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COMPUTER CODE FOR SHIELDING CALCULATIONS OF X-RAYS ROOMS

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ABSTRACT

The building an effective barrier against ionizing radiation present in radiographic rooms requires consideration of many variables. The methodology used for thickness specification of primary and secondary, barrier of a traditional radiographic room, considers the following factors: Use Factor, Occupational Factor, distance between the source and the wall, Workload, Kerma in the air and distance between the patient and the source. With these data it was possible to develop a computer code, which aims to identify and use variables in functions obtained through graphics regressions provided by NCRP-147 (Structural Shielding Design for Medical X-Ray Imaging Facilities) report, for shielding calculation of room walls, and the walls of the dark room and adjacent areas. With the implemented methodology, it was made a code validation by comparison of results with a study case provided by the report. The obtained values for thickness comprise different materials such as concrete, lead and glass. After validation it was made a case study of an arbitrary radiographic room. The development of the code resulted in a user-friendly tool for planning radiographic rooms to comply with the limits established by CNEN-NN-3:01 published in september/2011.

1. INTRODUCTION

The purpose of the use of shields is to ensure the safety of members of the public and Occupationally Exposed Individuals (OEI) from exposure to ionizing radiation.

In consideration of medical applications using X-rays involves the study of primary and secondary beams. The primary beam is the emitted radiation from the X-ray tube directed to a patient. The primary beam due to its ability to not interact with the patient and to achieve other targets need to be shielded. This type of shielding is called primary barrier and is responsible for ensuring the integrity of those who may be exposed to it [1]. The secondary beam emanates from X-rays scattered due to the interaction of the primary beam with the patient and other objects. The Fig. 1 illustrates the interaction of the primary beam with a patient and the production of the scattering and leakage beam.

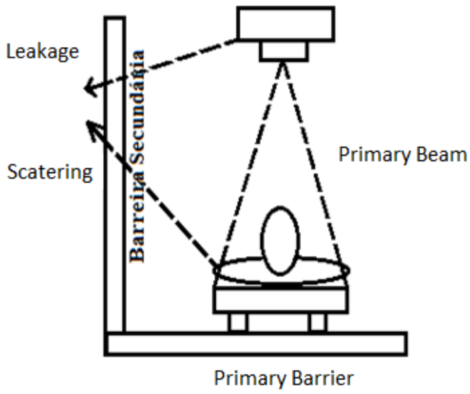


Figure 1. Beams and shieldings [2].

The motivation for the creation of effective methods for radiation shielding is due to concern about effects that ionizing radiation may cause. This work includes the use of Structural Shielding Design for Medical X-Ray Imaging Facilities (NCRP-147) [3], which establish calculations to be adopted in order to ensure safety to those who may be exposed to ionizing radiation in radiographic facilities, according to the dose limits set by the standard CNEN-NN-3:01 published in September / 2011 [4]. The final result of the work is a source capable of providing data on the thickness of materials that can be used to effectively shield against ionizing radiation.

2. METODOLOGY

A radiographic system has the purpose of producing exposures of short duration of time. The source consists of an X-ray tube in the range from 50 to 150 kVp. The beam produced by the source is directed to the patient, the radiographic table and the floor. The X-ray tube can have rotary motion, causing the beam to be directed to other barriers. Many radiographic rooms have the ability to perform chest X-ray, where the primary beam is directed to a set of vertical cassettes, known as Chest Bucky Wall. The Fig. 2 shows the illustration of a radiographic room and internal environments. At point A there is a window responsible for allowing the operator to view the patient, at the point B is located the table used for positioning the patient for obtaining a radiographic image and point C is the Chest Bucky Wall.

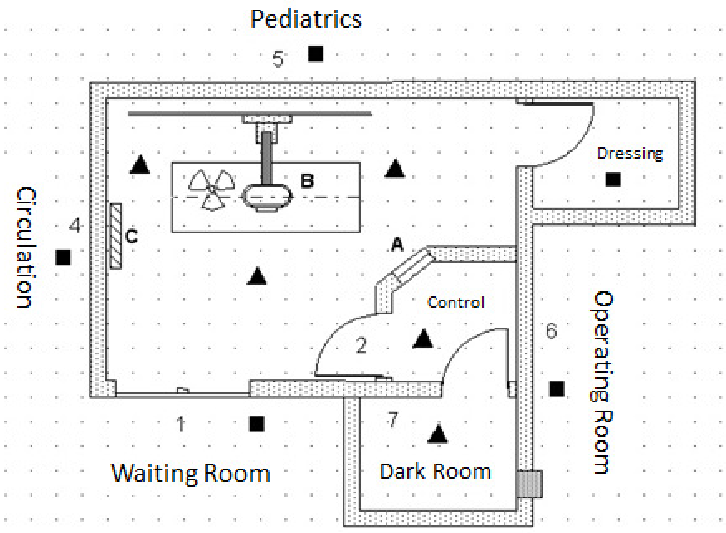


Figure 2. Radiographic room [5].

