OPTIMIZATION OF A BUNKER FOR GAMAGRAPHY OF PIPES WITH A DIAMETER OF 2m

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ABSTRACT

A radioactive source of 192Ir with a maximum activity of 2.22×10^{12} Bq (60 Ci) is used and the material to be irradiated are steel pipes with a thickness of 1 to 4.4 cm, diameters up to 2 m, and up to, 6 m of length. For the bunker wall calculation it was considered a supervised area of up to 1 m distance with greater distances considered as non designated areas. The main protection options that we have for the bunker project are: a) that the pipes can enter into the bunker from the front; b) from behind, by means of a rail road car; c) from the ceiling, using a crane; d) from the ceiling slipping over the rail road, in this case the pipe would enter from the front or from behind the bunker; e) the pipe could enter from the side by way of a removable sliding wall. The best option will be studied by quantitative decision-aiding techniques used in the radiation protection optimization. Besides the two obliged factors that will be used in the calculation, using the cost benefit analysis technique, it will also be introduced the maximum individual dose by means of more complex techniques than the cost benefit analysis. For this calculation, two annual effective dose limits will be used, i.e.: 20mSv.y^{-1} from national Brazilian regulation and 5 mSv.y^{-1} from international recommendations. For the non classified area, the value of 1 mSv.y^{-1} for the Representative Person, public annual limit, will be used. The bunker shielding material will be normal concrete but conversion factors will be provides for other usable materials.

Key Words: shielding, optimization, gammagraphy, industry

1. Introduction

This paper presents a project of a bunker for gammagraphy of pipes with a diameter of 2m. The authors observed different options to operate this bunker that will be discussed later. The data offered by the interested organization by the bunker were: the radioactive source is 192Ir with a maximum activity of 2.22×10^{12} Bq (60 Ci) and the material to be irradiated are steel pipes with a thickness of 1 to 4.4 cm, diameters up to 2 m and up to 6 m of length. For the bunker wall calculation it was considered a supervised area of up to 1m distance with greater distances considered as non designated areas. Two annual effective dose limits were used, namely.: 20mSv.y^{-1} from National Brazilian Regulation [1] and 5 mSv.y^{-1} from international recommendations. For the non classified area, it will be used the value of 1 mSv.y^{-1} for the Representative Person, public annual limit. The bunker shielding material will be concrete but conversion factors for other construction materials is also provided.

2. Selection of Options and Factors

The authors visualized different options to introduce the pipes. They are: a) that the pipes can enter the bunker from the front; b) from behind by means of a rail road car; c) from the ceiling using a crane; d) by the ceiling slipping over the rail road, in this case, the pipe enters from the front or from behind o the bunker; e) the pipe enters from the side by way of a removable sliding wall. To select the best option, the authors opted for the quantitative decision-aiding techniques used in the radiation protection optimization. Besides the two obliged factors that will be used in the calculation, using the cost benefit analysis technique the maximum individual dose will be introduced by means of more complex techniques than the cost benefit analysis. However, because the individual dose was already defined in the assumed data, it was observed that the collective dose and the individual dose are the same for all options and therefore the analytical solution is the option that presents the least cost for.placing the pipe into the bunker.

3. Description of Shielding Calculations

3(a). Calculation of Walls

For these calculations, the computer code “MegaShield Version 3.0” was used.[2]

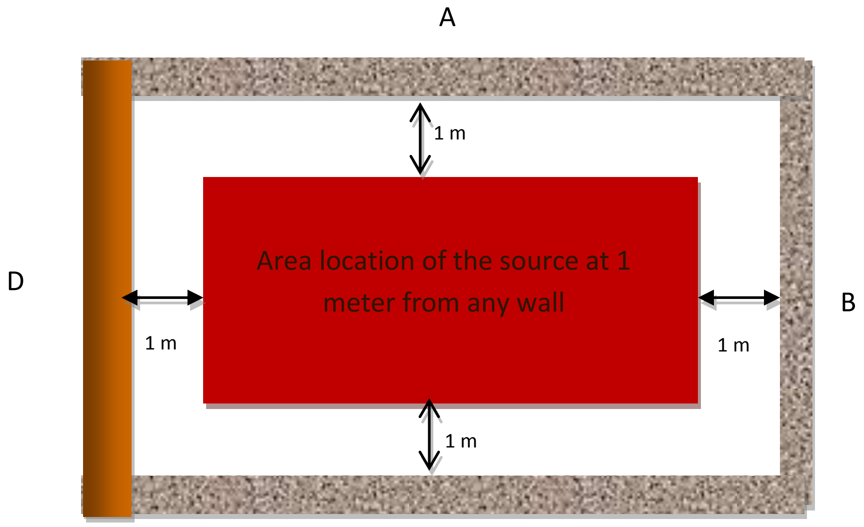


Figure 1 - Target irradiated

The results are presented below:

