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Technical note

Photon dose at the maze entrance door: The comparison of flattening filter and flattening filter free working modes

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ABSTRACT

In recent years, field flattening free accelerators have been introduced in therapy practice. One of the objective of these measurements was to establish if the maze door, designed for accelerators operating with flattening filter can provide adequate shielding in field flattening free mode of operation. Linac installed in this standard one band maze vault is equipped to operate at 6 MV with field flattening filter and in field flattening free mode of operation. Series of measurements of the photon dose at the maze door (with different jaws openings and gantry positions) were performed in both operation modes with and without water canister to mimic standard therapy conditions. In this paper results of photon dose measurements, performed at the maze door of the therapy linear accelerator vault are presented in order to compare photon dose in flattening filter and flattening filter free operation modes. It was obtained that in field flattening free mode of operation, the dose at the maze door is always lower than the dose measured in standard mode of operation with the field flattening filter. In the case when FFF therapy practice should start in some existing therapy vault, no additional shielding measures need to be added at the existing maze door.

1. Introduction

Linear therapy accelerators that operate without flattening of the photon beams, so called Field Flattening Free accelerators (FFF) have been introduced in usage in several recent years [1–3]. In standard protocols for design of therapy vaults [4,5], calculation procedures for shielding are suggested for therapy accelerators having flattening filter (FF) only. Although FFF accelerators are commercially available, radiation protection aspects of unflattened photon beams were described in just a few publications [6–8]. In a recently published report [9] is recapitulated that the thicknesses of the primary and secondary barriers can be up to 20% less for FFF beams. However, no information concerning the entrance door can be found in that Report.

There are several new properties of FFF photon beam which could be interesting from the point of view of the shielding. Absence of flattening filter in accelerator's head makes the photon dose across the beam non-uniform; however it allows faster delivery of the photon dose at target volume and consequently shorter exposure time. It is reported that flattening filter can be one of the most important sources of scattered radiation [10,11] which have to be taken in consideration in shield design. The removal of flattening filter can reduce radiation from the accelerator head [7] and the photon dose at the entrance door. However, FFF photon beam has a significantly higher presence of the low energy component [12,13]. Low energy photons have different scattering properties than high energy ones. In publication of Kry et al. [7] is shown that TVLs for FFF mode are smaller for both, primary and secondary barriers, than those of the FF mode. Also patient scatter fractions for the FFF beams can be slightly higher at larger scatter angles (90° and more) than for FF beams. In the same publication can be found useful information that wall reflection coefficients are increased about 40% when the flattening filter is removed due to decrease of average energy of the FFF beam. It indicates that more photons can enter in the maze if low-energy component is more abundant in photon spectra. It is a question if the standard shield at the entrance door, designed for FF mode of operation is effective enough for FFF therapy procedures.

There are a number of publications where FFF accelerators were investigated through MC simulations or other theoretical approach, but only a few of them report experimental measurements [10,14–17]. Therefore, the objective of this paper is to present results of dosimetric measurements performed to compare the photon dose at the entrance door of the therapy vault measured in two different working regimes of

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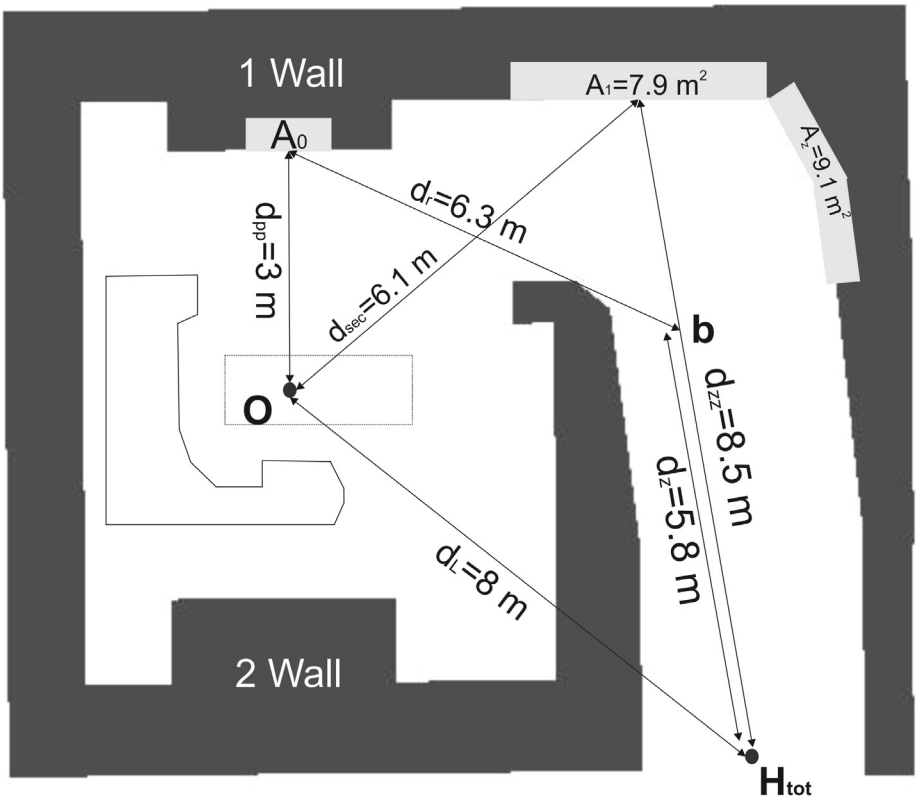

