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# Establish of instant performance testing systems for neutron area monitor by using the movable neuron irradiator

Seung Kyu Lee[a*], Sang In Kim[b], Insu Chang[a], Jungil Lee[a], Hyoungtaek Kim[a],
Min Chae Kim[a,c], Jang-Lyul Kim[a], Bong-Hwan Kim[a]
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, 34057, Republic of Korea*
[b]*Naieel technology, Cooperation Center for Industry 708, Chungnam National University Daehak-ro 99, Daejeon 34134, Republic of Korea*
[c]*Department of Nuclear Engineering, Hanyang University, 222, Wangsimni-ro, Seongdong-gu, Seoul, 04763, Korea*
[*]*Corresponding author: sklee11@kaeri.re.kr*

## 1. Introduction

Neutron area monitors are installed at airports, harbors, and nuclear related facilities and are mainly used for radiation protection, radiological emergency, and security. In recent years, the use of neutron area monitors has been increasing with neutron generators in airports and harbors in order to achieve the purpose of anti-terrorism and to search for unidentified materials in unopened state. Since the performance test of the neutron area monitors is only possible in the calibration facility of the Korea Atomic Energy Research Institute (KAERI) or Korea Research Institute of Standard and Science (KRISS), it must be removed from the installation site and be moved to the calibration facility to performance testing. Such periodical detachments and movements can cause serious problem in the electrical and mechanical stability of the neutron monitor. In addition, it is impossible to perform the performance testing of the neutron area monitors in abnormal situations such as terrorism and accidents. In order to solve these problems, the need for the movable neutron irradiator and the radiological performance testing scheme has been raised. However, there is no calibration system other than the fixed facilities of the standard institutes.

In this study, the movable neutron irradiator was designed and fabricated that considers mobility and radiological safety by using Monte Carlo N-Particle (MCNP) simulations, and the correction factors which required for actual field calibration and performance testing were calculated using a neutron survey meter [1,2,3].

## 2. Experiments and Simulations

### *2.1 Movable neutron irradiator*

In this study, the geometry, material and size of the movable neutron irradiator that considers mobility and radiological safety by using MCNP simulations. The material of the movable neutron irradiator was determined as high-density polyethylene (HDPE) and the size was determined as 50 cm (L) × 50 cm (W) × 46 cm (H). In order to increase the mobility, the irradiation device was manufactured in six equal parts so as not to exceed 25 kg. A cylindrical simple source container (diameter 20 cm, height 28 cm) was designed and manufactured to secure the maximum mobility with minimum exposure when moving the source. The collimator of the movable neutron irradiator was designed to maximize the required dose for the performance testing while minimizing the neutron scattering.

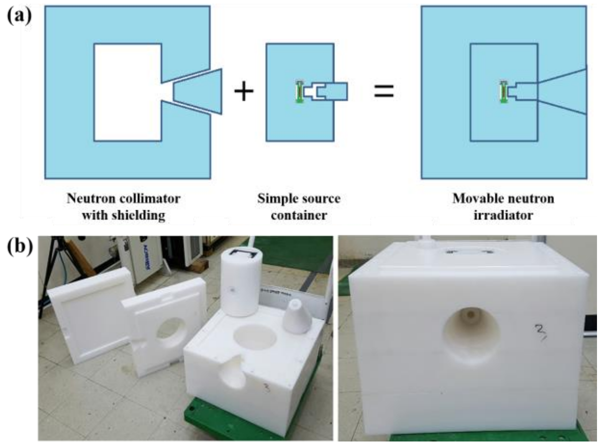


Fig. 1. (a) Concept of packaging for neutron source combined with neutron irradiator, (b) Pictures of movable neutron irradiator combined with neutron source packaging.

In order to satisfy the reference dose rate, the neutron sources that has been applied to the movable neutron irradiator and evaluated its performance were the $^{252}Cf$ and the $^{241}Am$-Be source which have been retained by the KAERI. The neutron sources are as shown in Table 1.

Table I: Variation cases of the experimental setup

| Source | Reference Date | Activity (MBq) |
|---|---|---|
| $^{252}Cf$ | 2006.03.24 | 46.86 |
| $^{241}Am$-Be | 1979.04.18 | 390 |

### *2.2 MCNP Simulation*

MCNP6 simulation code was used to evaluate the performance of the manufactured movable neutron irradiator. The volume fluence tally (F4 tally) was used to obtain the neutron fluence at each reference position, and the energy of the neutron fluence spectrum was set from 0.01 eV to 50 MeV considering the maximum energy of the neutron source and minimum energy of scattered neutrons.

### 3. Results

The dosimetric quantities of the neutron generated by the neutron irradiation system were produced by computer simulation, and the reference position was set 20 cm intervals from 80 to 200 cm from the center of the neutron source. Fig. 2. shows the neutron fluence spectrum for each neutron source and Table 2 is the dosimetric quantities for $^{252}$Cf neutron fields generated by movable neutron irradiator. As a result, the neutron fluence decrease rapidly as the reference distance increases for each source in the whole energy region. However, the percentile to the total fluence rate of the thermal and fast neutron is almost unchanged at various position from the neutron source.

