# Preparation of the Fast Neutron Irradiation System Using a DT Neutron Generator at KAERI

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## 1. Introduction

Korea Atomic Energy Research Institute (KAERI) is establishing the fast neutron field of 14 MeV to be used for a neutron shielding test and a dosimetry purpose. It is optional to neutron sources, $^{252}$Cf and AmBe, which is being used for routine calibration and irradiation test at KAERI. A 14 MeV neutron is produced by using a nuclear fusion reaction of Deuterium and Tritium (DT reaction). A portable DT neutron generator with a Poly-Ethylene collimator was installed and tested recently at the radiological calibration laboratory of KAERI.

This paper shows a part of work to prepare the 14 MeV neutron irradiation system using the DT neutron generator which was manufactured at the EADS SODERN, France. It especially describes the radiation level due to operation and neutron spectra to be produced after an additional collimator is assembled with the neutron generator.

## 2. Methods and Results

### *2.1 Production of the Fast Neutron Fields*

The neutron generator mainly consist of two part, a neutron tube contained tritium target of about 120 GBq and a high voltage supply unit to accelerate deuterium ion. It is a vacuum-sealed ceramic metal tube with tritium inside and an insulating gas of $SF_6$ was filled inside a generator body with a pressure of about 5 bars.

Fig. 1 shows a dimension of a part of irradiation room of KAERI and neutron and a Neutron Emitting Module (NEM) with a controller unit. The neutron generator provides a controllable emission of a stabilized neutron flux in both continuous and pulsed modes.

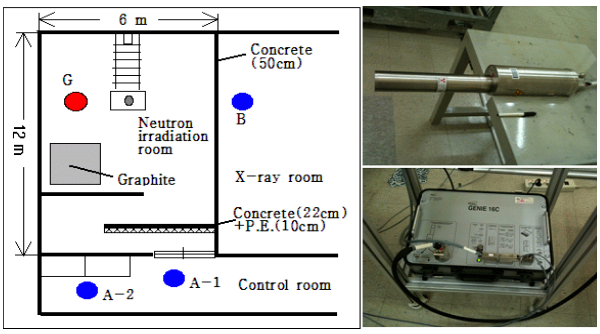


Fig 1. A schematic drawing of neutron irradiation room of KAERI(left), a NEM(right up) and a controller(right down).

NEM of the KAERI neuron generator nominally emits 1.4 x $10^8$ neutrons per second in the operation point of an applied voltage of 90 kV and the beam current of 50 μA. It was determined by radio-activation analysis method using copper disk foils. Induced radioactivity was measured by using a 2”×2” NaI(Tl) detector. The neutron pulse frequency is changeable from 10 Hz to 20 kHz and the applied high voltage to accelerate ions is variable from 70 to 90 kV depending on the neutron emission rate required.

A 14 MeV neutron emission may be considered isotopic and mono-energetic. The neutron generator can be operated with continuous, pulsed and burst modes. Dimensions of the NEM are 10.8 cm diameter and 71.5 cm length.

The collimator of Poly-Ethylene (P.E.) is designed to control the direction of main neutron beam and to reduce a neutron dose rate both inside and outside the irradiation room. Two kinds of beam direction, front and side direction to the NEM, can be used for neutron irradiation. Neutron dose rate can be decreased at the outside of the irradiation room as well as at a nearby P.E. collimator due to the use of a PE collimator.

The collimator has a dimension of is 50(H) x 50(W) x 95(L) $cm^3$. As shown in Fig 2, the P.E. collimator has two neutron beam ports, a side of the collimator and a front of the collimator. Additional metal filters of 5 cm a copper or a lead disk can be inserted inside the PE collimator to change a neutron field at the reference position.

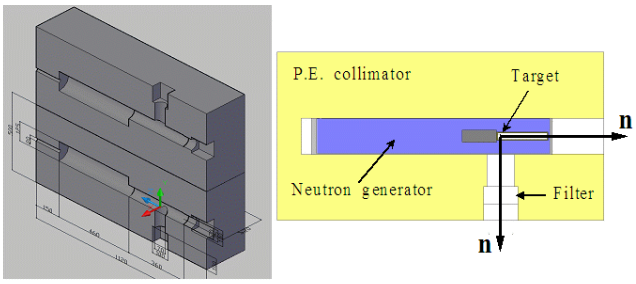


Fig 2. A schematic drawing of the P.E. collimator which is unfolded upward(left) and the beam directions(right).

### *2.2 Calculation of the Fast Neutron Spectra*

The MCNPX code[2] was used to calculate the neutron fluence spectra, the neutron fluence mean energy and ambient dose equivalent both at outside of the neutron irradiation room and at a circumference of DT neutron generator. The positions of calculation at the outside of the irradiation room are shown in Fig. 1 and they are symbolized as the front of the control console(A-2), the front of an entrance(A-1), and the next room of the irradiation room of X-ray(B), respectively. Fig. 3 shows the position of neutron spectrum calculation near the neutron generator assembly.

