LNE
Le progrès, une passion à partager

ANDRA
French national radioactive waste management agency

METRODECOM
Metrology for Decommissioning Nuclear Facilities

Calorimetry for radioactive waste characterization

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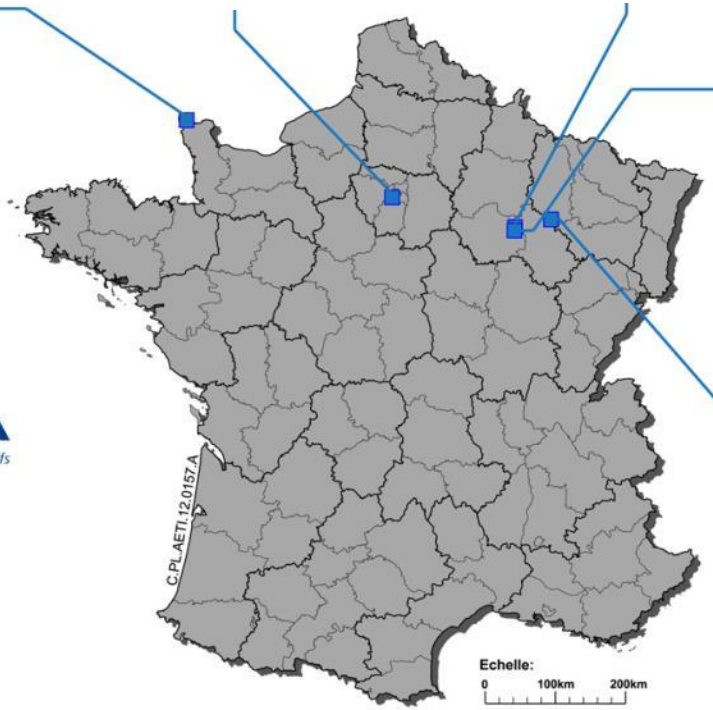
MetroDecom Workshop, JRC Ispra -
October 12th, 2016

Andra (National radioactive waste management agency)

