Small Cobalt-60 Irradiator—Gamma Dose Distribution in its Working Chamber

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An irradiator containing about 10 curies cobalt-60 designed and constructed foı use in studies of radiation effects in glasses and crystals, is described. The dose rate distribution in its working chamber (80 mm in dia. ×110 mm in height) determined by the use of the glass dosimeter is given.

INTRODUCTION

For the investigations of the effects of gamma radiation in glasses and crystals, a small specially designed cobalt-60 irradiator, about 1000 kg in weight, 43 cm in dia. ×64.5 cm in height, containing 9.8 curies cobalt isotope was installed at the Ceramic Laboratory, Institute for Chemical Reseach, Kyoto University, Takatsuki, on February 17, 1958. The irradiator was designed and made at Kobe Kogyo Corporation, Kobe, at the following requests of the authors : (1) The irradiator must provide satisfactory lead protection so that the specially shielded room is not required. (2) It must be convenient in putting test specimens easily and quickly in and out of the working chamber so that the measurements of radiation effects, *i.e.*, color changes, could be made without delay for minimizing the effect of their color fading. (3) In its working chamber the test specimen must be placed as close as posible to the cobalt source, if necessary, so that the efficient provision of gamma-ray flux of high dose (5×10^4 roentgen per hour if possible) could be secured even with the cobalt source of small curie.

The present report contains a rough sketch of the construction of irradiator together with the results of the authors' measurements of the gamma-ray dose distribution in the working chamber by the use of the glass dosimeter.

CONSTRUCTION OF THE IRRADIATOR

The cross section of the irradiator containing about 10 curies of Co-60 is shown in Fig. 1 and 2. Four pieces of source of the coin type (C), each 10 mm in dia. ×1 mm in thickness, whose total strength was 9.8 curies (Feb. 5, 1958), are encased in piles in a small aluminium case (N) and are placed in a hole made on a circumference of a lead drum of 16 cm in dia. (F). A screw pin (P) is used to fasten the aluminium case (N) to the lead drum (F). Test specimens to be irradiated are placed on shelves of vinyl plate in the working

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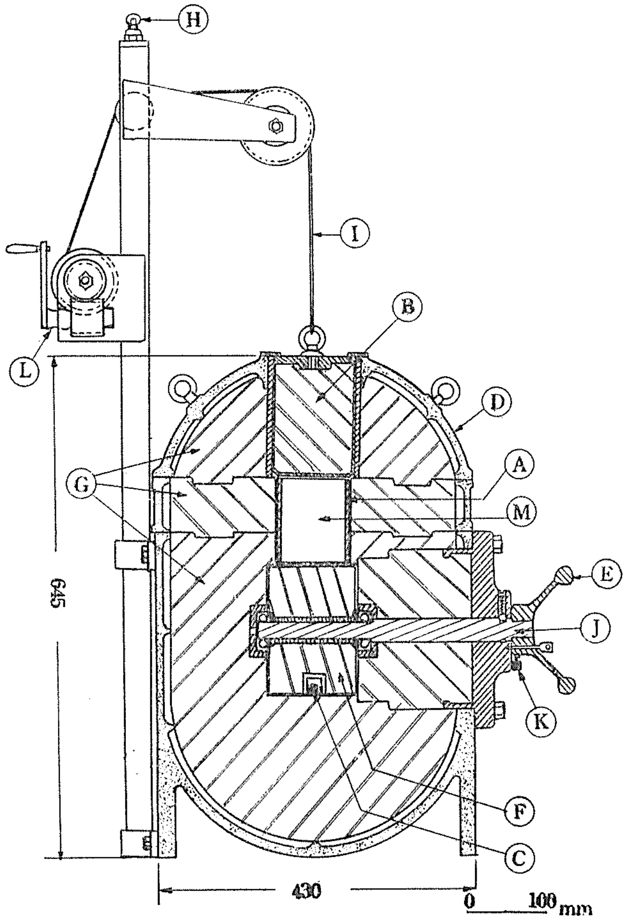

Fig. 1. The cross section of the irradiator.

A : Aluminium can B : Brass cover C : Co-60 source D : Cast iron cover
E : Handle F : Lead drum G : Lead wall H : Pilot lump
I : Steel rope J : Steel shaft K : Switch L : Winch
M : Working chamber

chamber (80 mm in dia. ×110 mm in height) (M) hemmed in the aluminium wall (A) of 1-3 mm in thickness. The Co-60 source may be brought to either position, directly below the bottom of the working chamber or below but 16 cm apart from it, by rotating the lead drum at the turn of the handle (E). When the Co-60 source is in the latter position, the test specimens can be put in and out of the working chamber by hand without any danger while a brass cover (B), 90 mm in dia. ×160 mm in thickness, is raised by a steel rope (I) with a winch (L). When the Co-60 source is in the former position, *i.e.*, in process of irradiation, the distance between the Co-60 source and the test specimen placed at the center of the bottom of the working chamber is 7 mm (Fig. 2). As will be described later the dose rate at this position is 45×10^3 roentgens per hour. The working chamber is enclosed with a lead wall (G)

