EMRP
European Metrology Research Programme
Programme of EURAMET
The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

Nineteenth Symposium on Thermophysical Properties
19
http://thermosymposium.boulder.nist.gov
June 21 - 26, 2015
University of Colorado at Boulder

LNE
Le progrès, une passion à partager

Traceable Calorimetric Measurements of Large Radioactive Waste Packages

ANDRA

R. Razouk, B. Hay, S. Plumeri, P. Sollet, J. Hameury,
O. Beaumont and G. Failleau

Presented by J. HAMEURY

19th Symposium on Thermophysical Properties

University of Colorado, Boulder (USA)

June 21-26 2015

- Introduction
- « MetroDecom » Project
- Objectives
- Measurement approaches and first results
- Conclusion

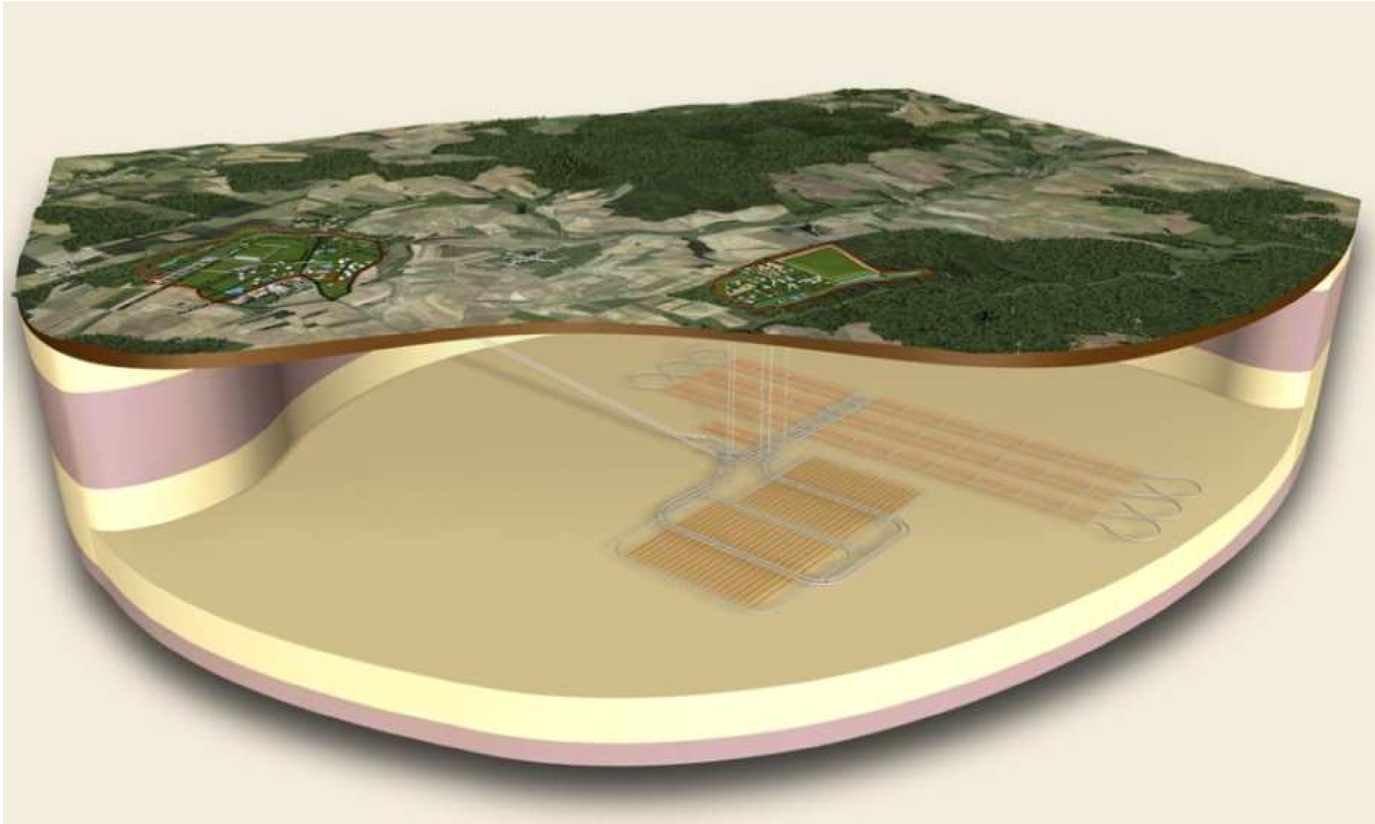
Introduction

- **Nuclear waste management in France by ANDRA (National Radioactive Waste Management Agency)**