Headquarters

Aube disposal facility

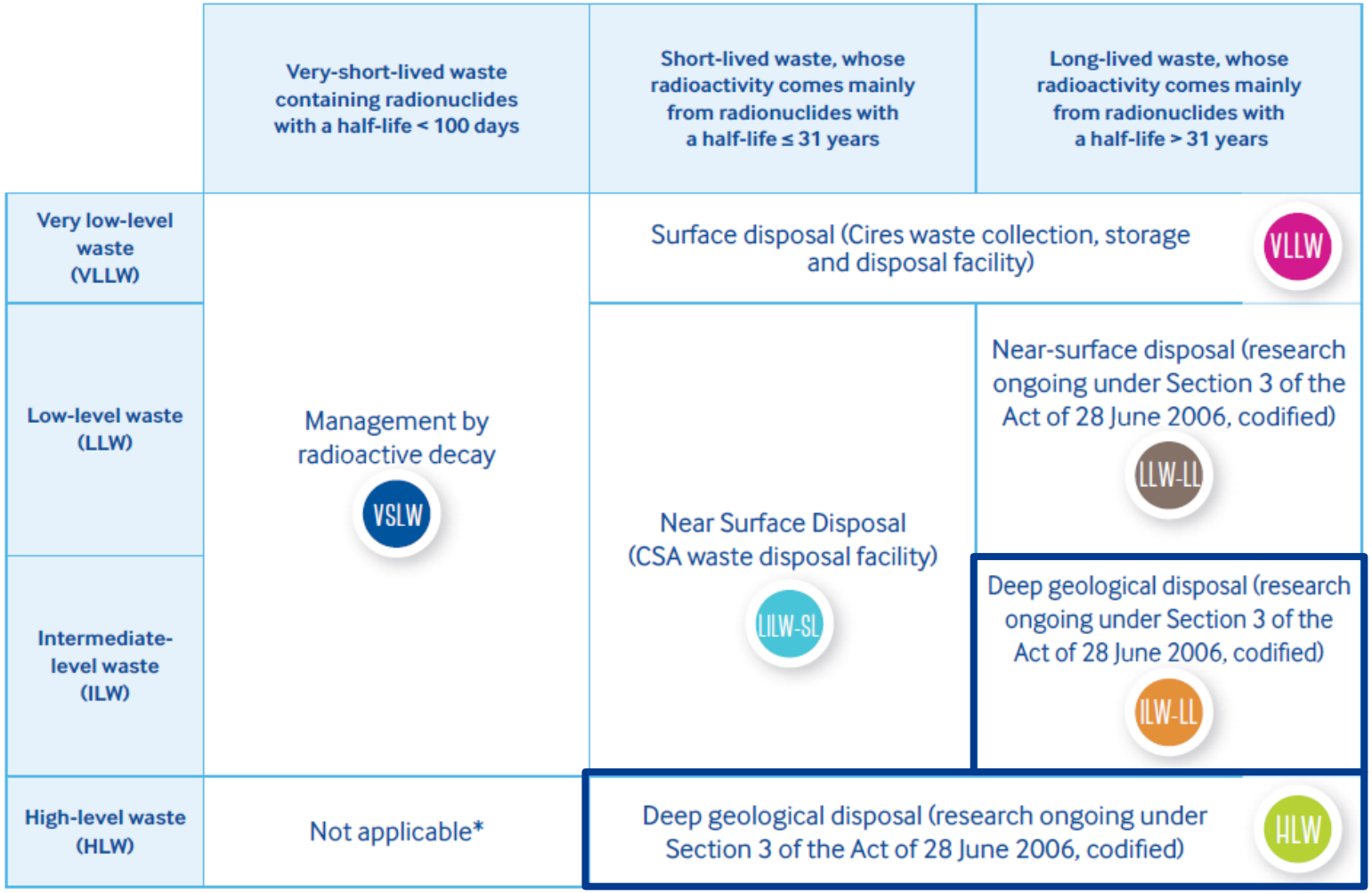
Manche disposal facility



Industrial facility for grouping, storage and disposal

Meuse / Haute-Marne Centre

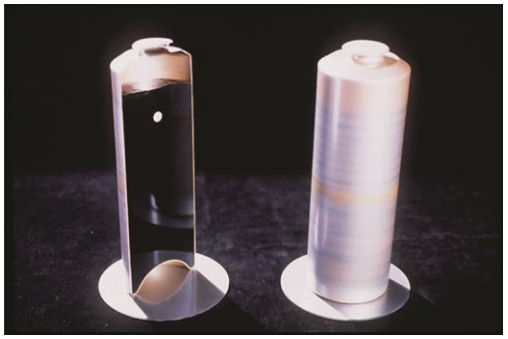
French classification of radioactive waste & associated management solutions



HIGH-LEVEL WASTE (HLW)

It mainly arises from reprocessing spent fuel. Most of this waste is vitrified in stainless steel containers. Because of its high radioactivity (several 10^9 Bq/g) this type of waste gives off heat. It contains:

- short-lived fission products such as cesium-134 and cesium-137
- long-lived fission products such as technetium-99
- activation products and minor actinides, some of which have half-lives of several thousand years, such as neptunium-237



INTERMEDIATE-LEVEL LONG-LIVED WASTE (ILW-LL)

This waste mainly comes from spent fuel reprocessing and activities involved in the maintenance, operation and dismantling of nuclear plants.

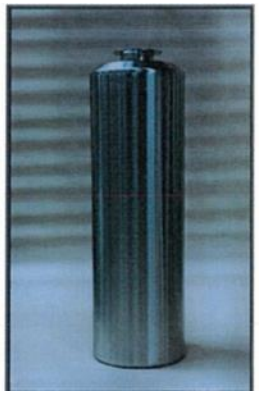
- structural waste from fuel assemblies (end caps and cladding hulls)
- technological waste (used tools, equipment, etc.)
- waste resulting from the dismantling of PWR plants

It is characterized by the presence of significant amounts of long-lived radionuclides such as nickel-63 (half-life: 100 years). Because of its high radioactivity (10^6-10^9 Bq/g) some ILW-LL gives off heat.

