Infrastructure Commission (INFCOM)

Standing Committee on Measurements, Instrumentation and Traceability (SC-MINT)

Expert Team on Quality, Traceability and Calibration (ET-QTC)

Calibration of Temperature Instruments

Part-5: Characterization of Isothermal Enclosures

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Content

Definitions: Unit of temperature

The Unit of Temperature in the International System of Units is the **kelvin** (K)

The current definition of the kelvin was agreed by the 26th CGPM (November 2018) and came into force the 20th May 2019 (1):

The kelvin, symbol K, is the SI unit of thermodynamic temperature (*T*). It is defined by taking the fixed numerical value of the Boltzmann constant *k* to be 1.380 649 x 10^{-23} when expressed in the unit J K^{-1}, which is equal to kg m^2 s^{-2} K^{-1}, where the kilogram, metre and second are defined in terms of *h*, *c* and $\Delta\nu_{Cs}$.

By this new definition, the unit of temperature is related to a universal constant:

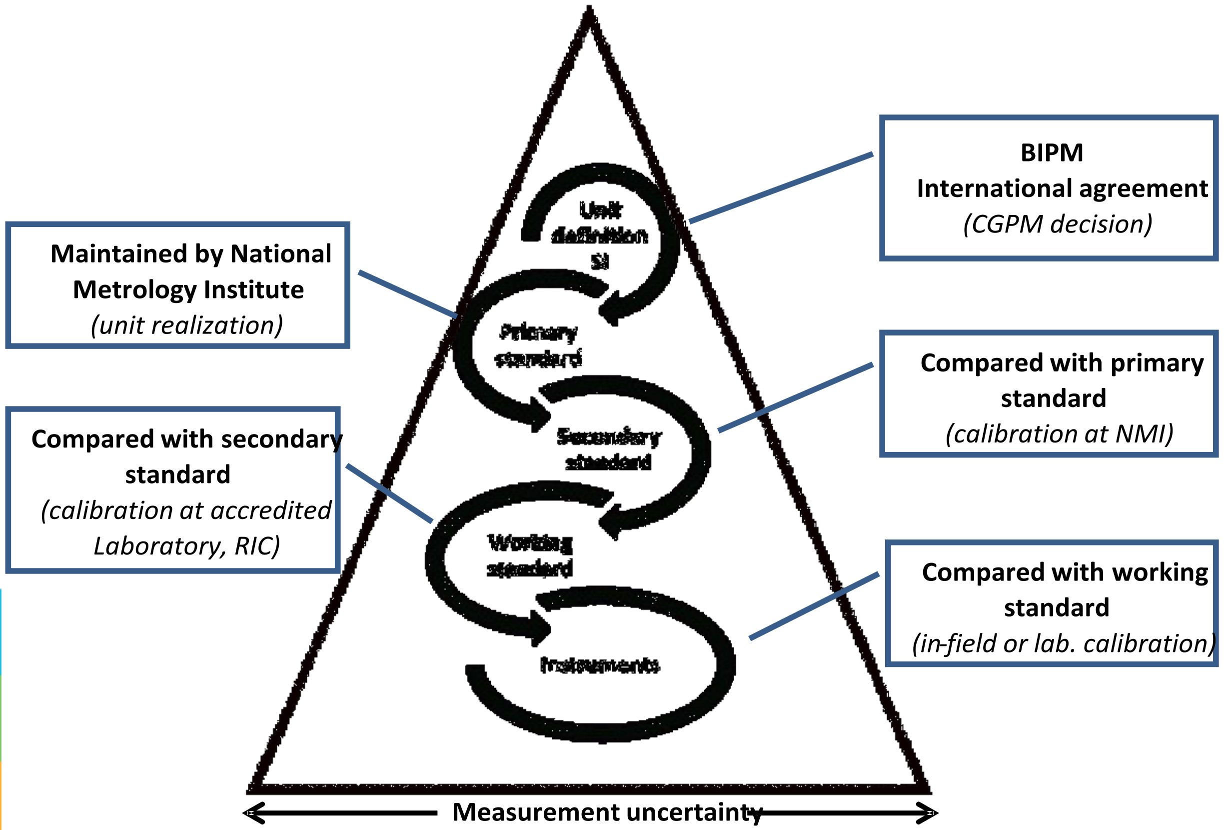
-The purpose of this new definition is to lay the foundations for future improvements by making the kelvin independent of any material element, measurement technique or temperature range in agreement with the overall definition of the seven base units of the SI.

