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INFLUENCE OF THE PROFILE OF IRIDIUM-192 WIRE IN MEASUREMENTS OF QUALITY CONTROL FOR USE IN BRACHYTHERAPY

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ABSTRACT

Brachytherapy is a method used in the treatment of cancerous tumors, by ionizing radiation produced by sources, introduced into the tumor area, this method seeks a more direct attack to the tumor, thereby maximizing the radiation dose to diseased tissue, while minimizing the dose to healthy tissues. One of the radionuclides used in brachytherapy is iridium-192. The Radiation Technology Center (CTR), of the Nuclear and Energy Research Institute (IPEN), has produced commercially, since 1998, iridium-192 wires used in low dose rate (LDR) brachytherapy. To produce this radionuclide, firstly an iridium-platinum wire is irradiated in the nuclear reactor IEA-R1 for 30 hours, with a neutron flux of 5×10^{13} n cm^{-2} s^{-1}, the wire is left to decay by 30 days to remove the main contaminants, and then goes through a quality control, before being sent to the hospital. In this quality control is checked the radiation homogeneity along each centimeter of the wire. To implement this procedure, is used a device, consisting of an ionization chamber, surrounded by a lead shield, with a small 1 cm wide slit, linked to the ionization chamber is a voltage source, and a Keithley 617 electrometer, 2 minutes is the range used to measure the charge by the electrometer. The iridium wire is considered in accordance, when there is no variation higher than 5%, between the average measures and the maximum and minimum values. However, due to design features of the measurement system, the wire may appear to the detector through the slit in larger sizes than the ideal, improperly influencing the final quality control. This paper calculates the difference in size of these variations in profile, and their influence on the final count, it compares the actual values obtained, and describes the improvements, made in quality control procedures, that provided more accurate measurement data, analyzes the results, and suggests changes in devices, aimed at further improving the quality control of iridium-192 wires produced at IPEN, and used in hospitals in Brazil.

1. INTRODUCTION

Brachytherapy uses radioactive sources, that are placed within the volume of tissue being treated, or adjacent to the volume (Aird and Williams, 2000). Among the radionuclides used in brachytherapy, iridium-192 stands out thanks to its physical characteristics, as the half-life of 74 days and an average energy of 380 keV (Khan, 1994). The Radiation Technology Center - CTR, of the Nuclear and Energy Research Institute - IPEN, has produced commercially, since 1998, iridium-192 wires, used in low dose rate (LDR) brachytherapy (Rostelato, 1997).

2. MATERIALS AND METHODS

To produce the iridium-192 wire is used a platinum-iridium wire, 50 cm long, from Goodfellow company, this wire has a core of 0.1 mm in diameter, composed of 25% iridium and 75% platinum, and a platinum sheath 0.1 mm thick, resulting in an overall diameter of 0.3 mm. The wire is wound in helical form, and inserted into an aluminum tubular shape capsule, with 2 cm diameter and 7 cm in height. The capsule is sealed and placed into the core of IEA-R1 nuclear reactor, under a neutron flux of 5×10^{13} n cm^{-2} s^{-1}, for a period of 30 hours. After irradiation the wire goes through a decay period of 30 days, to reduce the main contaminants. After the decay, begins the quality control of the wire.

The capsule containing the wire is brought into a hotcell with 5 cm lead wall, the capsule is cut and iridium wire is removed. The wire is inserted in the mechanism shown in Fig. 1, and pulled by pulleys through the guide pipe, to be positioned in front of the slit made in the lead shield. The slit has a dimension of 10 mm wide and 5mm in height near the position of the wire, and its width increases at an angle of 20°, as shown in Fig. 2.