Highly radioactive long-lived (HLW) and intermediate-level long-lived (ILW-LL) wastes are to be stored in Cigéo geological disposal facility.

Start of operation is scheduled for 2025 ,

Wastes will be buried at 500 meters below ground level.



- **HLW and ILW-LL quality control**
  - **Inspection on radwaste package before storage in Cigéo (radioactivity, thermal power…)**
    - Safety of radwaste repository underground facility depends on waste thermal power
    - ⇨ *Avoid temperature above 100 °C in geological medium to maintain argillite properties*
  - **Typical thermal powers**
    - Intermediate-level long-lived waste (ILW-LL) : Thermal power from 1 W to 50 W per package
    - Highly radioactive long-lived (HLW) : Thermal power up to 500 W per package

HLW
175 l
h = 1.015 m
ϕ = 0.498 m
300 kg to 450 kg
Stainless steel

ILW-LL
2 m³
4500 kg to 6500 kg
h = 1.300 m
ϕ = 1.400 m
Concrete

→ **Thermal power should not exceed specific thresholds to be accepted for storage**

→ **Thermal power must be measured with an uncertainty better than 5 %**

- **Thermal power measurement of radioactive waste packages - State of the art**
  - **Evaluation by applying non-destructive radioassay methods**
    - Calculation of the thermal power of HLW and ILW-LL packages from their radioactive spectra and activity,
    - Method sensitive to attenuation and heterogeneity problems due to matrix effects
  - **Thermal characterization by direct measurement methods (calorimetry)**
    - Some measurements are already performed using commercial calorimeters (Sétaram…)
      - *Optimized for low thermal power (less than 1 W)*
      - *Not designed for large samples*
      - *Uncertainties of measurements are not known*

Necessity to improve the metrology of thermal power measurements by calorimetry for real size packages

European joint research project aiming to solve metrological issues related to the decommissioning of nuclear sites

Support decommissioning of European nuclear sites with improved metrology, and innovative solutions

Build public trust in nuclear technologies:

- **Monitoring of radioactive waste repositories.**

WP4

Radioactive waste repositories monitoring

Task 4.3 (Sensors for monitoring of repository sites)
&
Task 4.5 (Thermal power of radioactive waste packages)

METRODECOM
Metrology for Decommissioning Nuclear Facilities

Partners (14)

CMI, LNE, ANDRA, EDF, STUK, ENEA, IFIN-HH, NPL National Physical Laboratory, PTB, SCK•CEN, cea list Laboratoire National Henri Becquerel LNE-LNHB, MIKES, ENVINET a.s., JRC European Commission

Task 4.5

Design a calorimeter for the measurement of thermal power of nuclear waste packages

- ***Calorimetric method for real size packages***
- ***Thermal power range : 1 W to 500 W***

Insure traceability of thermal power measurements to SI units

- ***Uncertainty of measurements : < 5 %***

Prove the endurance in radioactive environment

- ***Irradiation of elements that constitute the designed calorimeter***
- ***Tests before and after irradiation***

