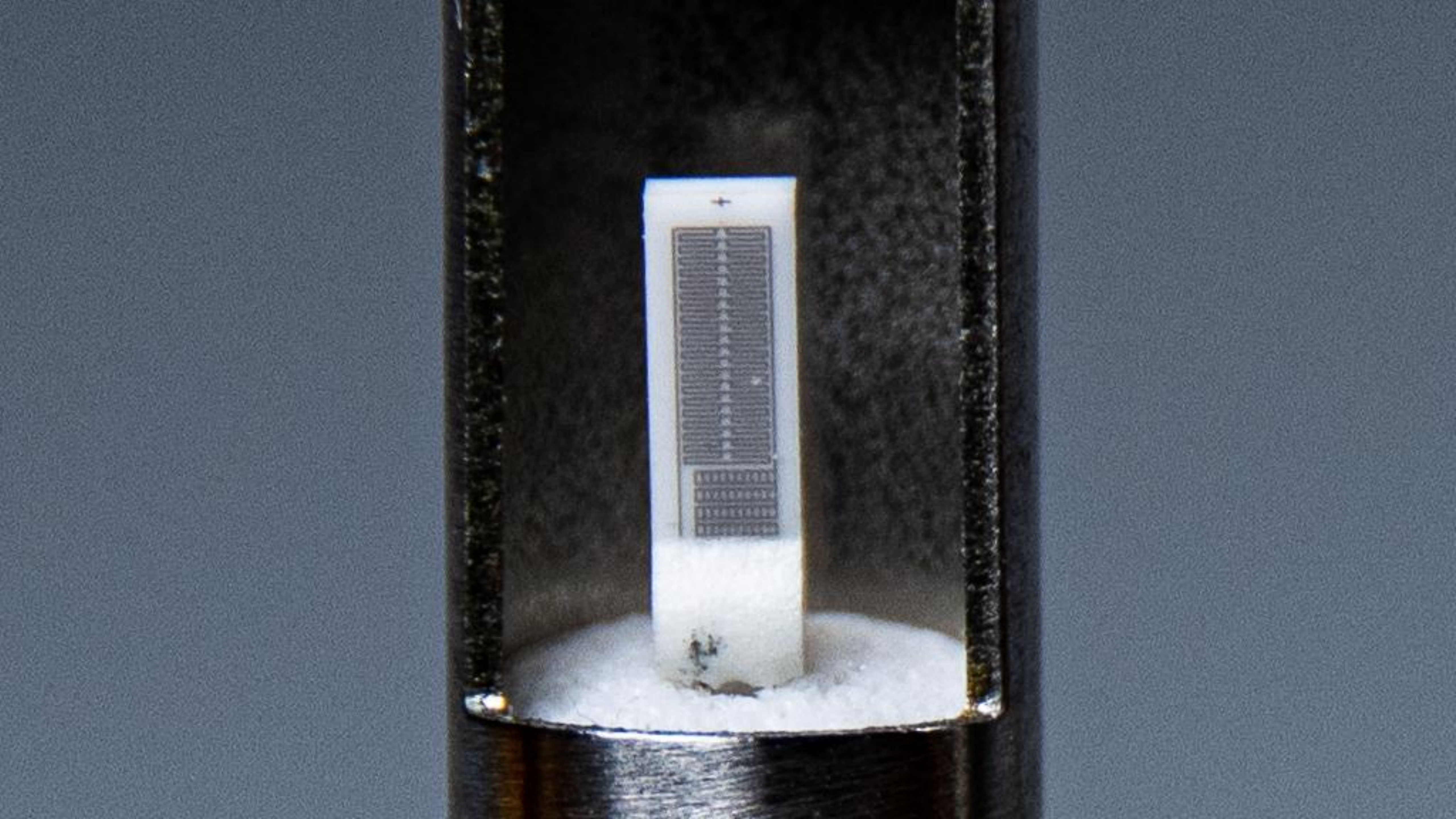


Error ≈ 0

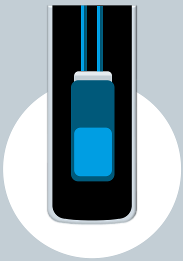
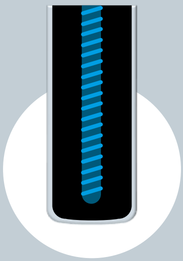
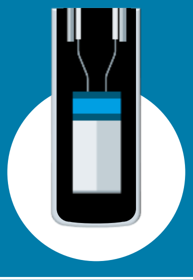
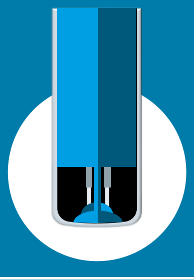
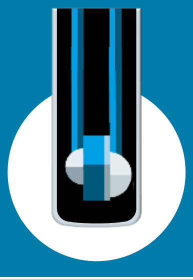
4 wire connection



Error: No systematical error



RTD sensor technologies

		Innovative sensor technologies		
Standard thinfilm	**Wirewound**	**Vibration robust sensors**	**Quick response sensors**	**Self calibrating sensors**
Pt100	Pt100	Pt100	Pt100	Pt100
-50...400°C	-200...600°C	-50...500°C	-50...200°C	-40...190°C
				
⊞ Long-term stability ⊞ Vibration resistance ⊟ Limited measurement range Industrial standard	⊞ Long-term stability ⊞ High measurement repeatability ⊟ Relative cost ⊟ Susceptible to mechanical stress Industrial standard	⊞ Robust ⊞ Long lifetime and plant availability ⊟ Response time	⊞ Suitable for short immersion depths ⊞ Maximum process safety ⊟ Limited measurement range	⊞ Risk reduction ⊞ High accuracy ⊞ Reliability ⊞ High degree of automation ⊟ Limited measurement range

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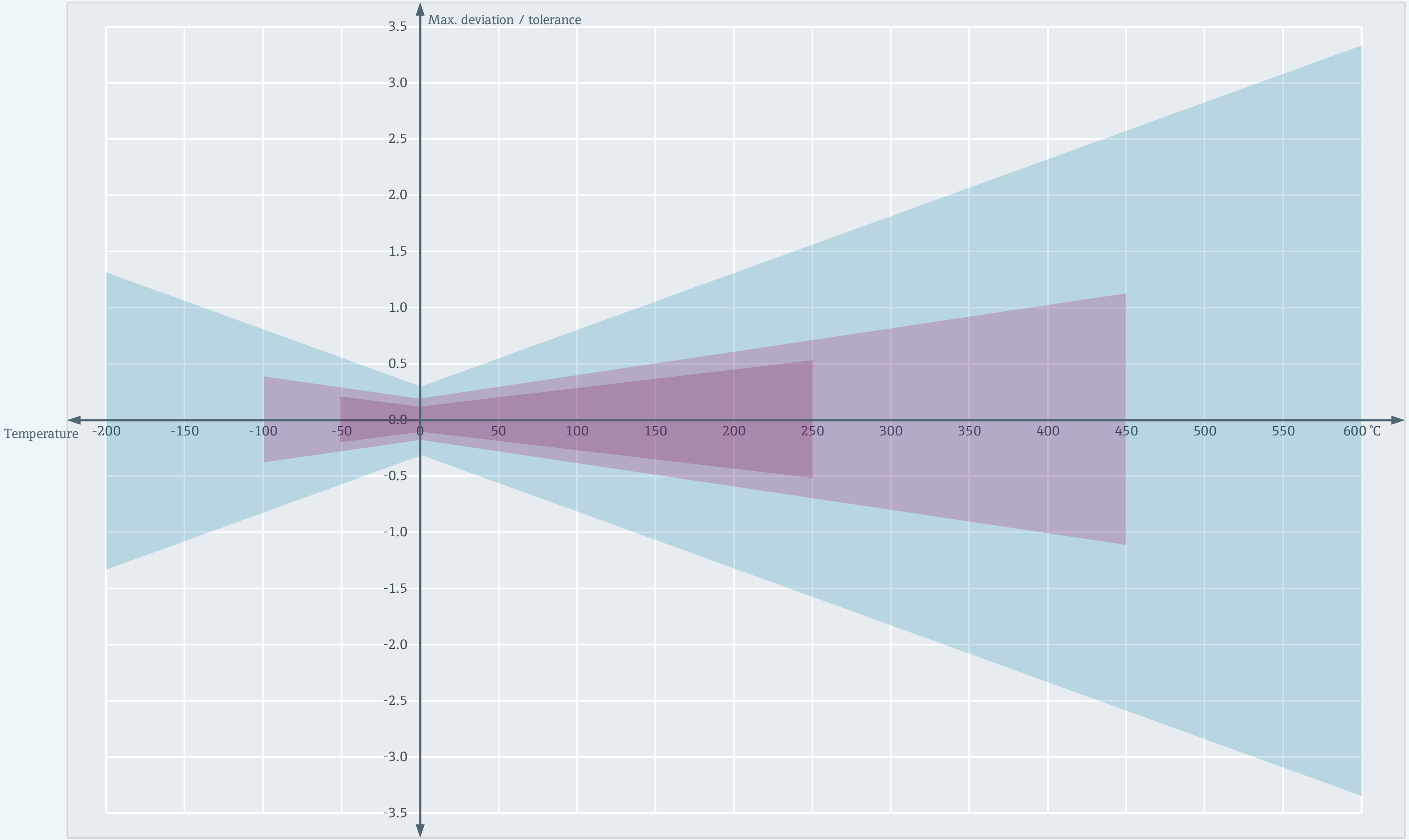
RTD Accuracy – Max. deviation



Accuracy according to DIN EN 60751

Class B
0.3+0.005*|t|

Class A
0.15+0.002*|t|

Class AA
0.1+0.0017*|t|

|t| = absolute value °C

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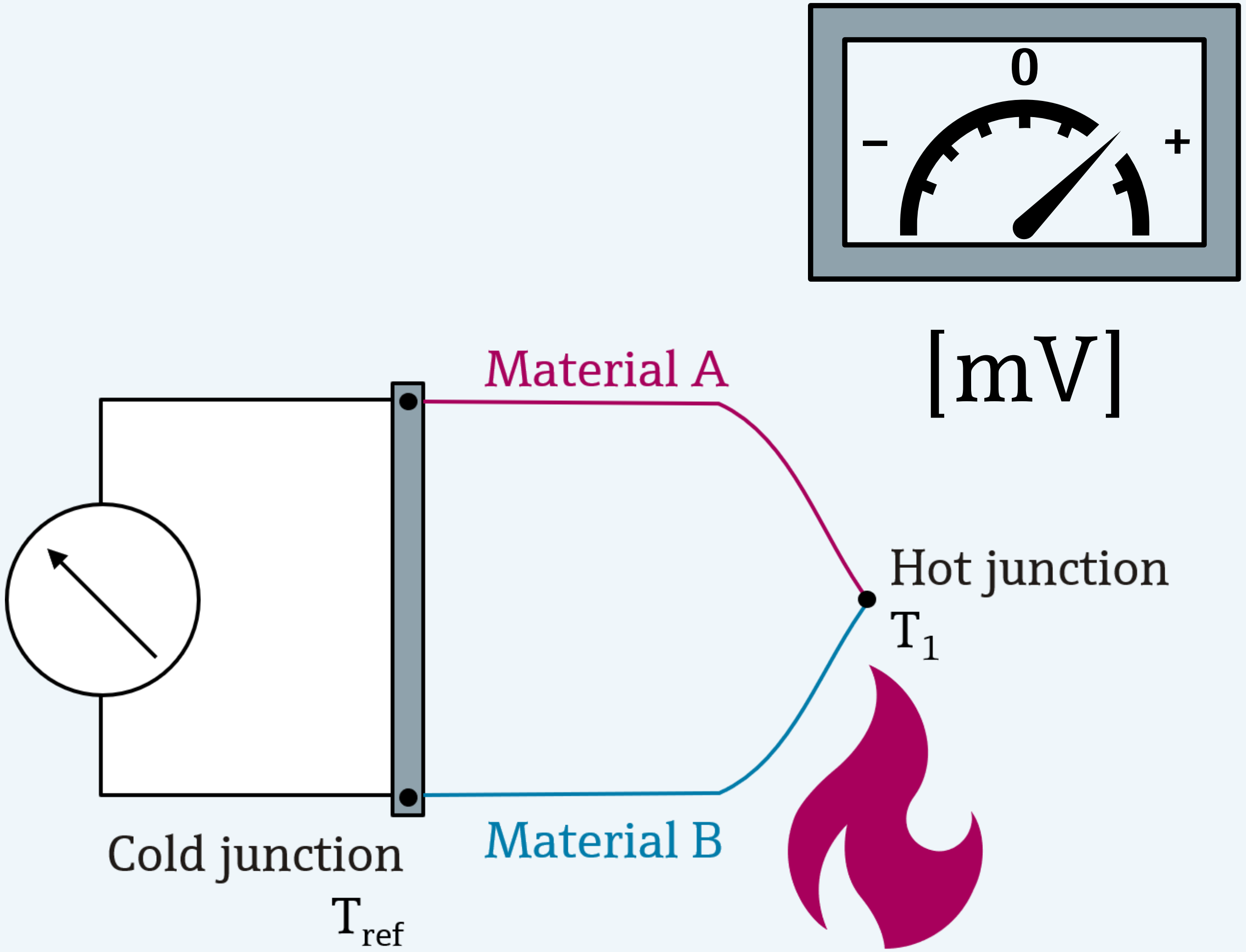
TC – Thermocouple

