Measurements of Nuclear Heating Rate and Neutron Flux in HANARO CN Hole for Designing the Moderator Cell of Cold Neutron Source

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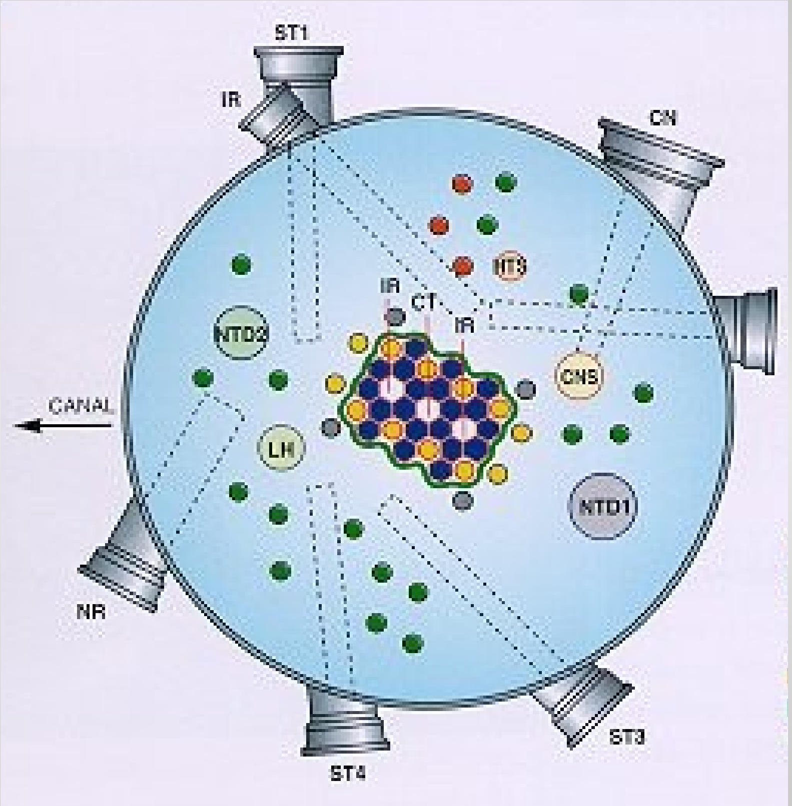
Introduction-1



- Design of cold neutron source facility in HANARO : now in progress.
- Heat removal capacity of moderator cell : essential information for source design.
- Determination of nuclear heating rate at CN hole of HANARO.

  → Determination of the capacity of refrigerator.

Introduction-2

- Nuclear heating : nearly all the energy absorbed in a material placed in the radiation field of a research reactor appears in the form of heat.
- Nuclear heating in research reactors : interactions with gamma-rays, fast neutrons and thermal neutrons.
- Determination of nuclear heating rate by calorimetric dosimeter (calorimetry) : advantages for high-dose applications.
- In this research,
  - Designing and constructing a calorimeter,
  - Measuring the nuclear heating rate at CN hole of HANARO with it,
  - Measuring the thermal neutron flux at CN hole.

Concept of calorimeter operation

- **In equilibrium condition of steady state, the power integrated over the volume of the sample,**

