KENS Radiation Activity : Structural Materials

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1. Introduction

Studies of residual radiation leveles concerning to KENS are reported. The saturated activities of produced nuclide in samples (of materials exposed to either the direct or the scattered beam of 500-MeV protons from the KEK Booster Synchrotron) were obtained by analyzing a pulse height distribution measured with a Ge(Li) spectrometer. The residual radiation levels were calculated with using the obtained saturated activities.

γ-ray spectrum measurements near accelerator structure were also done by using a pure germanium detectors and the decay cureves of residual activities were calculated with the same method used in the sample exposure.

2. Measurement of Nuclides Induced in Various Materials

0.1 cm thick samples of Al, Fe, stainless steel and Cu are placed at the beam dump entrance and the surface of the extraction septum magnet of the KEK Booster Synchrotron. At the sureface of the extraction septum magnet, the samples

were irradiated with the secondary particles produced by 500 MeV protons. (secondary particle irradiation). The gamma-ray activities of the samples were detected with a Ge(Li) detector having a detection efficiency of 10% compared to a 3"ϕ × 3" NaI(Tl) detector coupled to a multichannel pulse height analyzer. Fig. 1 shows the saturated activities per incident high energy particles (≥30 MeV) for the Al and Fe samples. The incident beam intensity for the direct exposure was obtained using the reaction $^{27}Al(p, spal.)^{18}F$. In the case of the secondary particle irradiation, it is very difficults to known the total particle flux. So the high-energy particle flux above 30 MeV was calculated with the saturated activities of $^{27}Al(n, x)^{22}Na$ and the average cross section is 20 m barn. From Fig. 1, neutron contributions were clearly seen in the secondary particle irradiation.

The exposure dose rate after irradiation time t_{ir} and cooling time t_c is given by

$$D(d) = I_0 \sum_{i=1}^{j} Q_i \cdot \Gamma_i \cdot [1 - \exp(\lambda_i t_{ir})] \exp(-\lambda_i \cdot t_c)/d^2, \quad R/h/cm^3 \qquad (1)$$

where

I_0= incident high energy particles (≥30 MeV)/sec,

Q_i= saturated activity of i-th nuclide, Ci/cm^3 per high particle

Γ_i= specific gamma-ray constant, R/h/Ci at 1 m,

λ_i= decay constant of i-th nuclids

d = distance from the material, m

The residual radiation levels for thin samples irradiated for 100 day is shown in Fig. 2. The material dependence of the residual radiation levels is nearly same with the published data. The saturated activities obtained in the measurement cannot be directly applied to the thick sample. It may be useful for the study of residual radiation level to measure the saturated activities both for the direct and the secondary particle irradiation as the function of the sample thickness.

3. Measurements of Gamma-ray Spectrum Inside the Accelerator Room.

Radionuclides induced in accelerator structures were measured by using a pure Ge detector having a detection efficiency of 3% compared to a 3"ϕ × 3" NaI(Tl) scintillator and a portable multichannel pulse height analyzer. Fig. 3 shows the measured pulse-height spectrum 2 hours after the beam-off near the extraction septum magnet of the Booster Synchrotron. (Booster M3) Identfied nuclides except ^{24}Na in Fig. 3 mainly produced in the vacuum chamber or the magnet. ^{24}Na may be produced in the concrete walls via the spallation reaction of Si or the thermal capture reaction of ^{23}Na.

The relative activities of identified nuclide were obtained from the photo-peak area and their relative detection efficiencies.

The decay of the exposure dose rate can be calculated with eq. (1) by using the relative activities instead of the saturated activities. In Fig. 4, the decay of the total exposure dose rats at the Booster M3 is shown with that of the exposure dose rate due to each individual nuclide. The shape of the decay curve is similar to that of stainless steel by 500 MeV protons in Fig. 3 after 100 hours. This shows that the residual radiations in the accelerator tunnel are caused from the nuclides produced in the vacuum chamber by the direct reaction of 500 MeV protons except ^{24}Na in the concrete wall.

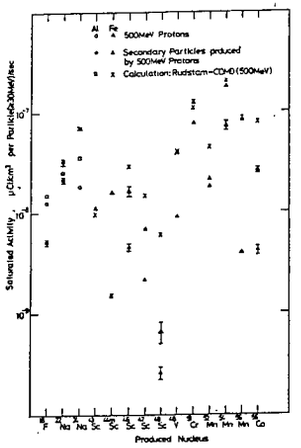

Fig. 1 Saturated activities induced in Al and Fe.

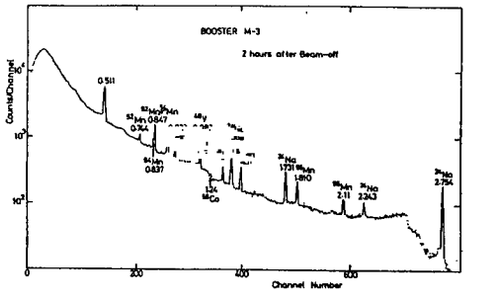

Fig.3 Pulse height distribution of gamma-rays in the Booster room.

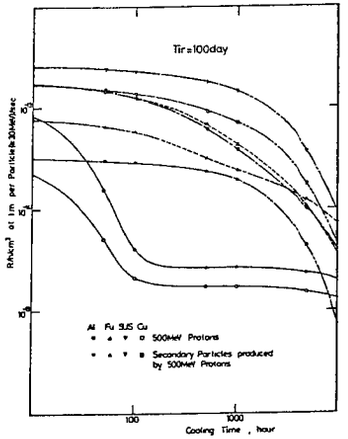

Fig.2 Residual radiation decay curves for thin samples for 100 days.

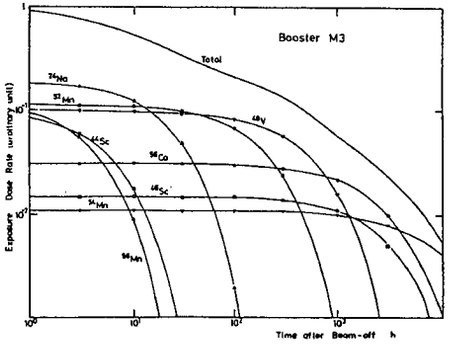

Fig.4 Residual radiation decay curve in the Booster room.