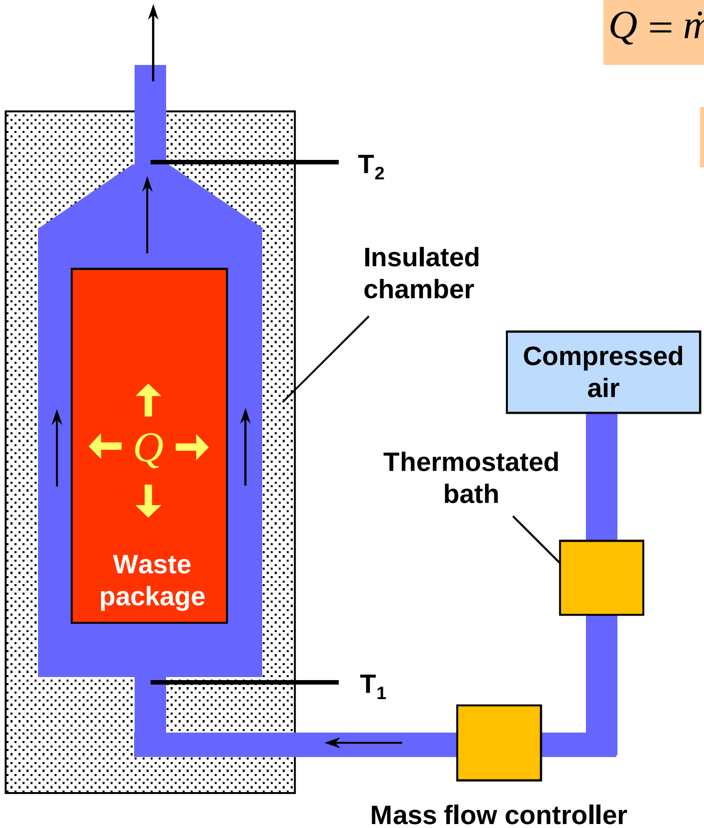
▪ "Air flow calorimeter"

- Measurement of the temperature variation of a fluid circulating around the package
- Calculation of the thermal power from the increase of air temperature
- Assumption of a constant power dissipation of the package during the measurements

Nickel wire (D= 50 µm)
Length ≈ 1.2 m

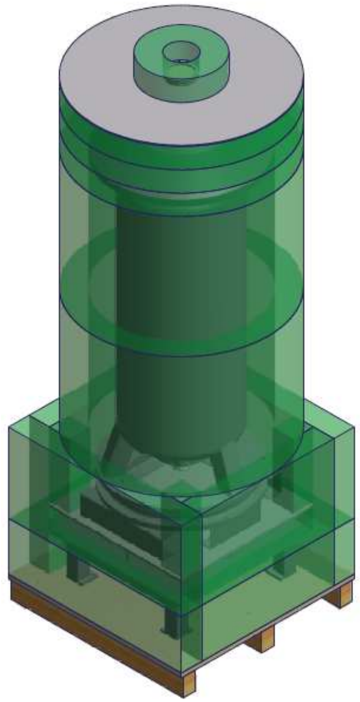
$T = f\,(R)$

(Sensitivity ≈ 0.17 Ω/°C)



$$Q = \dot{m} \cdot C_{p\,air}(T_3) \cdot (T_2 - T_1) + K \cdot (T_3 - T_{amb})$$

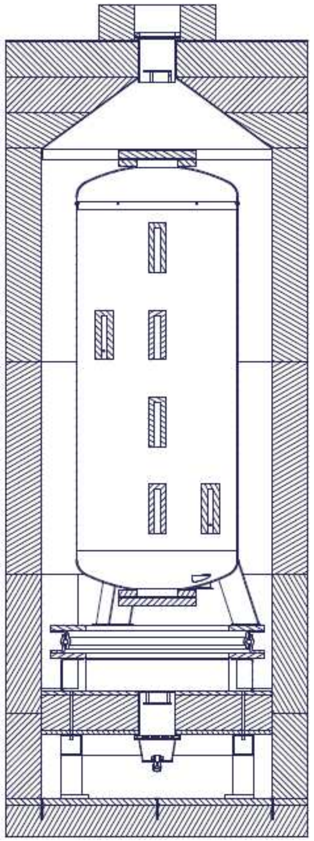
$$T_3 = (T_2 + T_1)/2$$



- "Air flow calorimeter"

