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A practical guide in traceable measurement of air temperature

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The Danish Meteorological Institute, which has a key role in monitoring Greenland's climate, last week reported a shocking August temperature of between 2.7 °C and 4.7 °C at the Summit weather station...

...DMI has now estimated that the temperature was closer to -2 °C

What could have caused such a significant measurement error?

Danish climate body wrongly reported Greenland heat record

The Local
news@thelocal.dk
@thelocaldenmark

8 August 2019
20:39 CEST+02:00

greenland

climate

temperature

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The DMI last week reported a record temperature of up to 4.7C at the Summit station on Greenland. Photo: Christian Brøndum/Scanpix

Denmark's national climate body has admitted it wrongly reported record warm temperatures on the centre of the Greenland ice sheet last week, in what it called "good news from a climate perspective".

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What went wrong?

The thermometer measures the temperature of the thermometer!

What is Temperature..

Two systems are in contact – energy is exchanged – when the energy exchange stops, we say they are in thermal equilibrium – they share something.....

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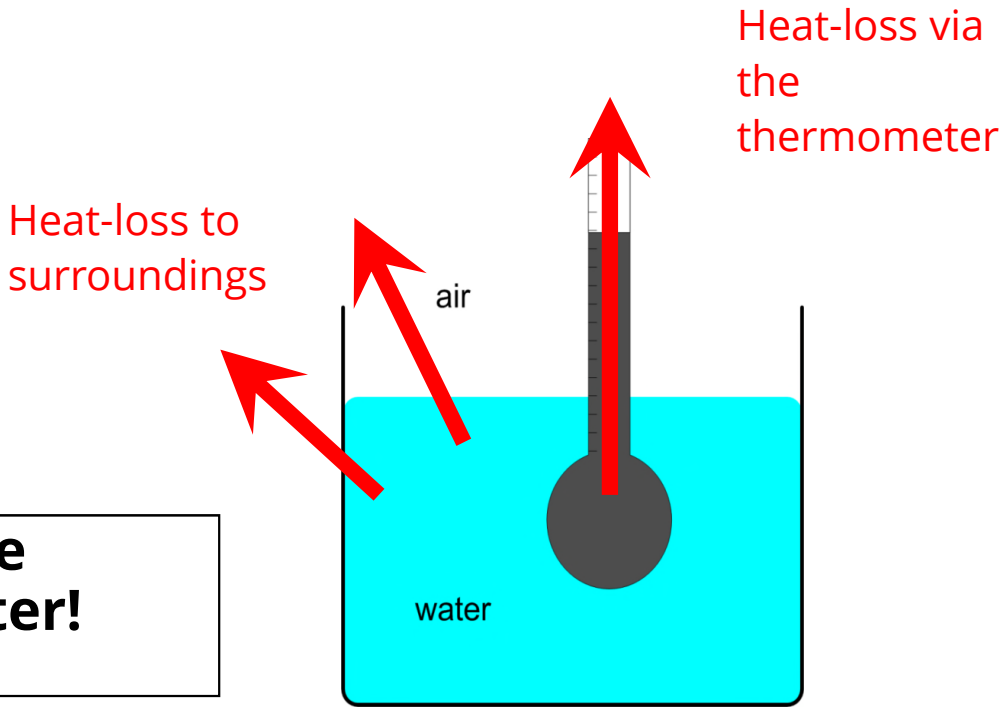
Heat transfer

But does thermal equilibrium ever exist in practise?



The thermometer measures the temperature of the thermometer!

