Characteristic Examination of the HANARO Pneumatic Transfer Irradiation System for a Neutron Activation Analysis

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1. Introduction

A quantitative analysis of major, minor and micro component elements as a trace impurities in subject materials are essential in many fields of science and technology as well as commercial and industrial fields. In particular, direct analysis of a sample offers a more effective investigation method in these fields. Reactor-based instrumental neutron activation analysis (INAA) has an inherent advantage of being a non-destructive, simultaneous multi-elemental analysis with high accuracy and sensitivity.

However, when a defined volume sample to be analyzed using INAA, neutron flux distribution with geometric position within a reactor irradiation hole and a type of matrix is one of major source of measurement uncertainty. For analytical assurance and control in the management of laboratory accreditation, an accurate irradiation characteristic data of irradiation facility have to checked and monitored.

A pneumatic transfer system (PTS) is one of the important facilities used in an irradiation of a target material for an instrumental neutron activation analysis (INAA) in a research reactor. There are new three PTS at the HANARO research reactor involving the manual system (PTS #1, 3) and the automatic system (PTS #2) for a delayed neutron activation analysis (DNAA). This system consists of many devices and assemblies, for the sending and loading of the irradiation capsules from the NAA Laboratory into three holes in the reflector tank of the reactor, the retrieving of the irradiated capsules after an irradiation and an automatic counting of the radiation level. The irradiation tubes of PTS are installed at three NAA holes in the reflector of the reactor as shown Figure 1.

The temperature on the irradiation position of the polyethylene rabbit has to be limited to less than 80 ℃ because the melting point of the PE is about 120℃. The temperature of the irradiation sites at 30MW thermal power were measured with the irradiation time using the thermo-label for the inside and surface of the rabbit. That is, optimum irradiation time of PTS is depended on the real temperature on the irradiation position.

The basic requirement of an irradiation for the PTS is based on the parameters such as the neutron flux and distribution, temperature, gamma heating of the irradiation site, the radiation dose rate and materials and types of rabbit and the sample for quantitative elemental analysis under a safe operation of the reactor. In this paper, the results of the irradiation characteristics such as neutron flux and its distribution with sample geometry of three PTS for analytical quality control are reported

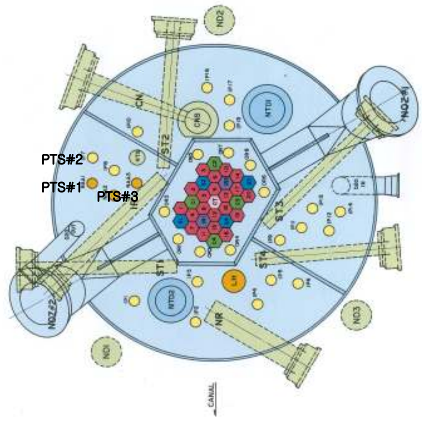

Figure 1. Three irradiation sites of PTS at HANARO research reactor.

2. Methods and Results

2.1 Irradiation Tube Description

The structure for the irradiation tubes of PTS #1, 2 is a single tube which is contacted with cooling water to increase the cooling efficiency. The length of the irradiation tube is about 50 cm and the outer and inner diameters of the transfer tube are 34.1 and 27.5 mm, respectively. Transportation of the capsule (so called rabbit) is performed by N_2 gas pressure of the PTS lines within the range of 20 to 35 psi. To obtain an accurate and a precise irradiation time, the transfer time of the rabbit in the PTS was measured by an acoustic method in both the manual and automatic modes of the controller. The average sending time to the reactor was 12.5±0.1 sec. and the average receiving time back to the receiver was 6.1±0.1 sec.

2.2 Flux Monitoring and Rabbit Geometry

The geometric effect of a large volumetric rabbit always has to be considered when a sample is irradiated by using a PTS. The length of the used rabbit is 54.7 mm, and its inner and outer diameter are 19.9 mm and 25.2 mm, respectively. For the evaluation of the thermal neutron flux variation along with the height (axial) and width (radial) of the rabbit, flux distribution at 10 mm intervals as a distance from the bottom and 5 mm cross intervals as a radius of the rabbit were measured using an Au-Al wire monitor.

