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ARAB REPUBLIC OF EGYPT
ATOMIC ENERGY ESTABLISHMENT
RADIATION PROTECTION DEPARTMENT

RADIATION SAFETY GUIDES FOR THE INSHAS ELECTROSTATIC GENERATOR UNDER PROTON ACCELERATION

By

A.M. EID and S.M. MORSY

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NUCLEAR INFORMATION DEPARTMENT
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ABSTRACT

The photon dose distribution along the beam direction of the 2.5 MeV electrostatic generator of the Nuclear Physics Department, AEE of Egypt has been measured by differnt types of detectors. The experiments were carried out under different machine operating conditions while the (p,α) reaction on a Co^{59} target takes place. In this case detectors of high sensitivity and known energy dependence are required to measure only one sort of radiation (photons). The detectors were located at sites where personnel might possible be exposed to an adverse amount of radiation. The results afforded, give usefull estimate of the photon dose distribution at the different Van De Graaff areas.

1. INTRODUCTION

The 2.5 MeV Van De Graaff of the Physics Department of the Egyptian AEE is vertically mounted, and designed to accelerate both positive ions as well as electrons[1]. The Radiation Protection Department attempts to describe the radiation field as accurately as possible and to gain more knowledge about the nuclear reaction and the spectra and intensity of the emitted radiations. From the description of the radiation field, it becomes possible to derive by calculation farther parameters of interest such as the energy dependence response of the detectors, and the relation between dose values and fluences. Such information will provide more insight into the physical basis of radiological effects, and give more understanding to their implications in radiation protection.

Generally, the electrostatic generator is operated with proton or deutron beams, when operated with proton beam, it becomes a source of electromagnatic radiation; and when operated with deutrons, it becomes a source of neutrons and photons.

The present work aims to investigate the photon level distribution in the beam path where the (p, α) reaction takes place on a Co^{59} target. There are two sources of photons in and around the accelerator. a) scattering of charged particles or radiative capture (p, γ) taking place somewhere in the beam path. b) X-ray may be produced whenever the Van De Graaff collector (made from stainless steel of diameter 70 cm) is bombarded by high speed electrons. From the protection point of view, this situation demonds some attention to be given towards the measurements around the ion source.

2. EXPERIMENTAL PROCEDURE

2.1 Detectors:

The detectors used in these investigations were chosen not only to estimate the quantity but also the quality of radiation in order to correct the energy dependence response of the detectore to be used. For radiological protection purposes, the quantity of interest in radiation field is the mean exponsure rate (in R/h) or dose-equivalent rate (in rem/h) at any point. The following detectors were used to assess the radiation level :-

a) Survey meter Type H-1326 with external G.M. tube. It is a direct reading battery operated count rate meter which is used for the detection of extremely low levels of radiation (5 μ rem/h-3mrem/h) gamma-rays with an accuracy of $\pm$ 13%.

b) Survey meter type PYTT-1 with external G.M. tube. It is a direct reading battery and A.C operated rate meter which covers the range from less than 1 mrem/h up to 36 rem/h with an accuracy of $\pm$ 6%.

c) Perssonel monitoring film which consists of a cellulose base coated on both sides with emulsions containing silver halide crystals in gelatine. This covers the range from 22 mrem to 800 rem with an accuracy of $\pm$ 20%. With the help of suitable holder containing appropriate filters the monitoring film can record both quantity and quality of photons.

d) Thermoluminescent dosimeter (TLD) in the form of ^{7}LiF loaded Teflon discs. These are 0.8 cm diameter, 0.4 mm thick, with 6% phosphor loading (Teledyne type S.D-LiF-7). This covers the range from 100 mrem-1000rem with an accuracy of $\pm$ 5%.[5]

2.2 Calibration:

Calibration of the different types of detectors was performed by the use of standard gamma-ray sources such as 2.9 μCi of Co^{60} ; 50 mg of Ra^{226} and TLD calibrator containing 120 mCi of Cs^{137}.

2.3. **Experimental:**

Measurements of radiation levels at different localities of the Van De Graaff building were performed during proton acceleration with energies between 1-2.5 MeV and Faraday input current between 5 - 50 μA. The work areas of interest were the measuring, target and Vacuum rooms on the ground floor, and on the first floor were the control and ion source rooms. Preliminary results indicate background radiation level in the counting and the control rooms. In the vacuum and the target rooms, the radiation level is low. In the ion source room the radiation level is relatively high. These results provide an incentive to investigate the photon radiation exposure in several strategic sites in the area around the steel pressure vessel. The layout for these sites is shown in Fig.(1). The detectors were placed at six positions (P_1 - P_6), that represent the passage of the radiation worker from the door to the upper plexi-glass window. These are as follows:-

1) At the outer side of 13 cm diameter plexi-glass window at 280 cm height (used for watching the beam focusing) (P_1).