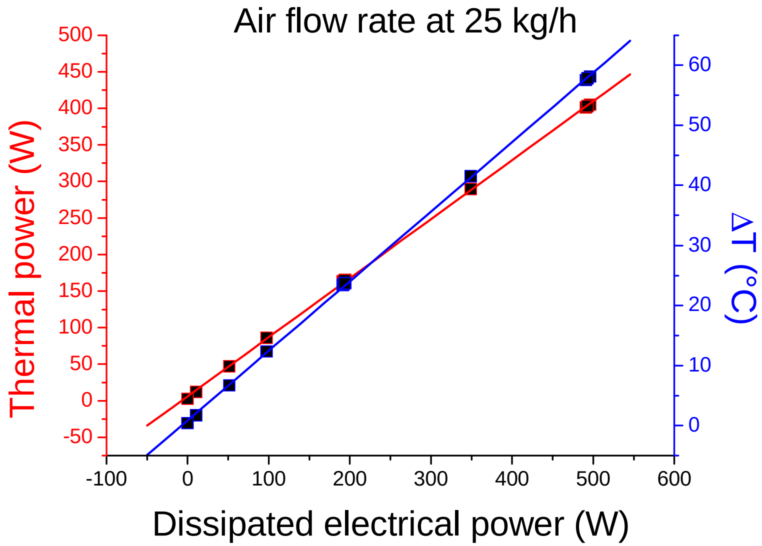
  Calibration of the calorimeter by electrical substitution (between 0 and 700 W)

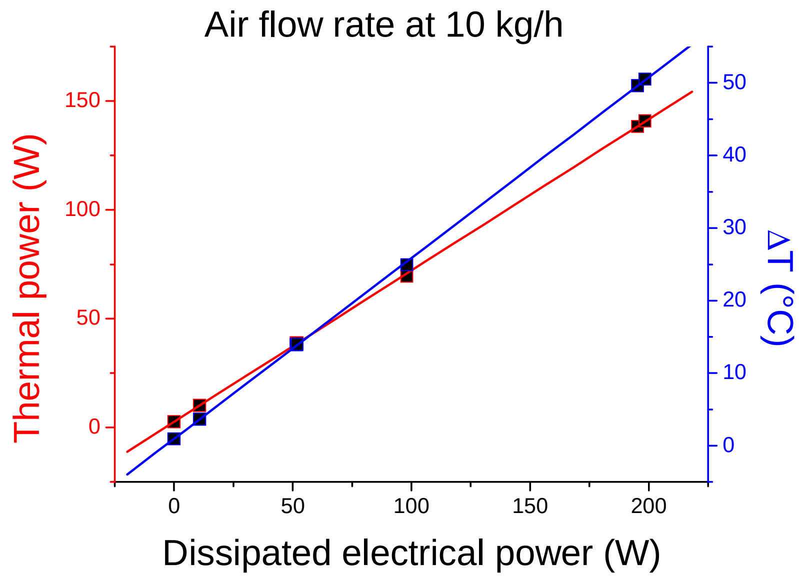
$$P = U_{heat} \cdot I_{heat} = (U_{heat} \cdot U_s) / R_s$$