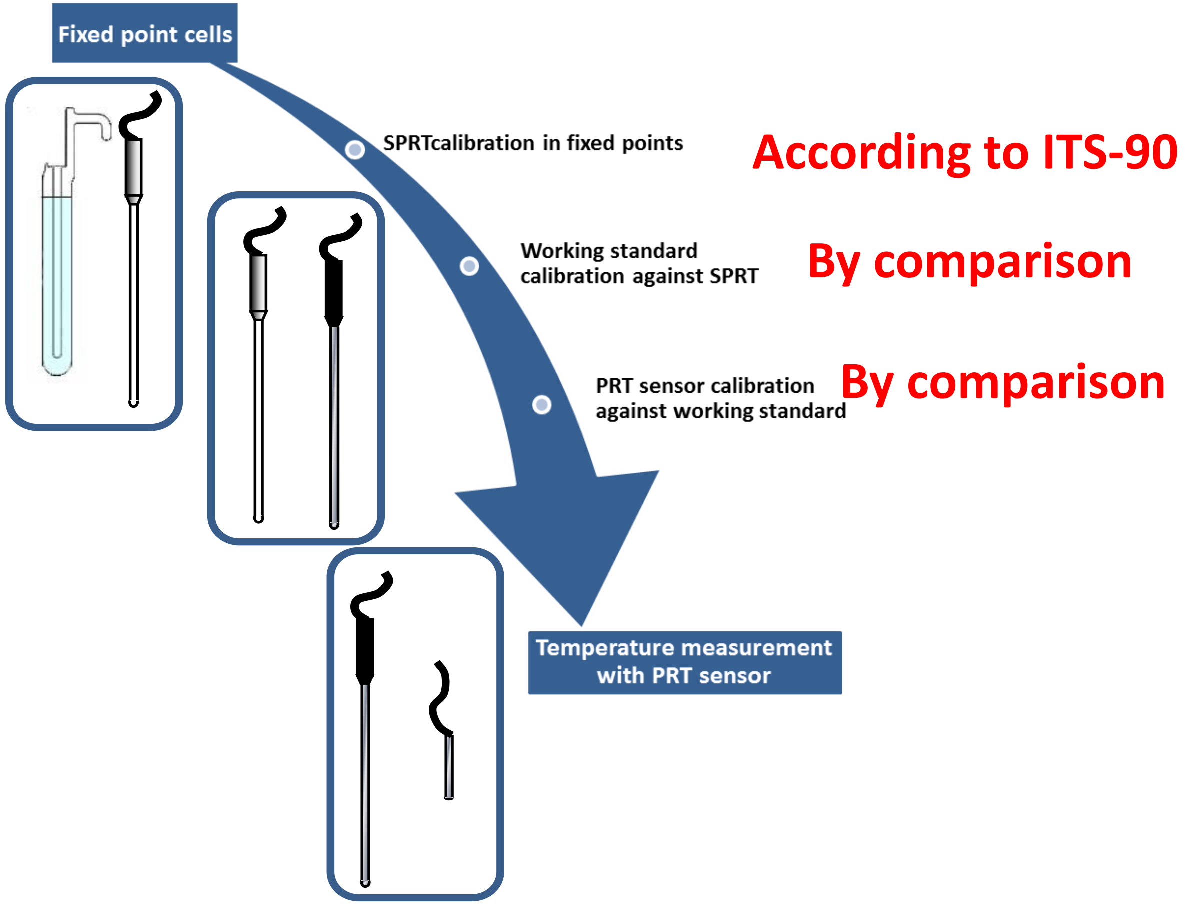
-Although the kelvin redefinition fundamentally modifies the principles and practices of thermometry, the temperature calibrations performed according to ITS-90 are valid and traceable to the SI after the kelvin redefinition