Table 1 – Thickness and External Dose for Walls and Gate

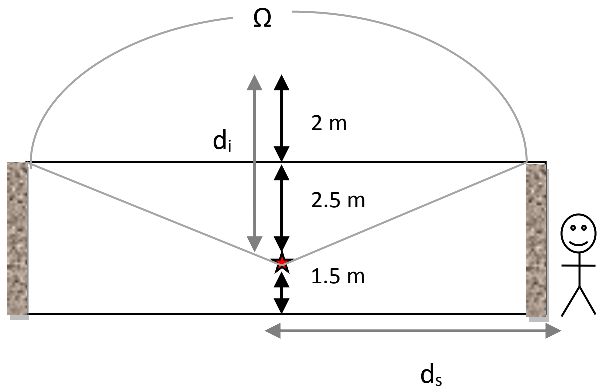
Wall and Gate	Material	Thickness (cm)	Dose (mR/h)
A, B, C	Concrete	80.0	4.13×10^{-2}
D(Gate)	Concrete	80.0	4.13×10^{-2}

3(b) . Floor Calculation

For the floor, there is no need of shielding, since the room is located at ground level.

3(c). Ceiling Calculation

The ceiling calculations were performed according to the equations mentioned in the reference [3], showed below. Walls gave the estimation of the dose due to the "skyshine", leaning on the external surface of the walls of the irradiation room. Given that the total allowable dose is 1.0×10^{-1} mR/h, the dose contribution from the ceiling was considered to be 50% of the total dose, i.e, 5.0×10^{-2} mR/h .



$$D_{Is,d_s} = \left[\left(2.5 \times 10^{-2}\right) D_{I0} \Omega^{1,3}\right] \Big/ d_s^2$$

$$B_{xs} \leq 0.67 \times 10^{-3} \left[\frac{\dot{H}_M d_i^2 d_s^2}{\dot{D}_{Is,d_s} \Omega^{1,3}} \right]$$

Where

$$\dot{D}_{Io} = 0.4816\frac{Rm^2}{\min}$$

$$\Omega = 4.7927 steroradiano$$

$$d_S = (1 + x)m$$

$$x = \text{ thickness material changing on the wall material}$$

$$d_i = 4.5m$$

$$\dot{H}_M = 5.0x10^{-2}\frac{mR}{h}, \text{brazilian standard CNEN/1/}$$

The results are presented below:

Wall and gate made in concrete

Wall and gate made in concrete with thickness x = 80 cm and dose, leaning on the external surface, with $4{,}13x10^{-2}$mR/h, see table 1.

A Total Dose (D_T) is always obtained aiding the dose from the wall and the dose from the ceiling

Then, D_T= $9.13x10^{-2}$ mR/h.

Table 2 – Thickness and Dose for the Ceiling

Ceiling		
Material	**Thickness (cm)**	**Dose (mR/h)**
Concrete	28.0	$5.00x10^{-2}$

4. Results of the Optimization

The different costs for each options are presented in Table 3. It can be seen that the least expensive options are: a) that the pipes can enter the bunker from the front; b) from behind, by means of a rail road car,. Conversion factors for other materials are shown in Table 4. These factors were obtained from NCRP publication nº 49.

Table 3 – Options for Cost Variation

OPTIONS	COST US$
a	120,000.00
b	120,000.00
c	180,000.00
d	300,000.00
e	420,000.00

Table 4 – Correlation Factors

Shielding Material	Correlation Factor
Concrete	1.00
Barite Concrete	0.70
Iron	0.30
Lead	0.21

The bunker may be optimized using a combination of the different materials showed in table 4, making the bunker less expensive and another paper has been prepared in which 18 options have been identified.

References

[1] - Norma CNEN-NN 3.01 “Diretrizes Básicas de Proteção Radiológica” (Resolução CNEN/ CD 48 de 09/09/2005,Publicação D.O.U de 14/11/2005 (Alterações), Portaria CNEN/ PR 007 de 17/01/2006 (Alterações), Publicação D.O.U de 18/01/2006).)

[2] – Computer Code “MegaShield Version 3.0” from WMG Inc., Peeskill, NY.

[3] - NCRP (1977). National Council on Radiation Protection and Measurements. *Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerator Facilities*, NCRP Report No. 51 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).