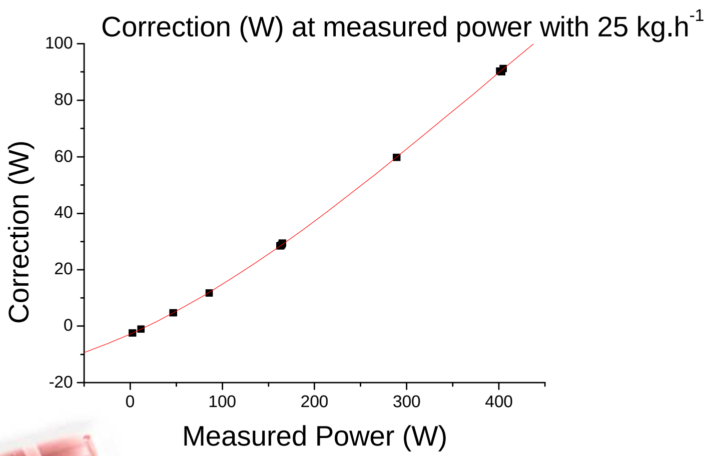


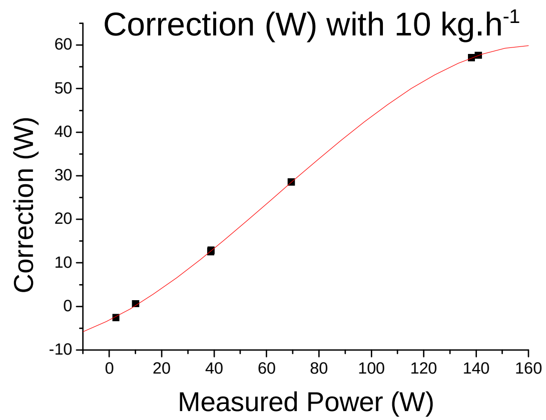
Reference packages

▪"Air flow calorimeter"



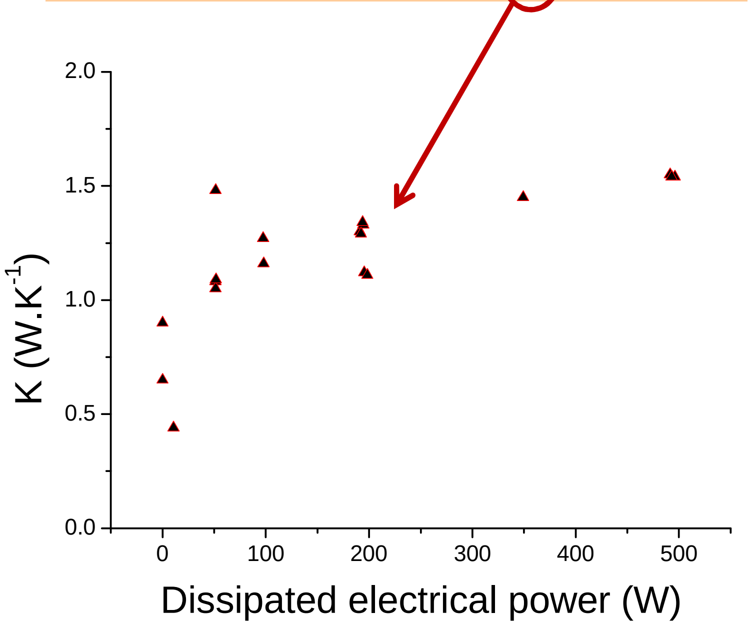






▪"Air flow calorimeter"

$$Q = \dot{m} \cdot C_{p\,air}(T_3) \cdot (T_2 - T_1) + K \cdot (T_3 - T_{amb})$$



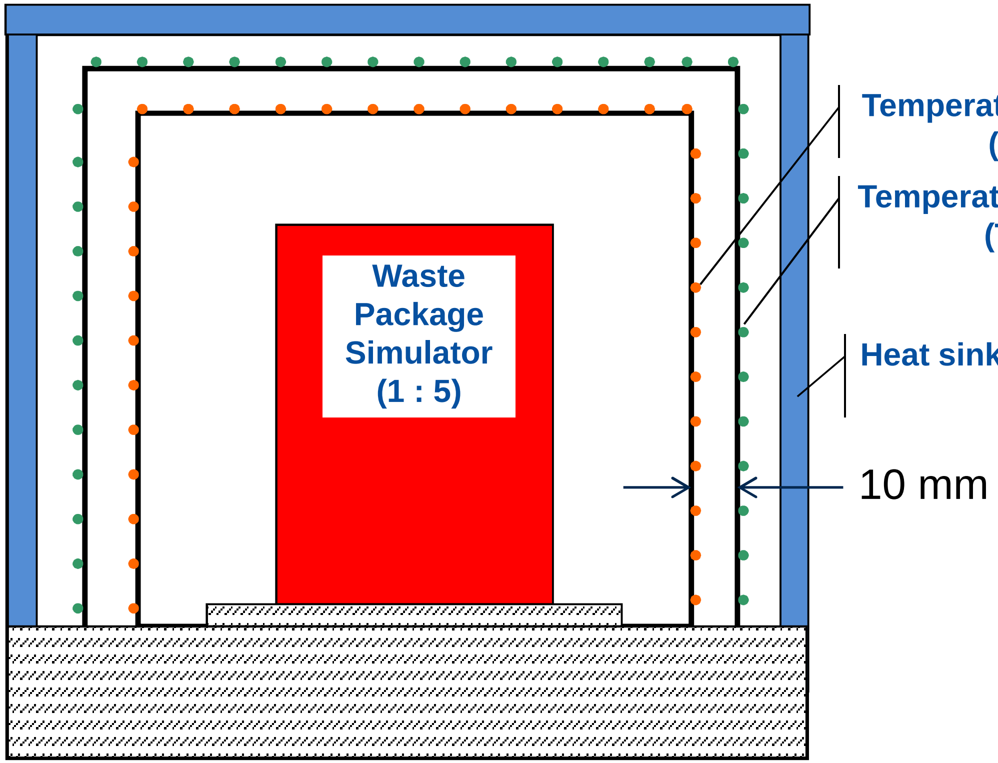
Necessity to calibrate the calorimeter over the power range