HLW and ILW-LL packages

HLW and ILW-LL waste packages characteristics :

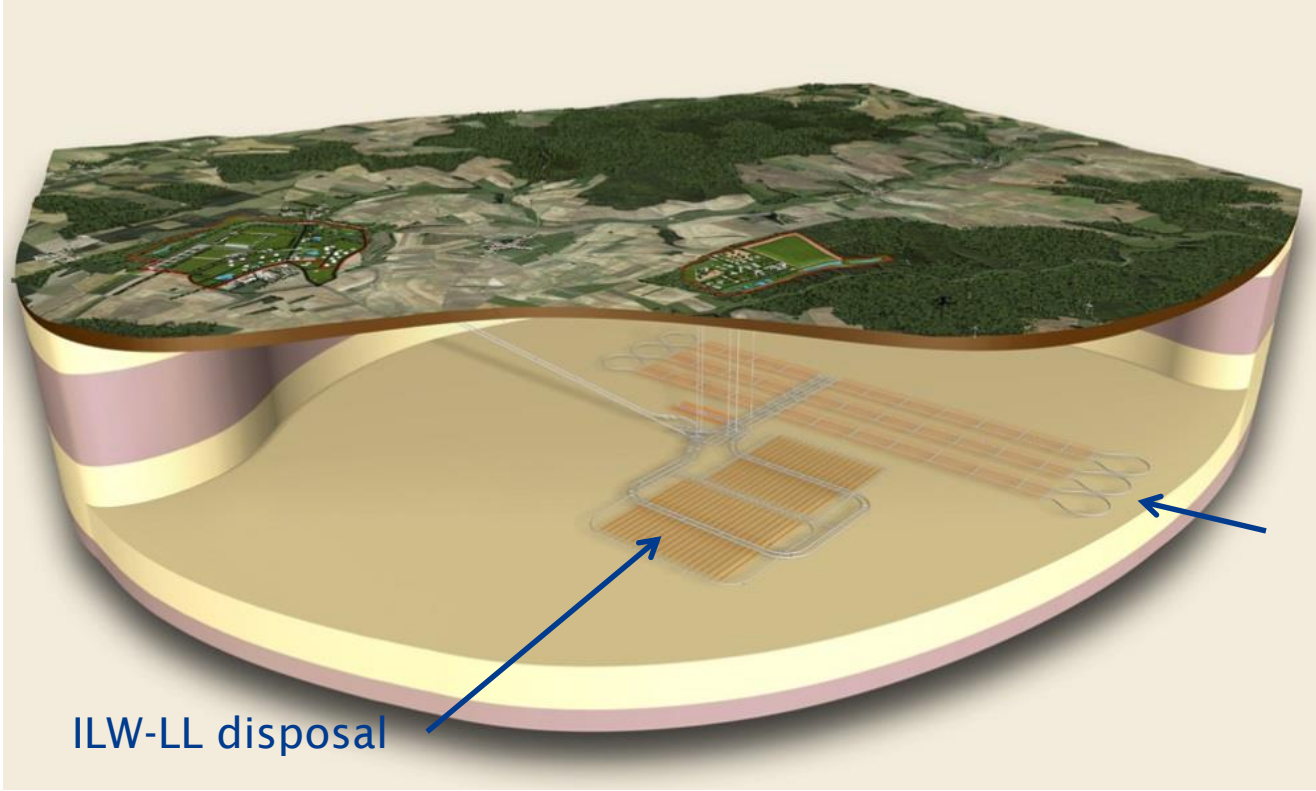
- Volume: 0.175 m^3, 1.5 m^3 and 2 m^3
- Geometry: cylinders
- Materials: stainless steel, except for the 2 m^3 containers that are concrete ones
- Weight: from 300 kg up to 6500 kg
- Dose rate: up to 100 Gy/h