The unit of Celsius temperature (*t*) is the **degree Celsius**, **symbol °C**, which is by definition equal in magnitude to the unit kelvin; both are units of the International Temperature Scale of 1990 (ITS-90).

$$t/°C = T/K - 273.15$$

Traceability chain in contact thermometry





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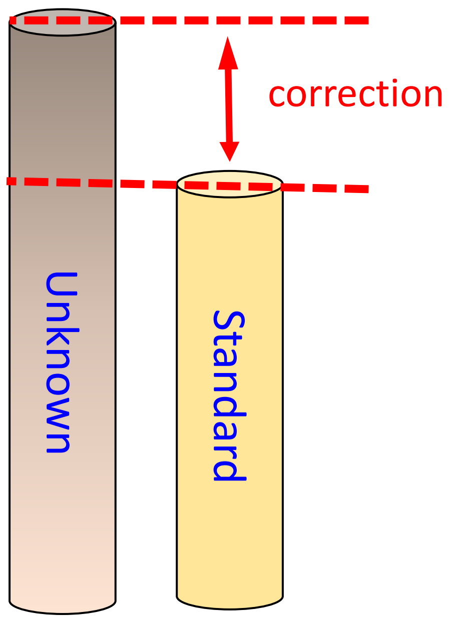
Calibration by Comparison: Isothermal enclosure

-Calibration [(1)] **:** operation that, under specified conditions, in a first step, establishes a relation between the **quantity values** with **measurement uncertainties** provided by **measurement standards** and corresponding **indications** with associated measurement uncertainties

and, in a second step, uses this information to establish a relation for obtaining a **measurement result** from an indication



Correction = Standard – reading of instrument under calibration

Error = - Correction

-The Calibration by the Comparison Method in contact thermometry: the measurements of the thermometer under calibration are compared with the ones of standard thermometers (traceable to the ITS-90) in **an isothermal enclosure.**

Characterization of isothermal enclosure is extremely important in providing calibrations with assuranced quality

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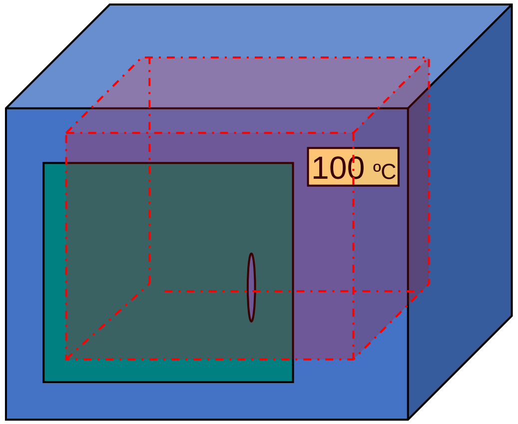
[(1)] International Vocabulary of Metrology, VIM. www.bipm.org