$$P = hs(T_s - T_e)$$

T_s, T_e **: sample and container temperatures,**

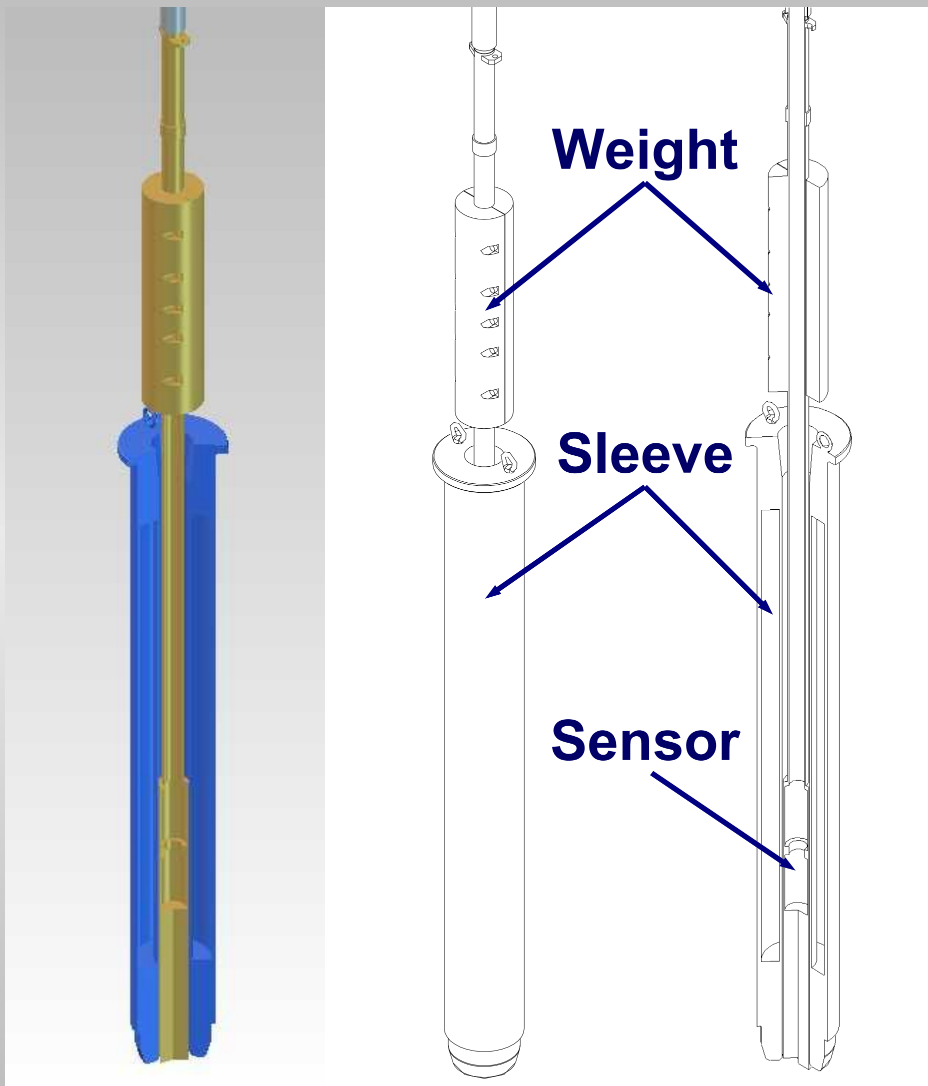
h **: heat transfer coefficient,**

s **: sample surface area,**

$1/hs$ **: thermal resistance.**

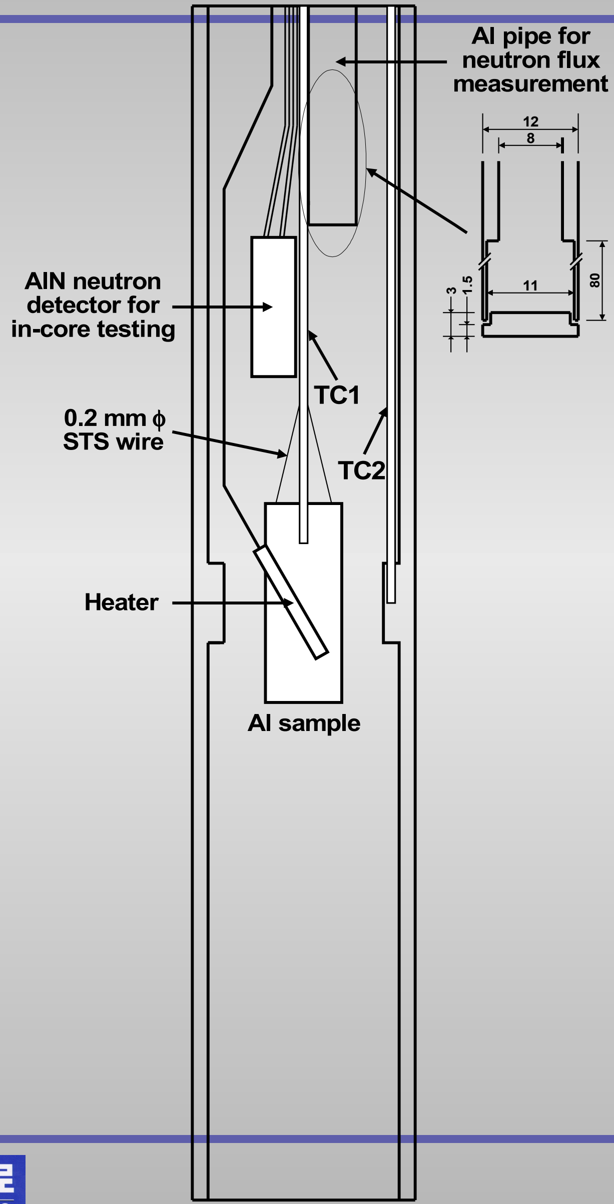
- **If thermal resistance is known, the nuclear heating rate can be obtained by measuring the temperature difference in the steady state.**

Experimental setup



- Applicable for heating rate measurements in another vertical irradiation holes of HANARO.
- Components
  - a calorimeter sensor,
  - an air containing aluminum sleeve for fitting the sensor to the CN hole,
  - aluminum weight,
  - a lead wire assembly.

