Calorimetry instrumentation

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Principle

Activity $\mathcal{A}$ is related to power $\mathcal{P}$ through:

$$\mathcal{A} = K_a \, \mathcal{P} \tag{1}$$

with $K_a = 7.991 \pm 0.044\,\mathrm{W/kCi}$ $(0.56\,\%)$ according to ENDF, to be confirmed with our studies of $^{144}\mathrm{Pr}$ spectrum shape.
The power measured by the calorimeter is:

$$\mathcal{P} = C_p \; D_m \; \Delta T + F_{th} \tag{2}$$

with C_p the heat capacity of water, D_m the massive flow rate, ΔT the difference of temperature between entry and exit of the calorimeter, and F_{th} the thermal leaks, measured through calibration with an electric source:

$$F_{th} = \mathcal{P}_{watt} - C_p \; D_m \; \Delta T \tag{3}$$

Goal

Precision goal

Uncertainty on activity:

- required to be below 2 %
- limited by uncertainty on K_a (0.56 %)

Goal:

- reasonable: uncertainty on activity at 1 %
- ultimate: all calorimeter uncertainties negligible in front of uncertainty on K_a
  $\Rightarrow$ calorimeter uncertainties at the 0.1 % level

Schedule

- Test of components: first half of 2014
- Construction, test: second half of 2014
- Calibration: end of 2014 or very beginning of 2015
- Transport to LNGS, re-calibration with mock-up shield, measure: mid-2015

Uncertainties

Rough uncertainty

Activity can be written:

$$\mathcal{A} = K_a \times \left(C_p \ D_m^{mes} \ \Delta T^{mes} + \mathcal{P}_{watt} - C_p \ D_m^{cal} \ \Delta T^{cal} \right) \tag{4}$$

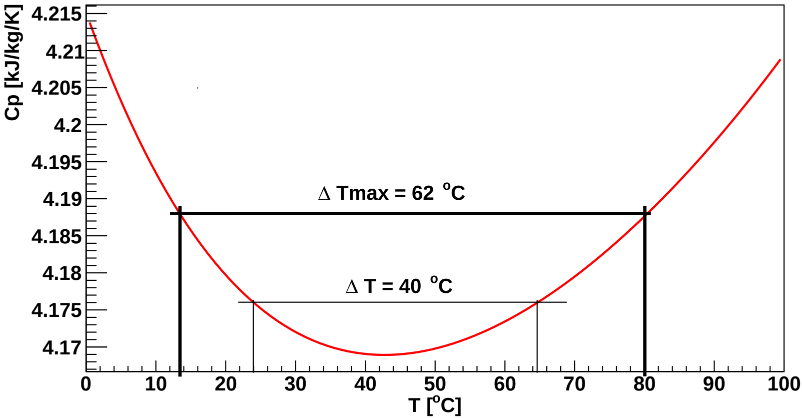
Then:

$$\delta \mathcal{A}^2 \propto \delta K_a^2 + \delta \mathcal{P}_{watt}^2 + 2 \times \left(\delta C_p^2 \ \delta D_m^2 \ \delta \Delta T^2 \right) \tag{5}$$

Remarks

- Detailed uncertainty calculation ongoing (Mathieu Durero)
- Here good reproducibility is assumed between measurement and calibration. Uncertainty due to difference between calibration and measurement has to be studied.
- If T is measured absolutely, $\delta \Delta T^2 \approx 2 \ \delta T^2$.
- Heat leak specification to be defined (temperature of vacuum tank ?).
- C_p depends on T, with a minimum at 36 °C.

C_p of water


Cp [kJ/kg/K]
4.215
4.21
4.205
4.2
4.195
4.19
4.185
4.18
4.175
4.17
Δ Tmax = 62 °C
Δ T = 40 °C
0
10
20
30
40
50
60
70
80
90
100
T [°C]

General specifications

System requirements

- 3 days of measure maximum
- Temperature on capsules $< 400\,°\mathrm{C}$ (each point)
- Repeatability and calibration
- Shielding instrumentation limited

Fluid: Pure water (to be defined). $C_p = 4185\,\mathrm{J\,kg^{-1}\,K^{-1}}$.

Pressure : Atmospheric or almost

Power : $600\,\mathrm{W} < \mathcal{P} < 1200\,\mathrm{W}$
A calibration point above 1200 W could be useful, so maximal power could reach up to 1.5 kW.

Flow rate : $2.39\,\mathrm{g/s} < D_m < 7.16\,\mathrm{g/s} \iff 0.14\,\mathrm{L/min} < D_m < 0.43\,\mathrm{L/min}$
Good stability to prevent exit temperature variation.

Temperature : $10\,°\mathrm{C} < T_{\mathrm{entry}} < 20\,°\mathrm{C}$ (close to ambient)
$40\,°\mathrm{C} < \Delta T < 60\,°\mathrm{C}$
Temperature values should be chosen according to $C_p(T)$ variation

Uncertainty : $\delta\Delta T/\Delta T < 0.5\,\%$, if possible $\delta\Delta T/\Delta T \simeq 0.1\,\%$.
So $\delta\Delta T < 0.25\,°\mathrm{C}$, if possible $\delta\Delta T \simeq 0.05\,°\mathrm{C}$ (for $\Delta T = 50\,°\mathrm{C}$).
$\delta D_m/D_m \simeq 0.1\,\%$ with Coriolis flow rate meter

Component specifications

Pump : Flow rate must be adjustable and stable, maximum $> 0.45\,\text{L/min}$ and minimum $< 0.1\,\text{L/min}$, avoid contamination and leak possibility.

Hot source: $\mathcal{P} \sim 1500\,\text{W}$, adjustable and measured with a wattmeter, one pair only of wires.
Watt meter precision must be 0.1 % (0.025 % exists).

Cold source : A cryo-thermostat has been found. Stability at $0.1\,^{\circ}\mathrm{C}$, cooling power 1.5 kW.

Flow rate meter : A Coriolis flow rate meter has been bought. Uncertainty at 0.054 % on the whole range (enlarged uncertainty), certified.

Thermometers : Pair of Pt100 bought. Several thermocouple are considered, they could be installed to measure directly ΔT.
Pt100 and thermocouple can reach some 0.01 K with proper calibration.
Temperature measurement will probably limit the final precision.

To date, best uncertainties with known components: $\pm 2\,\text{W}$

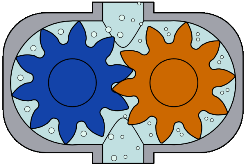
Back-up

Flow rate meter and cryo-thermostat

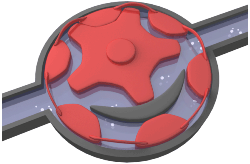
Figure: **Flow rate meter Coriolis Cubemass**

Figure: **Cryo-thermostat**

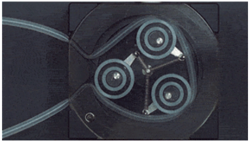
Pump principles



(a) **External gear pump**



(b) **Internal gear pump**



(c) **Peristaltic pump**

Figure: **Pump principles**