Characterization of isothermal enclosures

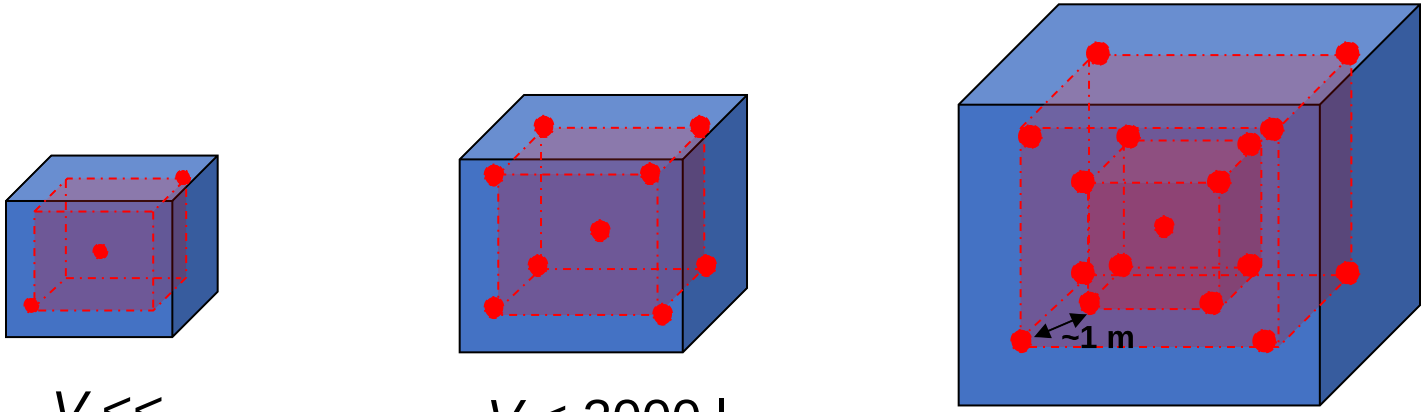
1st: Definition of the working volume

The working volume is the volume (inside the isothermal enclosure) where the calibrations will be performed. <u>This volume can't be in contact with the walls of the isothermal enclosure.</u>



2nd: Measurements points and number of sensors involved

The number of measurements points depends of the working volume size. The sensors will be located in the measurements points for the characterization of the isothermal enclosure.



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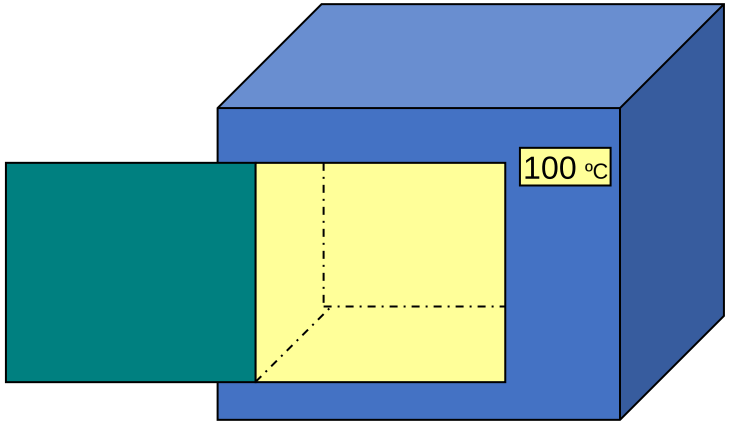
Characterization of isothermal enclosures

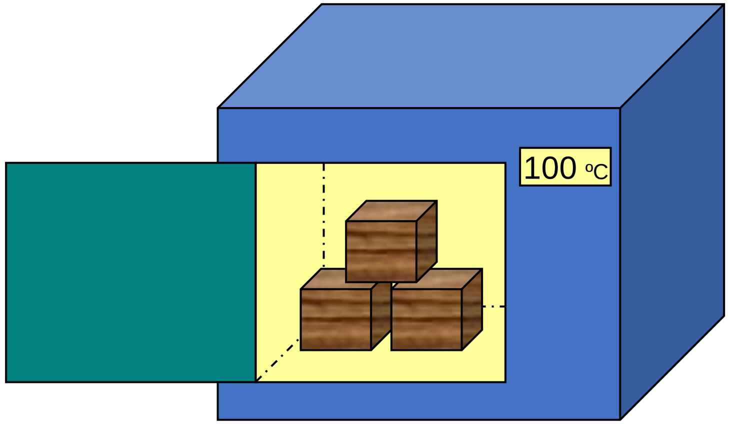
3rd: Parameters to be determined

- **Stability:** maximum temperature difference during the characterization process. BUT, maximum difference between all the sensors?, maximum difference of a predefined thermometer? Or could it be determined by the standard deviation of each of the sensors?