2) At the outer side of 13 cm diameter plexi-glass window at 120 cm height used for watching the belt (P_2).

3) The positions (P_3 - P_6) were 150 cm height placed on wooden holders (to correspond to the mean height of human chest), and at distances 1.5, 4.5; 8 and 9.5 meter from the outer surface of the steel pressure vessel respectively. Measurements were done at different machine energies from 1 - 2.3 MeV where the input Faraday current is constant at 15 μA. Also at different Faraday input current from 5 - 50 μA where the machine energy was 2.0 MeV. The proton energy (E_p) may be calculated from the magnetic field strength (H) in Oristed using the relation[3],

$$E_p = K H^2$$

Where K is a constant value determined experimentely during the calibration of the Van De Graaff and was found to be $K_p = 5.897$.

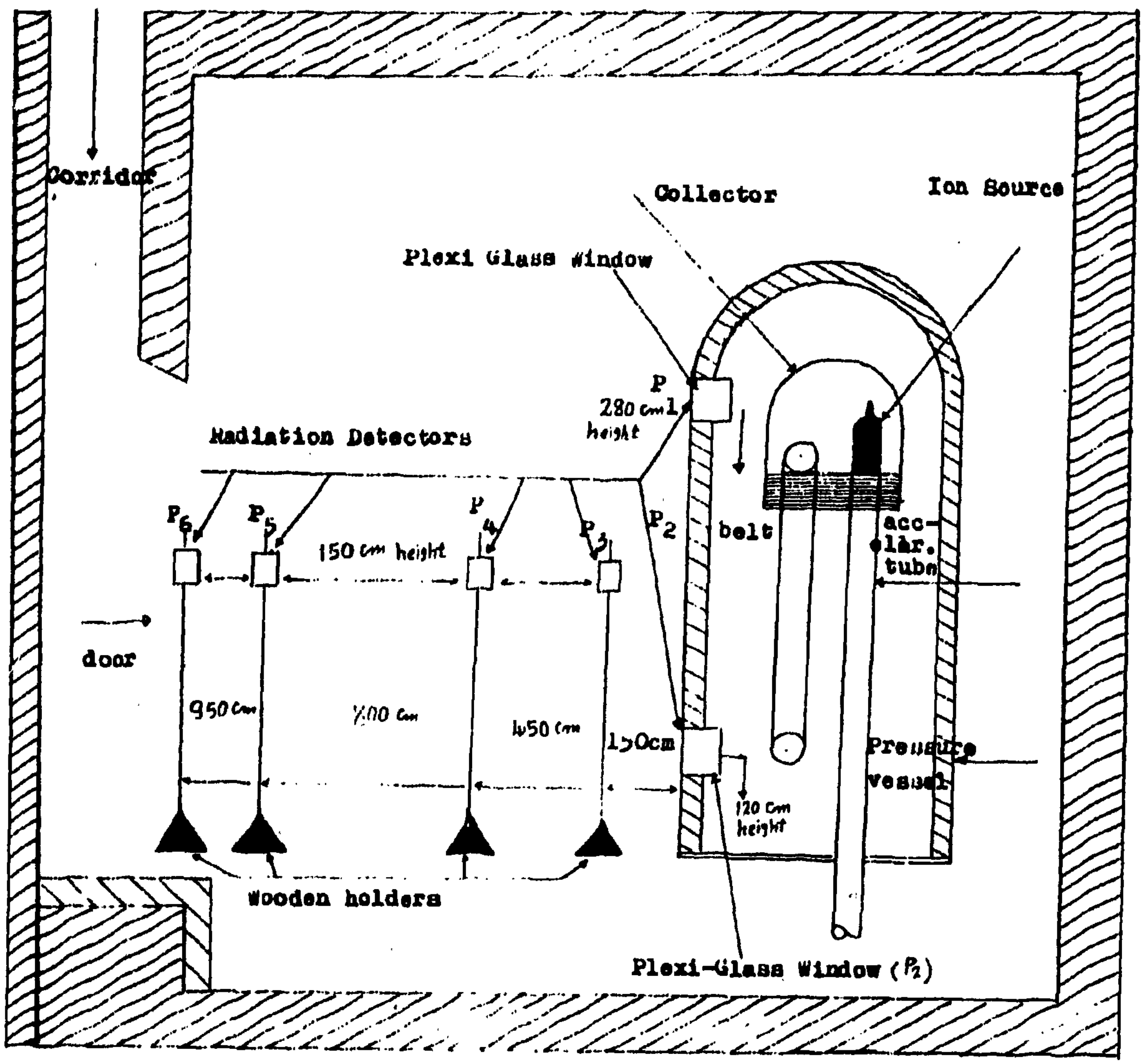


Fig. (1) Schematic Diagrame of Experimental Layout Inside The Van De Graaff Ion Source Room.