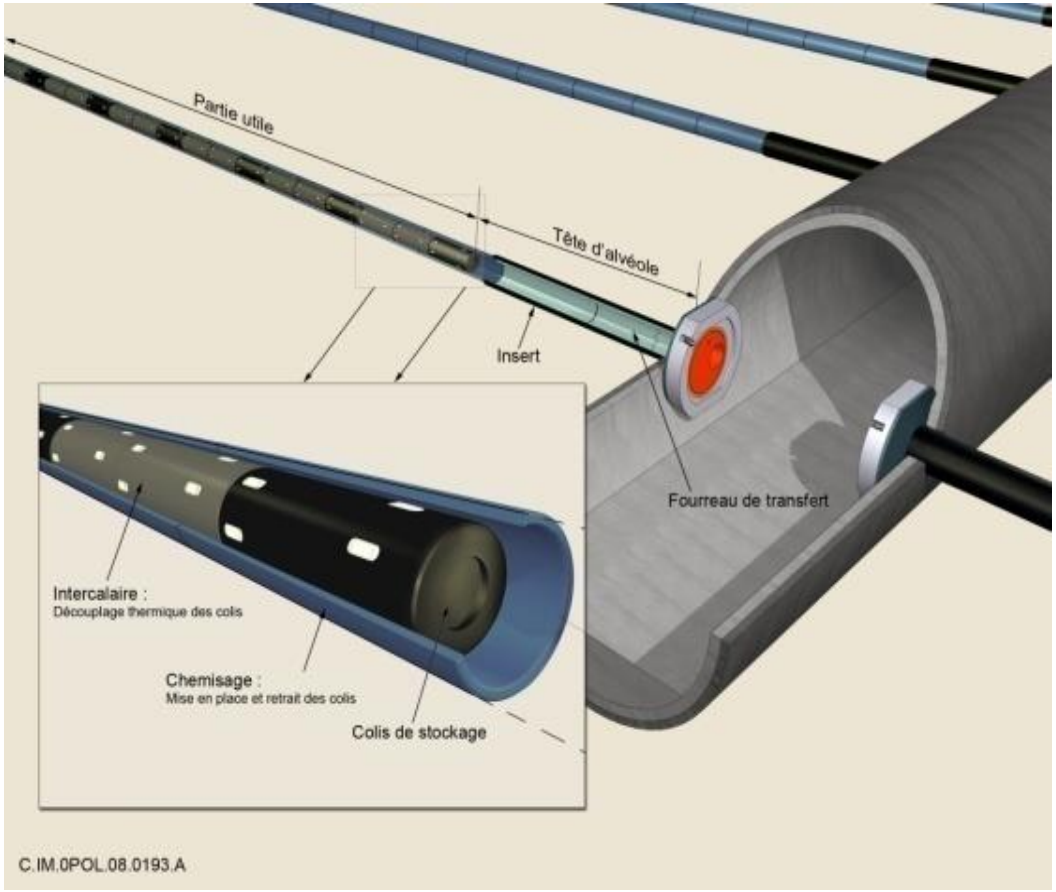
Cigéo Project - geological deep disposal center for French radioactive waste

Cigéo will serve as a repository for highly radioactive long-lived waste (HLW) and intermediate-level long-lived (ILW-LL) waste.

- Start of operation is scheduled for 2025
- Wastes will be buried some 500 meters below ground in an impermeable argillaceous rock formation

