Determination of Personal Dose Equivalent at INFLPR 7 MeV Linear Accelerator

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ABSTRACT

This paper presents the measurements of the personal dose equivalent performed in INFLPR - 7 MeV Linear Accelerator building by means of the secondary standard chamber Hp (10), T34035 type. The conventional true value of the personal dose equivalent $Hp(10, R, \alpha)$, in a slab phantom for the radiation quality $R$, at $\alpha$ angle of incidence between the radiation beam and the normal to the chamber front face, is directly proportional with the electric charge measured by the chamber, $QR$, for the radiation quality $S$ and the angle incidence $\alpha = 0^0$. The measurements were made for the accelerator electron operation mode.

Key Words: Radiological Protection/Personal Dose Equivalent.

INTRODUCTION

As concerns the external exposure at radiations, two operational parameters exist and show special interest for characterizing the radiation fields for radioprotection purposes. This ICRU parameters are: personal dose equivalent, penetration $Hp(d)$, personal dose equivalent, superficial, $Hs(d)$, where $d$ is the depth under a specific point on the body, or * direction inside the ICRU Parallelepiped, which is proper for the powerful penetration radiation. All this parameters are based on the absorbed dose equivalent concept in on point rather than the equivalent dose concept. After presenting the concept for these two operational parameters which characterize the radiation fields, a presentation of the some details on an ionization chamber, standard measure method and dosimetric measurements results. Measurements made in one room adjacent on irradiation hall where the 7 MeV linear accelerator, as also made available is placed.

PERSONAL DOSE EQUIVALENT

To define the parameters (1,2) related to the effective dose equivalent and equivalent in skin it is useful to stipulate some radiation fields derived from the radiation field. In ICRU 30 (ICRU, 1985) the “expanded” and “aligned” terms are given to characterize those derived radiation fields. With the expanded field, a theoretical construct, the fluence and its angular and energy distribution have the same values throughout the volume of interest as in the actual field at the point of reference. In an aligned and expanded field, the fluence and its energy distribution are the same in the expanded field, but the fluence is unidirectional.
For individual monitoring two concepts are introduced. The first one, the personal equivalent penetration $H_p(d)$ is proper for an organ or tissue placed deep into the body and that can be irradiated with powerful penetration radiation. The second concept, the personal dose equivalent - superficial, $H_s(d)$, is proper for superficial organ and tissue which that are to be irradiated will be irradiated with powerful and soft penetration radiation. The personal dose equivalent penetration $H_p(d)$, is the dose equivalent in soft tissue.

Fig. 1 - Cross section among one parallelepiped with dimensions (30 x 30 x 20) cm.

Fig. 1 shows the general view for radiation geometry, i.e. a parallelepiped phantom used for personal equivalent dose measure.

**STANDARD IONIZATION CHAMBER**

Secondary standard chamber $H_p(10)$, type 34035 was developed by Ankerhold et al. at PTB (1). The device consists in an ionization chamber made in one PMMA phantom with (30 x 30 x 15 cm) dimensions for personal equivalent dose measure $H_p(10)$, namely quality radiations that include radiation field and scattered radiation for the phantom. Main characteristics for $H_p(10)$ are: measurement volume: 10 cm$^3$; reference point: in the chamber centre, at 13.5 mm under chamber surface; answer: approximate 285 nC/Sv; chamber voltage (300 ... 500) V; leakage current: ± 10 fA and is used for photons with energy about range 15 keV – 1 400 keV. Environmental conditions in which the measurements with this chamber must be performed, are: temperature: (20 ... 40) °C, humidity: (10 ... 80) % and air pressure (700 ... 1 060) hPa.

Fig 2 - Secondary standard chamber used for personal dose equivalent.
Fig 2 is the general view of the PTW secondary standard chamber use for personal dose equivalent. Entering the ionization chamber parameters in UNIDOS dosimeter memory, including the calibration factor $NH = 3 \times 10^6 \text{ Sv/C}$ (2), the dose equivalent in Sv at $d = 10 \text{ mm}$ depth under the marked point, is obtained. Secondary standard ionization chamber was calibrated at PTW for narrow spectrum radiation quality (N), in conformity with ISO 4037-1 with the help of gamma radiation emitted by radionuclide Cs137 (661.6 keV; $T_{1/2} = 11.500 \text{ days}$, $0.079 \mu \text{Sv m}^2/\text{hMBq}$) (3).