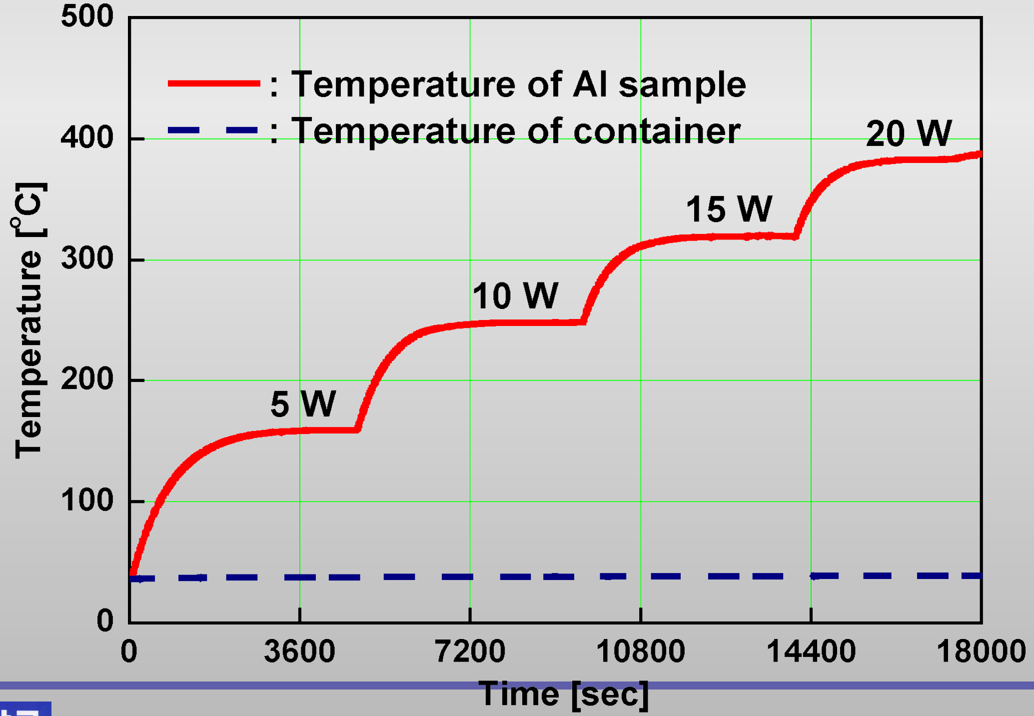
Sensor part of calorimeter



- A cylindrical Al sample.
- Al container.
- Al pipe for the neutron flux measurement.
- Two thermocouples.
- Electric heater for a calibration.
- Air gap.
- Longitudinal center of Al sample is equal to the center of reactor core.
- Calibration : a simulation of the heat transfer of the calorimeter over the temperature range and under the irradiation condition.