3. RESULTS AND DISCUSSION

3.1 Assessment of radiation dose-equivelent:

As previously mentioned, two direct reading dosimeter of radiation survey instruments type were used, as well as two personnel monitoring devices, the film badge and TLD.

For the film badges; the exposed films are simultaneously developed with a set of calibrated films (exposed to known values). Comparison of densitometer measurements of both sets of films, helps to evaluate the unknown photon dose-equivalent using the characteristic curve.[4]

For the ^{7}LiF - TLD discs, the exposed discs are simultaneously measured with a set of calibration discs 24 hours after exposure to allow for the natural fading of the low peaks. Comparison of the TL signals of both sets of discs measured by Harshaw TLD reader (where the maximum tray temperature is 240°C in 30 seconds), helps to evaluate the photon dose-equivalent. The response is linear up to about 10^3 rem gamma-rays.[5]

3.2 Effective energy Measurements:

The mean effective energy of photons may be estimated from the film badge quality ratio.[4] This is defined as the ratio between the apparent dose under the dural filter and the apparent dose under the ten filter in equivalent Ra^{226}-gamma-rays. Fig.(2) represents the quality ratio as a function of effective photon energy. This calibration was done by exposing the photographic film badges to different photon energies emergent from Philips 250 kV_p-25 mA deep therapy X-ray unit type 11645/08 operated at different voltages and using different filterations. From the quality ratio, the mean effective photon energy may be estimated with an error of ± 8%.

