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Preliminary Examination of a New Pneumatic Transfer System for a Neutron Activation Analysis at the HANARO Research Reactor

Yong-Sam Chung, Sun-Ha Kim, Jong-Hwa Moon, Sung-Yeol Baek and Hark-Rho Kim

Korea Atomic Energy Research Institute
(150-1 Deokjin-dong), 1045 Daedeokdaero, Yuseong, Daejeon 305-353, Korea
yschung@kaeri.re.kr

1. Introduction

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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. In particular, a fast pneumatic transfer system is essential for a measurement of short half-life nuclide and a delayed neutron counting system. There are 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). These systems were reinstalled with new designs for an improvement according to the purpose of usage in 2006.

In this paper, the new designs of the PTS are described as well as the facilities which are used in an irradiation of a target, the operation and control of the system and future applications are presented. In addition, the irradiation test and the characteristics of the PTS for user information and the reactor management and safety are reported.

2. Methods and Results

2.1 Description of PTS

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 which is made of Al6061 are installed at three NAA holes in the reflector of the reactor as shown Figure 1.

The structure for the irradiation tubes of PTS #1, 2 is changed to a single tube from double tubes of an old type to increase the cooling efficiency. PTS #3 is only used for a short irradiation of less than 60 sec. The length of the irradiation tube is about 14 m from the bottom of the core to the top of the reactor and that of the transfer tube which is made of SUS304 is about 28 to 35 m between the end of the irradiation tube and each shielding receiver. The outer and inner diameters of the transfer tube are 34.1 and 27.5 mm, respectively. There are six components as shown in Figure 2 ; 1) irradiation and transfer system (system controller, irradiation tube, transfer tube, auto-loader, loader-receiver, shielding receiver, air cushion valve assembly which is used for the prevention of a strong impact at the end of the irradiation tube and the receiver, 4 way-diverter, photo sensor and high purity polyethylene capsule), 2) N_2 gas supplier system, 3) gas exhaust system, 4) emergency system, 5) shielding system (loader-receiver, receiver, transfer line), 6) DNAA counting system. N_2 gas pressure of the PTS lines is adjusted to within the range of 20 to 35 psi.

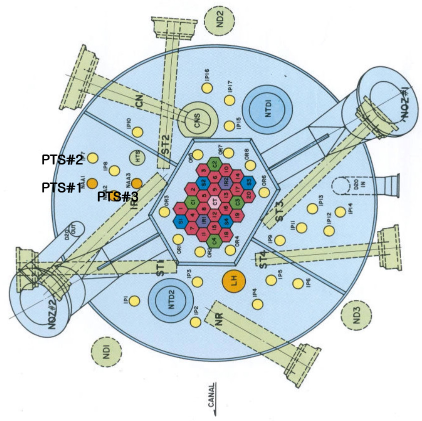

Figure 1. Irradiation sites of PTS installed at HANARO research reactor.

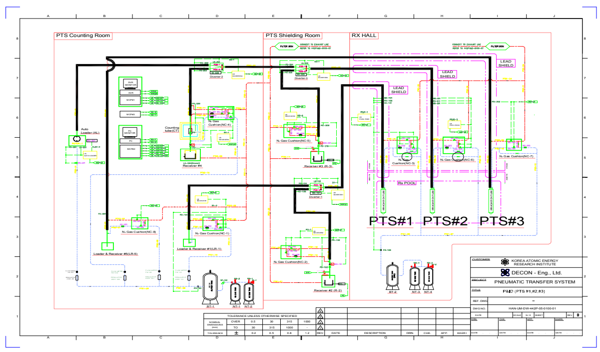

Figure 2. P&ID of PTS at HANARO research reactor.

2.2 Transportation of Irradiation Capsule

Test of the PTS operation made with a mock-up before the system was installed, and the capsule (so called rabbit) was filled with a weighted material (about 5 g). The inspection and the accomplishment of the system was carried out by a national qualified auditing organization. The sending and receiving of the capsule in the PTS is controlled by a system controller with a preset timer, manually or automatically. The transportation of a rabbit is detected by the photo-sensor which is located at the end of loaders and irradiation tubes. To obtain an accurate and a precise irradiation time, the transfer time of the capsule 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.

2.3 Characteristics of Irradiation holes

The 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 a safe operation of the reactor. Therefore, the condition and the damage of an irradiation tube and transfer tube should be checked regularly. The gamma heating rate was estimated to be about 5 $Watts \cdot g^{-1}$.

The temperature on the irradiation position of the PE 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 capsule. In the PTS #1 and #2, when the capsule is irradiated for 10 sec. to 60 min., the measured temperature was the range of 50 to 70 ℃. In the PTS #3, when the capsule is irradiated for 10 sec. to 80 sec., the measured temperature was the range of 50 to 80 ℃. That is, optimum irradiation time of PTS is depended on the real temperature on the irradiation position.

2.4 Radiation Monitoring of Working area and Noble gas

The loader of new PTS is purged by N_2 gas before sample irradiation for the control of gas activation. The radiation level of the noble gas exhausted from the PTS is checked by RMS of the HANARO and maintained less than 10^{-7} Bq/m^3 at the steak monitor (RE022).

When the irradiated capsule is returned, the radiation dose rate of the near receiver was in the range of 20 to 70 $\mu Sv\ h^{-1}$ and that of the transfer line in the reactor hall was less than 15 $\mu Sv\ h^{-1}$.

2.5 Neutron Flux Monitoring

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, Co, Fe and Zr and Cd box were used. The measurements were carried out using a calibrated gamma-ray spectrometer (HP-Ge detector, GEM 35185P and 919A MCB, Gamma Vision software, EG&G ORTEC, USA). The calculation 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 at preset detection conditions.

The thermal, epithermal and fast neutron flux together with the cadmium ratio, R_{Cd}, of PTS #1, #2 were measured. The neutron fluxes of PTS #3 at 30 MW thermal power were estimated to 1.42E+14 $n \cdot cm^{-2} \cdot s^{-1}$, 1.02E+11 $n \cdot cm^{-2} \cdot s^{-1}$ and 2.50E+10 $n \cdot cm^{-2} \cdot s^{-1}$, respectively. The cadmium ratio, R_{Cd}, was about 9.5.

2.6 Applications

The new PTS will be mainly used for an instrumental neutron activation analysis which contains a delayed neutron activation analysis using a nuclear fission reaction. In addition, the system will be used for the production of a radioactive tracer, an irradiation test of several materials, a nuclear fission track method, etc.

3. Conclusion

For a promotion of a utilization and effectiveness of the facility by the improvement of the PTS for a NAA in the HANARO research reactor, the functional test of the system and an irradiation test was carried out and the result of the parameters measured such as the transfer time, the neutron flux, the temperatures of the irradiation position with a irradiation time, the radiation dose rate when the rabbit is returned, etc. were reported.

The results will be used for wider applications for the NAA in many fields by an enlargement of the HANARO utilization facility.

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