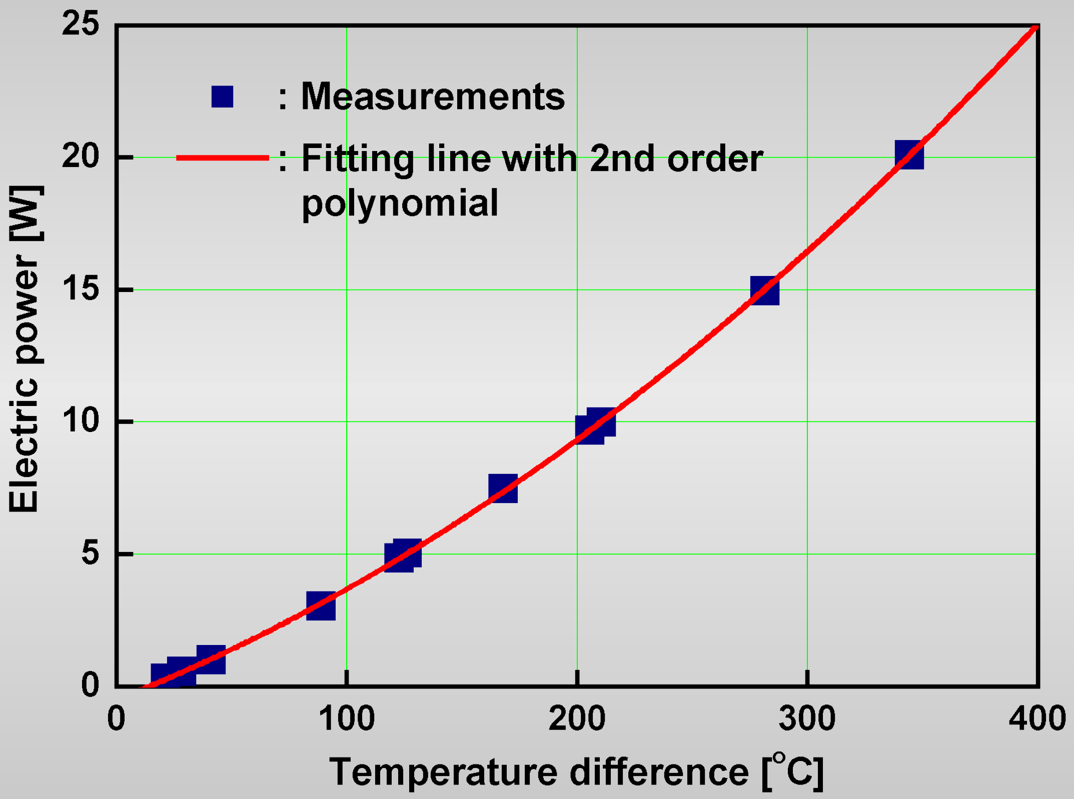
Calibration experiments

- Installation of facility at CN hole of HANARO (zero reactor power).
- Measurements of sample and container temperatures with the electric power supplied to the heater loaded in the sample.
- The maximum sample temperature : 385 ℃ at 20 W.
- The change of container temperature : several ℃.



- whole trends of the temperature changes in the calibration experiment.
- Temperature change : exponential growth function.

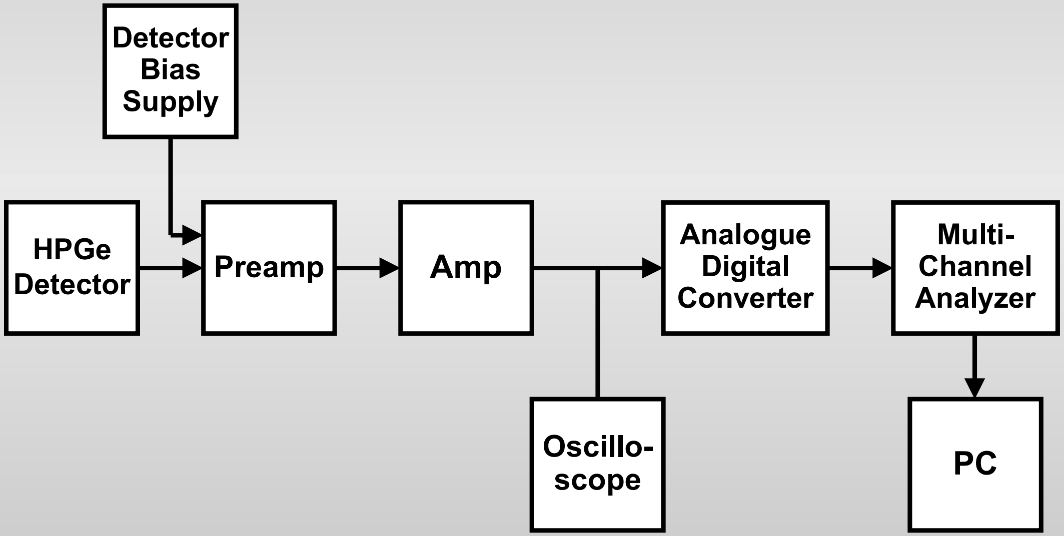
Calibration curve



- Relationship between the power supplied to the heater and the temperature difference : not linear.
- Convective and radiative heat transfers are increased in high sample temperature range.

Measurements of nuclear heating rate and neutron flux

- Measurements of nuclear heating rates at the CN hole at three reactor powers of 1, 4 and 8 MW.