**MEASUREMENT METHOD**

For X or $\gamma$ rays of R quality, conventional true value for personal dose equivalent in PMMA phantom, $Hp(10, R, \alpha)$, at the $\alpha$ incidence angle $\alpha$ between the beam and the normal to the phantom surface is given by the relation:

$$Hp(10, r, \alpha) = NHk(R, \alpha)Q, \quad (1)$$

where:

- $NH$ - is the calibration factor for the reference quality radiation N – 60 and the reference angle of radiation incidence angle $\alpha = 0^\circ$.
- $K(R, \alpha)$ – correction factor for the radiation quality R and the angle of a radiation Incidence $\alpha$;
- $Q$– is charge measured by the chamber.

The calibration factor $NH$, with respect to the personal dose equivalent $Hp(10)$, is determined with the radiation quality $S$-Cs and incidence angle $\alpha = 0^\circ$. It is given by the expression:

$$Nh = h_{pk}(10; S - Cs, 0^\circ) \frac{K_{a}}{Q} \quad (2)$$

where:

- $K_a$ is the conventional true value a air kerma free in air
- $h_{pk}(10)$ is conversion coefficient from Ka to $Hp(10)$ and $S$-Cs137 shows that the measurements were made for a PMMA phantom to a reference radiation $S$-Cs137 and incidence angle $\alpha = 0^\circ$.

The correction factor $k(R, \alpha)$ for the radiation quality $R = S$-Cs137 ($keV E_{pk} 662 =$) at $\alpha$ incidence angle is given by formula:

$$h_{pk}(10, R, \alpha) = (h_{pk}(10; R, \alpha) \frac{K_{a}}{Q}) \frac{1}{Nh} \quad (3)$$

where $h_{pk}(10, R, \alpha)$, Q, Ka and NH as given above.

Fig. 3 shows the correction factor values $k(R, \alpha)$ for $Hp(10)$ chamber at $\alpha$ incidence angle , at $0^\circ$, $45^\circ$, $60^\circ$, $75^\circ$ (1), so: (a) these factors are presented in ISO for radiation quality from N-10 to N-80, (b) all of them are presented in ISO for quality radiation from H-20 to H-100 plus C40 and C80 for C series in compliance with DIN 6818-1 (German standard). $\bar{E}_{ph}$ is mean value for photon energies.
Fig. 3 - Correction factor $k(r, \alpha)$ versus photon mean energy from 10-70 keV domain, for different incidence angle and different quality radiations.

Fig. 3 show the variations for correction factor of appropriate ± 20% in photon mean energy domain 10-70 keV for incidence angle between 00 and 750 and for quality radiations from N-10 and N-80; from H-20 to H-100, C40 & C80 (3).

Fig. 4 - Correction factors $k(R, \alpha)$ for different quality radiation and incidence angle.
In Fig. 4 shows one can see the correction factor value \( k(R, \alpha) \) for radiation quality N-10 to N-300 and S-Cs ISO at incidence angle \( \alpha \), at 0°, 45°, 60°, 75° and for S-Co at angles \( \alpha = 0° \) and 60°. \( ph E \) represents the mean value for photon value given from N-10 to N-120 and for N-150 to N-300, S-Cs and S-Co with ISO/FDIS 4037 (4).

From curves interpretation made in fig. 5 it results correction factor variation about ± 20% in 10-1250 keV energy domain for incidence angle between 00 and 750 and radiation quality N-10, N-300, N-10, N-120, N-150 & N-300, S-Cs and S-Co.

Further the theoretic calculation for personal dose equivalent calculation is presented for:

(a) occupational exposure considering a working daily program of 7 h/day accept him professional exposure which have like program about 7 hours/day and (b) 24 h/day population exposure.