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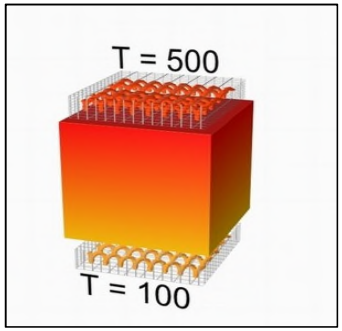
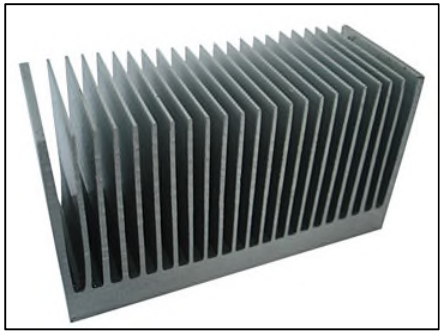
Which mechanisms are the troublemakers in contact thermometry?

Heat conduction



Kilde:http://www.mece.ualberta.ca

Convection



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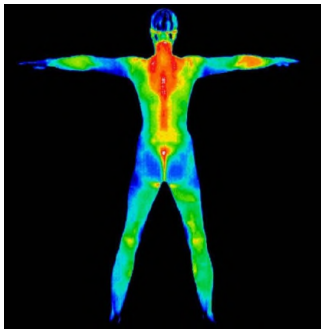
Radiation



http://www.applewoodacupuncture.com/

Self-heating

http://www.dhgate.com/

Mechanism: Temperature differences

Mechanism: Power dissipation in RTD's

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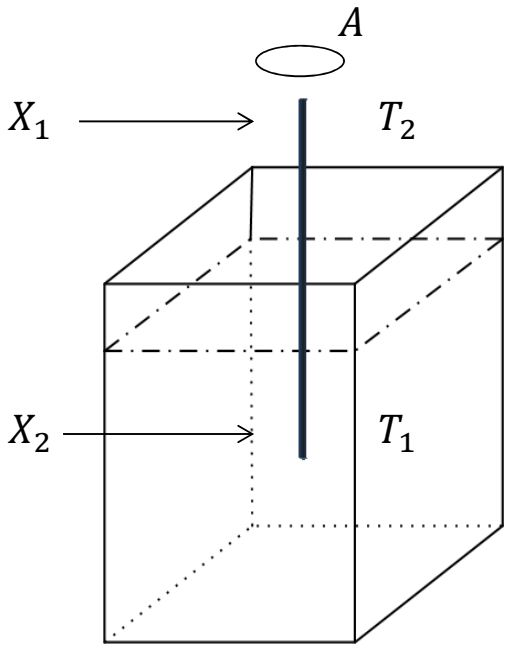
Heat-conduction

$$\frac{\Delta q_{cond}}{\Delta t} = \lambda \cdot A \cdot \frac{T_1 - T_2}{X_1 - X_2}$$

λ:	*thermal conductivity*
A:	*cross sectional area*
T_1-T_2:	*Temperature difference at X_1 og X_2*
X_1-X_2:	*Distance between the two regions with different temperature*



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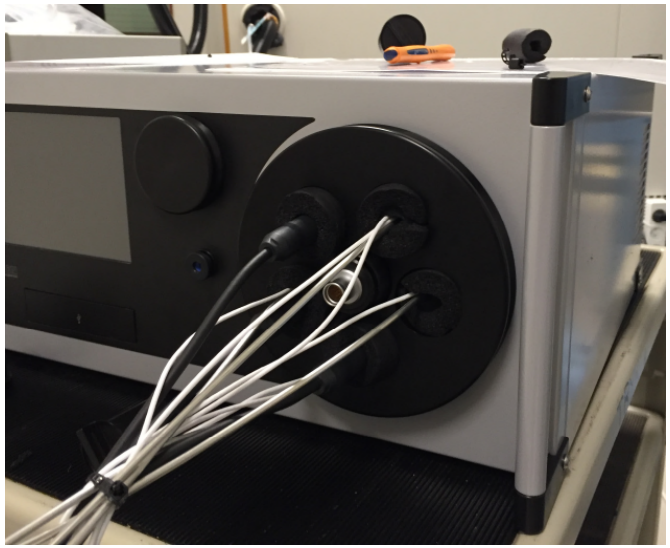
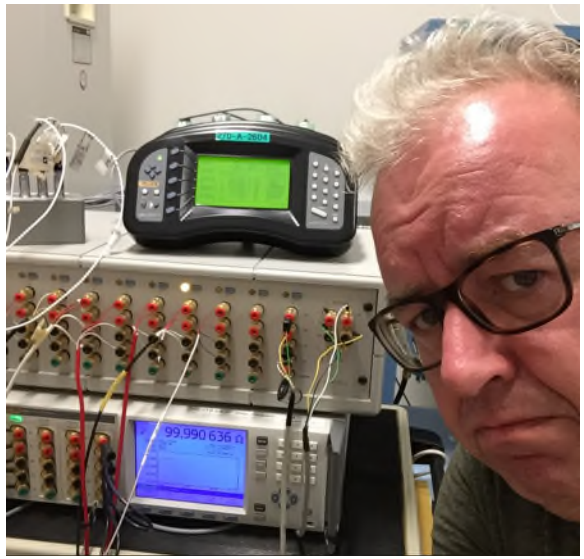
Heat-conduction