The methodology consists of the use of NCRP-147 Report as the basis for determining the wall thickness of a radiographic room. The report provides data to fit in ALARA Principle. The result is a computational code, developed in C/C++ language, which determines the shielding of a radiographic room. The calculations performed by the code limit the results to comply with the determinations of the Standard CNEN-NN-3.01 for the dose limits for stochastic and deterministic effects.

2.1. Calculations Methods

One method of determining the thickness of the barrier is given by Eq. (1).

$$\frac{1}{B} = \frac{N.T}{P.d_p^2} \qquad (1)$$

Where N is the number of patients, d_p is the distance between the isocenter of the source of X-rays and the barrier, P is the area factor and T is the occupational factor.

By Eq. 1 is possible to determine the barrier thickness with the aid of a "thickness map", which was inserted in the code using regression methods for nine degree equations. Another alternative calculation can be obtained from Eq. (2).

$$\mathbf{B_p(x_{barrier} + x_{pre}) = \frac{P}{T.K_p(0)}} \quad (2)$$

Where $K_p(0)$ is the amount of weekly unshielded primery air kerma to an area occupied by N patients. This variable is calculated by Eq. (3).

$$\mathbf{K_p(0) = \frac{K_p^1.U.N}{d_p^2}} \quad (3)$$

K_p^1 is the value of the unshielded primery air kerma per patient at 1 m, for each of the workload distributions (W), d_p is the distance (in meters) from the x-ray tube to the occupied area.

For the calculation of the secondary barrier Eq. (2) can be used with a slight modification in its structure, and thus, Eq. (4) is presented as a calculation method for secondary barrier.

$$\mathbf{B_{sec}(x_{barrier}) = \frac{\left(\frac{P}{T}\right)}{K_{sec}(0)}} \quad (4)$$

The variable $K_{sec}(0)$ is the total quantity of secondary air Kerma without shield and its value can be obtained using Eq. (5).

$$\mathbf{K_{sec}(0) = \frac{K_{sec}^1}{d_{sec}^2}} \quad (5)$$

The variables shown in calculating the secondary shielding are equivalent to the primary barrier.

2.2. The Computer Code

To validate the computer code, it was used a modeling problem provided by NCRP-147 Report. The problem is to determine thickness values for radiographic room shown in Fig. 3.

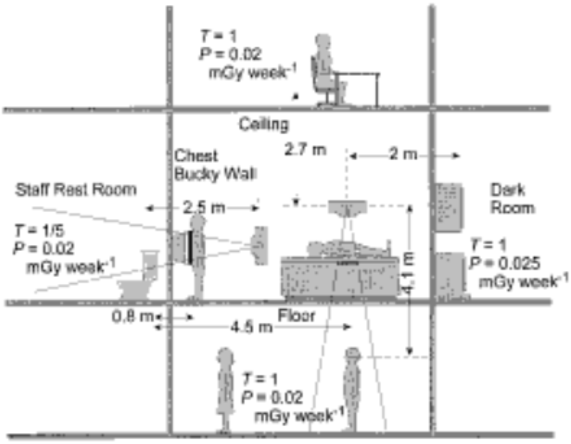


Figure 3. Model for code validation [3].

Based on the design presented, the Table 1 shows a comparison between the results obtained with the computacionl code and with the results of NCRP-147 Report. Note that if the results are close, thus validating the computational code.

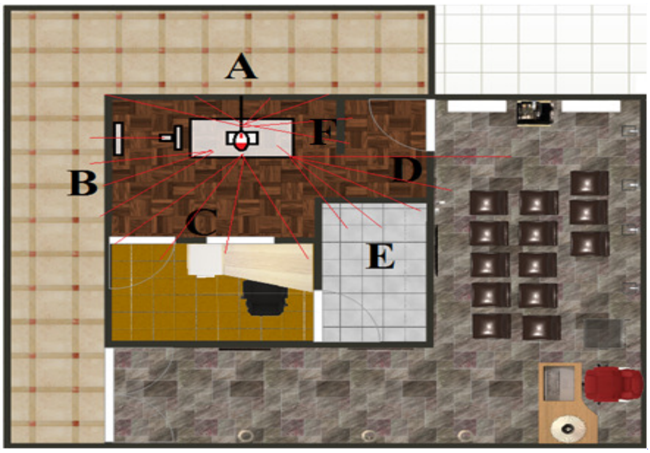
Table 1. Comparison between the comnputer code and NCRP-147 Report.