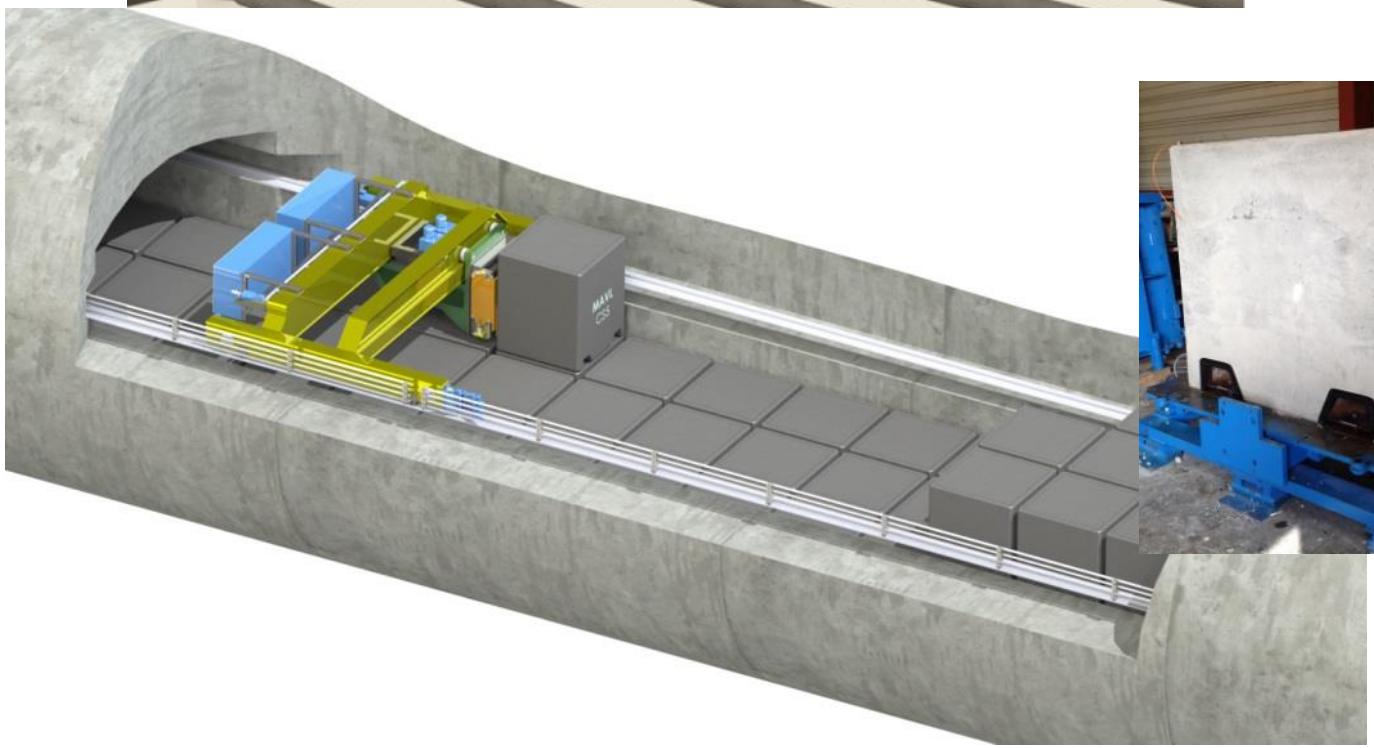


Cigéo – HLW disposal concept



40 m long, Ø 70 cm, Metallic liners

Cigéo – ILW-LL disposal concept



Cigéo - Waste acceptance criteria

Cigéo concept implies two specific constraints on temperature:

- For HLW, argillaceous rock temperature must be < 90 °C
- For ILW-LL, concrete temperature must be < 65 °C
- To maintain materials characteristics for radionuclides containment

That implies waste acceptance criteria (WAC) on radioactive waste packages.

WAC are not fixed yet. Present estimations are:

- For HLW, P_{th} < 500 W/package at reception on the disposal
- For ILW-LL, P_{th} < 15 W/package or 60 W/package at reception on the disposal depending on package conditioning

Andra will perform quality control inspection on radwaste package before storage:

- To ensure the compliance of the radwaste characteristics with WAC

➔ A method has to be defined to measure thermal power.

State of the art

When produced, HLW and ILW-LL packages thermal power is evaluated from its known radioactive spectra.

In France, radwaste producers usually don't perform a direct measurement of thermal power.