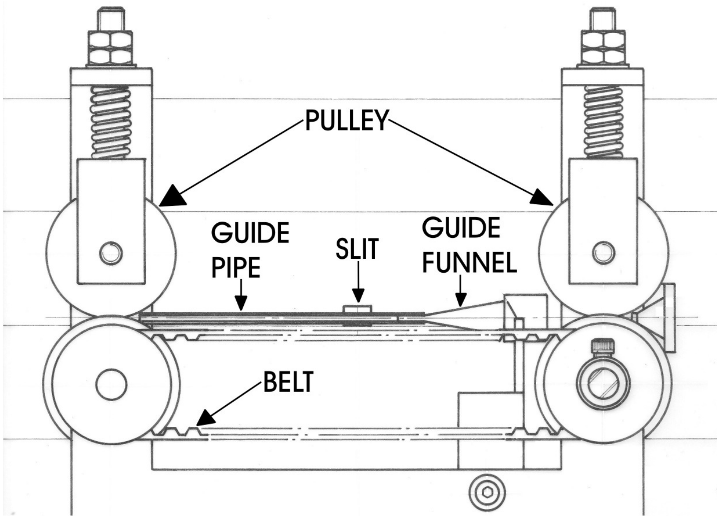

FIGURE 1: Iridium-192 traction mechanism

Inside the lead shielding is placed an ionization chamber, which "sees" only 10 mm iridium-192 wire through the slit. This ionization chamber is fed with a 300 V source voltage of the Canberra brand, model 3002D. The chamber is also connected to a Keithley electrometer model 617, which performs the counting of the charge, produced by ionizing radiation from the piece iridium-192 wire, that is opposite the slit, the charge is counted for 2 minutes. Three passages of wire are performed by pulleys and, with each pass is performed to measure the charge along the wire. To be considered according, none maximum or minimum reading of the charge, has to be more than 5% difference, in relation to the average value of the readings along the wire.

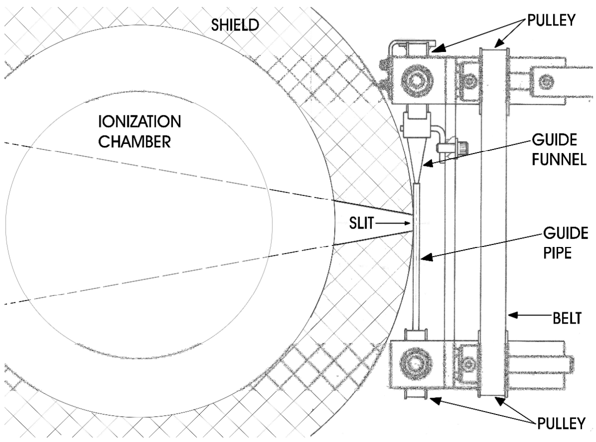

FIGURE 2: Ionization Chamber and shielding

After quality control, wires have their activity measured in ionization chamber Capintec brand model CRC-15R.

3. RESULTS E DISCUSSION

Analyzing the graphs of the quality control of iridium wires 1 and 2 (Fig. 3 and 4), we note that there is a decrease of peak height values in the second and third measurement, in relation to the first measurement, this can also be verified, by variation of averages of measurements shown in Tab. 1. Rostelato et al. (2008) also present values with this type of variation, in his study about the production of radioactive sources, these values are shown in Tab. 1. There is also a gradual decrease of the values of standard deviations of the wire 1, while the wire 2 had its standard deviation values increased slightly in the second measurement, and then returned to the same level in the third measurement. The maximum and minimum values of the wire had a downward trend, when compared with the arithmetic average of the measurements, in the case of wire 2, maximum and minimum values showed an oscillating behavior, similar to the standard deviations.