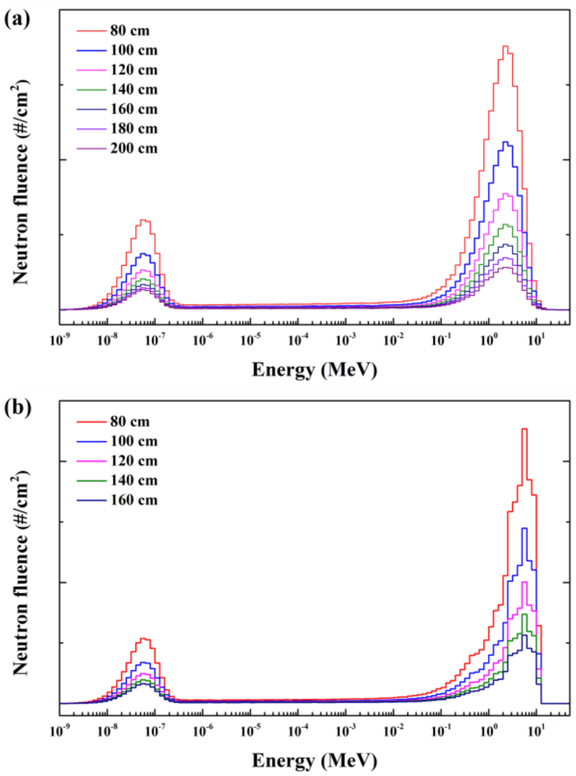


Fig. 2. Neutron fluence spectra at various position from (a)$^{252}$Cf source, and (b)$^{241}$Am-Be source.

Table II: Dosimetric quantities of neutron field constructed by movable irradiator at various position from $^{252}$Cf source setup

| Reference position (cm) | $E_{av}$ (MeV) | $h$*(10)[1] (pSv·cm²) | Percentile to the total fluence rate | | |
|---|---|---|---|---|---|
| | | | < 0.5 eV | 0.5 eV ~ 10 keV | > 10keV |
| 80 | 1.42 | 275 | 20.0 | 6.3 | 73.7 |
| 100 | 1.41 | 272 | 20.3 | 6.5 | 73.2 |
| 120 | 1.39 | 270 | 21.0 | 6.5 | 72.4 |
| 140 | 1.36 | 264 | 22.0 | 6.8 | 71.2 |
| 160 | 1.32 | 257 | 23.3 | 7.2 | 69.5 |
| 180 | 1.30 | 255 | 24.0 | 7.5 | 68.5 |
| 200 | 1.26 | 249 | 24.7 | 7.8 | 67.5 |

1) $h$*(10): ambient dose equivalent conversion coefficient

The movable neutron irradiator must be corrected to test the performance in the fields. The correction provision proposed by ISO-8529 include "correction of emission rate of source". "correction of geometrical anisotropically emitting source", "correction of fluence-dose conversion factor", "correction of neutron decay rate" air-attenuation correction factors", "correction of scattered neutrons", and "calibration of the measured value of devices"[1,2,3]. However, it is difficult to correct for the uncertainty factors because the environment changes every time when the movable irradiation device is used. Therefore, the correction coefficients were calculated by comparison of the quantified standard dose value and the dose measured by the standard neutron survey meter (Berthold, LB6411, calibration date: May 2016). Table 3 shows the correction coefficient, and reference and measured ambient equivalent dose rate of neutron field constructed by movable irradiator at various position from $^{252}$Cf source.

Table III: Correction coefficient, and Reference and measured ambient equivalent dose rate of neutron field constructed by movable irradiator at various position from $^{252}$Cf source

| Position (cm) | Reference dose rate (μSv/h) | Rate of change | Measured dose rate (μSv/h) | Rate of change | Correction coefficient |
|---|---|---|---|---|---|
| 80 | 66.2 | - | 49.0 | - | 0.96 |
| 100 | 43.2 | 0.65 | 45.9 | 0.67 | 0.94 |
| 120 | 30.5 | 0.71 | 32.4 | 0.71 | 0.94 |
| 140 | 21.9 | 0.72 | 23.1 | 0.71 | 0.95 |
| 160 | 16.6 | 0.76 | 18.0 | 0.78 | 0.92 |
| 180 | 13.0 | 0.78 | 14.7 | 0.82 | 0.88 |
| 200 | 10.3 | 0.79 | 12.1 | 0.82 | 0.85 |

### 4. Conclusions

In the present study, the correction coefficients of manufactured movable neutron irradiator were varied from 0.85 to 0.96 at various reference positions. With these results, it is expected that this irradiator is possible to perform the testing at real workplace by using correction factors. In a further study, we are going to simulate and experiment for more detail correction coefficient, and extend this field performance testing systems.

### REFERENCES

[1] ISO 8529-1:2001, Reference Neutron Radiations-Part 1: Characteristics and Methods of Production.
[2] ISO 8529-2:2000, Reference Neutron Radiations-Part 2: Calibration Fundamentals Related to the Basic Quantities Characterizing the Radiation Field.
[3] ISO 8529-3:1998, Reference Neutron Radiations-Part 3: Calibration of Area and Personal Dosimeters and Determination of Their Response as a Function of Neutron Energy and Angle of Incidence.