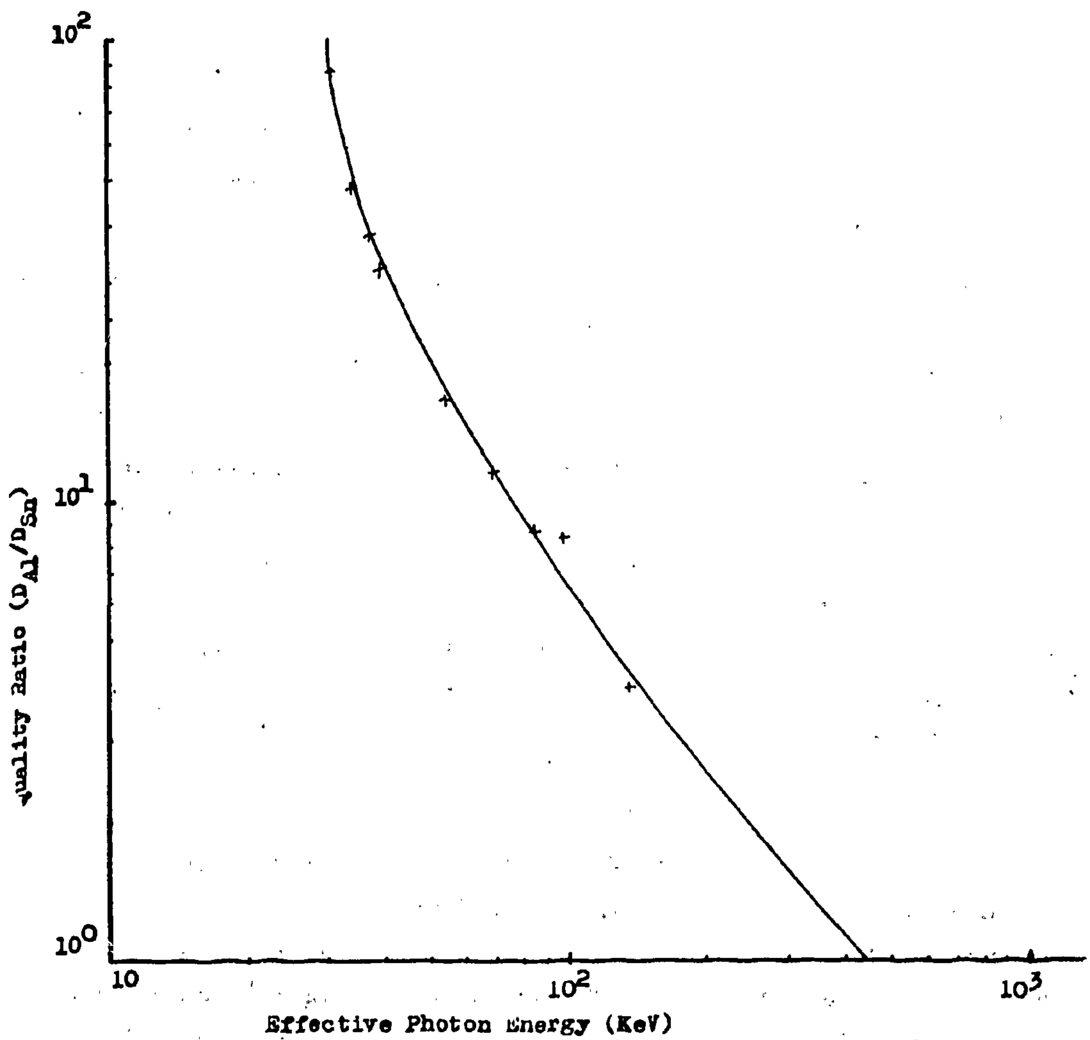


Fig. (2) Variation of the Quality ratio Factor with Photon Effective Energy.

The mean effective photon energy were estimated in the present experiments at different Van De Graaff proton acceleration energies as given in Table(1).

Table (1)

Variation of Mean Photon Energy with the Van De Graaff Acceleration Energy

Van De Graaff Acceleration Energy	Mean Effective Photon Energy
1.0 MeV	165 ± 13 KeV
1.5 MeV	195 ± 15 KeV
1.8 MeV	200 ± 16 KeV
2.0 MeV	208 ± 17 KeV
2.3 MeV	220 ± 18 KeV
2.5 MeV	225 ± 18 KeV

These results will be used for correcting the apparent values measured by the detectors used. The correction factor (K) (detector response factor) as a function of the effective photon energy for the different detectors use are given in Fig.(3). It is clear from the figure that the estimated dose-equivalent using TLD_s and photographic films under Sn filter is energy independent in the range of the photon effecttive energies during these Van De Graaff experiments. For the G.M. Tube detector, the estimated dose equivalent may also be corrected according to the correction factor (K) given in Fig.(3).

3.3 Photon dose-equivalent levels

The photon radiation level inside the ion source room at the six positions indicated for the different machine energies and constant input Faraday current (15 μA) are given in Table(2). Results are corrected for energy dependence.

