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RADIATION DOSES INSIDE INDUSTRIAL IRRADIATION INSTALLATION WITH LINEAR ELECTRON ACCELERATOR

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ABSTRACT

Acelétron Industrial Irradiation Company is the unique installation in South America to provide industrial irradiation service using two linear electron accelerators of 18 kW and 10 MeV energy. The electron beam technology allows using electrons to irradiate many goods and materials, such as hospital and medical equipment, cosmetics, herbal products, polymers, peat, gemstones and food. Acelétron Company uses a concrete bunker with 3.66 m of thickness to provide the necessary occupational and environmental radiation protection of X-rays produced. The bunker is divided in main four areas: irradiation room, maze, tower and pit. Inside the irradiation room the x-rays radiation rates are measured in two ways: direct beam and 90^{o}. The rates produced in the conveyor system using 10 MeV energy are 500 Gy/min/mA and 15 Gy/min/mA, respectively. For a 1.8 mA current, the rates produced are 900 Gy/min and 27 Gy/min, respectively. Outside the bunker the radiation rate is at background level, but in the tower door and modulation room the radiation rate is 10 µSv/h. In 2014, during a routine operation, an effective dose of 30.90 mSv was recorded in a monthly individual dosimeter. After the investigation, it was concluded that the dose was only in the dosimeter because it felt inside the irradiation room. As Acelétron Company follows the principles of safety culture, it was decided to perform the radiation isodose curves, inside the four areas of the installation, to know exactly the hotspots positions, exposure times and radiation doses. Five hotspots were chosen taking into account worker's routes and possible operational places. The first experiment was done using a package with three TLD and OSLD dosimeters to obtain better statistical results. The first results for the five hotspots near the accelerator machine showed that the radiation dose rates were between 26 Gy/h and 31 Gy/h. The final measurements were performed using a package with one TLD and one OSLD dosimeter distributed in the main four areas of the installation. This paper presents the methodology to obtain the radiation isodose curves and the experimental results.

1. INTRODUCTION

Acelétron Industrial Irradiation Company is the unique installation in South America to provide industrial irradiation service using two linear electron accelerators of 18 kW and 10 MeV energy. The electron beam technology allows using electrons to irradiate many goods and materials, such as hospital and medical equipment, cosmetics, herbal products, polymers, peat, gemstones and food. One most important advantage of using linear electrons accelerator instead of gamma installation is related to the radiological hazard because when the accelerator is off there is no more hazard.

This kind of installation has defence in depth as important safety and security philosophy conceptions. When the accelerator is in operation, many mechanisms, barriers and redundant measurements with high reliability reduce the risk of radiological accidents to extremely low levels. Then, with these safety devices, is practically impossible any worker enters in the irradiation room when the accelerator is in operation.

Despite the low radiological risk for situation showed above, the same level of risk cannot be assigned in case of permanence of a worker inside the irradiation room in the beginning of accelerator operation. In this case, the worker would receive a high dose radiation depending on his position inside the irradiation room [1].

A common incident in this type of installation is the unintentional fall of the personal dosimeter in the irradiation room, the maze, the tower or the pit. If the dosimeter was together irradiated with the products, that is, directly in the electrons beams, the dose will be very high (above 1 kGy), but it was irradiated in other places, the dose will be near or above the occupational dose limits depending on its position.

In 2014, during a routine operation, an effective dose of 30.90 mSv was recorded in a monthly individual dosimeter. After the investigation, it was concluded that the dose was only in the dosimeter because it felt inside the irradiation room. As Acelétron Company follows the principles of safety culture, it was decided to perform the radiation isodose curves, inside the four areas of the installation, to know exactly the hotspots positions, exposure times and radiation doses.

This paper presents the methodology to obtain the radiation isodose curves and the experimental results.

2. LINEAR ELECTRON ACCELERATOR - ACELÉTRON COMPANY

The linear accelerator is the main component of the system, and in the Acelétron Company (Figure 1) there are two accelerators in vertical position: one installed in the tower room, with the electron beam output from top to bottom and the second one installed in the pit room, with the electron beam output from bottom to top; both beams are directed to the conveyor system inside the irradiation room [2, 3].

Using two accelerators at the same time, the level of radiation inside the installation is very high, and then it is necessary to have some hard shielding to shield the X-rays generated by the bremsstrahlung effect in the installation.

