A Monte Carlo Simulation for a New Neutron Counter Based on an Annular Tube Type He-3 Detector

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1. Introduction

Most well-type neutron counters like the ACP Safeguards Neutron Counter(ASNC)[1], in which a sample cavity is positioned at its center have been used widely for the special nuclear material(SNM) quantitative measurement in the safeguards field. Numbers of cylindrical He-3 tube detectors are usually embedded in the polyethylene moderator of the neutron counter surrounding a sample cavity in a ring type. Since the neutron counting efficiency is approximately proportional to the number of embedded cylindrical He-3 tube detectors, an appropriate number is determined so that the required efficiency could be realized. The number is usually from several pieces to more than one hundred pieces and the corresponding neutron counting efficiencies appear from several percent to about 60%[2,3]. Therefore, a high efficiency counter in which a lot of cylindrical He-3 tube detectors are embedded has such a complicated geometry and electronics that it is undesirable for a high-level radiation facility in which a repairing procedure is difficult. In this study, a new neutron counter in which an annular tube type He-3 detector is embedded instead of a group of cylindrical He-3 detectors has been suggested to achieve a high efficiency and to simplify the counter structure, simultaneously, so that it could be used in a pyroprocessing facility in which a PWR spent fuel is chemically processed.

2. Result and discussion

A new neutron counter has been conceptually designed on the basis of an MCNPX simulation, which is composed of a lead gamma detector, a polyethylene moderator and a He-3 tube detector which are annularly surrounding the sample cavity in that order. As for the results, the sample cavity, He-3 tube length and thickness, and the inner polyethylene thickness were determined to be 20 cm x H30 cm, L50 cm x T2.5 cm and 2.6 cm, respectively. The entire neutron counter has been optimized to be 72.0 cm x H68.3 cm with two annular He-3 tubes of 2.5 cm in thickness.

The spatial variance of the sample cavity which is defined as the relative error of the efficiency due to the position of the neutron source in the sample cavity has been calculated and is presented in Fig. 1. As shown in Fig. 1, the efficiency is distributed from a minimum value of 42.4 % at the top of the sample cavity to a maximum value of 46 % near the wall of the sample cavity at a height of 20 cm. The spatial variance is about 6.3 % at a maximum, but the actual variance seem to be less than 3 % because only a few large variances occur in the corner near the wall or in the top position. That is, since a sample such as a spent fuel powder or its metallic material powder will be filled in from the bottom of the sample cavity and the powder sample height is usually not up to the top of the sample cavity, so that the contribution at the top position is not included in most cases. And the fraction of the area near the wall seems to be negligible in the view of the contribution to the total neutron counting value.

The main conceptual design parameters and the estimated efficiency and spatial variance values are presented in Table 1. Since the estimated efficiency appeared to be more than 40 % which is the minimum efficiency to be a multiplicity counter and the estimated spatial variance is very small, it could be used as a neutron multiplicity counter which is useful for the safeguards of a pyroprocess facility in which a PWR spent fuel is chemically processed.

Table 1. Conceptual design specifications and performance results

Item	Value
Sample cavity	20 cm x H30 cm
Annular He-Tube	L50 cm x T2.5 cm
Lead thickness	2 cm
Inner PE moderator thickness	2.6 cm
2nd PE moderator thickness	3.0 cm
Entire neutron counter	72.0 cm x H68.3 cm
Efficiency	42.4 % - 46.0 %
Spatial variance	3 %

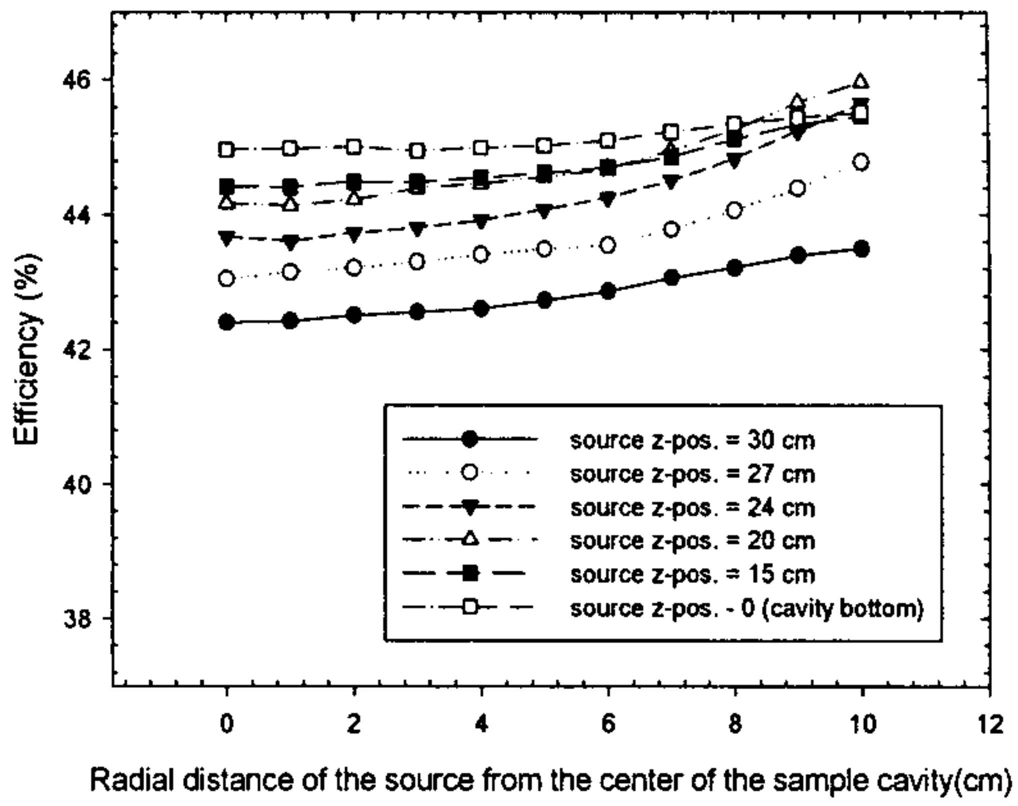

Fig. 1. Efficiency distribution depended on the source position.

3. Conclusion

A new neutron counter based on an annular tube type He-3 detector has been conceptually designed to be 72.0cm x H68.3cm through an MCNPX simulation with a developed computer program which automatically generated the MCNPX input for simulating the neutron counter. Its neutron counting efficiency and spatial variance in its sample cavity were estimated to be more than 42.4 % and less than 3%, respectively , this neutron counter could be used as a neutron multiplicity counter which is useful for the measurement of SNM treated in a pyroprocessing facility. The current conceptual design will be studied further and finalized by an additional electronic circuit optimization.

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