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■ 技術論文 ■

# Standard Neutron Irradiation Facility for Calibration of Radiation Protection Instruments by Radioactive Neutron Sources

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Abstract

In routine testing, the radioactive neutron sources are particularly suitable for producing standard neutron fields. The ISO TC-85 has proposed neutron reference radiation for the calibration of neutron measuring devices used for radiation protection purposes. Radiation laboratory of KSRI has installed a standard irradiation facility using $^{252}Cf$ and $^{241}Am$-Be sources for calibrating personal dosimeters according to the recommendations given in ISO TC-85. In this study, correction factors for calibration related to neutron scattering and anisotropy are obtained by experiments with commercial rem meter for demonstration purposes.

## INTRODUCTION

Measuring instruments used for radiation protection purposes in principle should be calibrated in terms of those quantities for which the limits have been specified by regulations or recommendations. At present, the dose equivalent, H, used in neutron dosimetry for radiation protection purposes is most commonly based on the fluence-to-dose equivalent conversion factors given by the NCRP[1] or ICRP[2].

Moderator type dose equivalent meters normally consist of a spherical or cylindrical polyethylene moderator surrounding a thermal neutron detector. The size of the moderator is selected so that the energy response of the monitor approximates as closely as possible to the variation with neutron energy of dose equivalent per unit fluence over the energy range of interest.

The monitoring of neutron fields is mostly done with moderator-type dose equivalent meters(rem meters). The frequent use of such devices has led to a high level of confidence in them, to the extent that they are often used as "references standards" for the calibration of less accurate neutron dosimeters.

## CALIBRATION PROCEDURE

To calibrate a rem meter, the instrument is brought into a well-defined neutron field. Calibrations is used here to mean that the reading of a device is related to the maximum dose equivalent that would be produced in a tissue equivalent cylindrical phantom by the neutron field at the same location. The calibration factors should be a unique property of the device and the neutron source spectrum, and should not be a function of the characteristics of the calibration facility. Dose equivalent, H, produced at the point of reference is related to the indication, M, of the instrument which would instead be produced at the same place under defined conditions. The calibration factor is then defined by N=H/M. In the case of neutrons with a broad energy spectrum as is generally emitted by radioactive neutron sources, the mean conversion factors, $h_\Phi$, averaged over the neutron energy spectrum are used together with the fluence,. In this case the mean fluence response is given by R=M/Φ. The calibration factor is then given by $N=h_\Phi/R$.

For an ideal irradiation facility there is no background due to air and room scattering and no source anisotropy in free space. In practice, air scattering generally amounts to only a few per cent, and the source anisotropy may be very small.

However, the contributions of room-reflected neutrons to the response of the dosimeter may be significant. These scattered neutrons have a different spectrum and a different variation with distance from the source. Therefore, they must not be considered a proper part of the calibration field but should rather be considered a type of background, and appropriate corrections made. Calibrations of the same dosimeter at different laboratories will then give the same results within the experimental uncertainties.

## EXPERIMENTS

### 1. SCATTERED NEUTRONS

For the determination of the mean fluence response, R, the fluence, Φ, and indication, M, of the instrument induced by neutrons coming directly from the source are needed. The contribution of room and air-scattered neutrons to the indication of the instrument can be taken into account by measuring the scattered portion by the shadow cone technique. Of cource the scattered neutrons derived from the wall of a hollow truncated cone filled with paraffin wax and the air-scattered neutrons between the shadow cone and the source would be exist, but they are negligible [3], Figure 1 is a schematic diagram of the neutron