➔ For direct measurement a method has to be developed

Specifications on the system for direct thermal measurement:

- A maximal power measurement of 500 W
- An uncertainty of about 5 % on the range 0-500 W
- Volume of measured radwaste package: 0.175 to 2 m^3

Calorimetry has already been studied and used for the thermal characterization of nuclear materials but existing systems are optimized for low thermal power (i.e. less than 1 W) and are not designed to measure packages up to 2 m^3. Existing systems are also not designed to operate with very high dose rates and with large objects.

➔ Feasibility for HLW and ILW-LL packages heat power measurement has to be demonstrated

Feasibility demonstration

Feasibility study through different measurement approaches

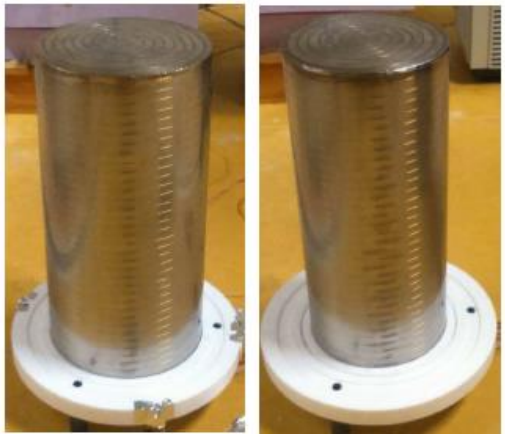
- Measurement of the warming of a fluid circulating around the package
  - Dedicated study in MetroDecom Project (task 4.5)
- Direct heat flow measurement with static heat flux calorimeter (not presented here)
  - Andra/LNE collaboration
- Thermography (not presented here)
  - Andra/LNE collaboration

Effect of radiation on calorimeter's components

- Andra/LNE/IRSN collaboration

Thermography test (@LNE)

Heat flux calorimeter prototype build by LNE (scale 1/5)



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Calorimetry within MetroDecom Project

MetroDecom Task 4.5: Measurement of thermal power of radioactive waste packages before repository (**LNE**, Andra)

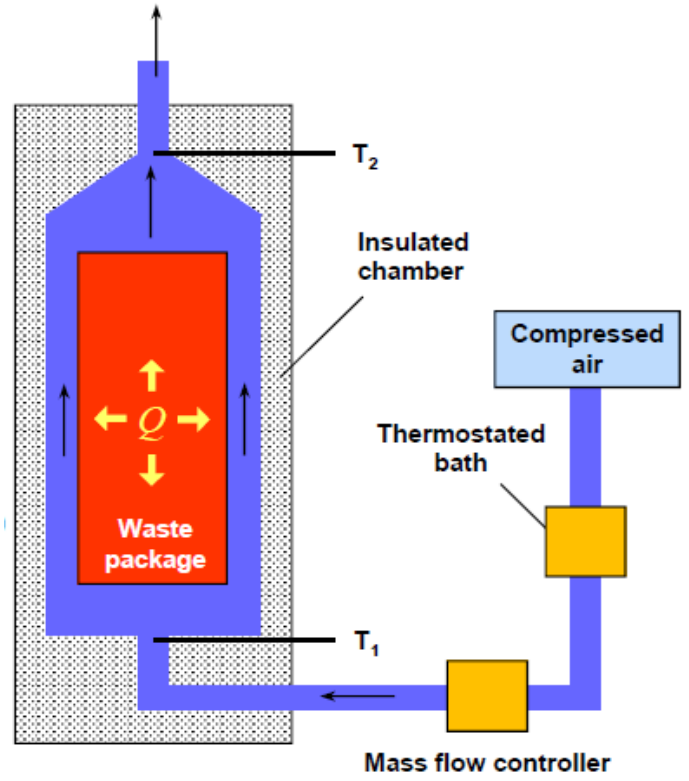
The aim of this task is to demonstrate the feasibility of a traceable calorimetric method for the direct measurement of thermal power (up to 500 W) of real size radioactive waste packages (from 0.175 m^3 up to 2 m^3) with an uncertainty of <5 %.