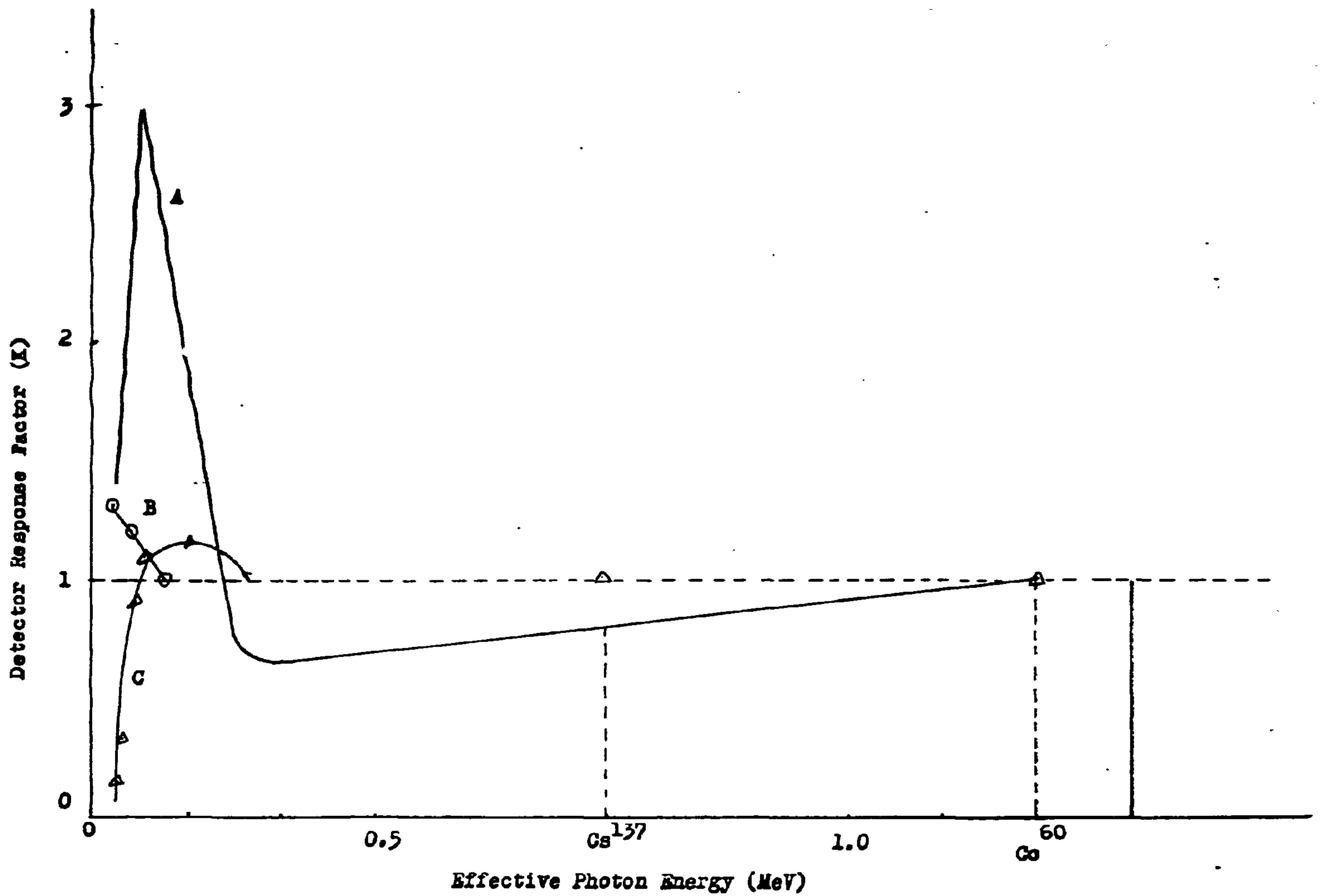


Fig. (3) Variation of Response Factor With Effective Photon Energy a) G.M.Detector b) TLD Detector.
c) Photografic Film Under Sn Filter.

Table (2)

Variation of Dose Equivalent with Machine Energy
At the Six Positions (P_1-P_6) Inside the Ion Source Room

Machine Energy	Dose-Equivalent Level in mrem/h At positions P_1-P_6					
	P_1	P_2	P_3	P_4	P_5	P_6
1.0 MeV	1)384 2)396 3)408	1)5.6 - -	1)9.8 - -	1)5.6 - -	1)2.7 - -	1)1.6 - -
1.5 MeV	1)1270 2)1075 3)1179	1)16.38 - -	1)29.0 - -	1)16.4 - -	1)8.2 - -	1)5.4 - -
1.8 MeV	1)3175 2)3120 3)3210	1)47.6 - -	1)73.6 - -	1)47.6 - -	1)21.0 - -	1)13.7 - -
2.0 MeV	1)4233 2)4120 3)4450	1)52.9 - -	1)94.1 - -	1)63.5 - -	1)31.7 - -	1)21.2 - -
2.2 MeV	1)8096 2)6780 3)6921	1)104.5 - -	1)190.1 - -	1)123.6 - -	1)66.5 - -	1)43.7 - -

1) The estimated dose equivalent given by G.M. tubes.
2) " " " " " by Film badges.
3) " " " " " by TLD discs.

Table (3) represents the relation between the photon dose equivalent and the input Faraday current at constant machine enrgy (2.0 MeV). The results are corrected for enegy dependence.

