Measurements of Nuclear Heating Rate in HANARO CN Hole

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1. Introduction

In HANARO, a 30 MW research reactor, the design of cold neutron source facility is on going. The heat removal capacity of moderator cell is essential information for source design. In order to determine the capacity of this refrigerator, we must know the nuclear heating rate at CN hole of HANARO. Nearly all the energy absorbed in a material placed in the radiation field of a research reactor appears in the form of heat. This nuclear heating in research reactors arises from the interactions with gamma-rays, fast neutrons and thermal neutrons, and this can be precisely determined by calorimetry [1,2,3]. Calorimetric dosimeters have various advantages for high-dose applications. The operation of the calorimeter is possible by measuring the total amount of energy that is deposited as heat in a thermally isolated mass [4,5].

In this research, we have designed and constructed a calorimeter, and measured the nuclear heating rate at CN hole of HANARO with it. The measurements are very useful in designing the moderator cell of cold neutron source of HANARO.

2. Experimental Methods

Figure 1 shows the layout of the sensor part of calorimeter for measuring the nuclear heating rate at CN hole of HANARO. The calorimeter sensor consists of a cylindrical Al sample, Al container, Al pipe for the neutron flux measurement, two thermocouples and the electric heater for a calibration. The sample is separated by an air gap from the Al container surrounded by an air containing Al sleeve. The longitudinal center of Al sample is equal to the center of reactor core.

The rate of rise of sample temperature is given by the following equation [6].

$$\frac{dT_s}{dt} = -\frac{a}{c}(T_s - T_e) + \frac{Q}{c} \quad (1)$$

where, T_s and T_e are the sample and container temperatures measured at time t, respectively, a is a heat transfer coefficient between the sample and the container, c is the specific heat of the sample, and Q is the rate of energy deposition per unit sample mass. If the a/c is known, the power can be obtained by measuring the steady state temperature difference, $(T_s - T_e)$.

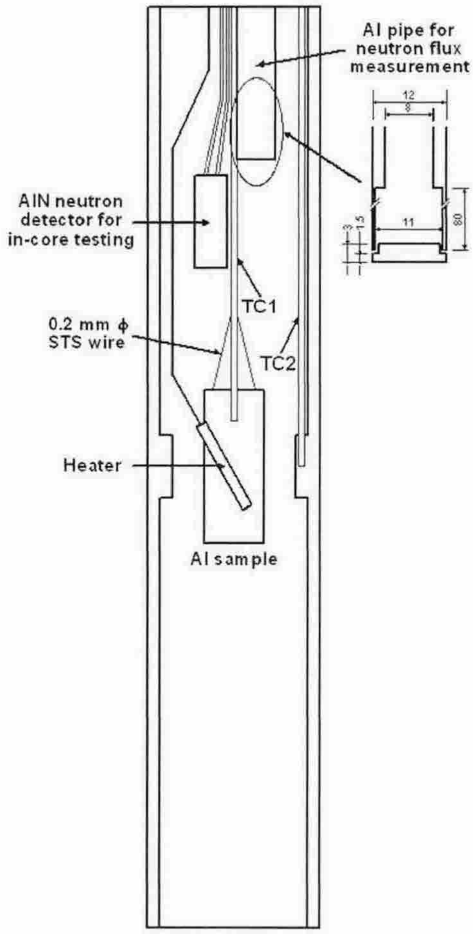

Fig. 1. Layout of the sensor part of calorimeter. The height of Al sample is 5 cm.

The calibration heater allows one to determine the a/c in eq. (1), and this calibration gives a simulation of the heat transfer of the calorimeter over the temperature range and under the irradiation condition.

3. Results

Figure 2 shows the temperature changes of Al sample and container during electric power supplying to the calibration heater. From this calibration experiment, the relationship between the power supplied to the heater and the temperature difference is determined.

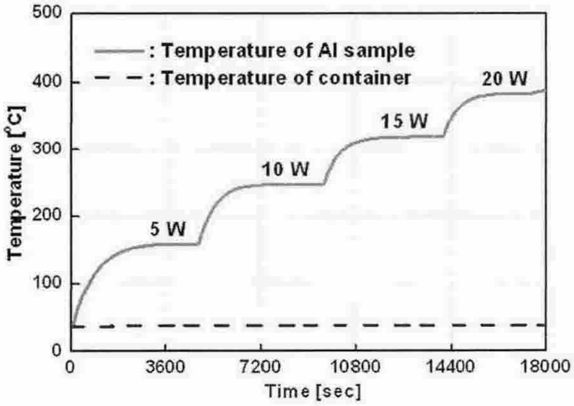

Fig. 2. Temperature changes of Al sample and container in calibration experiment.

The nuclear heating rates measured at three reactor powers are represented in table 1. Uncertainty of the measurements is within 2.0%, and the uncertainty in temperature measurement is a main contribution.

The measured nuclear heating rate per unit mass of Al sample at 8 MW reactor power is 0.143 W/g, from which, the heating rate at 30 MW is expected to be 0.536 W/g. This value is very useful for designing the moderator cell of cold neutron source of HANARO.

REFERENCES

[1] S. R. Gunn, Radiometric Calorimetry: A Review, Nuclear Instruments and Methods, Vol.**29**, p.1, 1964.
[2] Determination of Absorbed Dose in Reactors, Technical Reports Series No.127, International Atomic Energy Agency, Vienna, p.121, 1971.
[3] L. D. Hansen and R. M. Hart, The Art of Calorimetry, Thermochimica Acta, Vol.**417**, p.257, 2004.
[4] K. Haack and B. Majborn, Reactor Gamma Heat Measurements with Calorimeters and Thermoluminescence Dosimeters, Nuclear Instruments and Methods, Vol.**111**, p.283, 1973.
[5] W. L. McLaughlin, A. W. Boyd, K. H. Chadwick, J. C. McDonald and A. Miller, Dosimetry for Radiation Processing, Taylor & Francis, London, p.113, 1989.
[6] A. W. Boyd, H. W. J. Connor and J. J. Pieroni, "AECL-2203: Methods of Dosimetry and Flux Measurement and Their Application in the NRX Reactor", Atomic Energy of Canada Limited, Chalk River, Ontario 1965.

Table 1. Measured nuclear heating rates at three reactor powers.

Reactor power [MW]	Container temperature [℃]	Sample temperature [℃]	Temperature difference [℃]	Nuclear heating rate at sample [W]	Heating rate per sample unit mass [W/g]
1	31.167	63.284	32.118	0.859	0.022±0.00084
4	37.051	122.592	85.540	3.067	0.078±0.00237
8	40.158	177.220	137.062	5.621	0.143±0.00406