First results promising

Time constant is dominated by the time of stabilization of the waste package (few days)

Heat-Flux calorimetry

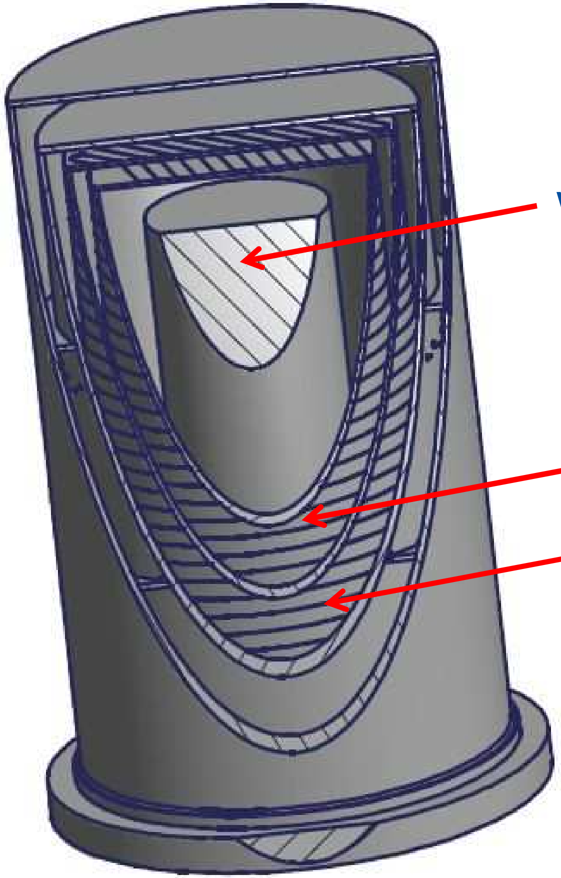
- **Measurement of the temperature difference ΔT =** (T_2-T_1)
- **Calculation of the thermal power from the temperature difference**
- **Assumption of a constant power dissipation of the package during the measurements**