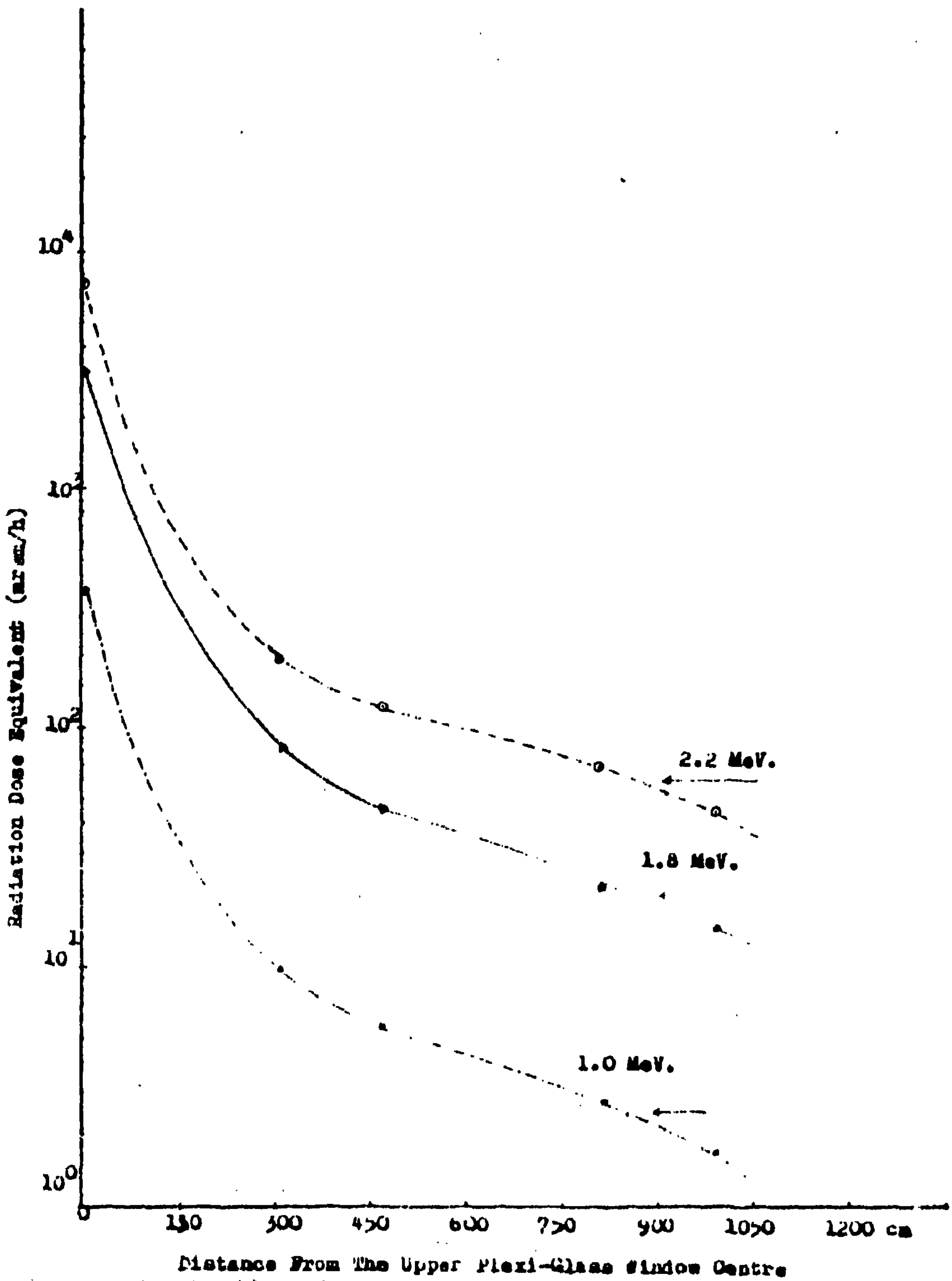
Table (3)

Variation of Dose-Equivalent with Faraday Input Current At Six Positions (P_1-P_6) Inside the Ion Source Room

Input Faraday Current	Dose Equivalent Level in mrem/h At Position P_1-P_6					
	P_1	P_2	P_3	P_4	P_5	P_6
5 μA	10512	158	231	147	68	42
10 μA	8409	116	189	105	53	31
20 μA	3889	63	95	63	32	21
30 μA	3416	53	84	53	26	16
40 μA	3258	47	74	52	24	16
50 μA	3153	42	70	47	21	14

The variation of radiation level with distance from the outer surface of the upper plexi-glass window at different machine energies are represented in Fig.(4). These results indicate that the maximum radiation level is around the upper plexi-glass window and decreases with distance from it. Results do not obey the inverse-square law since the photons may be emergent from different points of the 70cm diameter steel collector and the intensity is linear function with machine energy as presented in Fig.(5).

Fig.(6) shows the variations of radiation levels inside ion source room with Faraday input current. It indicates that the radiation level is dependent on the Faraday input current. The relation is inverse and sharp for the input current below 20 μA and slightly affected above this. These results may be explained by the fact that



Fig, (4) Variation of Radiation Level with The Distance From The Centre Of The Upper Plexi-Glass-Window.