- **Uniformity:** Maximum thermal difference between all the sensors during the characterization period.

4th: with load? Or without load?





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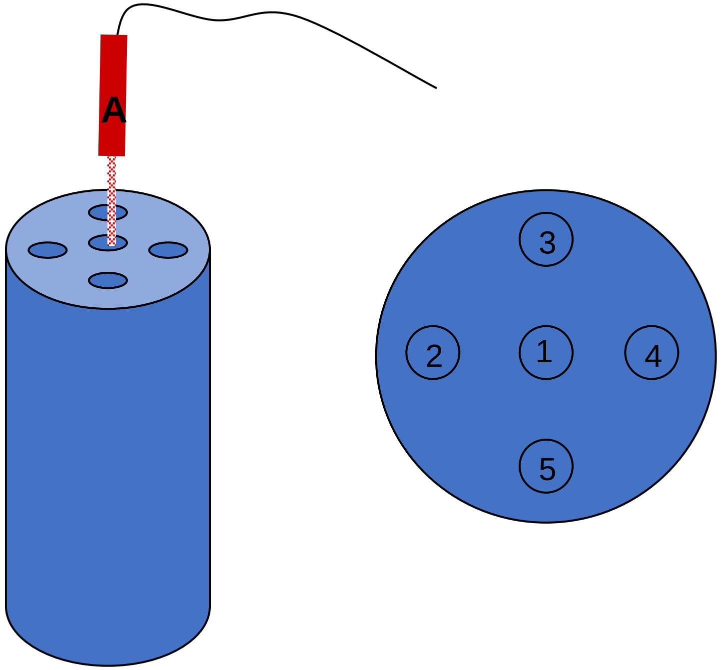
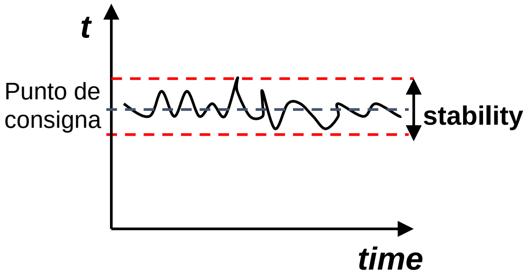
Characterization of isothermal enclosures: Equalizer block

a) Using calibrated thermometers



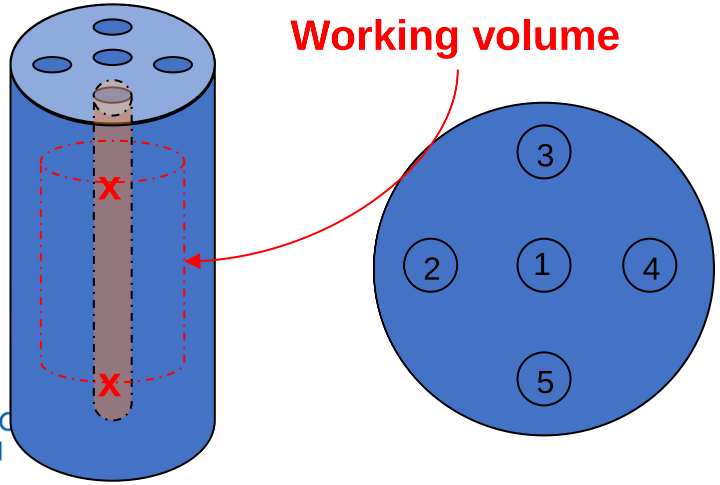
Stability: Reading of the thermometer in one of the wells (L_{A1}) for a time *t*



$$S = \max(L_{A1}) - \min(L_{A1})\Big|_t$$

Uniformity: with 2 calibrated thermometers

- Monitoring of thermometer A in the well 1 (for example) (L_{A1})
- Monitoring of the thermometer B in the wells 2, 3, 4 y 5 (L_{Bi}, i = 2,…, 5) at several immersion depths