Main deliverables

- Design and build a calorimeter prototype
- Design and build a power reference package
- Experimental tests to evaluate the uncertainty budgets for the measurement of thermal power

Concept of the thermal power measurement:

- Measurement of the warming of a fluid circulating around the package “air flow calorimeter”
- Calculation of the thermal power from the increase of air temperature



Calorimetry within MetroDecom Project

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Air flow calorimeter prototype

- Real scale (175 l)
- Temperature sensors are Ni wires
- Calibration of the calorimeter by electrical substitution
- Power reference package in real scale (h=1 338 mm, d = 430 mm)

Nickel wire (D= 50 µm)
Length ≈ 1.2 m

$T = f(R)$

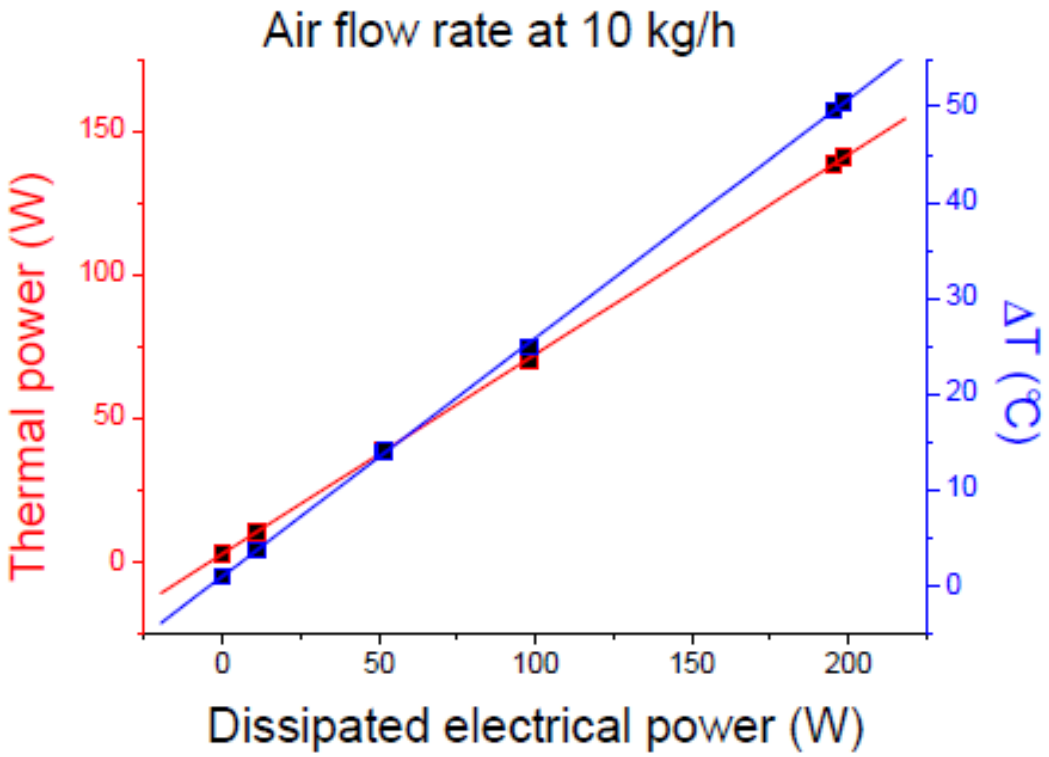
(Sensitivity ≈ 0.17 Ω/ C)