Fig. 1. Scheme of therapy room with major distances used for calculation of photon dose equivalent.

the same accelerator: with field flattening filter (FF) and in field flattening free (FFF) mode of operation, at the same nominal energy. The most important goal of our measurements is to check if existing shielding, projected for maze door of standard accelerators vault working with field flattening filter, is sufficient to provide adequate shielding for field flattening free mode of operation.

2. Materials and methods

Photon dose equivalent was measured in the radiotherapy vault at the Institute for Pulmonary Diseases of Vojvodina, Sremska Kamenica, Serbia. Elekta Versa HD linear accelerator is installed in this vault. The accelerator is operating at 6 MV, 10 MV and 15 MV nominal photon energies. The scheme of the vault is presented at Fig. 1. The height of the vault is 3.95 m, and it is designed as a classic one band maze room. The depicted values at Fig. 1 are: $A_1 = 7.9\,m^2$, $A_z = 9.1\,m^2$, $d_{pp} = 3\,m$, $d_r = 6.3\,m$, $d_z = 5.8\,m$, $d_{sec} = 6.1\,m$, $d_{zz} = 8.5\,m$, $d_L = 8\,m$. According to NCRP 151 procedure and assuming for the design of bunker and door a workload of 900 Gy/week, a photon beam energy of 15 MV and accelerator working in FF mode, H_{tot} at the maze entrance was estimated to be 283 μSv/week.

All measurements of photon dose equivalent presented in this paper were performed at the maze entrance (point signed by H_{tot} at Fig. 1) using 6 MV photon beam. At this energy, the accelerator can operate with flattening filter inserted as usual (FF mode) and without flattening filter (FFF mode). Two sets of measurements were performed: one in standard FF mode operation, and another one in FFF regime of irradiation. Both measurements were done with 90° gantry orientation (toward primary barrier signed as Wall 1 at Fig. 1) and at 270° gantry position (toward primary barrier signed as Wall 2 at Fig. 1). Square fields with 5 cm, 10 cm, 15 cm, 20 cm, 25 cm and 30 cm edges were used for both operation mode and both gantry orientation as well. All measurements were performed with and without water canister used to mimic approximately general therapy conditions with a patient positioned at isocenter (1 m focal distance). The thickness of water layer in the direction of beam propagation was 20 cm. In all measurements exposition was set on exactly 1000 MU. Both FF and FFF modes of Versa HD accelerators are calibrated such that 1 MU equals 1 cGy. This means that dose in the maze was measured until 10 Gy should be reached at d_{max} on the central axis of the beam. Since Elekta Versa HD operating at 6 MV in FF mode delivers 6 Gy/min (600 MU/min) (Elekta Versa HD automatic dose rate) and in FFF mode delivers 14 Gy/min (1400 MU/min), measuring time in FF mode was 1.6 min and in FFF mode 0.7 min.

The photon doses were measured using portable dose rate monitor LB 123 D-H10 (Berthold Technologies). The detector consists of basic evaluation unit LB 1230 UMo and dose rate probe LB 1236-H10. The dose rate probe is a proportional counter with a diameter of 50 mm and length of 275 mm. The dosimeter was positioned 1.5 m above the floor and 30 cm away from entrance door. The natural photon background in therapy room was 0.01 μSv/h. It is less than 0.5% of the lowest dose measured in this study and it was not subtracted of the measurements. According to the manufacturers statement that only significant digits are displayed (up to three), uncertainties of measured doses were estimated. It is obtained that uncertainties ranged from 10% (for the lowest dose values) up to 0.5% in the cases when high dose values were registered. The calibration of the dosimeter was checked one week before measurements at the referent laboratory at the Institute for Nuclear Sciences Vinca, Belgrade, Serbia. Dose rate monitor was calibrated to display photon doses directly.

3. Results

The obtained results of these measurements allowed us to compare the photon dose at the maze entrance for both accelerator working modes: standard FF and FFF. Let us begin with the results of the measurements in simple geometry where no scattering material was placed in the photon beam. Measured dose obtained without water canister for