- Two different metals which are joined at one end
- Changes in the temperature at that junction induce a voltage / electromotive force
- Seebeck Effect
- A TC is never measuring an absolute temperature, but only the temperature difference between measuring point (T1) and the reference point (T ref.)



Thermocouple Types

Calibration w/ANSI color coding		Material	Temp. Range (Continuous)	Temp. Range (Short Term)
Outer	Conductors			
K	+	Chromel	0 to 1100 C	-1800 to 1350 C
	-	Alumel	*(32 to 2030F)*	*(-292 to 2462F)*
J	+	Iron	20 to 700 C	-180 to 750 C
	-	Constantan	*(68 to 1292F)*	*(-292 to 1382F)*
E	+	Chromel	0 to 800 C	-40 to 900 C
	-	Constantan	*(32 to 1472F)*	*(-40 to 1652F)*
T	+	Copper	-185 to 300 C	-250 to 400 C
	-	Constantan	*(-301 to 572F)*	*(-418 to 752F)*
N	+	Nicrosil	0 to 1100 C	-270 to 1300 C
	-	Nisil	*(32 to 2012F)*	*(-454 to 2372F)*
R	+	Platinum/13% Rhodium	0 to 1600 C	-50 to 1700 C
	-	Platinum	*(32 to 2912F)*	*(-58 to 3092F)*
S	+	Platinum/10% Rhodium	0 to 1550 C	-50 to 1750 C
	-	Platinum	*(32 to 2822F)*	*(-58 to 3182F)*
B	+	Platinum/30% Rhodium	100 to 1600 C	100 to 1820 C
	-	Platinum/6% Rhodium	*(212 to 2912F)*	*(212 to 3308F)*

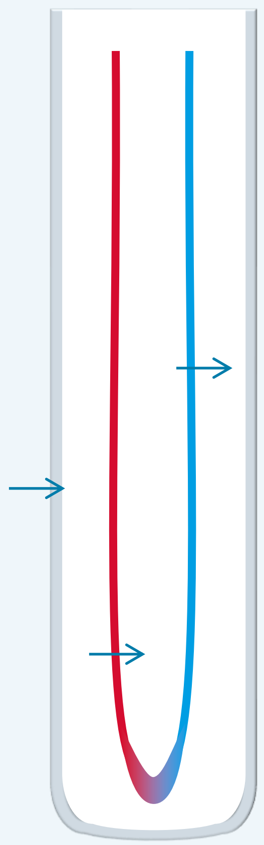
Type K is the most common thermocouple type because it has the largest temperature range.

Type T is most used in low temperature and cryogenic applications.

Type N is used in similar applications to Type K but has less drift over time.

Types R, S, & B are used in very high temperature applications. R is most common in industrial applications.

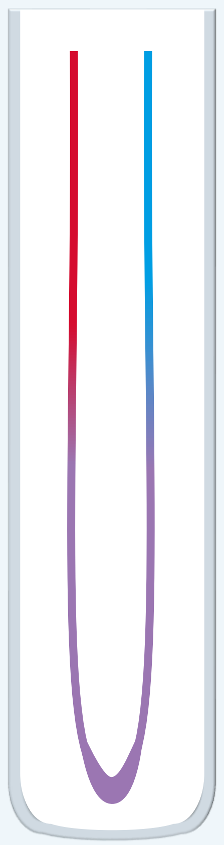
TC Theory - Why does a Thermocouple drift?



- The Seebeck-Effect results from the contact of 2 different alloys
- High temperatures can cause diffusion
- The materials (alloys) change

▸ The measuring point enlarges

▸ The induced voltage changes



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Thermocouples vs. RTDs

RTD Advantages

Accuracy over Temp. Range

Long Term Stability

Repeatability

Linear Output

RTD Disadvantages

Slower Response Time (standard construction*)

More Fragile (standard construction*)

Narrow Temperature Range w~1200ºF max.

Thermocouple Advantages

Broad Temperature Range

(-300 to ~3000ºF)

Rugged MI Cable Construction

Fast Response Time

Thermocouple Disadvantages

Short- and Long-Term Drift

Susceptible to Signal Noise (EMFs)

Accuracy at Lower Temperatures

Costly Interconnecting Wire

GOLDEN RULES for Contact-Thermometers

- Every contact-thermometer can only measure the temperature of the primary element (e.g. RTD like Pt100)

- So, a thermometer must be designed in such a way that it allows an energy transport:
  - from the medium to the primary element ($T_{Process} > T_{Ambient}$) *Heating*

- In reality, every contact thermometer is also influenced by the ambient temperature.

- Please consider, the primary element is located somewhere on this energy path between the process and the environment.

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Heat dissipation error

In addition to the **Golden Rules** you need to consider the general heat dissipation error, especially when dealing with barstock thermowells.

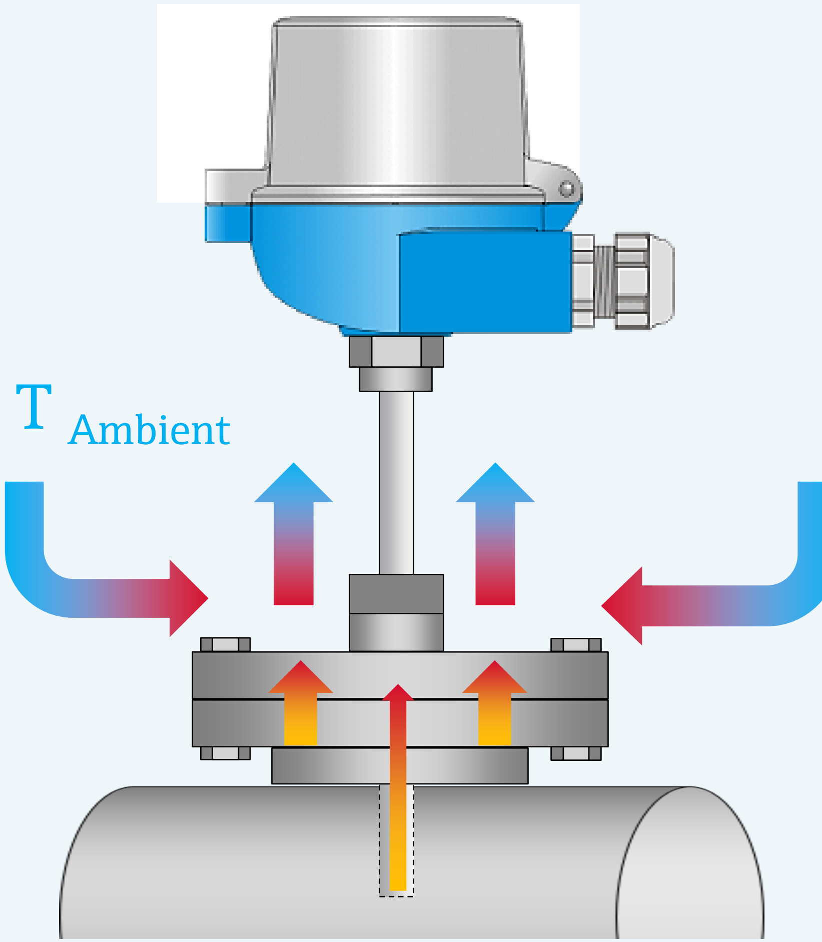
Increasing the immersion length helps to avoid the heat dissipation error!

Rule of thumb:

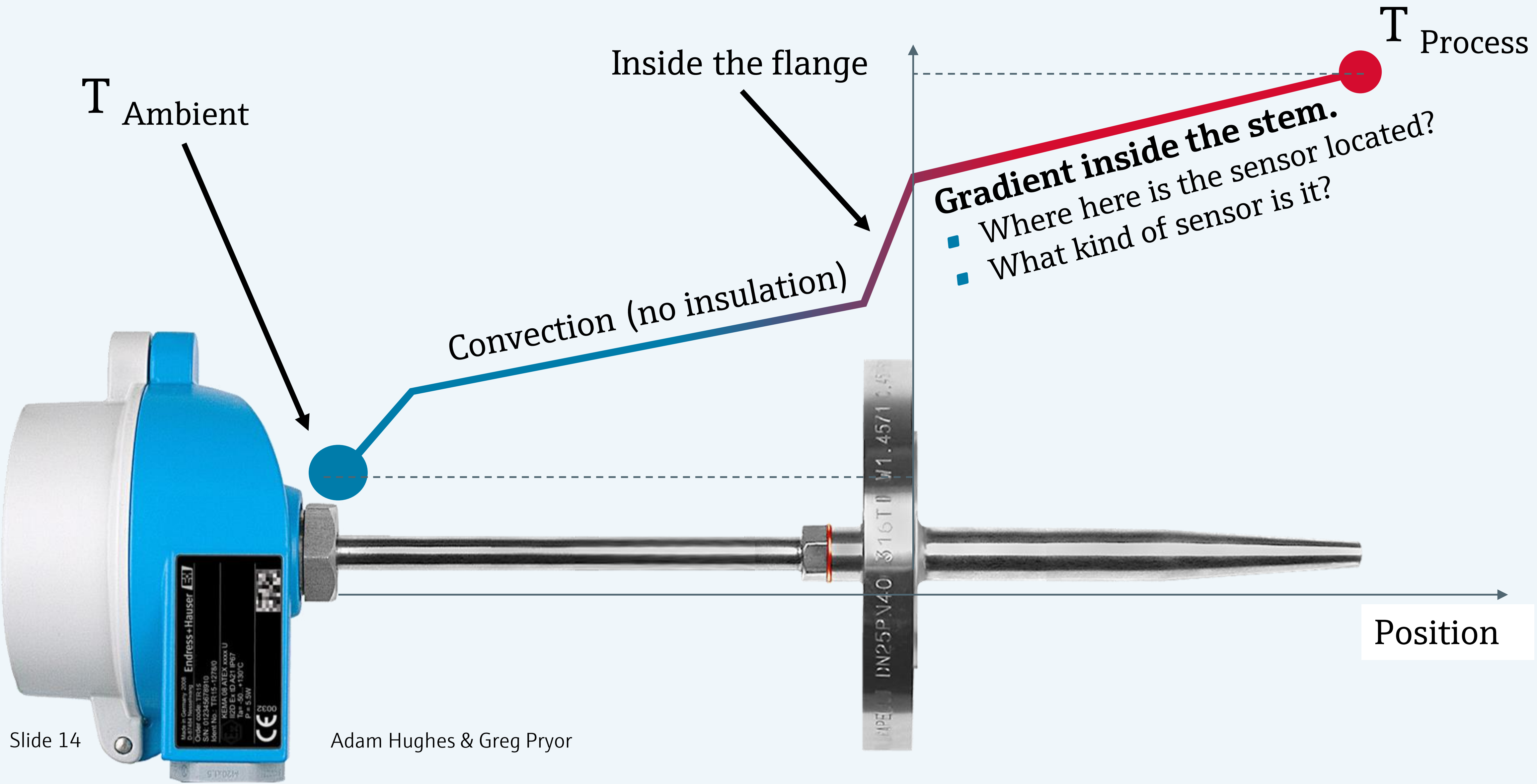
Liquids	At least **5 to 10** times the thermowell tip diameter
Gas	At least **10 to 20** times the thermowell tip diameter