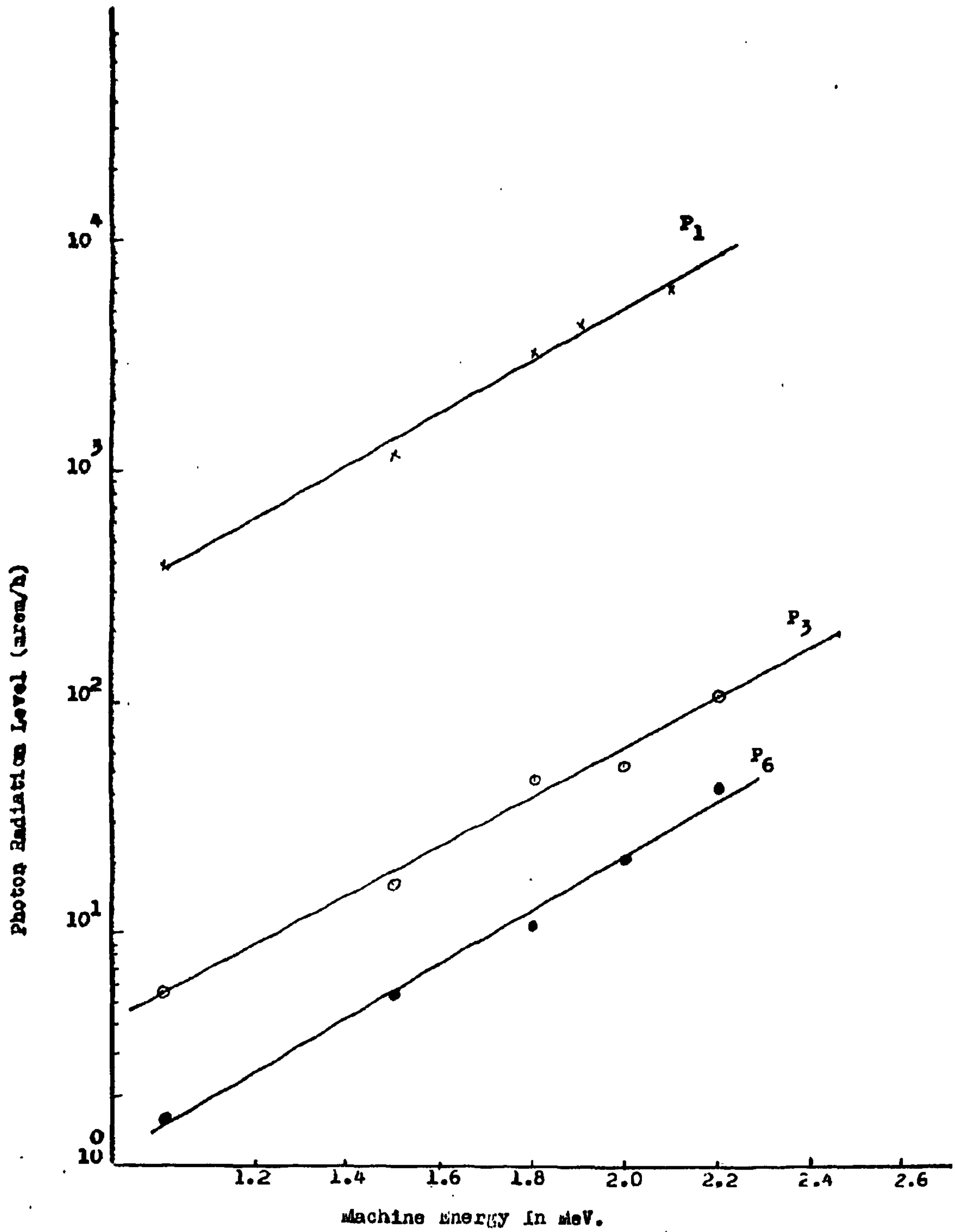


Fig.(5) Variation of Radiation dose Equivalent with the Van De Graaff Energy at Positions P_1, P_3 and P_6

