A Preliminary Study on a Configuration of the Irradiation Holes in the AHR

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1. Introduction

A multipurpose research reactor is usually designed for diverse users to utilize it efficiently for their different purposes. A selection of the utilization fields and an arrangement of the utilization facilities such as vertical holes and beam tubes are very important in the design of a research reactor [1]. As a part of the Advanced HANARO Reactor (AHR) conceptual design, utilization areas are examined and several configurations for vertical irradiation holes and beam tubes in the reflector region are studied.

2. Design Requirements

In this section some of the design requirements from the users in HANARO are described. Also thermal neutron fluxes at the irradiation sites are summarized for the proposed arrangement of the irradiation holes.

2.1 Design Considerations

Utilization areas considered in the AHR design are a radioisotope (RI) production, neutron transmutation doping (NTD), neutron activation analysis (NAA), fuel and material irradiation test, and neutron beam research including a cold neutron.

From the experiences on the use of the HANARO facility, vertical irradiation holes with relatively low neutron fluxes have a limited frequency of use and thus their number should be minimized. Because the importance of a cold neutron in a research reactor is increasing rapidly, a hole for installing a cold source should be arranged at a position of the maximum neutron flux. The number of vertical holes for a NTD irradiation is preferred to be as many as possible.

The irradiation holes for a RI production and NAA are preferred to be gathered together in one section of the reflector region. An interference due to the primary coolant pipe, the control rod driving mechanism, etc. should be carefully examined for determining the position of the utilization facilities.

2.2 Design Requirements

Some of the specific design requirements are described for each utilization field. For a RI production, 8~10 holes with diameters of 40~60mm are needed. Also 1~2 holes with a diameter of 150mm for a hydraulic transfer system (HTS) are necessary. Most of them should have a neutron flux higher than $1x10^{14}$ n/cm^2-s. A couple of holes having a neutron flux lower than $5x10^{13}$ n/cm^2-s are optional. An irradiation test of a nuclear fuel and material requires a high fast neutron flux of larger than $1x10^{14}$ n/cm^2-s and a high thermal neutron flux as well. Thus, an irradiation site for this purpose is usually chosen inside the reactor core. It is not described further here because only the irradiation sites in the reflector region are considered.

For the NAA, three holes are enough for a normal research. Only NAA holes utilizing thermal neutrons are considered. Main issue for installing a pneumatic transfer system is to keep the temperature inside the irradiation tube below 40~50℃ and the gamma heating below 50W. The proper size for the NAA is 40~60mm in diameter. The required thermal neutron fluxes are in the range of $1x10^{12}$~$1x10^{14}$ n/cm^2-s.

The demand for a NTD irradiation is expected to increase continuously in the future. The number of irradiation sites for a NTD should be more than two in order to meet the future demand. The size of the NTD hole should be determined to accommodate a wafer of a minimum of 8 inch in diameter. A uniform axial neutron flux distribution for a NTD irradiation is very important. Thus the NTD site should be located where the neutron flux doesn't vary much due to other utilization activities. Also it is recommended to position it in the same direction as a fuel transfer canal to facilitate a movement of the sample before and after its irradiation.

The number of beam tubes is proposed as four - one beam tube for a cold neutron, one for neutron radiography (NR) and two for thermal neutron (TG). The beam tube noses are 70mm x 200mm (WxH) for the thermal and cold neutron beam tubes and 150mm in diameter for the NR beam tube. They are disposed in regions of a thermal neutron flux higher than $2x10^{14}$ n/cm^2-s. All the beam tubes are arranged in a tangential direction to the reactor core.

3. Calculation and Result

3.1 Calculation

The reactor core is assumed to consist of 14 36-element and 4 18-element fuel assemblies. It has four Hf shrouds which act as not only a control rod but also a shutdown rod [2]. Taking the above design considerations and requirements into account, an example for the configuration of the irradiation holes and beam tubes is shown in Figure 1.

There are 10 vertical holes for a RI production, 3 for NAA, 2 for HTS, 3 for NTD and 4 beam tubes. In the calculation, air is filled inside the holes for the RI and NAA and beam tubes. Water is filled inside the holes for the HTS. A silicon crystal of 8 inch in diameter and 60cm in length is positioned inside the NTD holes.

Two other cases are configured for a comparison purpose. One is that 1 NTD and 2 RI holes are removed and 1 HTS position is moved to other position. The other is that the nose positions of the TG and NR beam tubes are moved near to the reactor core in order to get a higher thermal neutron flux at their noses.

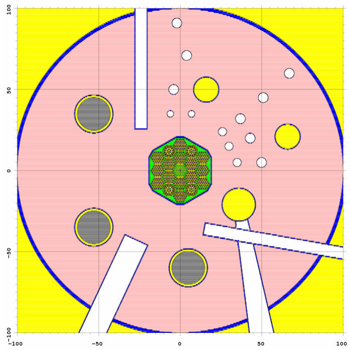
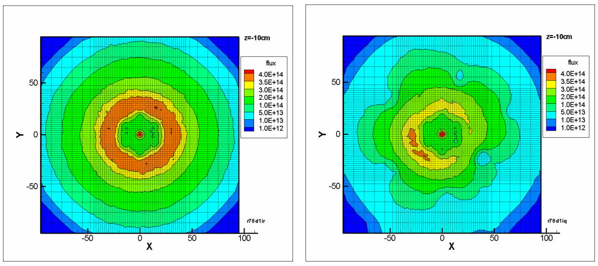


Figure 1. An example for the configuration of irradiation holes and beam tubes in the AHR.

3.2 Result

The reactivity effects due to an arrangement of the utilization facilities in the reflector region are 17~20 mk, which are a little higher than the expected. The radial thermal neutron flux distribution at the plane of z=-10cm is shown together with that for the case of no utilization facilities in Figure 2. The reactor power was assumed to 20MW and four control absorber rods were positioned at z=5cm.



(a) without holes (b) with holes

Figure 2. Thermal neutron flux distributions at a plane of z=-10cm with and without vertical holes and beam tubes

The thermal neutron flux distribution is severely perturbed due mainly to the large vertical holes. The thermal neutron flux averaged at a silicon sample is 4.3~4.7x10^{13} n/cm^2-s which is believed to be high enough for a commercial NTD service. Those at the RI holes range from 2.6x10^{13} n/cm^2-s at the farthest hole from the reactor core to 2.5x10^{14} n/cm^2-s at the holes near to the core.

When one of the HTS holes is moved into the opposite side, the thermal neutron fluxes at the RI and NAA holes which were positioned near the HTS hole, increase by more than 10%. If the beam tube nose is moved toward the reactor core, the thermal neutron fluxes at the nose increase by 14% for the TG beam tube and by 78% for the NR beam tube. The large increase in the NR beam tube is attributed to the big size of the beam tube.

Based on the above results, the irradiation holes and beam tubes satisfying their design requirements can be designed.

4. Conclusion

Some of the design considerations and requirements for an arrangement of the irradiation holes and beam tubes in the AHR are briefed. For a preliminary study, the vertical holes and beam tubes are arranged by considering the design considerations and requirements. Their reactivity effect and the average neutron fluxes inside the holes and at the beam tube nose are estimated. The results herein give us good information for an optimal design of the utilization facilities in the AHR.

Acknowledgement

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