- This is normally not a good idea:





Solution:
- Optimise heat transfer to sensor
- Reduce heat-loss by heat-conduction

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Radiation effects

$$\frac{\partial q}{\partial t} = \varepsilon \cdot \sigma \cdot A \cdot \left({T_s}^4 - {T_{sur}}^4 \right)$$

ε: Emmisivity, material dependant
σ: Stefan Boltzmann's konstant
A: Area of the surface
T_s: Temperature of the surface
T_{sur}: Temperature of surroundings

Solution:
- Remove the source
- Shield the sensor

Incandescent bulb (1800 °C -3300 °C)

Oven (200 °C – 1600 °C)

Sun light (5000 °C – 15000 °C)

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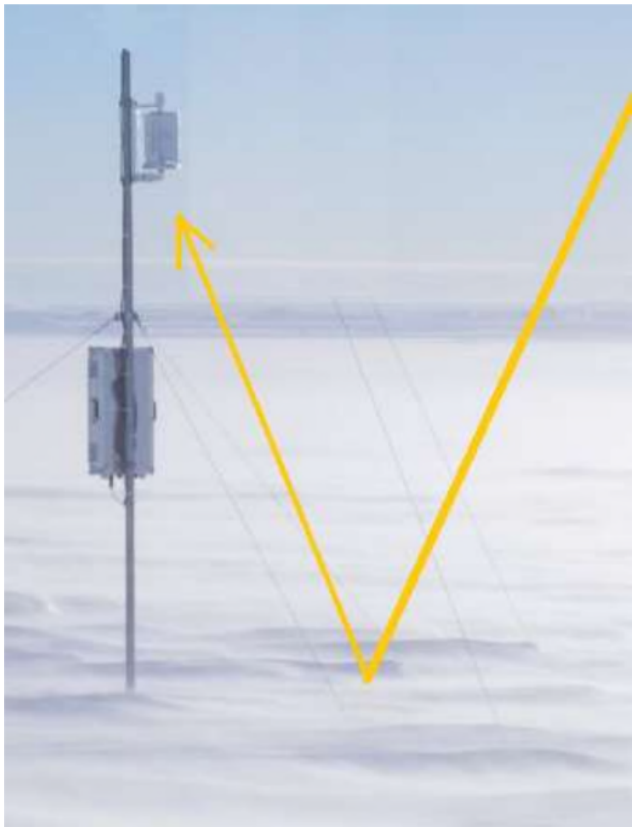
Albedo effect



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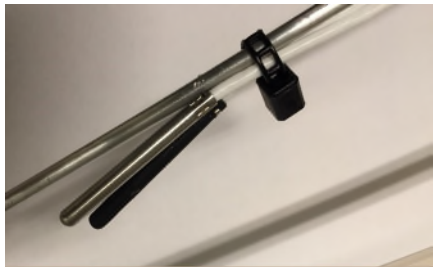
Radiation effect in a Climatic Chamber