Calorimeter prototype

Power reference package

Calorimetry within MetroDecom Project

Metrological assessment in progress…

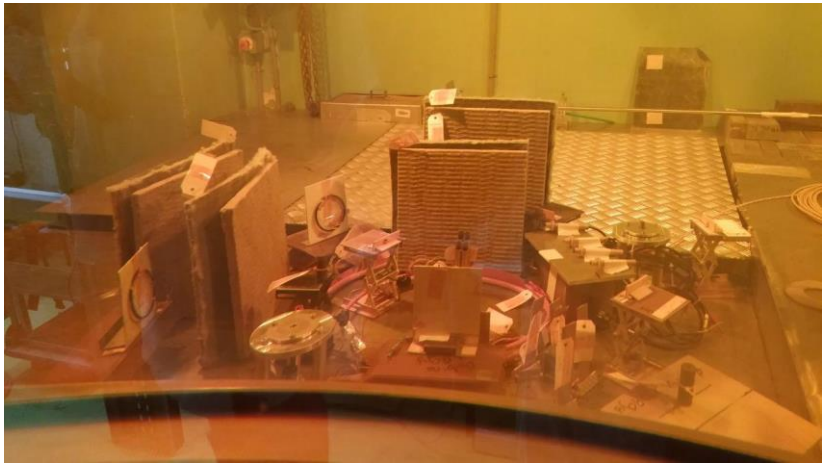


… and will be available and the end of MetroDecom

Effect of radiation on calorimeter's components

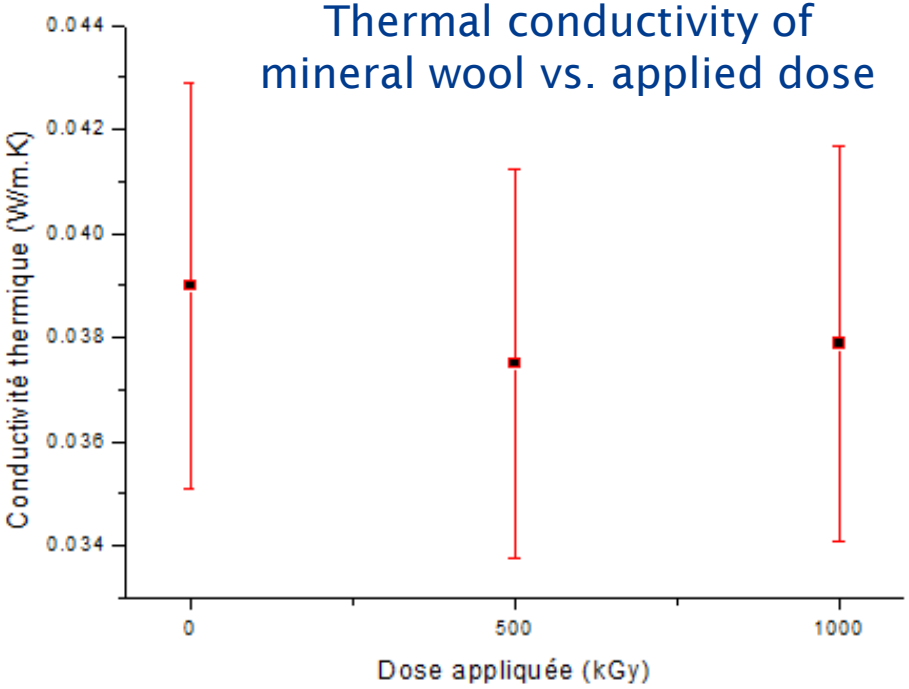
Dedicated test at IRMA facility (IRSN – Saclay)

- Total dose 1 MGy (^{60}Co)
- Thermal insulators
- Temperature sensors



Insulators samples (mineral wool and silica gel), wires during irradiation (and many others things for other project…)

Thermal conductivity of mineral wool vs. applied dose



➔ No dose effect seen on components characteristics

Summary

Feasibility study through different measurement approaches

- Calorimetric measurements of radioactive waste packages seems feasible

Next step

- Achieve feasibility study (metrological performances have to be evaluated)
  - In collaboration with LNE
- Use thermal power measurement to improve characterization of nuclear waste (decrease uncertainties on radiological content)
  - CHANCE project

CHANCE project “Characterization of conditioned nuclear waste for its safe disposal in Europe”

- Project submitted to H2020 Euratom Work Program 2016-2017 (NFRP 7 topic “Research and innovation on the overall management of radioactive waste other than geological disposal”)
- CHANCE WP3 - Benchmark of calorimeters and standard NDA (Non-Destructive Assay) methods for characterization of large volume waste drums (WP leader: KEP Nuclear)

Thank you for your attention !

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