4–11 Ensuring the Reliability of Measurements of Exposure of Workers and Public to High-Energy γ-rays

— Establishment of the High Energy γ-ray Calibration Field —

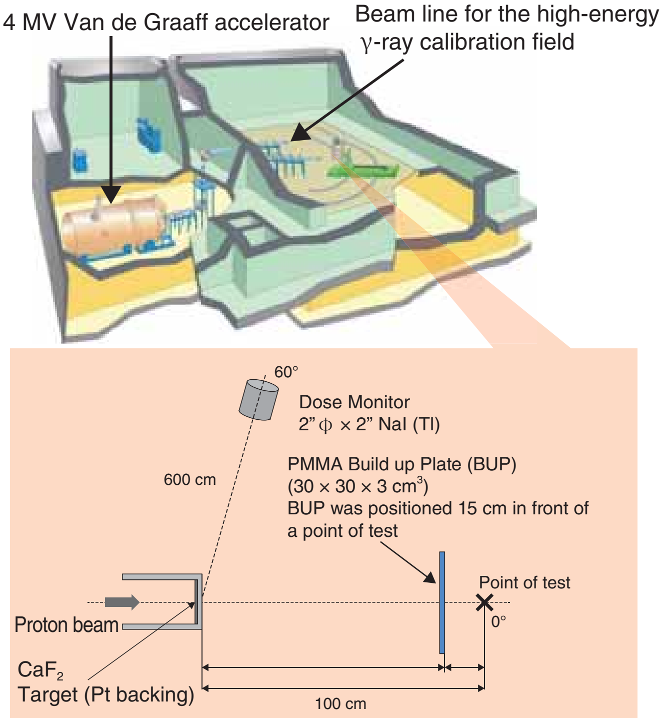

Fig.4-24 Schematic of the high-energy γ-ray calibration field (at Facility of Radiation Standards)

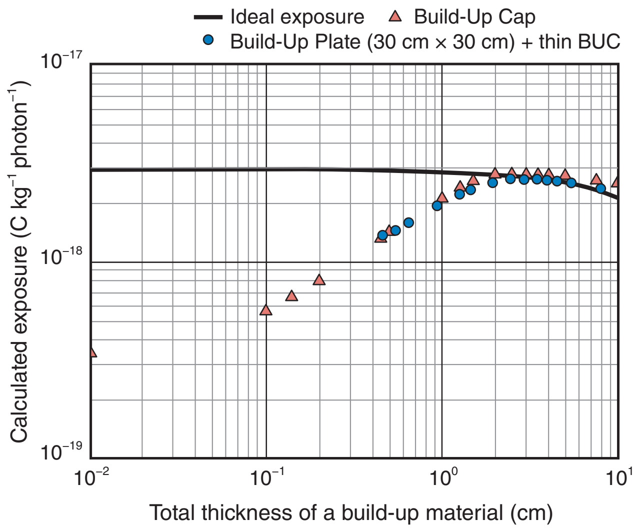

Fig.4-25 Exposures calculated at test point as a function of thickness and shape of build-up materials
Ideal exposures were calculated based on the γ-ray fluence at 100 cm and the mass-energy absorption coefficient for dry air, which reflects the attenuation of γ-ray fluence with increasing thicknesses of build-up materials. The ideal exposure represents the exposure predicted when electrons due to γ-rays fully contribute to charges collected at a point of test as well.

The 6-7 MeV high energy γ-ray calibration field was established at the Facility of Radiation Standards and serves to ensure the reliability of readings for dosimeters used in high-energy γ-ray fields.

The reliability of dosimeter readings is ensured by the so-called "calibration," which donates the periodic checks of whether dosimeter readings are correct. Well-defined radiation fields, called "calibration fields," are required for proper calibration. The FRS has established various types of radiation calibration fields, including X-ray, γ-ray, β-ray and neutrons, which it offers to companies and institutes working in the field of radiation protection.

For exposure to γ-rays, fixed γ-ray calibration fields are only available up to 2 MeV, and dosimeters have been calibrated in these fields. In contrast, the emission of 6 MeV γ-rays resulting from the $^{16}O(n, p)^{16}N$ reaction in the coolant water is widely recognized as a substantial source of radiation exposure, which is particularly relevant for BWRs. Furthermore, for therapeutic and industrial purposes, γ-rays with energies greater than several tenths of MeVs are produced by electron accelerators and high-energy X-ray generators. The calibration field for 6-7 MeV γ-rays should tell us how widely available dosimeters respond to γ-rays with these energies or higher. However, no high-energy γ-ray calibration field is available in Japan for radiation protection. We thus developed a 6-7 MeV γ-ray field produced by the nuclear reaction $^{19}F(p, \alpha\gamma)^{16}O$ using the 4 MV Van de Graaff accelerator at the FRS (Fig.4-24) for calibration purposes.

Because of the high energy of incident γ-rays, introducing an ionization chamber (IC) with a thicker build-up cap is required to precisely determine air kerma rates at a point of test (100 cm). This means that measurement conditions significantly differ from those of routine calibrations. We investigated the method of using a conventional IC coupled with the same build-up plate (BUP) introduced for routine calibrations. Throughout a series of Monte Carlo calculations, as shown in Fig.4-25, we assessed the measurement arrangement for the conventional IC and for the BUP, and found the optimal arrangement to be a BUP made of polymethylmethacrylate with the dimension of $30 \times 30 \times 3$ cm^3 and positioned 15 cm in front of a point of test. The method would allow us to properly calibrate the dosimeters that are most widely available.

In addition, introducing a cylindrical 2"ϕ × 2" NaI(Tl) scintillation detector as monitor allows us to quite precisely determine reference air kerma rates at a point of test when irradiating with γ-rays for regular calibrations.

Reference

Kowatari, M. et al., Measurement of Air Kerma Rates for 6- to 7-MeV High-Energy γ-ray Field by Ionisation Chamber and Build-Up Plate, Radiation Protection Dosimetry, vol.162, no.4, 2014, p.446-458.