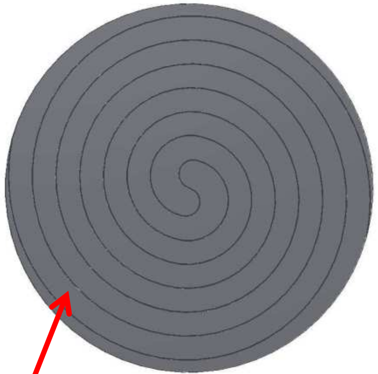


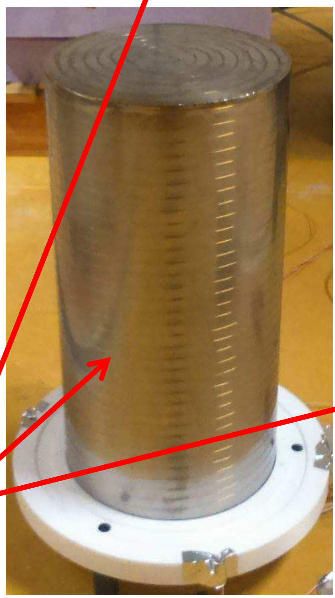
$$\phi = Sens \cdot \Delta T$$

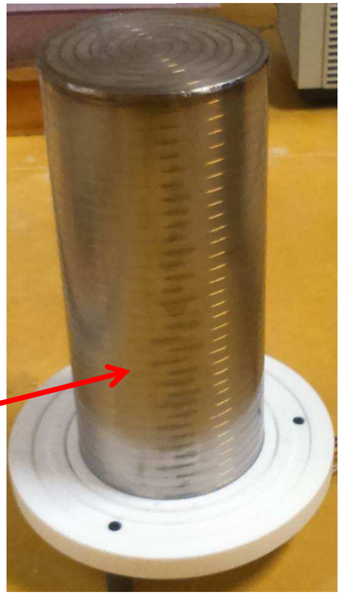
- **Heat-Flux calorimetry**

Reduced size to 1/5 respecting the same heat-flux density





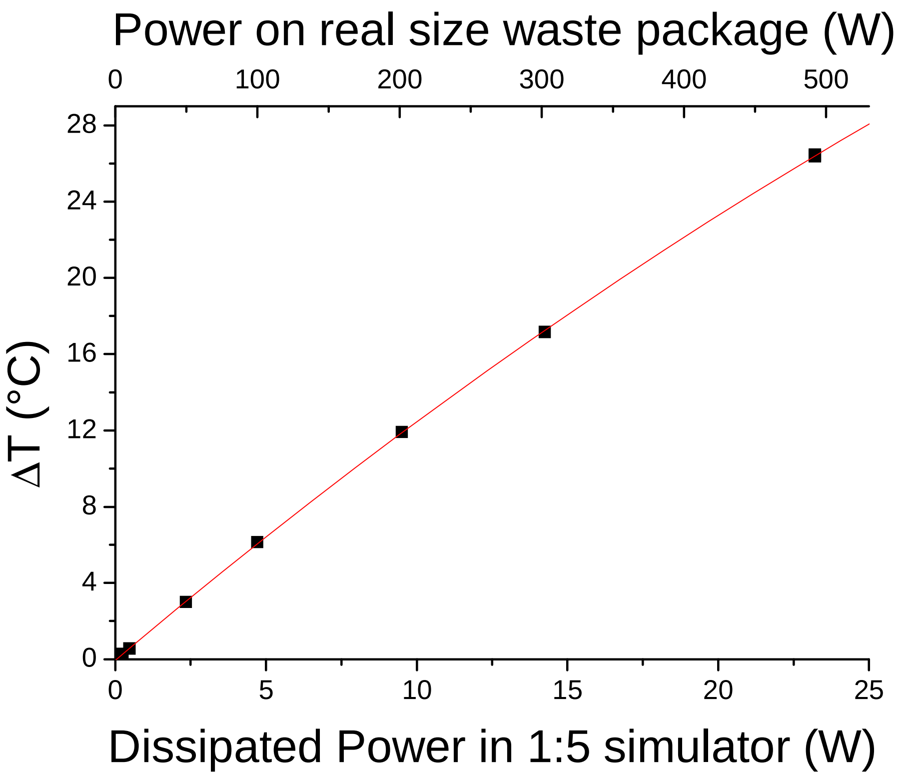




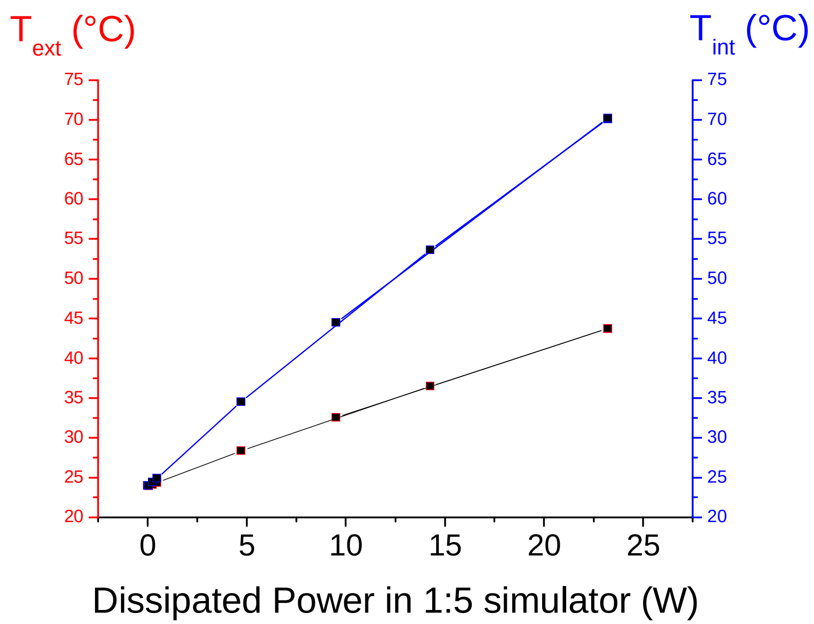
Insulated Nickel wire
0.125 mm
5 µm Plyimide

▪ Heat-Flux calorimetry

Calibration of the calorimeter (up to the equivalent of 500 W on real size waste package)

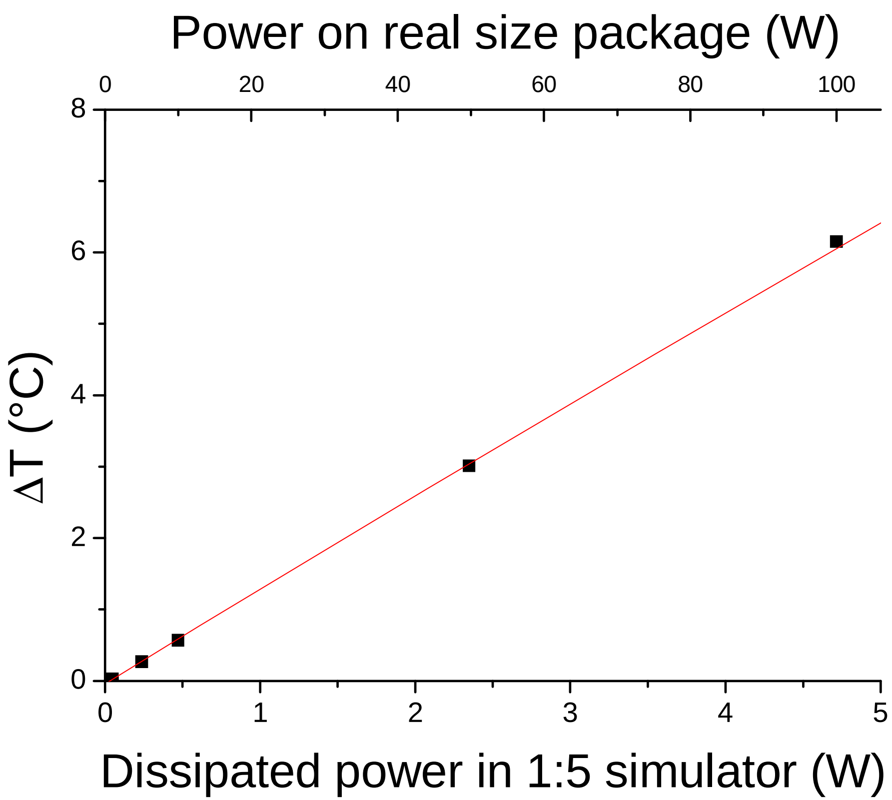


Temperatures of the two cylinders



Heat-Flux calorimetry

Calibration of the calorimeter – Low power



Promising results for low thermal power of radioactive waste packages

Conclusion

- **Summary**
  - Development of large volume calorimeters for the measurement of thermal power of real size radwaste packages
  - Preliminary tests performed with “reference packages” ⇨ First results promising
- **Next steps**
  - Optimising the two types of calorimeters in terms of heat loss,
  - Endurance in radioactive environment
  - Assessment of the uncertainty associated to thermal power measurements

This work is funded through the European Metrology Research Programme (EMRP) Project ENV54 - MetroDecom. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

Thank you for your attention