Take away message:

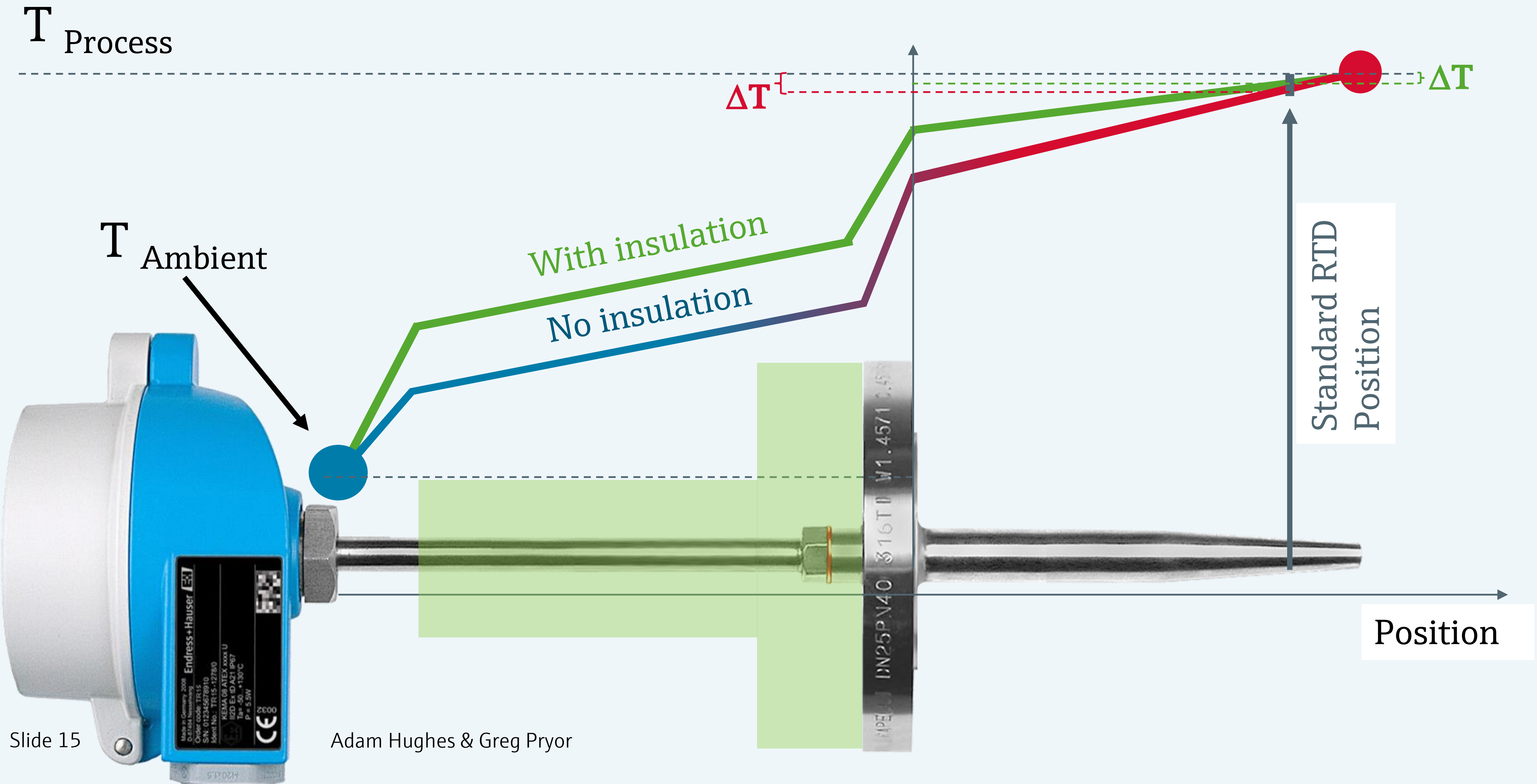
- When selecting short barstock thermowells (2.5”) use a reduced tip (and a sensor-on-tip-technology)!



Temperature gradient inside a thermometer (simplified)

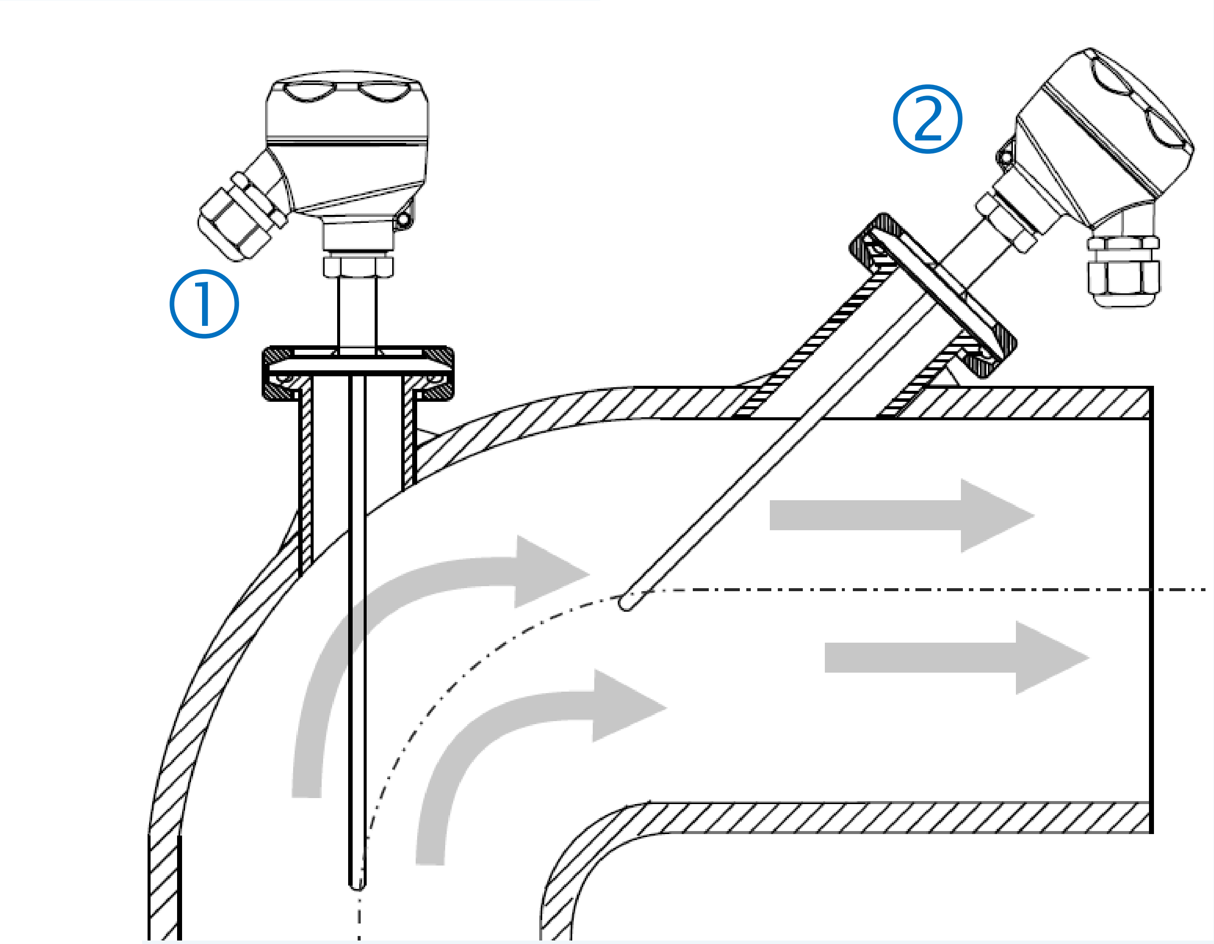


Minimize heat transfer errors by external insulation

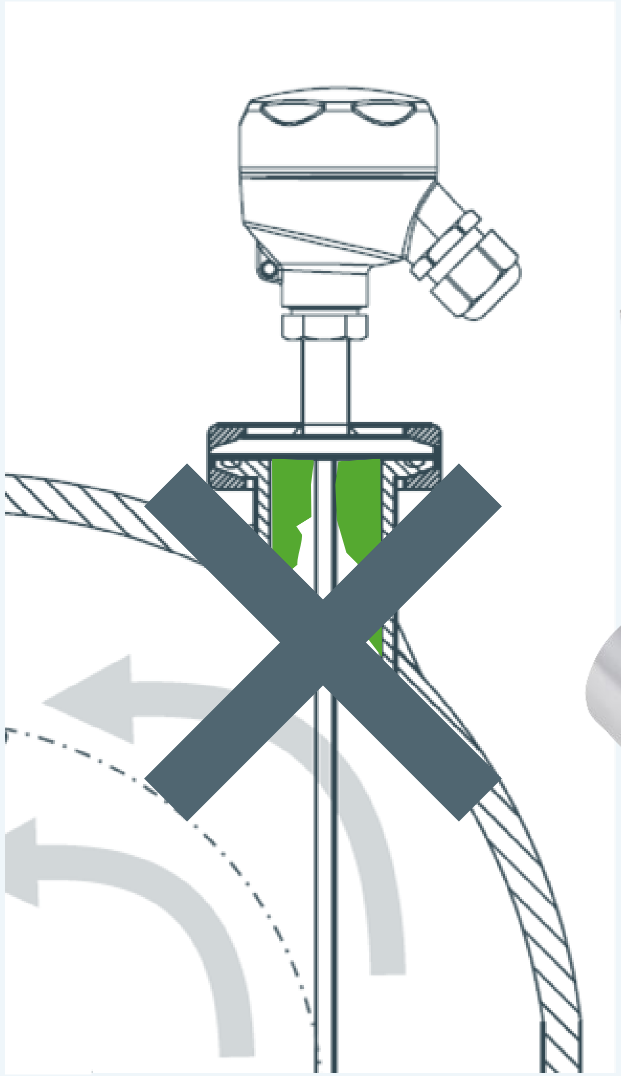


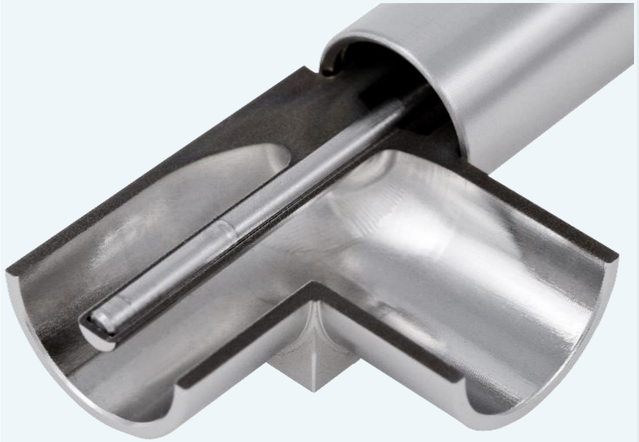
HOW TO increase the insertion length → decreasing deviations