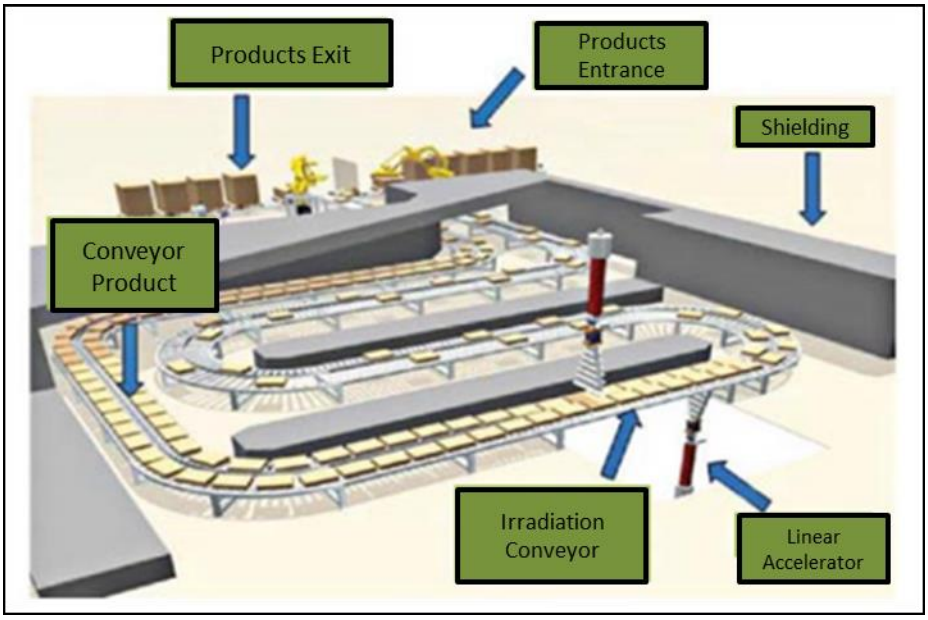

Figure 1: Linear Accelerator - Acelétron Company.

Acelétron Company uses a concrete bunker with 3.66 m of thickness to provide the necessary occupational and environmental radiation protection of X-rays produced. The bunker is divided in four main areas: irradiation room, maze, tower and pit. Inside the room the irradiation x-rays radiation rates were measured in two ways: direct beam and 90^o. Assuming that each electron beam of each accelerator is produced by an ideal target, it results in maximum of x-rays emission and the dose rates produced in the conveyor system using 10 MeV energy are 500 Gy/min/mA and 15 Gy/min/mA, respectively. For a 1.8 mA current, the dose rates produced are 900 Gy/min and 27 Gy/min, respectively. Outside the bunker the radiation rate is at background level, but in the tower door and modulation room the radiation rate is 10 µSv/h.

3. RADIATION ISODOSE CURVES AND EXPERIMENTAL RESULTS

To obtain the radiation isodose curves and the best experimental results some commercial dosimeters were used from an approved dosimetry laboratory called SAPRA-LANDAUER. A package with two types of dosimeters were used: Thermoluminescent Dosimeter (TLD – LiF:Mg,Ti and CaSO4:Dy) and Optical Stimulated Luminescent Dosimeter (OSLD – Al2O3:C). To ensure the balance of charged particles during exposure to radiation acrylic plates were used in front of the dosimeters. The measurement uncertainty is around 10% using these dosimeters.

Two experiments were done: the first one was to obtain an initial survey with the goal to select the hotspots, to optimize the time and the number of dosimeters; the second one was done to obtain the dose rates inside the linear accelerator installation. In both experiments was only used the accelerator with electron beam output from top to bottom.

For both experiments a number of hotspots were chosen taking into account worker's routes and possible operational places.

3.1. The first experiment

The first experiment was done using a package with three TLD and OSLD dosimeters to obtain better statistical results. The first results for the five hotspots near the accelerator machine showed that the radiation dose rates were between 433 mGy/min and 517 mGy/min. These results also showed that the irradiation time must be different for each hotspot inside the installation.

