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Transmission of Betatron Bremsstrahlung through Materials

Tomonori HYODO*

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Attenuation of dose rate of bremsstrahlung produced by 20 and 32 MeV electrons was calculated using attenuation kernel method for iron, lead, ordinary concrete, and heavy concrete barriers. The results are shown as attenuation curves.

I. INTRODUCTION

Betatrons have been constructed in many hospitals recently. Guide and data books of the shield design was published. In the usual calculation, of the data of one-tenth thickness or attenuation coefficient of one-third maximum energy are used. On the construction of the betatron of Kyoto University Hospital, the author made check calculation by multi-group attenuation kernel method. This method usually applied to the reactor shielding calculation, but no paper of application of the method to the bremsstrahlung appeared on periodicals before the betatron construction.

Experimental results of the penetration of betatron bremsstrahlung was published recently. The penetration calculation was carried out for the same material by the author using same computer code for the betatron shielding, and compared to the experimental results. The results of the calculation is shown in this paper.

II. PENETRATION OF BREMSSTRAHLUNG

The calculation was carried out by the multi-group attenuation kernel method. The exposure dose rate of a point A at a distance of x cm from a point isotropic bremsstrahlung source S and the absorber of t cm thick wall placed perpendicular to the line SA is shown as,

\[ D = \frac{1}{4\pi x^2} \sum_i \eta(E_i) B(E_i, t) E_i Q(E_i) \Delta E_i e^{-\mu(E_i)t} \]  

where \( E_i \) is an intermediate energy of the interval \( \Delta E_i \), \( \eta(E_i) \) transfer coefficient from energy fluence to exposure dose rate, \( B(E_i, t) \) a build-up factor for the gamma ray of energy \( E_i \) and for an absorber of thickness \( t \), \( Q(E_i) \Delta E_i \) photon number of \( i \)-th energy interval emitting from a point isotropic source per second, \( \mu(E_i) \) attenuation coefficient of gamma rays.

The energy intervals were decided considering the change of mass attenuation coefficients and bremsstrahlung spectra with energy as shown in Table I. Spectra of thin target bremsstrahlung for the incident electron energy of 32 MeV and 20 MeV

* Department of Nuclear Engineering, Faculty of Engineering, Kyoto University, Kyoto.
* Kyoto University Hospital Betatron was constructed in 1966.
Table I. Intermediate Energy of Interval, \( E_i \), Interval Width, \( \Delta E_i \), and X-ray Spectra \( Q_i \) in Equation (1).

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<tr>
<th>Energy Interval</th>
<th>X-ray Spectra Arbitrary Units</th>
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<tr>
<td>Intermediate Energy, MeV</td>
<td>Upper Energy MeV</td>
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<tr>
<td>0.2500</td>
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<tr>
<td>0.6000</td>
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The mass attenuation coefficients of iron, lead, ordinary concrete were interpolated from the table calculated by Davisson,\(^7\) the coefficient of heavy concrete was composed by Fe (54.81 wt\%), O (35.6 wt\%), Si (4.5 wt\%), Al (0.37 wt\%), H (0.25 wt\%), Ca (4.48 wt\%), Mg (0.08 wt\%).

Build-up factors of gamma rays for these material were interpolated by Barger's formula

\[
B(E_i, t) = 1 + c(E_i) \mu(E_i) t e^{d(E_i) \mu(E_i) t}
\]

where \( c(E_i) \) and \( d(E_i) \) are parameters. The values of these parameters were obtained from tables in a paper written by Trubey.\(^8\) For the gamma-ray energy over 10 MeV the build-up factors of 10 MeV were used in this calculation because there is no published data of build-up factors in this region.

### III. RESULTS OF CALCULATION AND COMPARISON WITH EXPERIMENT

Results of calculation are shown in Figs. 1. to 4. For the purpose to know the contribution of build-up factors, calculated data without build-up factor are shown in these figures.

In these figures measured values\(^5\) are plotted. They show good agreement.
Penetration of Bremsstrahlung

Fig. 1. Figs. 1-4 X-ray dose rate transmitted through barriers.
Fig. 2.
Penetration of Braggstrahlung

Fig. 3.
ACKNOWLEDGMENT

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REFERENCES