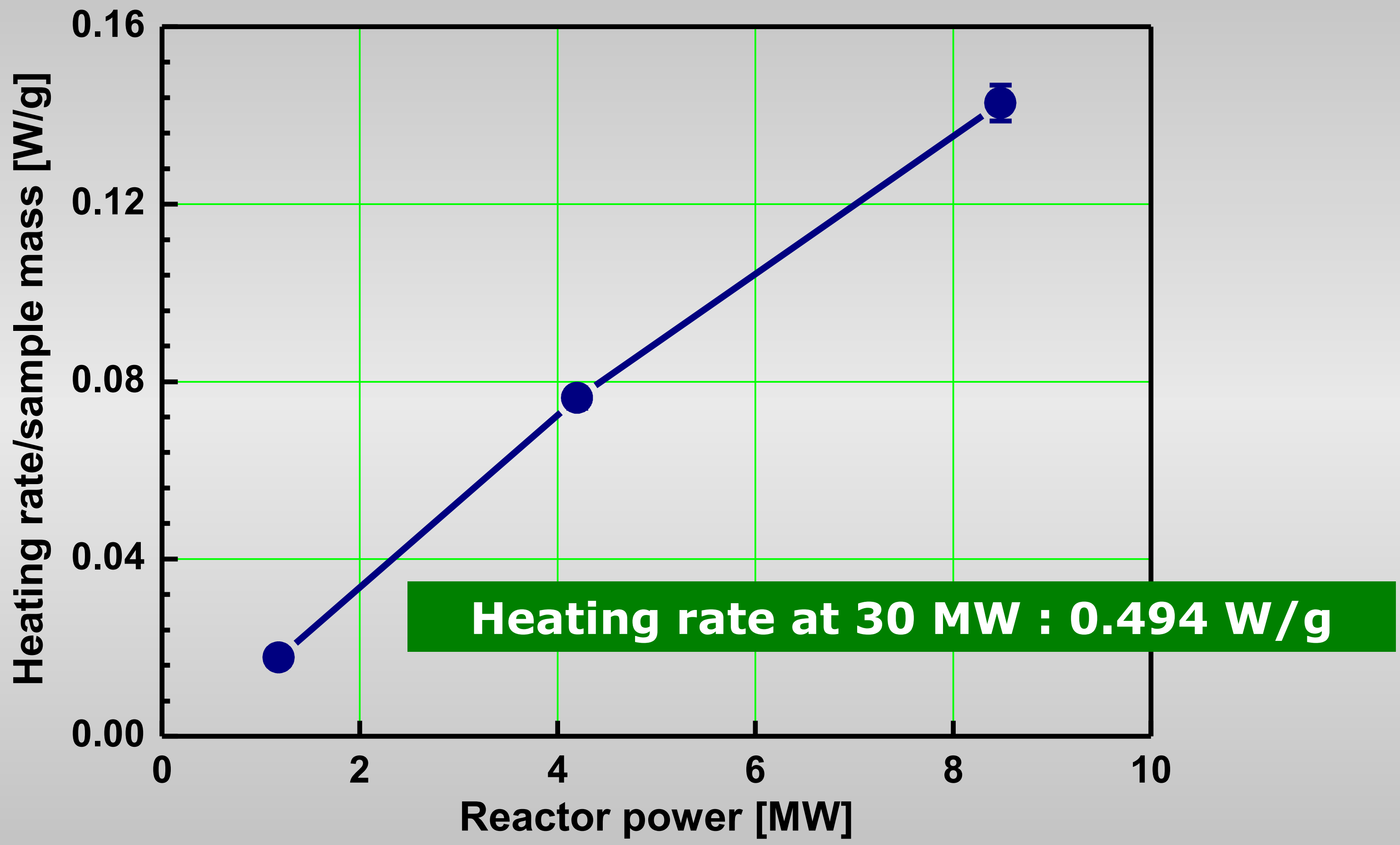


- Cobalt wire irradiations at the reactor powers of 1 and 8 MW for the neutron flux measurements.
- Measurements of the activities of the withdrawn cobalt samples : HPGe detector system.
- The diameter of the cobalt wire : 0.05 mm
  (negligible self- shielding effect).

Measured nuclear heating rates-1

Reactor power [MW]	Container temperature [℃]	Sample temperature [℃]	Temperature difference [℃]	Nuclear heating rate at sample [W]	Heating rate per sample unit mass [W/g]
1.18	31.167	63.284	32.118	0.697	0.018±0.0007
4.20	37.051	122.592	85.540	3.000	0.076±0.0023
8.48	40.158	177.220	137.062	5.618	0.143±0.0041
29.30 (30 MW_{th})				19.411	0.494

Measured nuclear heating rates-2



Measured neutron flux

Reactor power [MW]	Co-wire weight [mg]	Irradiation time [sec]	Saturated activity per nuclei [Bq]	Neutron flux [n/cm^{2}sec]
1.18	0.252	1800	1.224×10^{10}	3.294×10^{12}
8.48	0.395	600	8.602×10^{10}	2.314×10^{13}
29.30 (30 MW_{th})				7.450×10^{13}