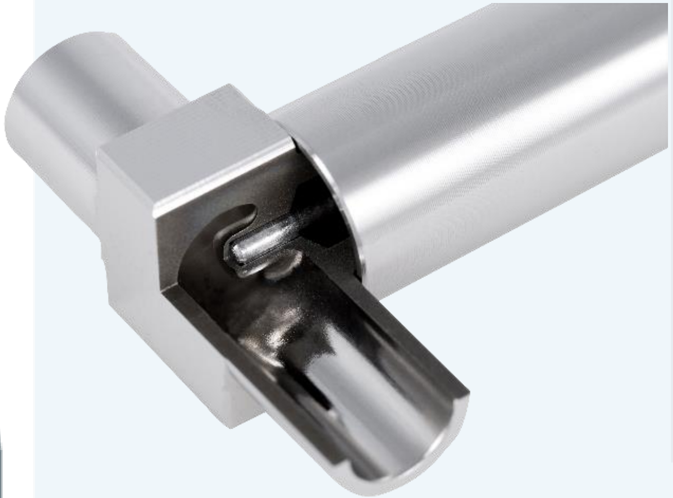
- The ②-best method is to mount the nozzle at an angle.
- Especially in small pipes, you will always find an elbow in a piping system, this gives you space to place a longer thermowell ① .
- But increasing the length will change the resonance frequency of the assembly, please **consider a THERMOWELL CALCULATION**



Innovative tee and elbow thermowells





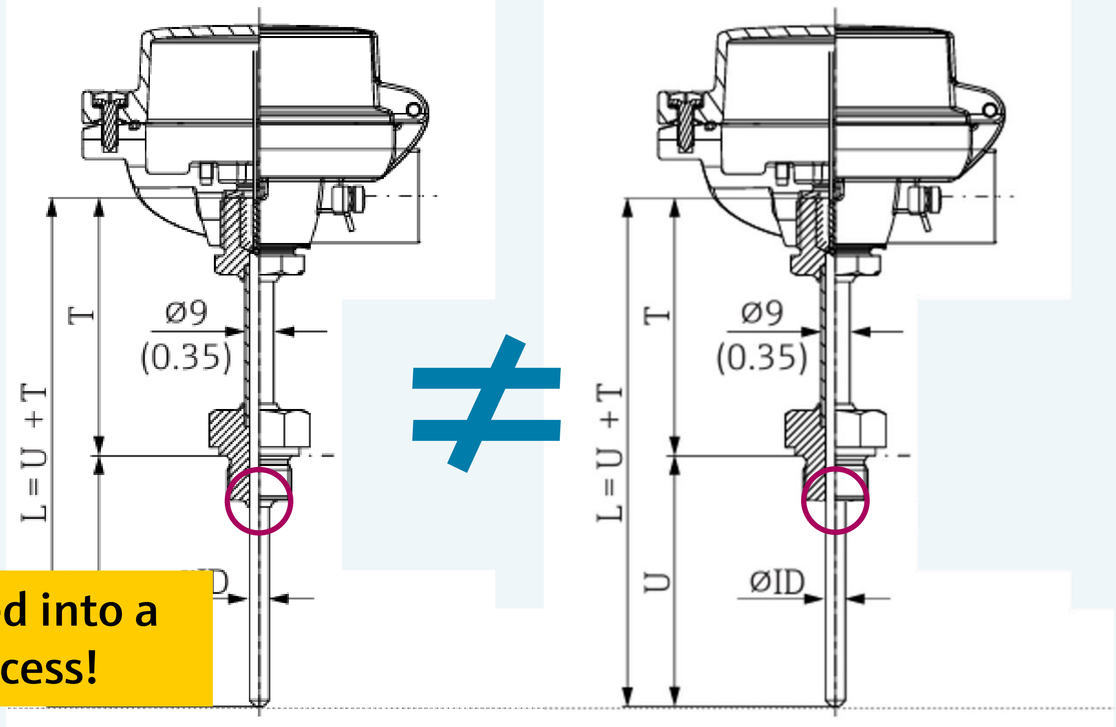


No dead legs

No welds

No!

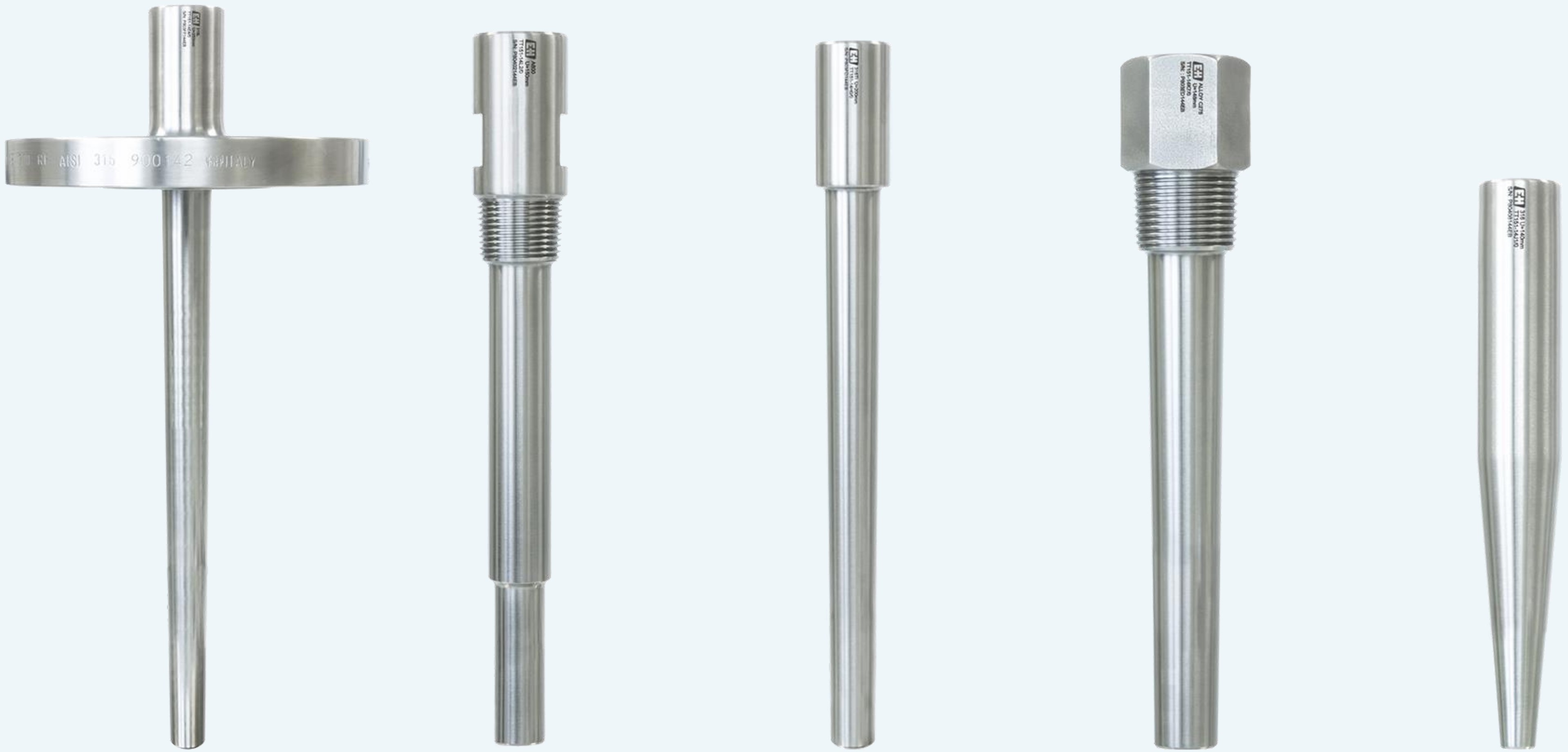
- This is a thermometer which is designed to be used in a thermowell, installed directly into the process



⚠ A thermometer, which is intended to be assembled into a thermowell is spring loaded and will not seal the process!

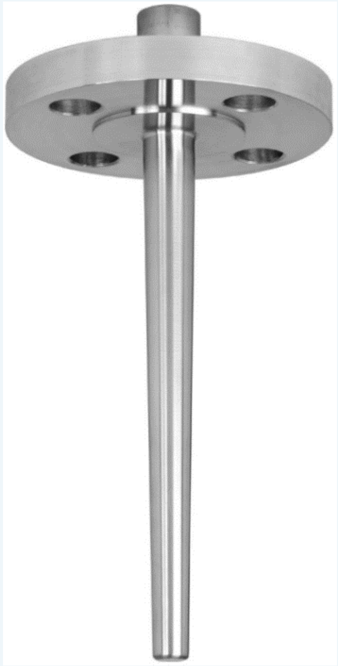
Barstock Thermowells

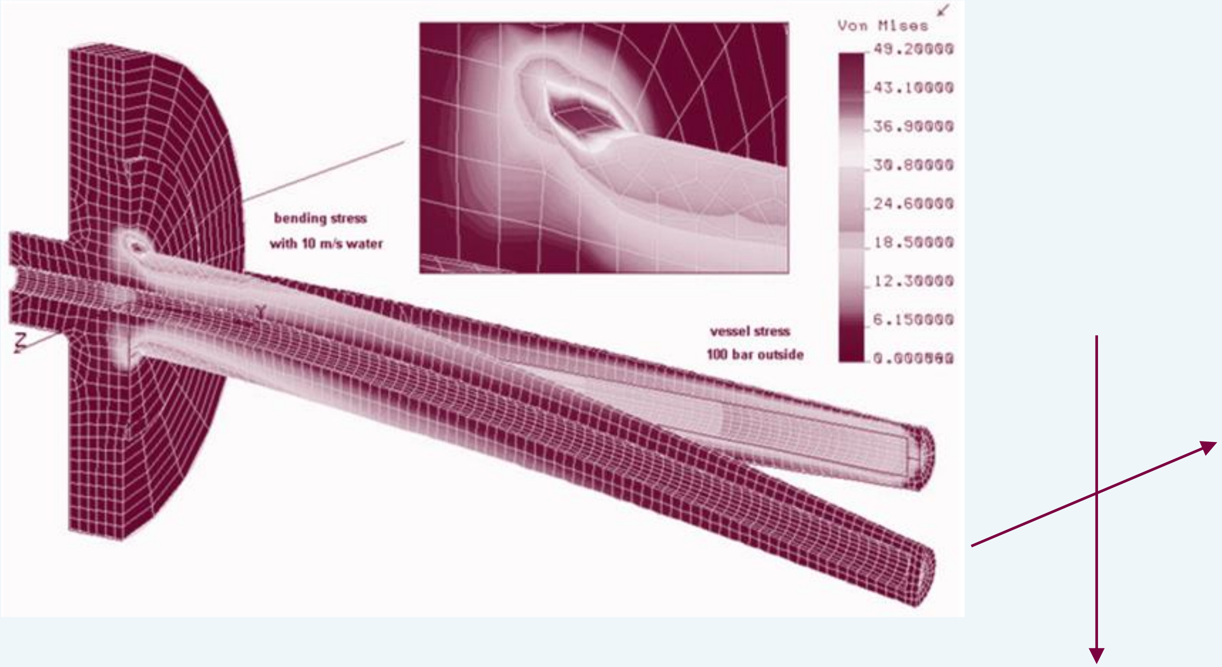
Flanged | Threaded (stepped) | Socket-Weld | Threaded (straight) | Weld-in