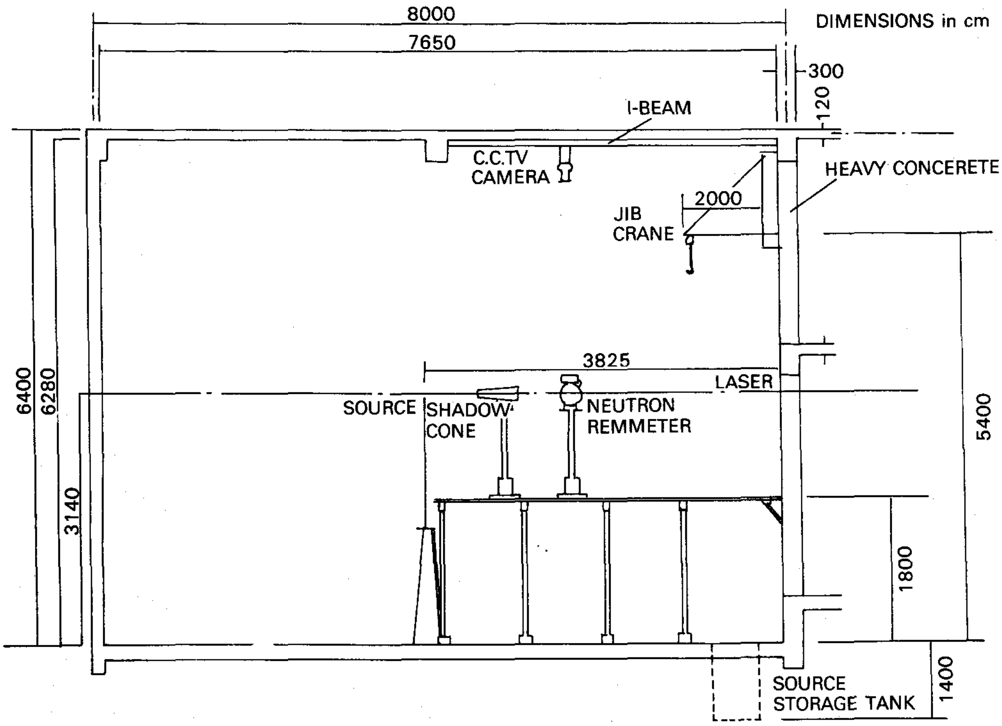


Figure 1. Schematic diagram of neutron dosimetry experimental room

dosimetry experimental room (8.0x6.6x6.4m³) at KSRI which shows to measure the scattered neutrons with shadow cone.

## 2. SOURCE ANISOTROPY

Neutron emission rate from a radioactive neutron source is used to determine the neutron fluence rate at unit distance as a isotropic point source. In practice, many of radioactive neutron sources are encapsulated and non-symmetrically formed so that there will be both elastic and inelastic scattering effects.

When these sources are used to calibrate neutron measuring devices, the detector is exposed to neutrons emerging to the source in a particular direction, usually perpendicular to the axis if the source is cylindrical.

The values of measured anisotropic factor, F (cosθ), for the neutron sources are given in Tables 1 and 2 by listing the results obtained by the neutron rem meter. Figures 3 and 4 show the anisotropic factor F(cosθ) as a function of angle θ for $^{252}Cf$ and $^{241}Am$-Be neutron sources manufactured by Amersham Co., which have been used in the radiation laboratory

**Table 1.** Measured anisotropic factor F(cosθ) as a function of angle θ for the $^{252}Cf$ neutron source.

| Cos θ | Count rate (cps) | Anisotropic factor F(cos θ) |
|---|---|---|
| -1 | 7.69 | 0.97 |
| -0.174 | 7.89 | 0.98 |
| -0.342 | 7.83 | 0.99 |
| -0.5 | 7.78 | 0.99 |
| -0.643 | 7.83 | 0.99 |
| -0.766 | 7.93 | 0.97 |
| -0.866 | 7.90 | 0.96 |
| -0.940 | 8.03 | 0.97 |
| -0.985 | 7.96 | 0.99 |
| 0 | 8.12 | 1.01 |
| 0.985 | 8.00 | 1.02 |
| 0.940 | 8.09 | 1.01 |
| 0.866 | 8.11 | 1.00 |
| 0.766 | 8.13 | 1.00 |
| 0.643 | 8.05 | 1.01 |
| 0.5 | 7.94 | 1.01 |
| 0.342 | 8.14 | 1.01 |
| 0.174 | 8.25 | 0.99 |
| 1 | 8.19 | 0.99 |

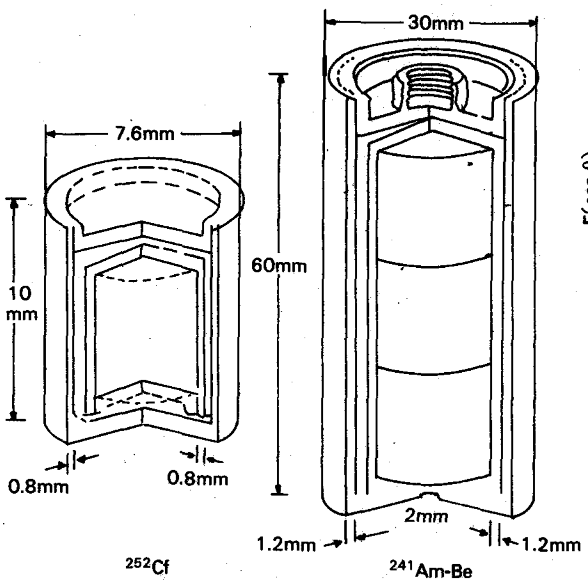


**Figure 2.** Schematic diagram of doubly-encapsuiated $^{241}Am$-Be and $^{252}Cf$ neutron sources

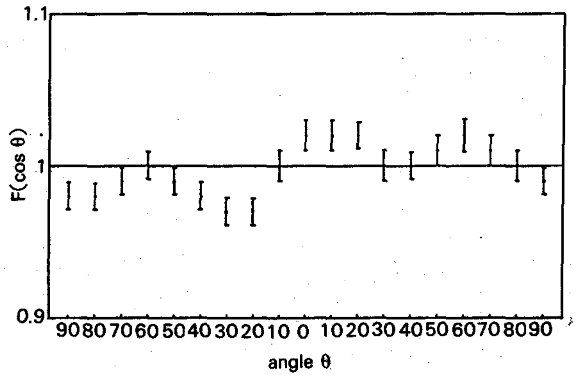


**Figure 3.** Anisotropic factor F(cos θ) to the angle θ for the $^{252}Cf$ neutron source. The quoted uncertainties are due to the statistics only.