2.3 Neutron Flux Distribution

For a neutron flux monitoring and a measurement of the cadmium ratio, activation wires (R/X activation wire, Reactor Exp. Inc.) such as Au-Al, Ni wire and Cd box were used. The measurements were carried out using a calibrated gamma-ray spectrometer combined with HPGe semiconductor detector (GEM 35185P), Multi-channel analyzer (919A MCB), Gamma Vision software of EG&G ORTEC company. The calculation of neutron flux was carried out using the new Windows PC-code, Labview software of KAERI with a nuclear data library, which was developed at this laboratory for a rapid and simple data treatment for a gamma-ray spectrum obtained from given measurement conditions.

The measured values for the flux variation and distribution within the rabbit geometry at the irradiation position of the PTS #1 and PTS #2 are shown in *Figure 2 and Figure 3*, respectively. In the case of PTS #3, the flux from the bottom to the top of the rabbit is decreased, but, in the cases of PTS #1 and #2, the variation of the flux is slight. The axial deviations for PTS #1, #2, #3 were 1.48%, 1.39%, 2.02%, respectively and radial deviations for PTS #1 and #2 were 3.64%, 3.28%, respectively. From our experimental results, we can conclude that the radial gradient is somewhat higher than axial gradient for the irradiation positions in the rabbit. These results will be used for an evaluation and geometry correction of a sample when a sample is irradiated. The information on a neutron flux and distribution of an irradiation site is a basic requirement for NAA due to the condition that reactor operation is variable. The thermal, epithermal and fast neutron flux together with the cadmium ratio, R_{Cd}, of PTS #1, #2 and #3 were measured at 30 MW thermal power. The measured average thermal neutron fluxes were estimated to 3.76 ± 0.04 x 10^{13}, 2.67 ± 0.02 x 10^{13}, 1.29 ± 0.03 x 10^{14} n/cm^{2}s, respectively. The cadmium ratio of PTS #1, #2 and #3 were about 85, 98, 10, respectively.

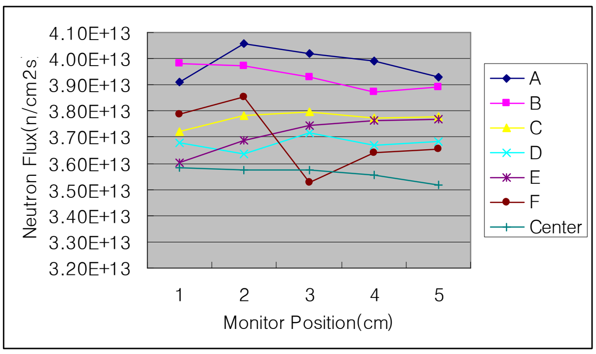

Figure 2. Axial and radial distributions of neutron flux with rabbit geometry at the HANARO PTS #1.

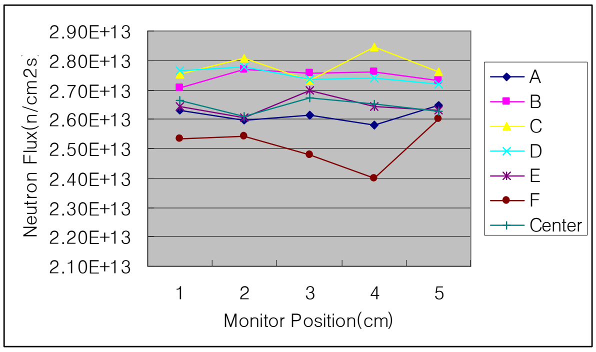

Figure 3. Axial and radial distributions of neutron flux with rabbit geometry at the HANARO PTS #2.

3. Conclusion

For a promotion of a utilization and effectiveness of the facility by the improvement of the PTS for a INAA in the HANARO research reactor, the basic functional test of the system and an irradiation characteristics was investigated and the result of the parameters measured such as the transfer time, the neutron flux distribution, the temperatures of the irradiation position with a irradiation time, etc. were reported.

The results will be used for a correction as well as the estimation of influence of these parameter on the measurement uncertainty of the final report, and wider applications for the NAA in many fields by an enlargement of the HANARO utilization facility.

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