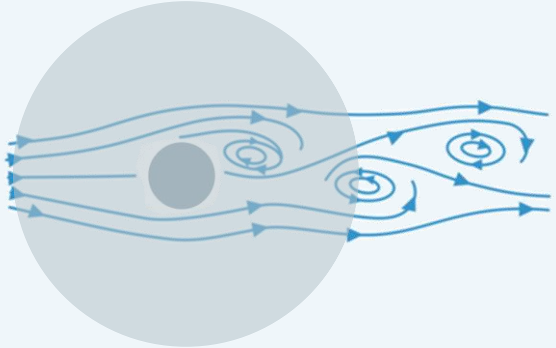


Thermowell – stress types

- Mechanical stress
- Vibration stress
- Thermal stress
- Chemical stress / corrosion stress
- Erosion stress







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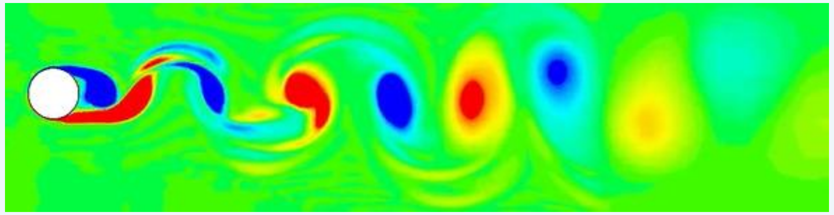
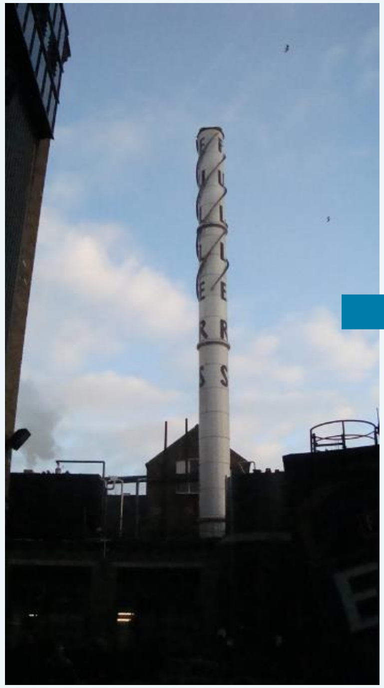
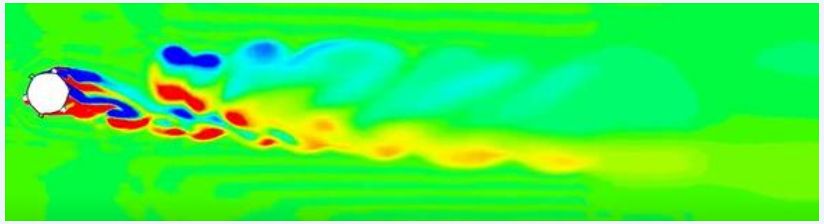
Helical Thermowells

- When objects are exposed to a flow/stream then vortex-induced-vibrations (VIV) can occur and bring the object into natural frequency. This will result in weakening and finally damaging the object.



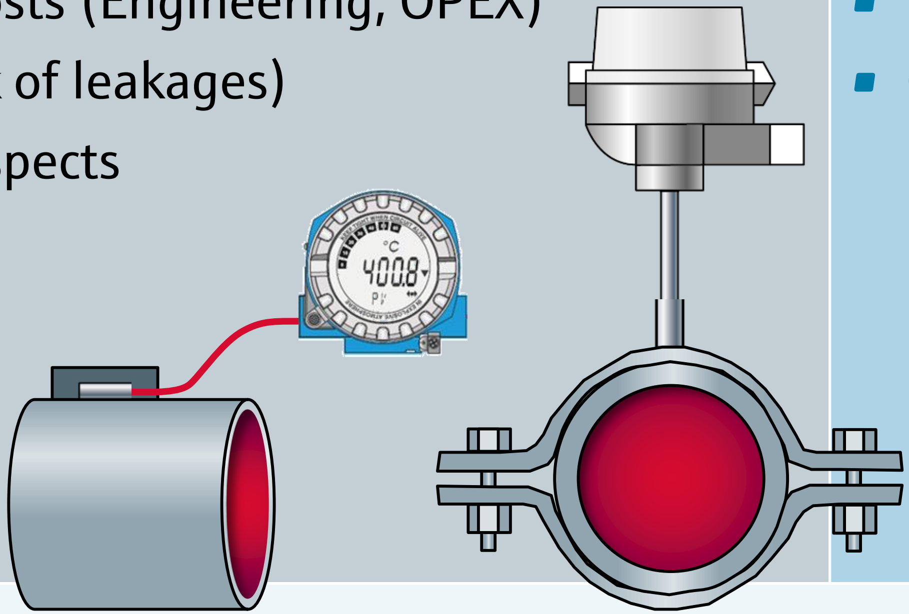


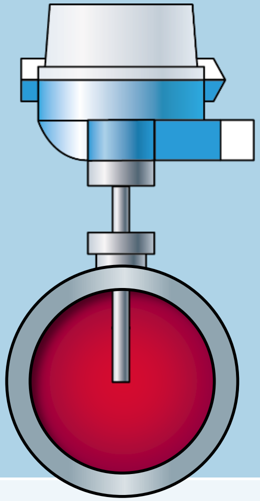
- Typical solution to reduce the VIV are helical designs on the object. One example are industrial chimneys.
- Result of this helical design is a drastic reduction of the VIV.



Advantages of each technology

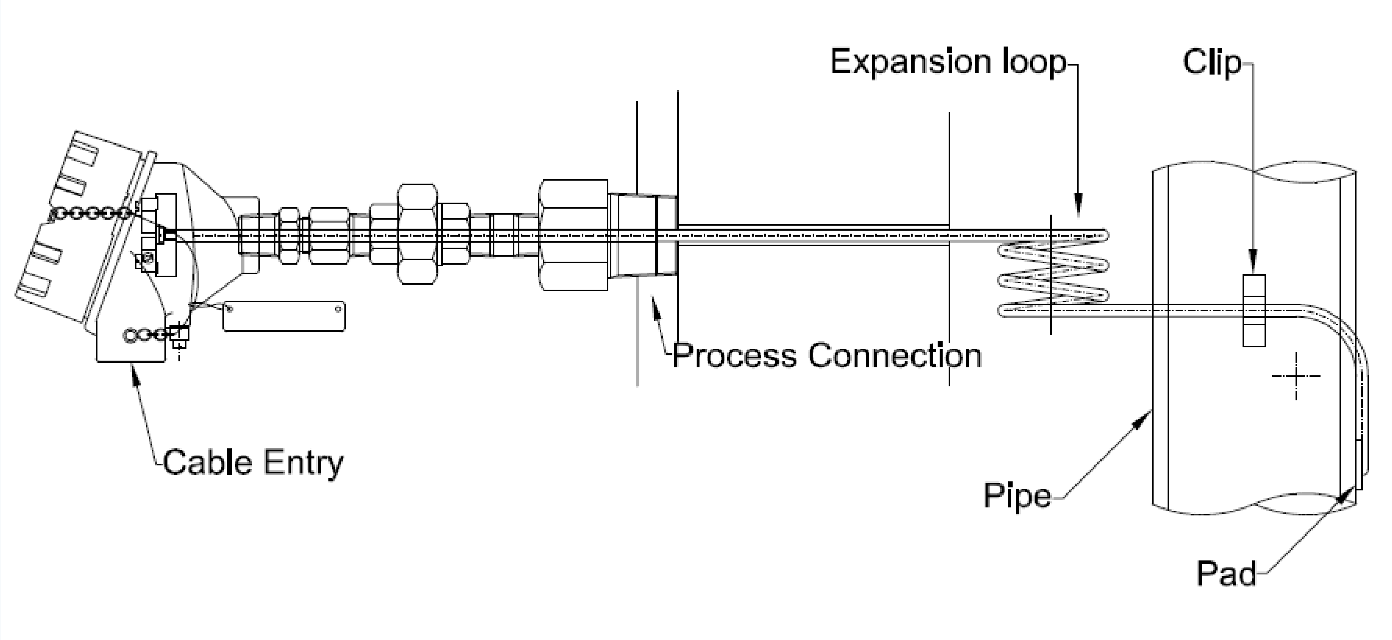
Surface measurement	Invasive measurement
▪ Easy Installation ▪ Simplified handling / maintenance ▪ Reduced costs (Engineering, OPEX) ▪ Safety (risk of leakages) ▪ Hygienic aspects	▪ Accuracy ▪ Dynamic behavior (response time) ▪ Repeatability ▪ Calibration possibilities

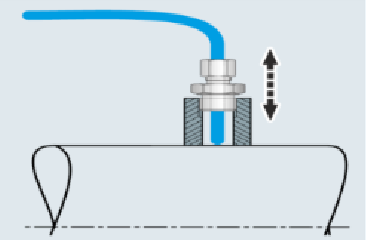


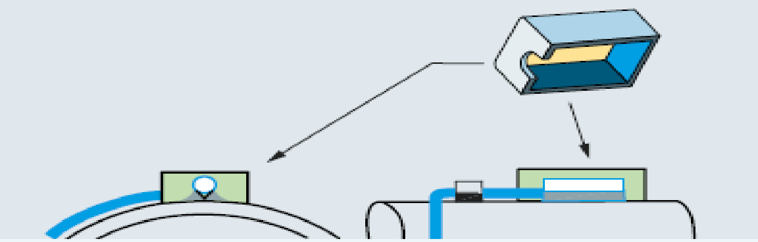


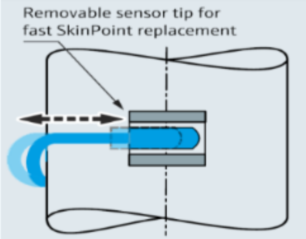
Skin point thermometers

- Modular design
- Sensor replaceable solution
- Components for thermal displacements compensation