3.2. The second experiment

For the final measurements 26 package of dosimeters with TLD and OSLD were used in the following hotspots: 5 dosimeters near the accelerator machine (dosimeters 001 to 005); 13 dosimeters inside the irradiation room and maze (dosimeters 006 to 019); 3 dosimeters in the pit (dosimeters 020 to 022) and 4 dosimeters in the tower (dosimeters 023 to 026). All dosimeters were fixed on the inner walls and at 1.3 meters height from the floor. The Figures 02, 03 and 04 showed the position of the dosimeters.

The experimental results of the radiation dose rates inside the industrial irradiation installation with linear electron accelerator are showed in the Table 1. It was calculated the average dose rate between the results of TLD and OSLD measurements.

The radiation dose rates near the accelerator machine were really very high as expected from 203.22 mGy/min to 2929.51 mGy/min. Inside the irradiation room the radiation dose rates were between 0.02 mGy/min and 61.34 mGy/min. Throughout the maze the dose rates were between 0.01 mGy/min and 0.08 mGy/min. In the tower the dose rates were 28.05 mGy/min and 51.33 mGy/min. In the pit there was no radiation dose because the accelerator machine was not operational.

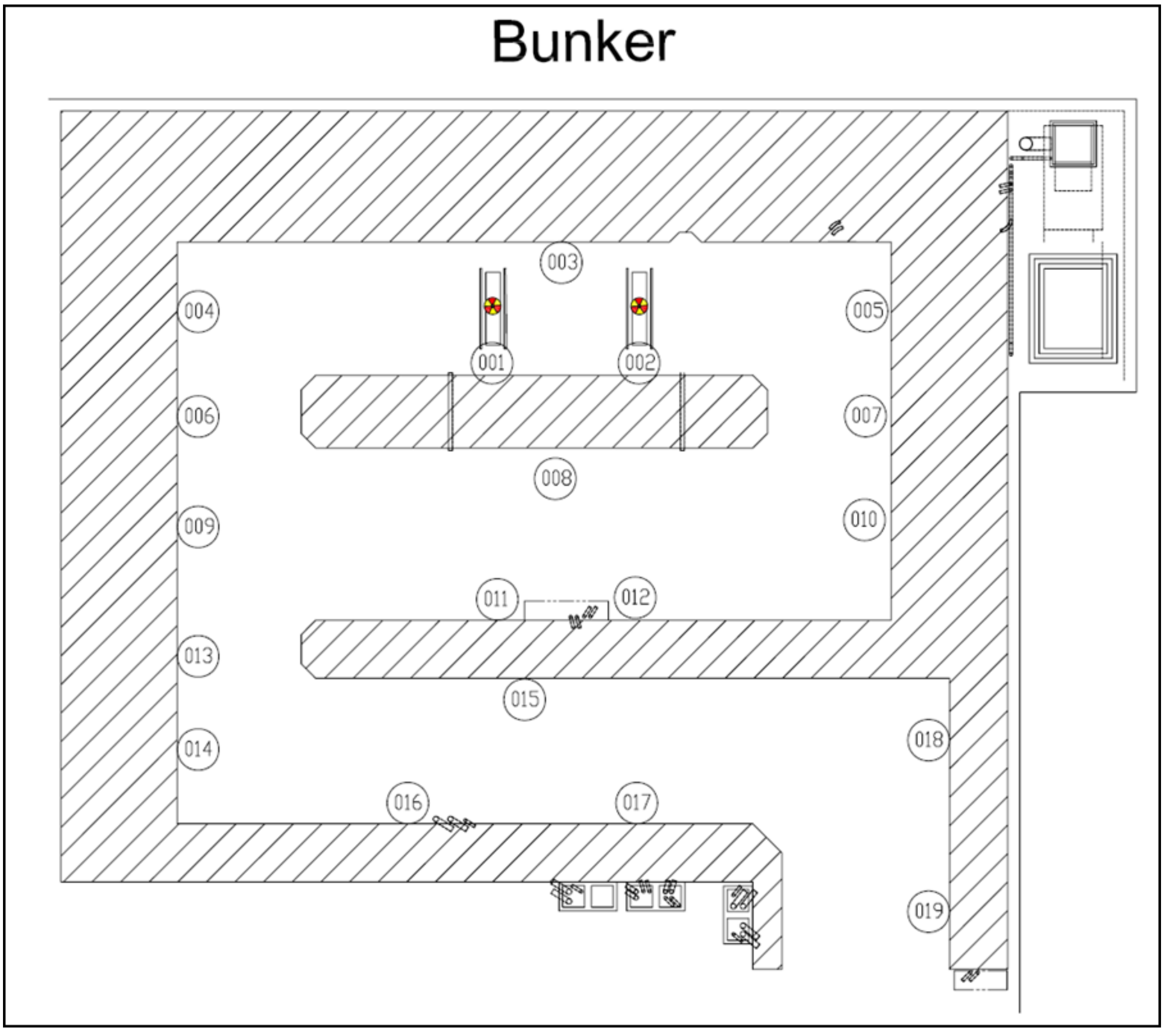

Figure 2: Position of dosimeters inside irradiation room and near the machine of the linear accelerator (dosimeters 001 to 019).

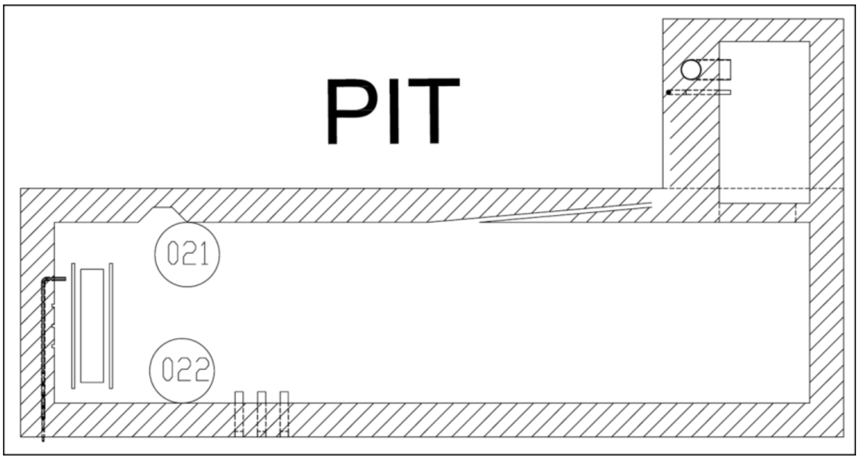

Figure 3: Position of dosimeters in the pit of the linear accelerator (dosimeters 020 to 022).