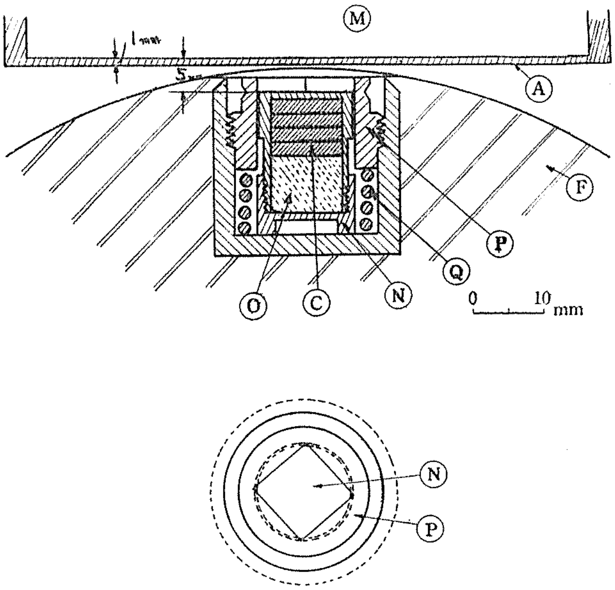

Fig. 2. The cross section of the Co-60 Source.

A : Aluminium can C : Co-60 source F : Lead drum M : Working chamber
N : Aluminium case O : Filler P : Screw pin Q : Spring

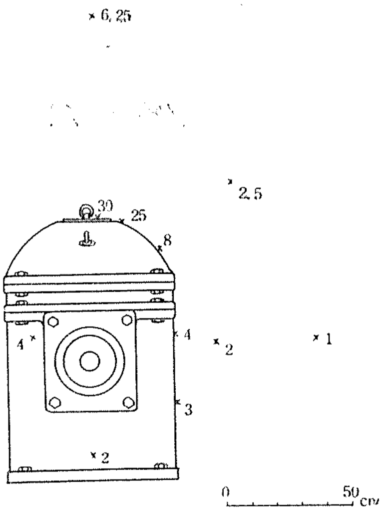

Fig. 3. Lealeage rodiation fluxes out side the irradiator (mr/hr)
(In process of irradiation)

of about 15 cm in average which protects gamma-rays almost completely so that no more shield is needed outside the irradiator; leakage radiation fluxes outside the irradiator, which were measured with a dose rate meter and a Geiger counter, are shown in Fig. 3.

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GLASS DOSIMETER

One of the characteristic features of the glass dosimeter is its small size compared with other dosimeters such as the ion chamber and the chemical dosimeter (Fricke's dosimeter[1]) *i.e.*, its minimum size so far as the authors know is about 3×3×1 mm which is satisfactory for measuring its color change before and after the irradiation by means of a commercially available spectrophotometer. Hence it is especially fit for use in dosimetry in a small space where the dose rate gradient is fairly steep; for instance in a case such as the working chamber of irradiator now being used by the authors. Among glass dosimeters[2~5] the glasses containing silver or cobalt have been known to be the best for its superiority in sensitivity to gamma-rays or non-fading characteristics after irradiation. At present, however, they are still unmarketable and hence expensive. Recently Bauman[6] and Kondo[7] have reported that the ordinary plate glass can be used satisfactory as the glass dosimeter. It has advantages in homogeneous quality and low price over any other glass dosimeters.

In the present study, pieces of glass cut from a mother plate-glass into 15×6×1.75 mm in size were used as the glass dosimeter. They were placed at various positions in the working chamber, exposed to the gamma-rays for a definite period, and, after taken out from the working chamber their increases in light absorption at 420 mμ were measured by the spectrophotometer (Hitachi EPU-2A type).

For the calculation of dose rate was used equation (2′) which was derived from Kondo's equation (1) with slight variations. Kondo's equation for the plate-glass irradiated by gamma-rays is

$$u = k\cdot\tau^{1-\lambda}\cdot d\cdot e^{-bd}/1-\lambda\cdot f(t/\tau) \qquad (1)$$

where: d = dose rate of gamma-rays (kr/hr);

u = increase in light absorption coefficient at 420 mμ per unit length (cm) of the glass irradiated;

τ = time of irradiation (hour);

λ = fading index obtained by the equation $\lambda = e^{-11+0.03T}$, where T is the absolute temperature;

t = time elapsed from the termination of irradiation to the light absorption measurement;

$f(t/\tau)$ = fading factor obtained by the equation

$$f(t/\tau) = (1+t/\tau)^{1-\lambda} - (t/\tau)^{1-\lambda};$$

k = constant for the plate-glass $= 1.60\times10^{-2}$;

b = constant for the plate-glass $= 2.2\times10^{-2}$.