(a) For occupational exposure the considered input data were: 364 days/year – 104 weekends = 260 days; 260 days – 5 celebration days = 255 days – 20 holiday days = 235 days; 235 days x 7 h = 1645 h/year days worked. So, 500 mSv: 1645 h/year days working = 0.303 mSv/h = 303 μSv/h. Allowable equivalent dose limit for occupational exposure: 500 mSv/year for skin, hands, legs and 150 mSv/year for lens.

(b) Allowable equivalent dose limit for population is 1mSv/years = 0.114 μSv/h meaning 365 days/years x 24 = 8760 h/year; 1mSv: 8760 h/years =1.14x10^-4mSv/h=0.114 μSv/h.

**RESULTS**

The calibration certificate for the secondary standard ionization chamber - PTW, type T34035 Hp(10), 0024 serial number, calibration mark 5576 PTB 07, specifies the following parameters: calibration factor \( NH = 3.17 \times 106 \) Sv/C (4), obtained to a Cs with source with equivalent dose rate \( H = 15.20 \pm 3\% \) mSv/h at DSC = 200 cm, the isodose diameter of 97% by 40 cm, incidence angle \( \alpha = 0° \), and correction factors \( k (Q, \alpha) = 1.00 \) for quality radiation Q and incidence angle \( \alpha \).

| Table1 |
|-----------------|-----------------|-----------------|
|                | Set 1           | Set 2           |
| \( Hp(10) \) [μSv/min] | 1.236           | 1.21            |
| \( Hp(10) \) [μSv/10 min] | 12.36           | 12.18           |
| \( Hp(10) \) [μSv/h] | 74.16           | 73.11           |
| **Equivalent dose, H, cf. NSR-01** | 500 mSv/year = 303 μSv/h; (7 h/d) | 50 mSv/year = 5.7 μSv/h; (24 h/d) |

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<th>Set 3</th>
<th>Set 4</th>
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<td>( Hp(10) ) [μSv/min]</td>
<td>1.533</td>
<td>1.43</td>
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<tr>
<td>( Hp(10) ) [μSv/10 min]</td>
<td>15.33</td>
<td>14.32</td>
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<tr>
<td>( Hp(10) ) [μSv/h]</td>
<td>91.98</td>
<td>85.92</td>
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<tr>
<td><strong>Equivalent dose, H, cf. NSR-01</strong></td>
<td>500 mSv/year = 303 μSv/h; (7 h/d)</td>
<td>50 mSv/year = 5.7 μSv/h; (24 h/d)</td>
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<td><strong>Equiv. dose population, H, cf. NSR-01</strong></td>
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Table 1 includes personal equivalent values measured with Hp(10) ionization chamber, in one chamber, the ionization chamber having the detector oriented to the hall wall where the linear accelerator is placed at 140 cm from the wall. On moment of measurement, for the sets 1 and 2 the linear accelerator was off, and 3 and 4 sets the linear accelerator was on at 2.4 Mrad/min dose rate. In the 2 and 4 sets the dosimetric measurements were obtained by accumulating the dose for in 1 hour.

In Table 1, the measurement individual equivalent dose effectuated in lab room of electronic, the phantom is installed in up position, oriented towards hall wall in which is the linear accelerator, at 140 cm visage of this; the sets 1&2 – the accelerator not was in function; the sets 3 and 4 – the accelerator in function up electrons with beam oriented towards to floor, 2.4 mrad/min.

CONCLUSIONS

The work present the ICRU concept: personal penetration dose equivalent, Hp(d) and personal superficial dose equivalent, Hs(d), where d is depth under a specified point, parameter can be determined with the Plexiglas phantom with cross section 30 x 30 cm and 20 cm depth. The measuring method with Hp (10), using secondary standard chamber Hp(10) type 34035 and its parameters, connected to UNIDOS dosimeter, is presented.

After the measurements made in room adjacent to the hall were INFLPR 7 MeV linear accelerator is placed it was fond that the obtained values are 3.7 times smaller than equivalent dose limit which is 1mSv/years = 0.114 \(\mu\)Sv/h, and consequently have no influence on the personal working in the building.

REFERENCES


(4) Calibration certificate, no. PTB-6.3-4033197 for Ionization chamber type T34035 Hp (10)-0024, PTW-Freiburg, Physikalisch-Technische Werkstatten, Germany (2007).