Variables	NCRP-147	Simulation	Relative Deviation (%)
FLOOR			
$K_p(0)$ (mGy.week^{-1})	39,00	38,6675	0.85
$B_p(x_{barrier} + x_{pre})$	0,000510	0,000517	1.37
$1/B_p$ (mGy^{-1})	372,00	371.802	0.05
$K_{sec}(0)$ (mGy.week^{-1})	0,47	0.47	0.0
$B_{sec}(x_{barrier})$	0,0430	0,0423529	1.40
$1/B_{sec}$ (mGy^{-1})	694,00	694.44	0.06
Thickness (concrete) mm	35,00	35,23	0.66
CEILING			
$K_{sec}(0)$ (mGy.week^{-1})	0,84	0,84	0.0
$B_{sec}(x_{barrier})$	0,024	0,024	0.0
$1/B_{sec}$ (mGy^{-1})	875,00	857,34	2.02
Thickness (concrete) mm	39,00	39,02	0.05
DARK ROOM			
$K_{sec}(0)$ (mGy.week^{-1})	0,21	0,21	0.0

$B_{sec}(x_{barrier})$	0.0023	0,0024	4.35
1/B_{sec} (mGy^{-1})	250,00	250,00	0.0
Thickness (lead) mm	1,30	1,34	3.08
CEST BUCKY WALL			
$K_p(0)$ ($mGy.week^{-1}$)	46,00	46,00	0.0
$B_p(x_{barrier} + x_{pre})$	0,0022	0,0022	0.0
1/B_p (mGy^{-1})	200,00	200,00	0.0
$K_{sec}(0)$ ($mGy.week^{-1}$)	1,10	1,11	0.91
$B_{sec}(x_{barrier})$	0,0910	0,090	1.09
1/B_{sec} (mGy^{-1})	200,00	200,00	0.0
Thickness (lead) mm	0,45	0,45	0.0
CROSS-TABLE WALL			
$K_p(0)$ ($mGy.week^{-1}$)	7,50	7,46	0.53
$B_p(x_{barrier} + x_{pre})$	0,00270	0,00268	0.74
1/B_p (mGy^{-1})	797,00	797,19	0.02
$K_{sec}(0)$ ($mGy.week^{-1}$)	0,72	0,719	0.14
$B_{sec}(x_{barrier})$	0,02	0,02	0.0
1/B_{sec} (mGy^{-1})	1562,00	1562,50	0.06
Thickness (lead) mm	1,03	1,03	0.0
CONTROL WALL			
$K_{sec}(0)$ ($mGy.week^{-1}$)	0,26	0,26	0.0
$B_{sec}(x_{barrier})$	0,00190	0,00191	0.53
1/B_{sec} (mGy^{-1})	15432	15432	0.0
Thickness (lead) mm	1,33	1,33	0.0

2.3. Methodology application

The installation structure does not follow any criteria, its design was totally arbitrary to be used only as a code demonstration, the Fig. 4 illustrates the structure of the installation. In the figure the floor and the ceiling are not identified, but will be considered in the calculations. Behind walls A and B are corridors. In B is located the "breast Bucky", behind the C is the control room, in D a waiting room, F is wall to prevent the shielding door and E is a film processing room.



[R1] Comentário: Retirar as retas em vermelho.

Figure 4. Estrutura da instalação.

The Table 2 shows the data used for the simulation. It was considered the amount of 200 patients per week. The distances are in meters, the Area Factor (P) in mGy/week, the Kerma in air at one meter in mGy/week and the Use Factor (U) and Occupational Factor (T) are dimensionless.

Table 2. Data for the simulation.

Parede	K_p^1	K_{sec}^1	d_p	d_{sec}	P	T	U
A	5,2	----------	1,87	----------	0,02	1,0	0,09
B	2,3	$2{,}3.10^{-2}$	2,7	3,7	0,02	1/2	1,0
C	----------	$3{,}4.10^{-2}$	----------	2,80	0,1	1,0	1,0
D	----------	$2{,}3.10^{-2}$	----------	2,0	0,1	1,0	1,0
E	----------	$3{,}4.10^{-2}$	----------	2,50	0,1	1,0	1,0
F	----------	$2{,}3.10^{-2}$	----------	1,10	0,1	1,0	1,0
Chão	5,2	$3{,}4.10^{-2}$	2,0	3,0	0,02	1,0	1,0
Teto	----------	$4{,}9.10^{-2}$	----------	2,0	0,02	1/5	1,0

The Tab. 3 shows the result obtained by the simulation.

Table 3. Results.

Wall	Lead Thickness (mm)	Concrete Thickness (mm)	Glass Thickness (mm)
A	1,40	105,00	----------
B	1,80	135,60	----------
C	1,00	85,00	90,0
D	0,72	55,00	----------
E	1,20	90,00	----------
F	0,90	80,00	----------
Chão	2,00	148,00	----------
Teto	0,30	28,00	----------

3. CONCLUSIONS

The determination of an effective barrier to the primary and secondary beam of X-ray rooms in fact requires consideration of many variables. This fact is a problem for manual determination of thickness values. The construction of a code made it possible applying shielding calculation techniques, simply and quickly.

Analyzing the values of the calculated thickness is evident the necessity of studies to determine thicknesses with greater efficiency. The radiographic rooms use considerable beams that merit special attention to ensure the safety of the OEI and the general public.

The computer code showed satisfactory results when compared with the model in NCRP-147 report and can be used as a tool to shielding calculations in x-ray rooms. All calculations made by it are within the dose limits established by the Comissão Nacional de Energia Nuclear (CNEN).

4. REFERENCIAS

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