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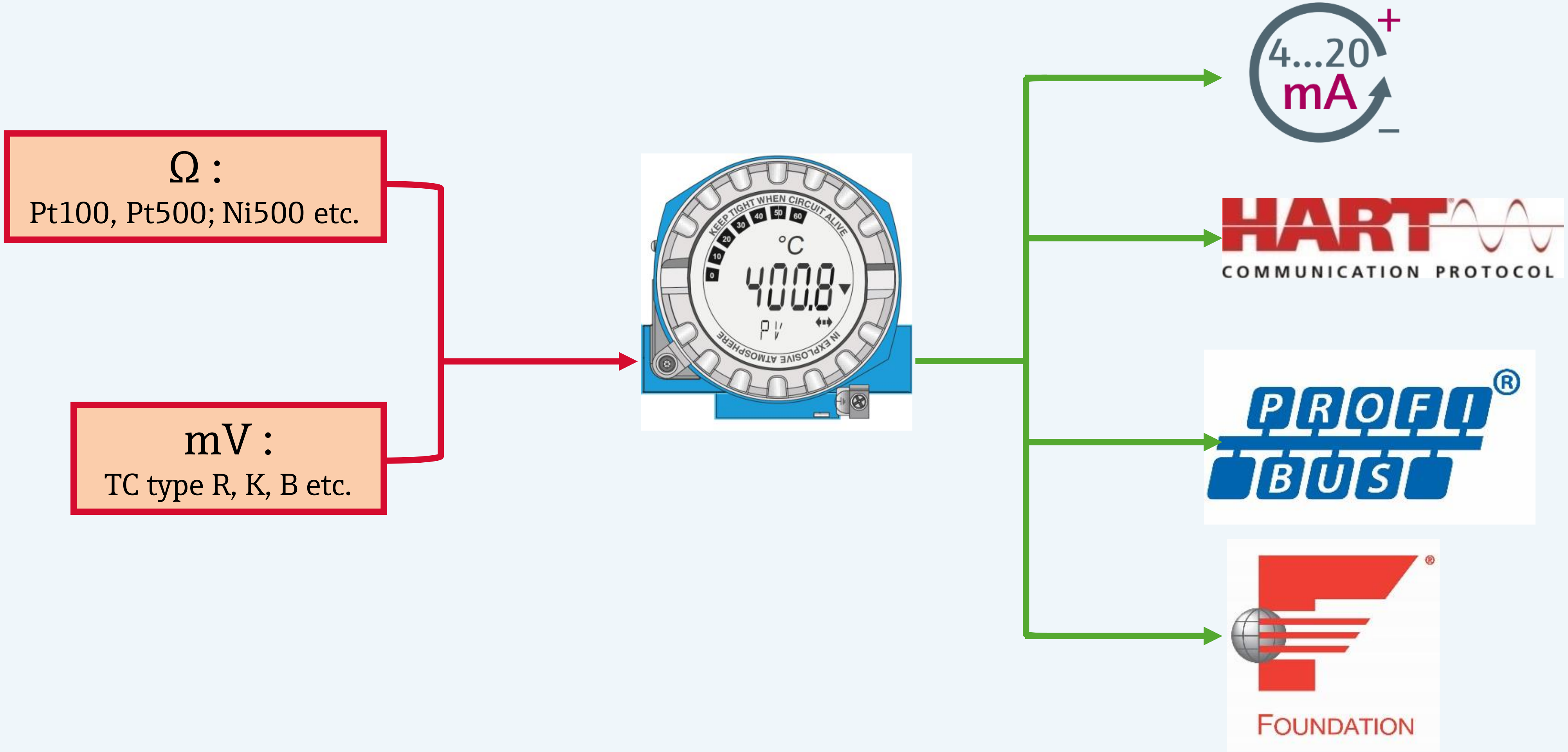
Transmitter – Communication protocols

From Sensor… **… to the control system**



Temperature Transmitters – Technology and Benefits

Linearization of sensor signal

Failure detection

- sensor break
- short circuit

Diagnostics – predictive maintenance

- corrosion detection
- sensor drift
- supply voltage monitoring

Additional functionality

- Calculation of differential and average values

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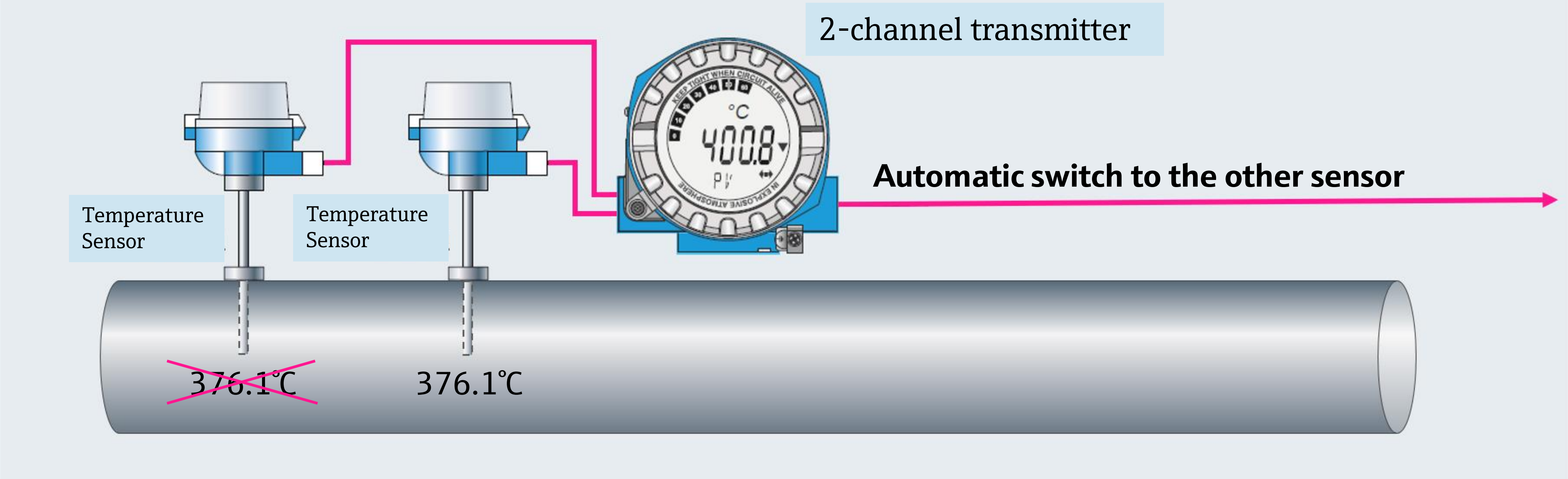
2 channel transmitter functions

Sensor backup function

- In case of the malfunction of the first sensor, the transmitter will switch automatically to the second sensor
- Transmission of the diagnostic information about the broken sensor



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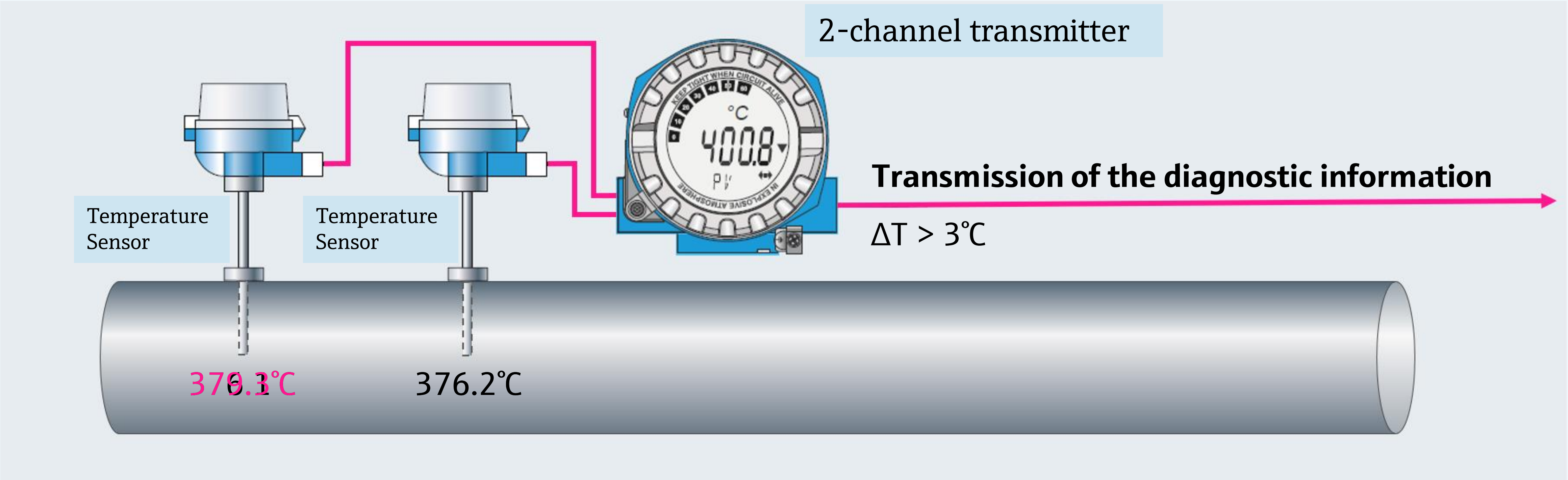
2 channel transmitter functions

Drift detection

- Alarm signal in case of violation of a limit value (can be set individually)
- Sensors should be calibrated in different intervals. This way drift caused by mechanical or thermal shocks can be identified



Sensor Transmitter Matching – Callendar/van Dusen

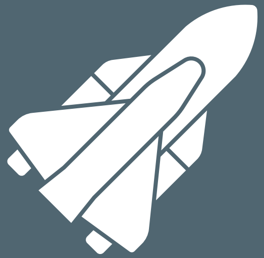
- The linearization curve in the transmitter needs to be adjusted to the real sensor characteristic curve → Measuring error is eliminated
- All platinum RTDs can be characterized according to IEC 60751 with the **Callendar/van Dusen polynomial (CvD):**

$$R(\vartheta) = R_0\left[1 + A\cdot\vartheta + B\cdot\vartheta^2 + C\cdot\vartheta^3(\vartheta - 100°C)\right]$$

- The coefficients A, B and C can be determined for every individual sensor by a calibration (at least 3-point)
- The coefficients can be stored within the transmitter