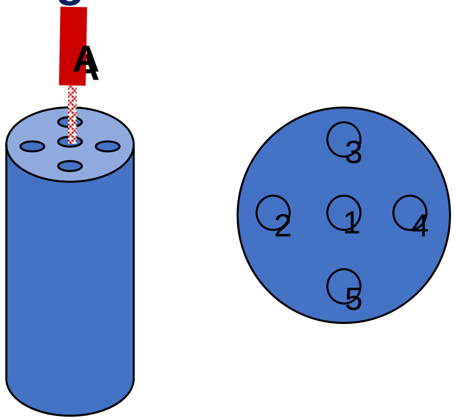


C_A is the correction of sensor A and C_B is the correction of sensor B:

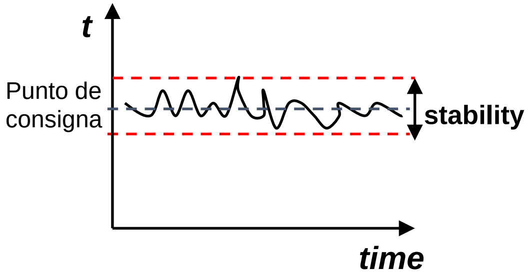
$$U = \left[\max\left(\left|L_{A1} - L_{Bi}\right|\right) + C_A - C_B\right]_t$$

Characterization of isothermal enclosures: Equalizer block

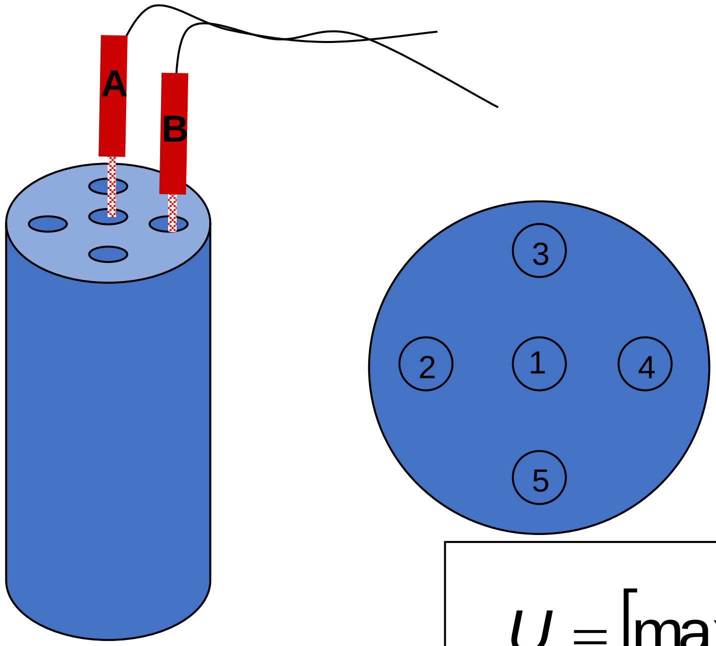
b) Using non-calibrated thermometers



Stability: Reading of the thermometer in one of the wells (L_{A1}) for a time t



$$S = \max(L_{A1}) - \min(L_{A1})\big|_t$$



For not calibrated thermometers, we have to find the relative correction between the thermometers. For doing this, the thermometers are interchanged between two wells:

$$L_{A1} + C_A = L_{B2} + C_B + U$$

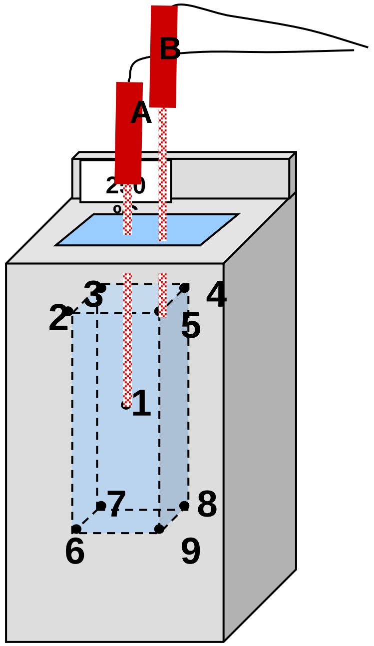
$$-\quad L_{B1} + C_B = L_{A2} + C_A + U$$