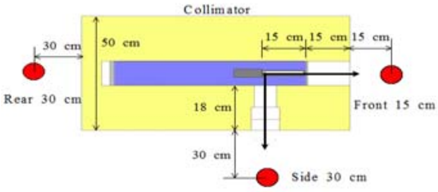


Fig. 3. Positions of neutron spectrum calculation around the NEM(An up-position is missing in this drawing).

### *2.3 Results of Calculation*

Table 1 shows the decrease of the fluence averaged energy, $E_{ave}$ and the ambient dose equivalent rate, H*(10), at the working area when using the P.E. collimator. It means that the attachment of P.E. collimator has the effect of radiation shielding as well as the effect of neutron collimation and that the safe operation of the DT neutron generator at the neutron irradiation room of KAERI is possible.

Table 1. The fluence averaged energy and the ambient dose equivalent rate at the outside of the neutron irradiation room.

| Position | Eave.(MeV) | | DE rate, H*(10) (μSv/h)[1] | |
|---|---|---|---|---|
| | without collimator | with collimator | without collimator | with collimator |
| Entrance(A-1) | 3.07 | 1.60 | $1.35 \times 10^{-1}$ | $2.54 \times 10^{-2}$ |
| Console(A-2) | 1.91 | 0.09 | $3.34 \times 10^{-3}$ | $7.22 \times 10^{-4}$ |
| X-ray room(B) | 5.34 | 4.77 | $3.42 \times 10^{-2}$ | $7.51 \times 10^{-2}$ |

[1] DE rate, H*(10) : Ambient dose equivalent rate determined by using the fluence to dose equivalent factor of ICRP 74). [3]

The shape of neutron spectra at four positions in two sides of neutron generator was similar as shown in Fig 5. Because neutron energy generated from the NEM is actually mono-energetic, most of the neutrons appeared as a fast neutron peak of line spectra and a thermal neutron peak also weakly appeared. It shows a typical neutron spectra consisting of fast, intermediate and thermal peaks.

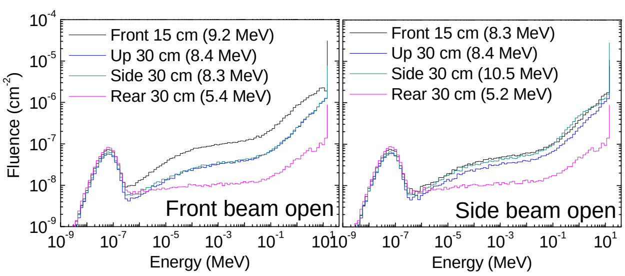


Fig 5. Comparison of neutron spectra at four positions of the neutron generator in case of the front and the side beam open condition. The fluence averaged energy is in a parenthesis.

The ambient dose equivalent rate at the reference point of the front beam open was about 27% higher than that of the side beam open case due to a short distance from the NEM as shown in Table 2. When the metal filters of copper and lead were changed in case of the side beam open, the ambient dose equivalent rate and the fluence averaged energy were not changed except those at the beam exit. Their values for a lead filter are bigger than those for a copper filter. It means that neutron multiplication process occurred in a lead struck by a 14 MeV neutron is more probable than that in a copper.

Table 2. The ambient dose equivalent and the fluence averaged energy at four positions with various irradiation conditions.

| Posi-tion | FBO[1] | SBO[2] | SBO+$F_{Cu}$[3] | | SBO+$F_{Pb}$[4] | |
|---|---|---|---|---|---|---|
| | H*(10)[5] | H*(10) | H*(10) | $E_{ave}$[6] | H*(10) | $E_{ave}$ |
| Front | 9.0 | 3.9 | 3.8 | 8.5 | 3.8 | 8.5 |
| Up | 2.7 | 2.7 | 2.5 | 8.3 | 2.5 | 8.3 |
| Side | 2.7 | 7.1 | 3.8 | 8.8 | 4.7 | 9.3 |
| Rear | 0.3 | 0.3 | 0.3 | 5.3 | 0.3 | 5.3 |

[1] FBO : Front Beam Open [2] SBO : Side Beam Open
[3] $F_{Cu}$ : Cu Filter [4] $F_{Pb}$ : Pb Filter
[5] H* : Ambient dose equivalent rate(mSv/h)
[6] $E_{ave}$ : Fluence averaged energy(MeV)

## 3. Conclusions

In order to establish the 14 MeV neutron irradiation system consisting of the DT neutron generator and a PE structure for the neutron shielding test and the dosimetry purpose, the effect of the neutron collimator made of PE was simulated by using the MCNPX code. The collimator made of PE was designed to control the direction of neutron beam toward the front and the side of neutron generator. Newly designed collimator successfully decreased the ambient dose equivalent dose rate at the working area during the operation of the DT neutron generator.

Neutron spectra at the reference position will be measured by using the KAERI bonner sphere system[4] in the next stage and they would be helpful to quantify the 14 MeV neutron calibration field effectively.

## Acknowledgement

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## REFERENCES

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