Innovative Technologies

G-Force Comparison



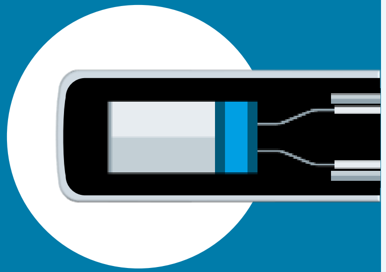
Standard RTD sensor

~3g

Space Shuttle Start

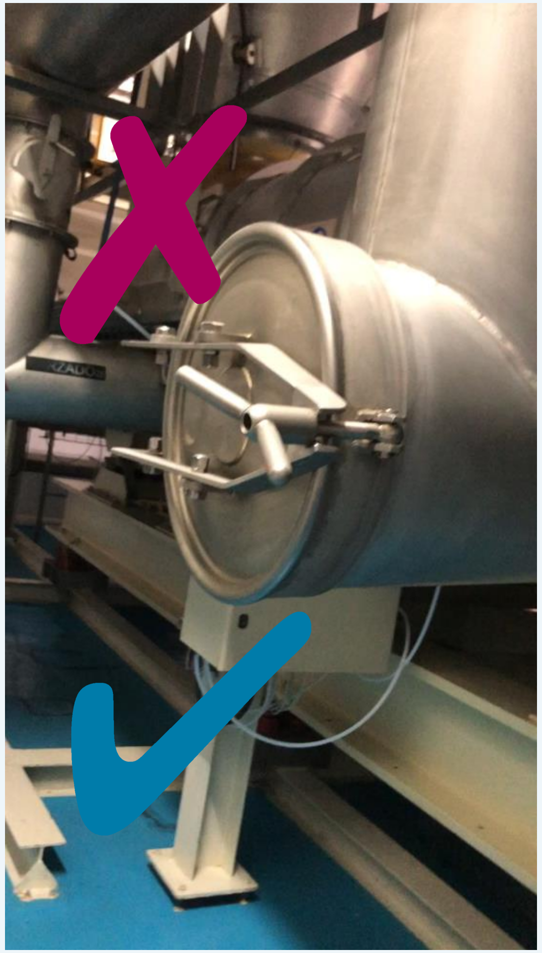
Vibration resistant sensor

~60g

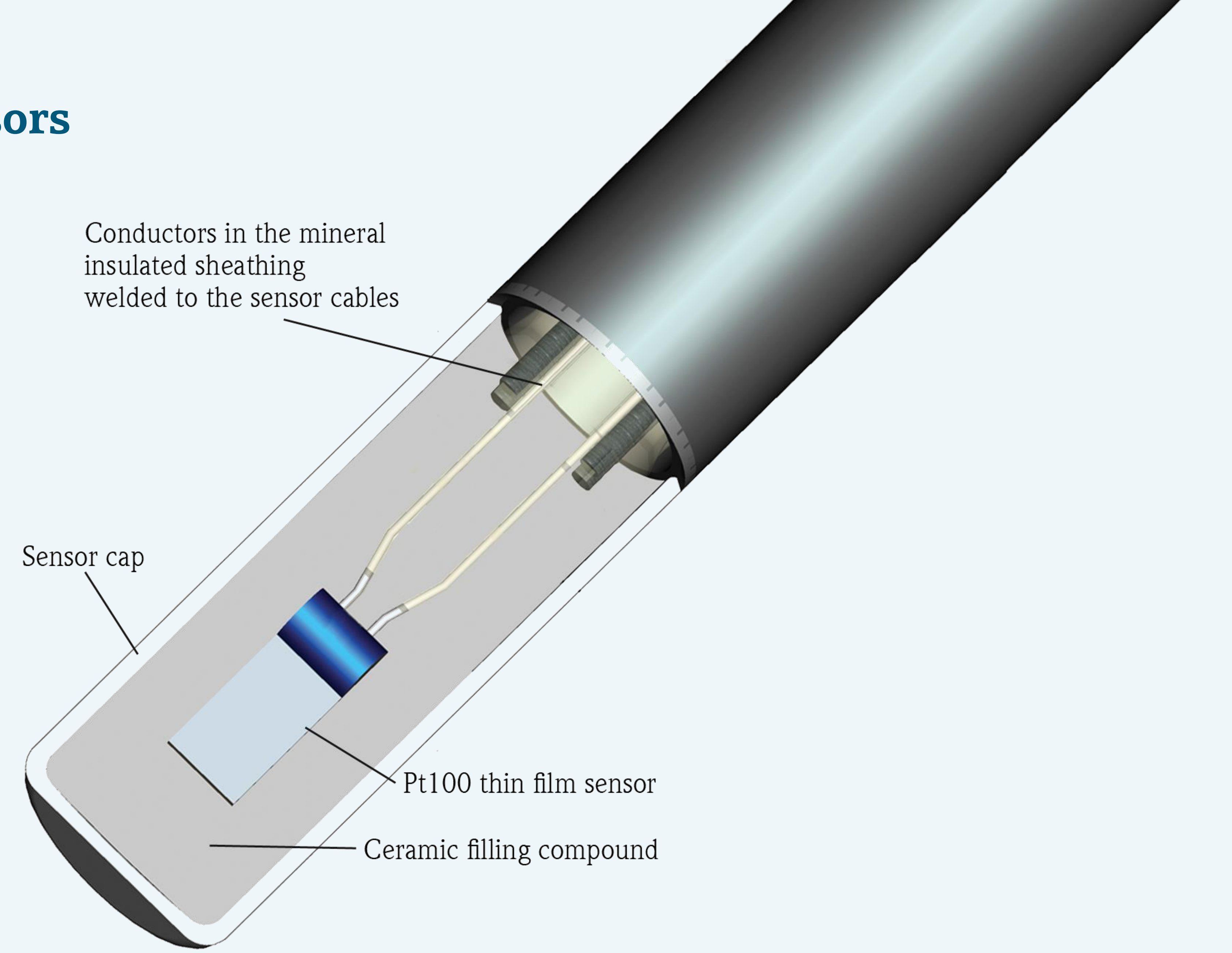


Car Crash with 90mph

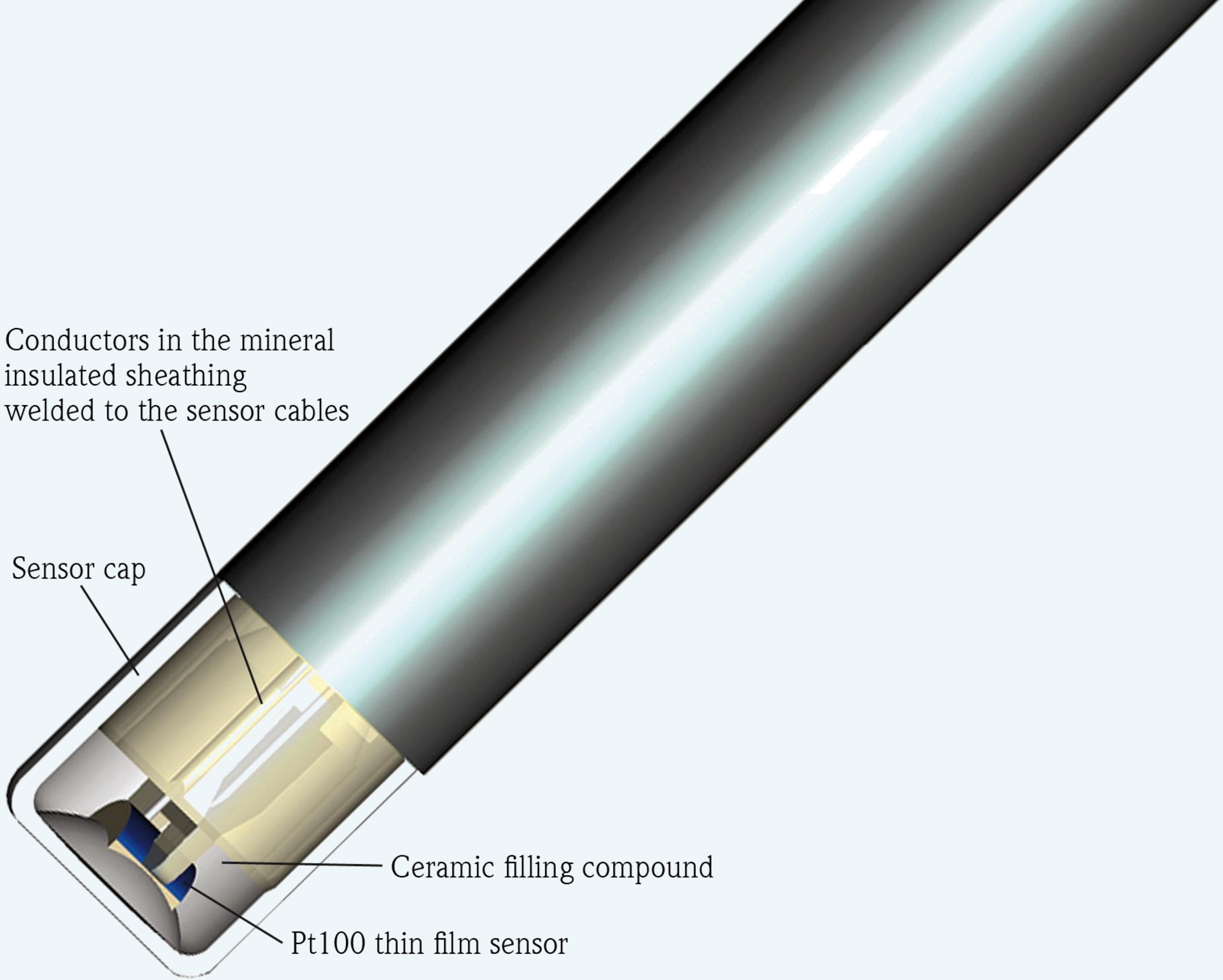
$41{,}67 m/s \div 0{,}072 s = 578{,}75 m/s^2 = \mathbf{59{,}004g}$



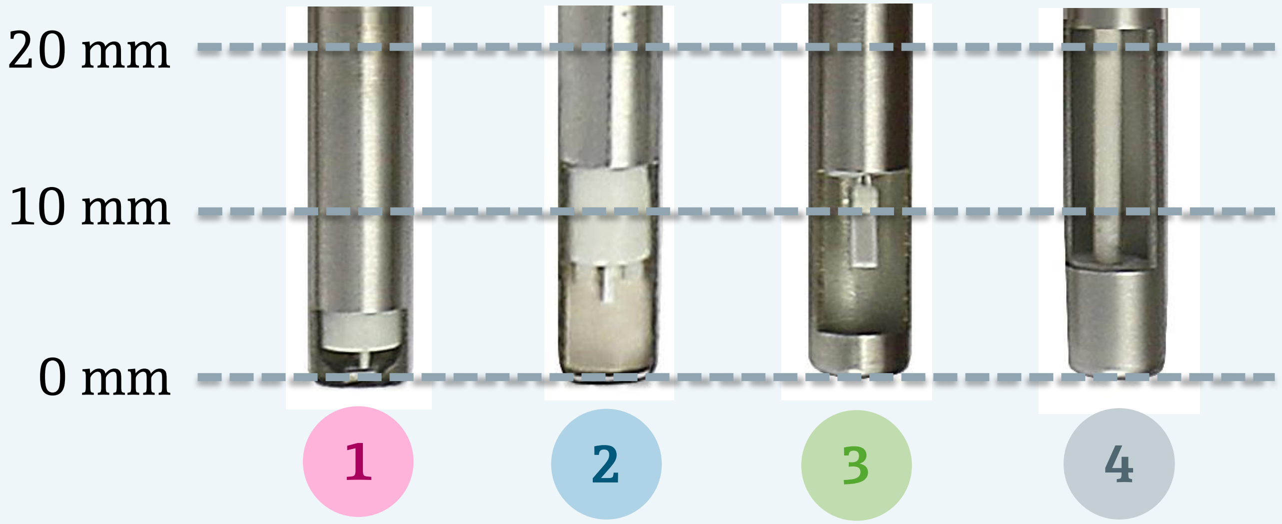
Vibration resistant sensors



Quick response sensors



How far away from the tip are the sensitive areas of temperature sensors?



Demo sensors for illustration
MgO powder removed

No.	Sensor	Distance from the tip
1	Quick Response Sensor	1mm
2	Vibration Resistant Sensor	5 - 7mm
3	Standard Thinfilm	5 – 10mm
4	Standard Wirewound	5 – 20mm (measures an average over its length)

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Traceable - INLINE- Calibration with smart technology vs. Offline

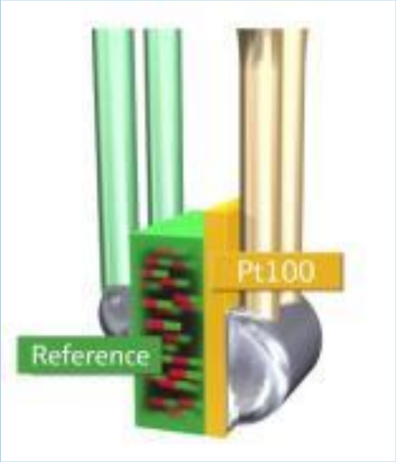
Block- or oil-calibrator

accuracy
homogeneity
repeatability

Reference thermometer

accuracy

Process – 244 °F/118 °C



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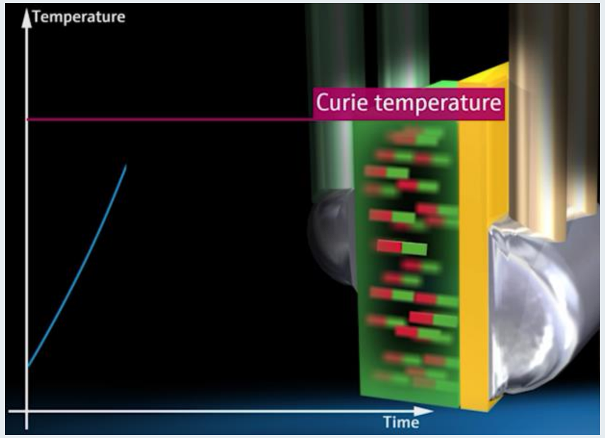
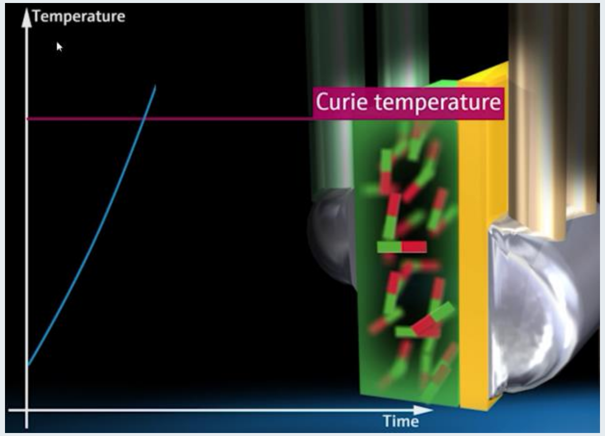
Offline fixed point vs. Inline fixed point