DEUTSCHER KALIBRIERDIENST DKD

Guideline DKD-R 5-7 **Calibration of Climatic Chambers**

Edition 07/2004 ♦ English translation 02/2009 Page 1 of 31

Guidelines on the Calibration of Temperature and / or Humidity Controlled Enclosures

EURAMET Calibration Guide No. 20
Version 5.0 (09/2017)

EURAMET

Thermometry

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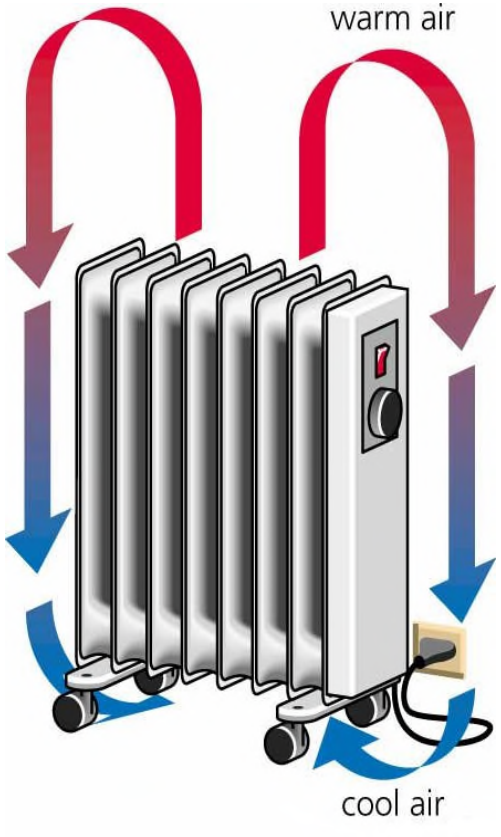
Convection

Convection takes place when a gas moves from one place to another and brings it's energy

$$\frac{\Delta q}{\Delta t} = h \cdot A \cdot (T_s - T_\infty)$$

h:	*Heat transfer coefficient (depends among others on the surface form and texture)*
A:	*Cross-section area*
$T_s - T_\infty$:	*Temperature difference between surface and gas*



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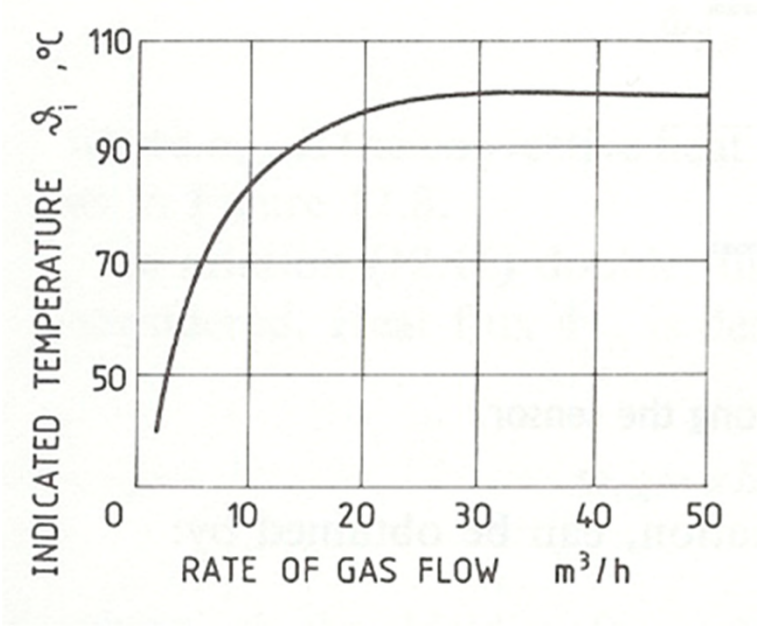
Temperature is dependent of the air-flow



Reduce measurement errors by:

1. Optimising heat transfer to sensor (optimise convection/heat-conduction)
2. Reduce heat-loss by heat-conduction
3. Place the sensor where the temperature is most representative

