Radiation Shielding Analyses of A 10 MeV, 15kW LINAC for Electron Beam and X-ray at KACST

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1. Introduction

The King AbdulAziz City for Science & Technology (KACST) in the Kingdom of Saudi Arabia has a plan to build a 10 MeV, 15kW linear accelerator (LINAC) for electron beam and X-ray, which is to be supplied by EB Tech in Republic of Korea. The design and construction of the accelerator building will be carried out jointly between EB Tech and KACST.

The electron accelerator is required to be properly shielded to protect the workers and public at the facility [1]. Recommendations for the design and installation of radiation shielding for x-ray and gamma-ray can be found in NCRP No. 49(1976) and for accelerators with energies over 10 MeV in NCRP No. 151 (2005) [2].

2. Methods and Results

2.1 Method

The MCNP5 and MCNP6 Monte Carlo particle transport codes were used in this shielding analysis. The MCNP transport code provides extensive continuous nuclear cross section libraries and is capable of describing complex 3D geometries and has been widely used in shielding design analyses of medical, industrial and experimental particle accelerators [3-4].

The deep radiation penetration of radiation in the shield building required the use of variance reduction schemes such as the weight window (WW) and DXTRAN spheres in MCNP [5] in order to improve the accuracy of point detector and reduce the computation time.

The F5 point detector flux tally was determined and then converted to the dose equivalent (μSv) values using the photon flux-to-dose rate conversion by MCNP [6].

2.2 Model

The electron beam accelerator and the irradiation facility are shown in Fig. 1. The electron accelerator, target and shielding barrier were modeled for the MCNP calculation:

(1) Electron accelerator
Electron energy: 10 MeV
Maximum beam power: 15 kW
Average electron beam current: 1.5 mA

(2) Target material: Tantalum
Width: 110 cm, depth: 10 cm, thickness: 0.9 cm

(3) Barrier
Material: concrete , density: 2.3 g/cm3
Primary barrier: 300 cm
Secondary barriers: 50 - 70 cm

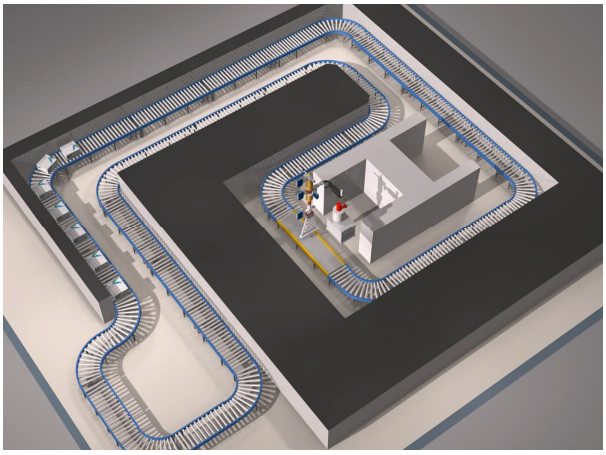

Fig 1. First-floor layout of the irradiation facility

Point detectors for F5 flux tallies were placed at 20 preselected locations surrounding the building. Table 1 lists the locations of point detectors tallies.

3. Results and Conclusions

Monte Carlo calculations were conducted using the MCNP6 code to determine photon fluxes and doses at the point detectors locations around the accelerator building. The problem was run as an electron, photon and neutron transport problem to account for all reactions including the (γ,n) reaction. The detectors where the DXTRAN spheres were used are indicated in the table. The computation was continued until electrons reached a total of $1x10^{+8}$ histories.

Table 1, Fig 2, Fig 3 summarize the results of dose calculations at the detector locations. The average error of point detectors is found to be 15.73% and the maximum relative error is about 30%. The tally #195 is

for a reference detector and its dose is higher than other tallies since it is located inside the building.

Table 1. Final Dose for the Accelerator Facility
Includes (γ,n) reaction, Unit = mSv/yr

Detector Tally No.	X [cm]	Y [cm]	Z [cm]	Mean value	Relative Error
5	150	810	100	6.8240E-02	0.0494
15	250	810	100	8.6658E-02	0.0549
25	340	680	100	2.2624E-01	0.0581
35[a]	770	-10	100	6.9478E-02	0.0826
45	1860	400	100	6.2218E-03	0.2051
55[a]	1860	680	100	2.0286E-02	0.0750
65[a]	1535	1720	100	7.3328E-04	0.3003
75	770	1720	100	9.0634E-04	0.0353
85	-10	1490	100	1.3967E-06	0.1938
95	770	1220	380	2.2366E-04	0.3150
105	1180	1220	380	4.2372E-01	0.3279
115	1320	680	380	3.9686E-01	0.1878
125[a]	1320	200	380	2.8006E-03	0.0986
135	770	1221	545	1.8812E-05	0.0860
145	1001	1221	545	4.5202E+00	0.2990
155	1110	681	610	1.8469E-02	0.2651
165	770	270	660	8.1032E-04	0.1038
175	560	1220	730	1.2886E-06	0.0688
185	770	680	910	5.5516E-01	0.0444
195[a]	175	1440	100	8.2238E+00	0.2591
Avg. Error					0.1555

Histories=1x10^{+8}, WW = Weight Window
a= WW+DXTRAN sphere

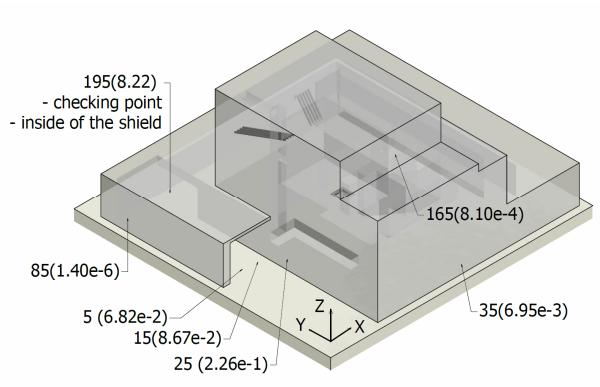

Fig 2. Dose and the locations of the detector tally

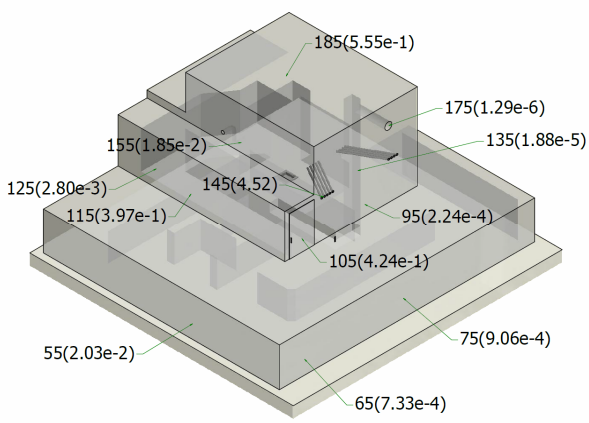

Fig 3. Dose and the locations of the detector tally

According to 10CFR20.1201 [7], the occupational dose limit for adults is 50 mSv/yr. This result shows that doses at all point detectors meet the NRC occupational dose limit.

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