The authors' own experimental tests on Kondo's equation has indicated that λ depends not only on the temperature but also on the time of irradiation and, hence, it accords more accurately with experimental results if a term $\tau^{1-\lambda}\cdot e^{-bd}/1-\lambda$ in Eq. (1) be substituted for $\tau^{1-\lambda_\tau}/1-\lambda_\tau$, where

$$\lambda_\tau = 0.120\, e^{0.0076\tau} \quad \text{at } 15^\circ\text{C}'.$$

The modified equation is

$$u = k' \cdot d \cdot \tau^{1-\lambda\tau}/1-\lambda_\tau \cdot f(t/\tau) \qquad (2)$$

If the light absorption measurement be made immediately after the irradiation, t becomes negligibly small, so that $f(t/\tau)=1$. Then Eq. (2) may be simplified to

$$d = k'' \, u \, 1-\lambda_\tau/\tau^{1-\lambda\tau}. \qquad (2')$$

where $k''=1.47\times10^2$ for the plate-glass at 15°C.

DOSE DISTRIBUTION IN THE WORKING CHAMBER

Dose rate was measured at 48 points by placing the glass dosimeters in the working chamber. The values corresponding to these points are given in Fig. 4. The hatched areas in Fig. 4 represent the effective area of the glass dosimeters through which monochromatic beams narrowed by a slit are passed in the spectrophotometer during absorption measurement. From the observed

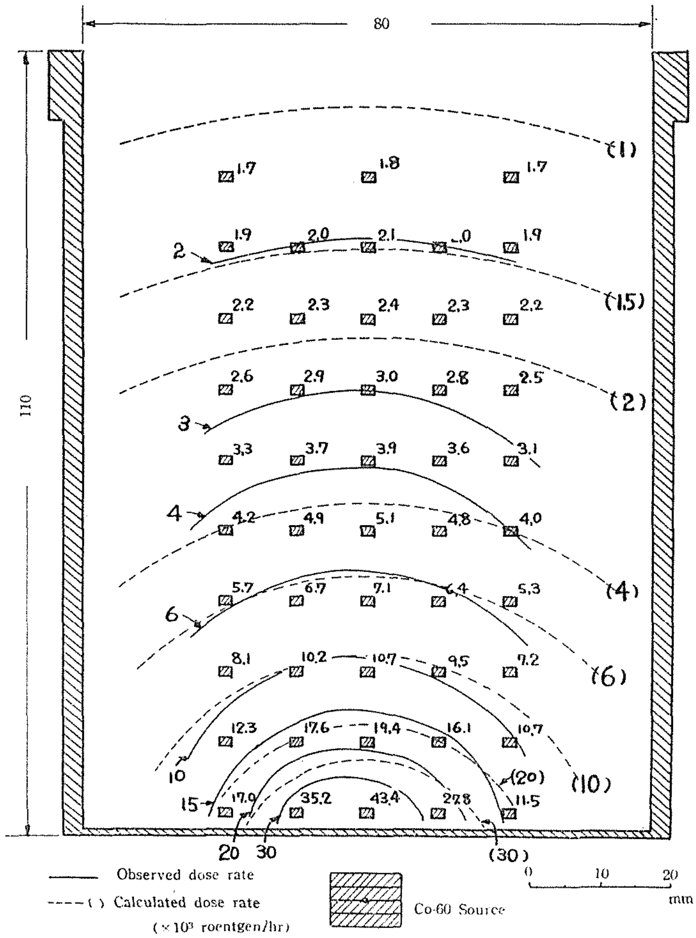

Fig. 4. Dose distribution in the working chamber.

values contours for dose rate were deduced which are shown by solid lines in Fig. 4. Fig. 4 indicates that the dose rate of gamma flux in the working chamber ranges from 45×10^3 to 1.7×10^3 roentgens/hour. The dose gradient at the point of the highest dosage, *i.e.*, 45×10^3, is about 15×10^3 and 20×10^3 roentgens/hour/cm in the longitudinal and latitudinal directions towards the Co-60 source, respectively, which still enables the irradiation with the uniformity within $\pm7\%$ if the size of specimen to be irradiated is smaller than $10\times10\times1$ mm.

Dashed lines in Fig. 4 represent contours for the dose rates calculated on the assumption that the total intensity of Co-60 source be concentrated to a geometrical center of the source. Moreover, in our calculations, scattering and build-up effects were ignored. A comparison between the observed and the calculated dose rate indicates clearly the effect of scattering by the lead wall, especially, at the part far away from the Co-60 source.

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