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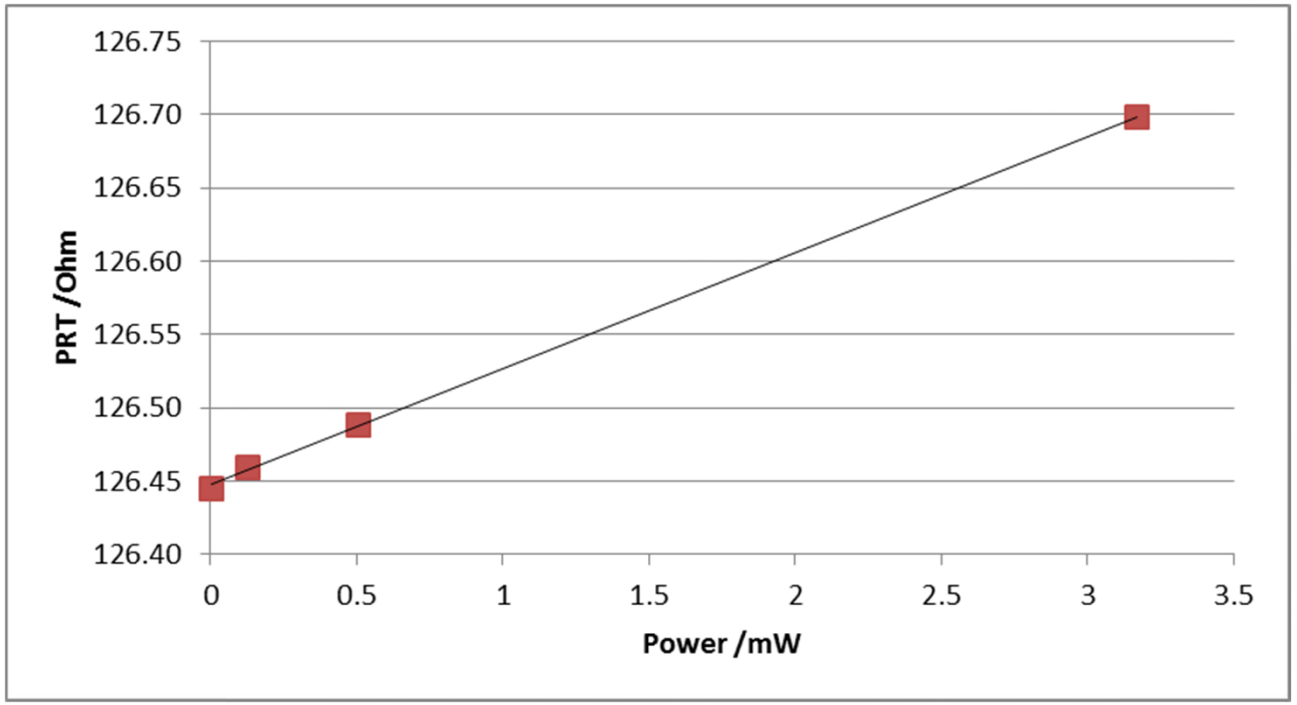
Self heating

Self-heat Pt100 in air:

Typical 0.26 K/mW

100 µA: < 0.003 °C
1 mA: ≈ 0.03 °C
10 mA: ≈ 2 – 3 °C



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Guideline

- Choose a sensor with small dimensions (to have a reasonable time constant) and optimize the heat transfer from the air to the sensor. The airflow around the sensor also needs to be considered for this.
- Heat-flux generated from radiation sources such as the sun, may influence the measurement and the sensors need to be sufficiently shielded to reduce this error source.
- Using resistance thermometers, self-heating of the reference sensors is an issue and **calibration of the sensors needs to be done in air**.
- Reduce heat-loss by heat-conduction along cables
- Place the sensor where the temperature is most representative
- Relax when making the measurement – it takes a long time

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Discussion:

What happened in Greenland?