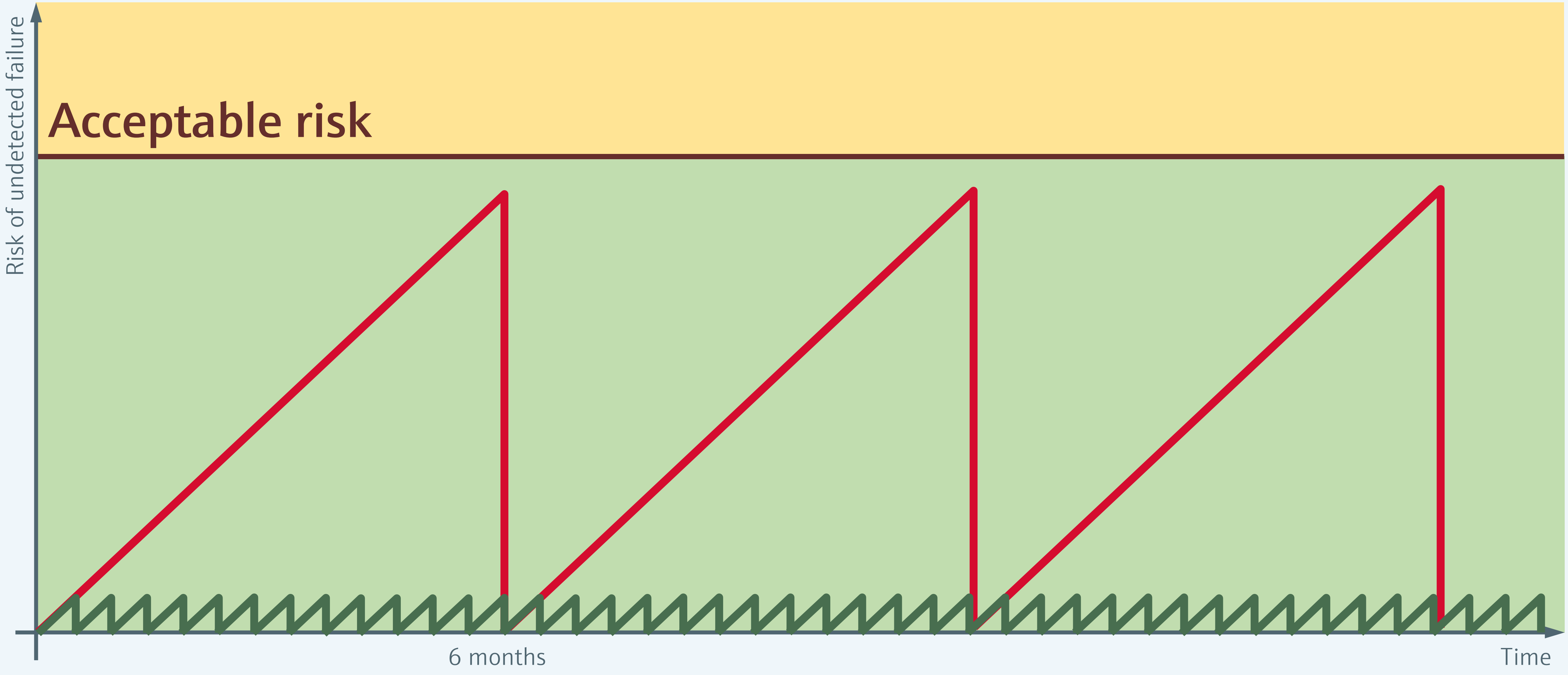
Water triple point @0.01°C

Ceramic Curie point @118°C (244°F)





Risk reduction with self-calibrating RTD



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Comparison chain

International
calibration standard

National
calibration standard

Test equipment

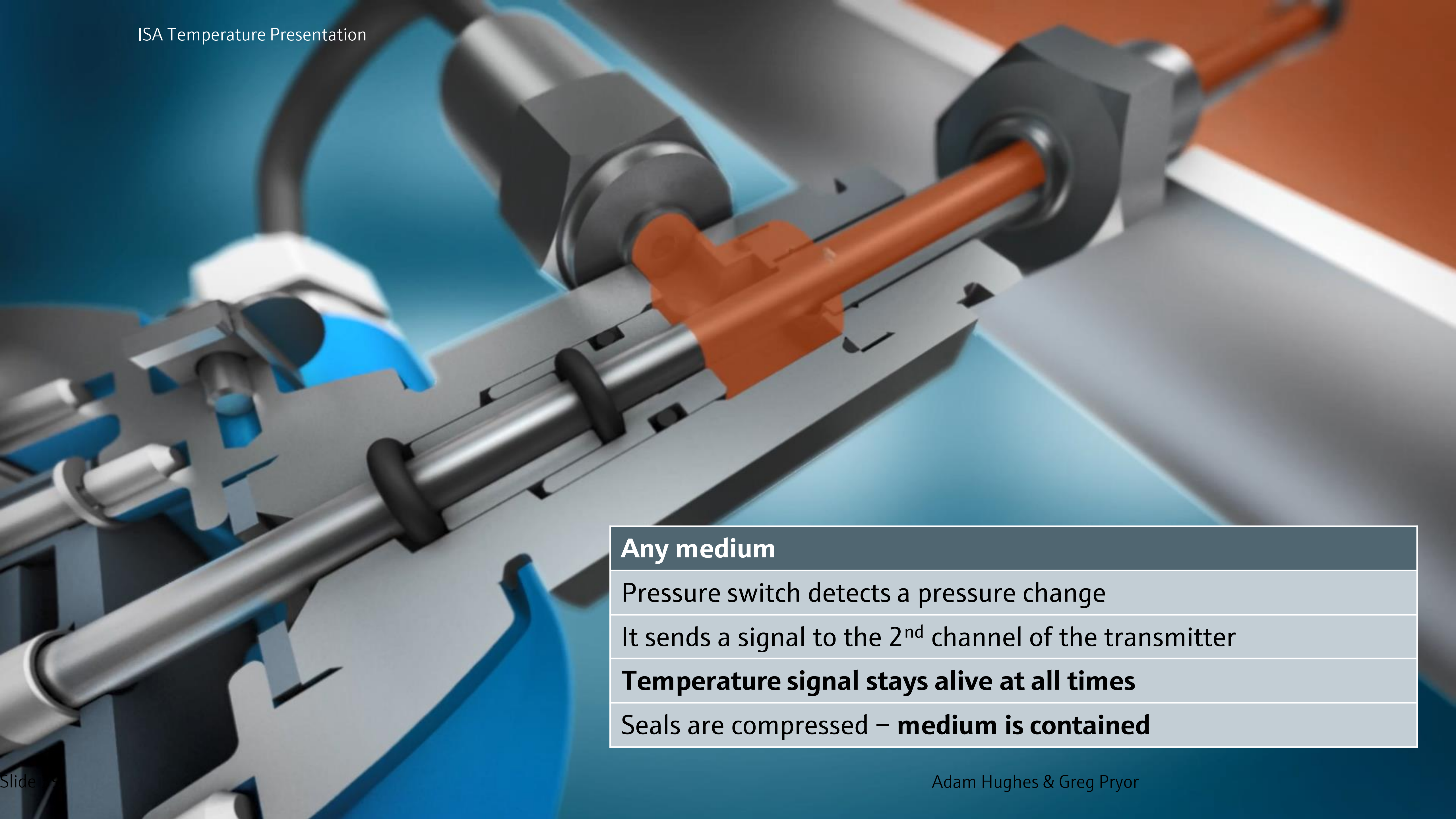
Measuring device

Second Process Barrier – Dual Seal

Temperature Assembly with second process barrier in combination with a 2-channel transmitter.

- Channel 1: Temperature signal (4 to 20 mA)
- Channel 2: Configured as TC, if pressure switch is turning a signal "sensor breakage" is generated
- Temperature signal stays alive

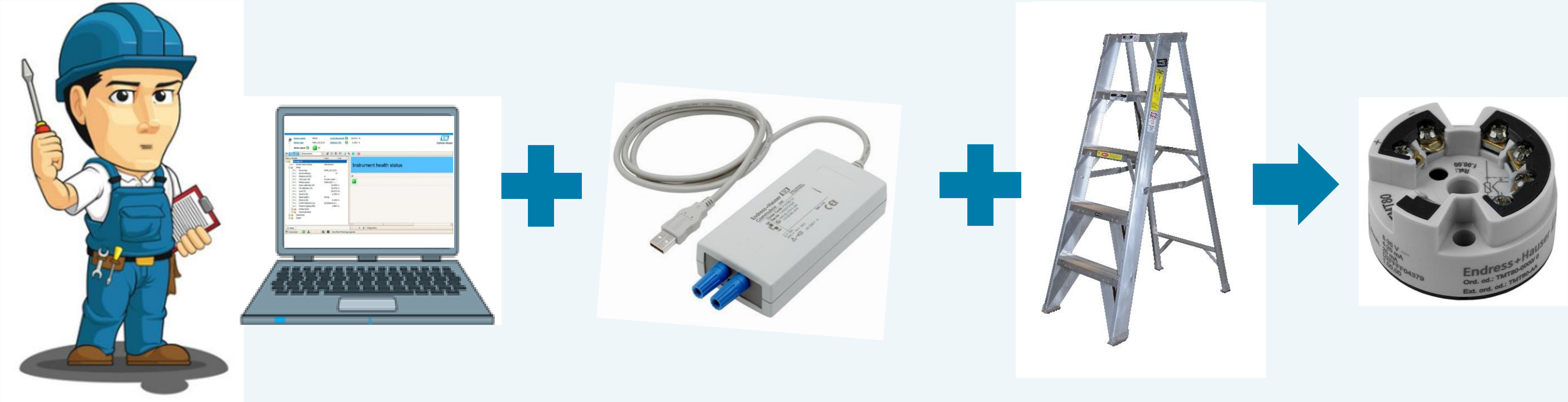
Technical Feature	Benefit	Added Value
▪ Second process barrier in case of thermowell integrity failure ▪ Signal to PLC if pressure in neck is rising to 3 bar +/-1bar	▪ Additional health information from measurement device ▪ Temperature signal stays alive	▪ Increased process safety ▪ Reduced unplanned shutdowns ▪ Health status information



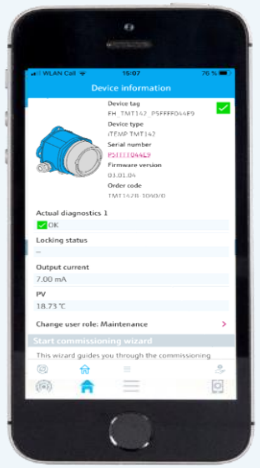
Any medium
Pressure switch detects a pressure change
It sends a signal to the 2nd channel of the transmitter
Temperature signal stays alive at all times
Seals are compressed – **medium is contained**

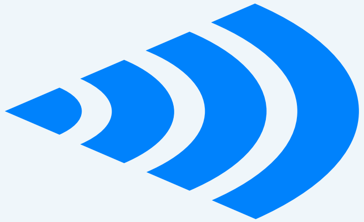
Adam Hughes & Greg Pryor

The problem with connectivity…



…the solution





- Convenient device operation from a distance
- Easily check the status of all your devices within Bluetooth® range
- Encrypted data transmission ensures highest security

Thank you for joining us!!

If anyone has questions, please put them in the chat and we will do our best to answer them.