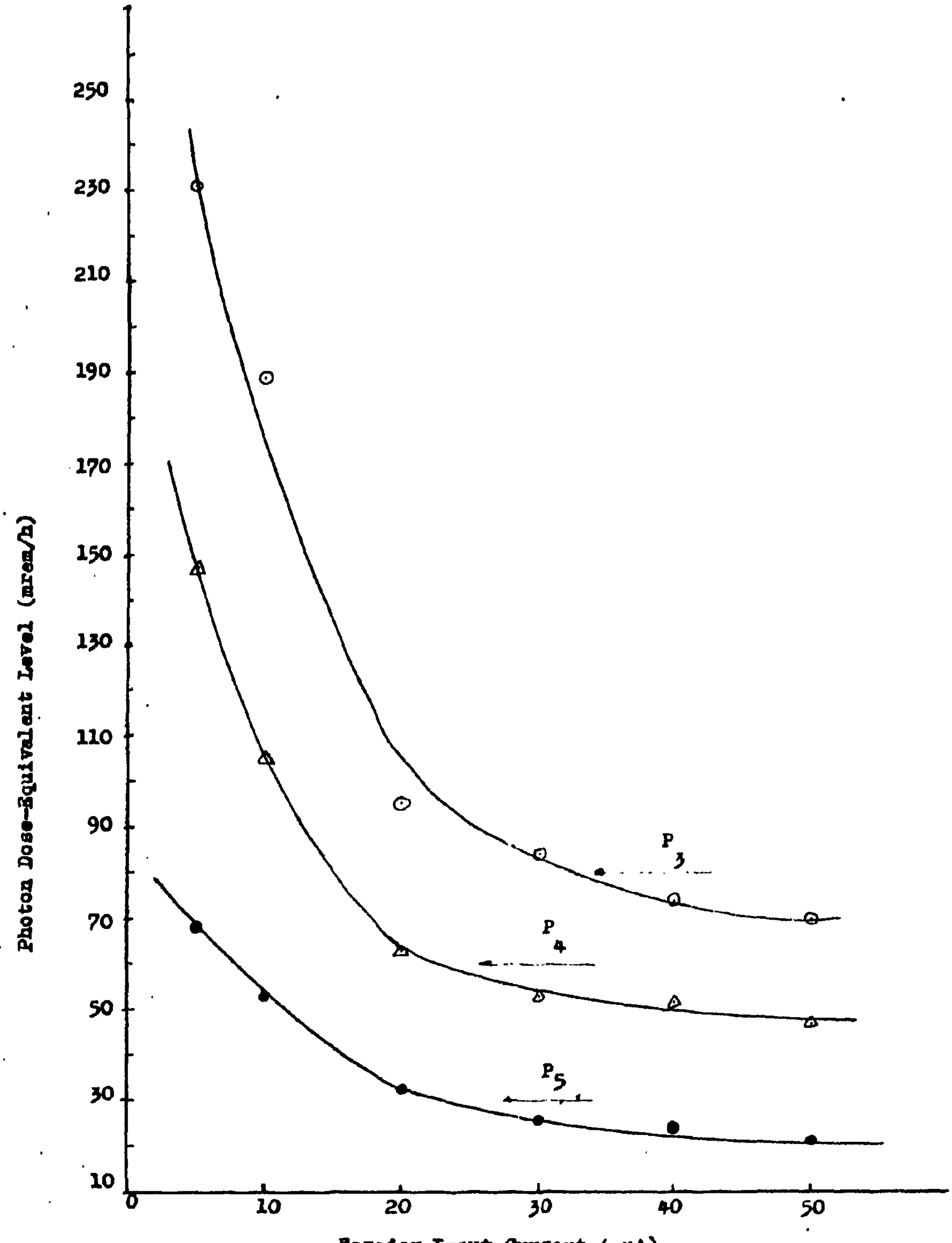


Fig. (6) Variation of The Radiation Level Inside Ion Source Room With The Faraday Input Current.

when the input current is low the charged particles intensity around the collector is high and subsequently the probability for X-ray emission increases.

To complete the measurements of radiation levels in the different Van De Graaff areas, Table(4) gives the maximum level of photon dose-equivalent inside the vacuum room as well as the target room at different acceleration energy. The maximum radiation level is found to be around the Faraday cup where secondary electrons are produced.

Table (4)

Maximum Radiation Level Inside the Vacuum and Target Rooms

Machine Energy	Radiation Level Inside	
	Vacuum Room	Target Room
1.0 MeV	317 μrem/h	9.5 μrem/h
1.5 MeV	317 μrem/h	11.7 μrem/h
1.8 MeV	2270 μrem/h	6.3 μrem/h
2.0 MeV	2370 μrem/h	9.5 μrem/h
2.2 MeV	3170 μrem/h	11.1 μrem/h

From this table, it is clear that the radiation level inside both target and vacuum rooms during (proton acceleration) is low and varing around the permissible level when avaraged over any area. The uncertainty of results inside the target room is due to the inadequate control of the Faraday output current.

The photon distribution in vacuum room at constant machine energy and different Faraday input current are shown in Table (5).

Table (5)
Maximum Radiation Level Inside Vacuum Room
at Different Faraday Input Current

Faraday Current	Max. Level	Faraday Current	Max. Level
5 μA	2690 μrem/h	30 μA	1900 μrem/h
10 μA	2220 μrem/h	40 μA	1580 μrem/h
20 μA	2370 μrem/h	50 μA	1580 μrem/h

From this table, it is clear that the radiation level inside the vacuum room is within the maximum permisible level at any beam intensity.

4. CONCLUSIONS

From the present experimental results and during proton acceleration to Co^{59} target through a potential difference between 1 - 2.3 MeV and Faraday input current between 5 - 50 μA, it is clear that the radiation hazards due to photons can be considered under the following headings.

a) In the ion source room; the photon dose-equivalent at position (P_1) is as high as 10 rem/h. This level decreases by distance from this position and does not obey the inverse square law.

Results from Figs.(5,6) reveal that the radiation level at any position in the ion source room is proportional to the machine energy and it is inversely proportional to the input current. Generally, the radiation level in the ion source room is high and this area should be considered as a forbidden zone during machine operation.

b) In the vacuum and target rooms, the radiation levels were found to be insignificant . Maximum values were found at points near the Faraday cups where secondary electrons are produced. Precautions should be taken to avoid the presence of personnel at this locality.

c) The radiation levels are negligible in both the operating and measuring rooms. This renders them safe for work occupancy.

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