**Table 2.** Measured anisotropic factor F(cos θ) as a function of angle θ for the $^{241}$Am-Be neutron source.

| Cos θ | Count rate (cps) | Anisotropic factor F(cos θ) |
|---|---|---|
| -1 | 6.16 | 0.94 |
| -0.174 | 6.19 | 0.96 |
| -0.342 | 6.37 | 1.02 |
| -0.5 | 6.71 | 1.06 |
| -0.643 | 6.99 | 1.04 |
| -0.766 | 7.15 | 0.98 |
| -0.866 | 7.27 | 0.91 |
| -0.940 | 7.47 | 0.89 |
| -0.985 | 7.36 | 0.94 |
| 0 | 7.57 | 1.01 |
| 0.985 | 7.43 | 1.05 |
| 0.940 | 7.51 | 1.05 |
| 0.866 | 7.49 | 1.03 |
| 0.766 | 7.30 | 1.02 |
| 0.643 | 7.42 | 1.04 |
| 0.5 | 7.23 | 1.06 |
| 0.342 | 7.20 | 1.06 |
| 0.174 | 7.41 | 1.05 |
| 1 | 7.48 | 1.04 |

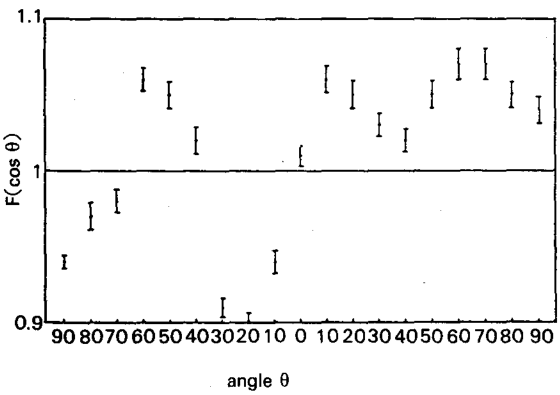


**Figure 4.** Anisotropic factor F(cos θ) to the angle θ for the $^{241}$Am-Be neutron source. The quoted uncertainties are due to the statistics only.

at KSRI.

### 3. INTERCOMPARISON OF KSRI AND ETL DATA

In measuring the neutron fluence for neutron sources which have the same neutron energy spectrum, a comparison study on the neutron fluence and be performed on the basis of international traceability of neutron standards. Neutron fluence from each of a $^{252}$Cf and an $^{241}$Am-Be neutron source were measured by the same device at the neutron dosimetry experimental rooms of ETL(Electrotechnical Laboratory, Japan) and of KSRI. Table 3 shows results of neutron fluence measurements at ETL and KSRI by means of shadow cone technique, respectively.

**Table 3.** Measured neutron fluence rate response, R, of the transfer instrument at ETL and KSRI.

| Irradiation Facility | Response, R(cm$^2$) | |
|---|---|---|
| | $^{252}$Cf | $^{241}$Am-Be |
| ETL | 0.01694 | 0.01834 |
| KSRI | 0.01904 | 0.02214 |
| Ratio R(ETL)/R(KSRI) | 0.8897 | 0.8284 |

## RESULTS AND DISCUSSIONS

For calibration procedure for a neutron radiation protection instrument using radioactive neutron sources, there are many requirements to be considered not only for the neutron irradiation facility but also for the experimental procedures. Anisotropy factors of neutron source of $^{252}$Cf and $^{241}$Am-Be are 0.9979 and 1.0124, respectively. From intercomparison of ETL and KSRI results obtained by the shadow cone technique, the difference turned out to be about 15% than to ETL result. It is necessary that the characteristics of neutron device calibration facility should be well defined by the experts and additional system in this field by means of further research and development.

## REFERENCES

1. National Council on Radiation Protection and Measurements, *Protection Against Neutron Radiation,* NCRP Report 38 (1971).
2. International Commission on Radiological Protection, *Data for Protection against Ionizing Radiation from External Sources, Supplement to ICRP Publication 15,* ICRP Publication 21 (1971).
3. Hermann Kluge, Physikalisch Technische Bundesanstalt(PTB), Private communication.

# 방사성 중성자선원에 의한 방사선방어측정기의 교정을 위한 표준 중성자 조사장치 연구

최 길웅 · 이 경주 · 황 선태
한국표준연구소, 방사선연구실

## 요 약

방사성 중성자선원은 일상적 시험에 있어 표준 중성자 방사선장을 형성하는데 적합하다. 방사선 방어상의 목적으로 사용되는 중성자 측정기기의 교정을 위한 기준 방사선이 ISO TC-85에서 제의되었다. 한국표준연구소 방사선연구실에는 ISO TC-85의 추천사항에 준하여 개인용 중성자 선량계를 교정하기 위하여 $^{252}Cf$와 $^{241}$Am-Be 선원을 이용한 표준조사시설을 설립하였다. 본 연구에서는 중성자 산란과 선원 비등방성에 연관된 교정상의 보정인자들을 실험에 의하여 결정하였다.