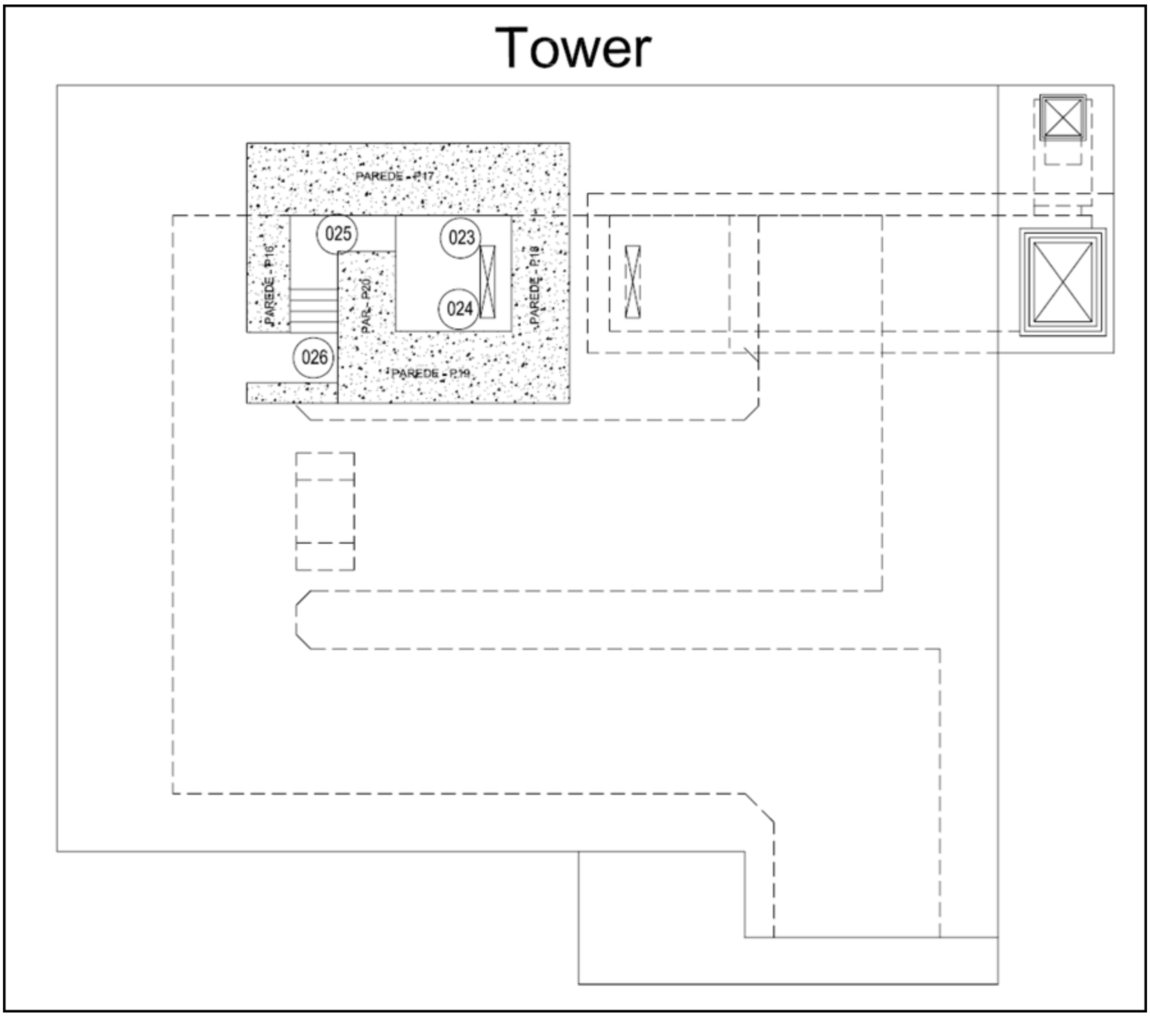

Figure 4: Position of dosimeters in the tower of the linear accelerator (dosimeters 023 to 026).

Table 1: Radiation dose rates inside the industrial irradiation installation with linear electron accelerator.

Dosimeter	Place - hotspot	Absorbed Dose (mGy)		Irradiation Time (min)	TLD and OSLD Average Dose Rate (mGy/min)
		TLD	OSLD		
001	Accelerator Machine	2912.00	2929.02	1	2920.51
002	Accelerator Machine	184.21	222.22	1	203.22
003	Accelerator Machine	778.40	1236.74	1	1007.57
004	Irradiation Room	70.56	52.12	1	61.34
005	Irradiation Room	22.75	17.67	1	20.21
006	Irradiation Room	23.39	36.84	1	30.12
007	Irradiation Room	11.13	14.60	1	12.86
008	Irradiation Room	0.10	0.15	5	0.03
009	Irradiation Room	8.57	6.76	5	1.53
010	Irradiation Room	69.02	51.75	60	1.07
011	Irradiation Room	1.58	1.84	60	0.02
012	Irradiation Room	3.12	3.37	60	0.05
013	Maze	6.26	3.21	60	0.08
014	Maze	1.43	1.37	60	0.02
015	Maze	0.07	0.15	60	0.01
016	Maze	0.04	0.00	60	0.01
017	Maze	0.03	0.00	60	0.01
018	Maze	0.03	0.00	60	0.01
019	Maze	0.03	0.00	60	0.01
020	Pit	Not used			
021	Pit	0.00	0.00	5	0.00
022	Pit	0.00	0.00	5	0.00
023	Tower	133.76	146.78	5	28.05
024	Tower	274.04	239.22	5	51.33
025	Tower	Not used			
026	Tower	38.15	44.03	5	8.22

4. CONCLUSIONS

The dose rates inside the radiation room, mainly near the accelerator machine (hotspots 001, 002 and 003), are extremely harmful. It means that an inadvertent exposure could lead a worker to death in few minutes.

The other hotspots 004 to 007 inside the irradiation room and the hotspot 023, 024 and 026 in the tower are high and they are enough to lead a worker to receive a radiation dose high than the CNEN annual limit in some minutes [4].

The other hotspots in the areas of the facility (hotspots 008 to 019) have low radiation dose rates because the barriers and shielding. But these areas must be avoided to work during the accelerator operation in order to ensure low occupational dose levels.

As during irradiation experiments, one accelerator machine had some problems and was out of order, it is recommended to perform another radiation survey with both accelerators to obtain a complete radiation dose rates inside the linear accelerator installation.

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