$$C_A - C_B = \frac{1}{2}\left(L_{B1} + L_{B2} - L_{A1} - L_{A2}\right)$$

$$U = \left[\max\left(\left|L_{A1} - L_{Bi}\right|\right) + C_A - C_B\right]_t$$

Characterization of isothermal enclosures: Without equalizer block

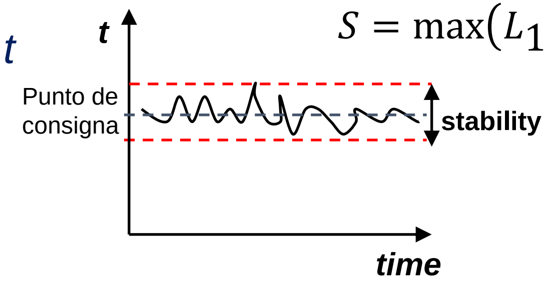
a) Movable thermometer: bath without equalizer block



Temperature measurements in the 8 positions of the figure and in the central point.

Stability: Reading of the thermometer in position 1 for a time *t*

$$S = \max(L_1) - \min(L_1)\Big|_t$$

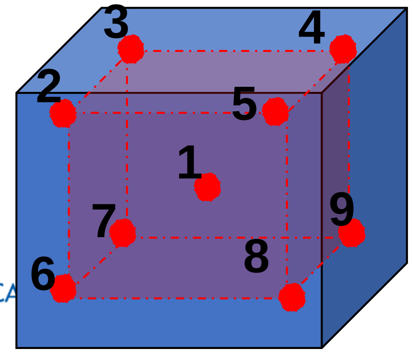


Uniformity: Depending on calibrated or non calibrated thermometers are used (see previous slides)

$$U = \left[\max\left(\left|L_{A1} - L_{Bi}\right|\right) + C_A - C_B\right]_t$$

b) Calibrated thermometers in defined positions: climate chambers.

$$E = \max\left[\max\left(L_j\right) - \min\left(L_j\right)\Big|_t\right]$$



Simultaneous monitoring of the 9 thermometers is needed

$$U = \left[\max\left(\left|L_j - L_i\right|\right) + C_j - C_i\right]_t$$

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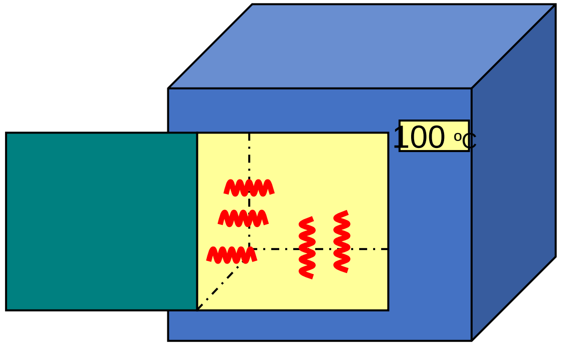
Characterization of isothermal enclosures: Other factors

Influence of the load: Characterization of the isothermal enclosure with the minimum load and the maximum load

Influence of the radiation walls: Could be significant for temperatures higher than **50 ºC or 60 ºC**.



Measurements of temperature with thermometers with different emissivity. The thermometer with lower emissivity will give the closest value to real air temperature inside the climate chamber

Uncertainty components of the isothermal enclosure stability

- thermometers:
  - o reading (resolution)
  - o drift in short term
  - o answer time
- Load effect

Uncertainty components of the isothermal enclosure uniformity

- thermometers:
  - o calibration
  - o reading (resolution)
  - o drift
  - o answer time
- load effect

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Thank you.

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