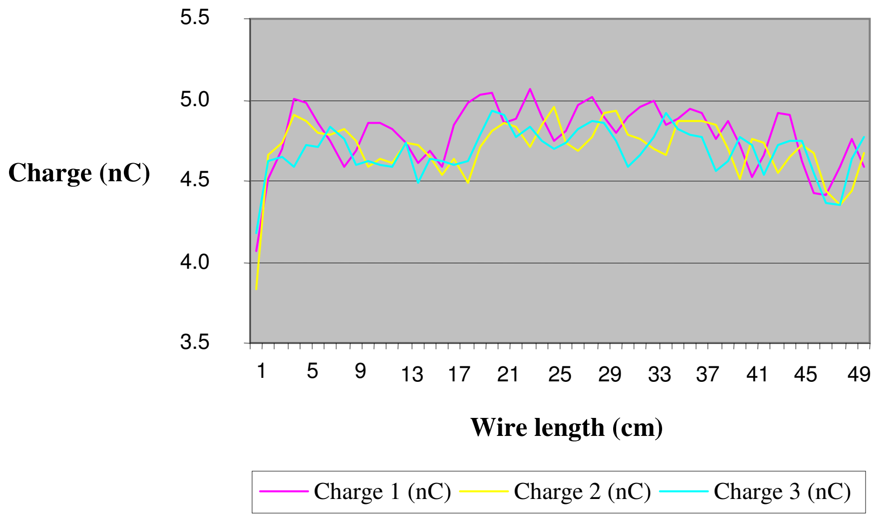

FIGURE 3 – Wire 1 quality control

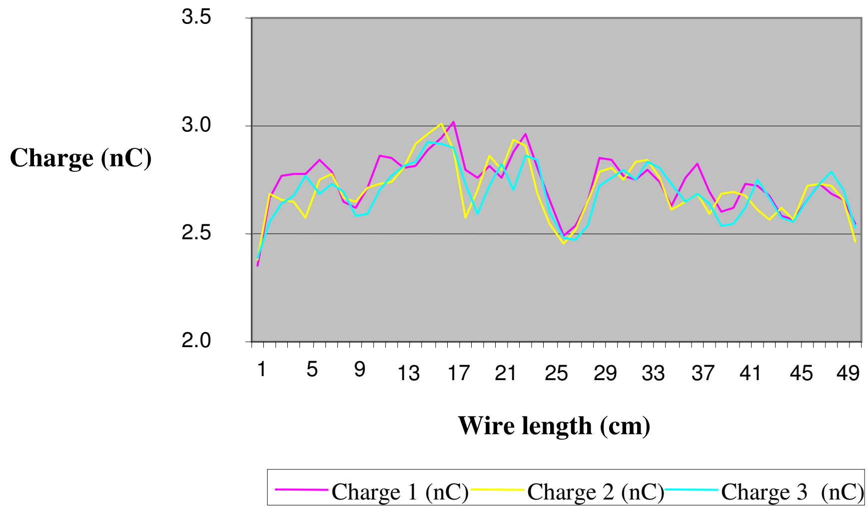

FIGURE 4: Wire 2 quality control

Table 1: Results from wires quality control

	Wire 1	**Wire 2**	**Ros. et al. wire**
Average 1	4.801 nC	2.741 nC	2.2056 nC
Average 2	4.719 nC	2.711 nC	2.0228 nC
Average 3	4.697 nC	2.697 nC	1.9230 nC
Standard Deviation 1	0.166 nC	0.114 nC	
Standard Deviation 2	0.135 nC	0.125 nC	
Standard Deviation 3	0.126 nC	0.115 nC	
Higher Measure 1	5.477%	10.000%	
Higher Measure 2	5.014%	11.045%	
Higher Measure 3	4.984%	8.484%	
Lower Measure 1	8.103%	9.227%	
Lower Measure 2	7.742%	9.430%	
Lower Measure 3	7.301%	8.349%	
Activity	244.0 mCi	143.5 mCi	

This quality control method aims to verify the homogeneity of the wire, with respect to the activity, over its 50 cm long. Variations in the activity of the wire along its length, are most often caused by irregularities in the concentration of iridium. However, such irregularities cannot explain the decrease of the peaks read, averages and standard deviations in the measurements sequences. These variations are related to two main factors:

1) The internal diameter of the glass pipe, where the wire goes through, which positions it in front of the slit, which provides the passage of radiation toward the detector, is much larger than the iridium wire diameter (iridium wire is 0.3 mm diameter, while the glass pipe is 2 mm diameter); and
2) The iridium wire reaches the hotcell in the helical form.

The iridium wire will lose its curl on its shape as it passes between the pulleys, which position the wire for measurement, losing their rolling shape, the length of wire that the detector sees through the slit goes down and, thus, the measured value also decreases.

In Fig. 5 are shown four examples of profiles, which can take iridium wire in front of the slit.

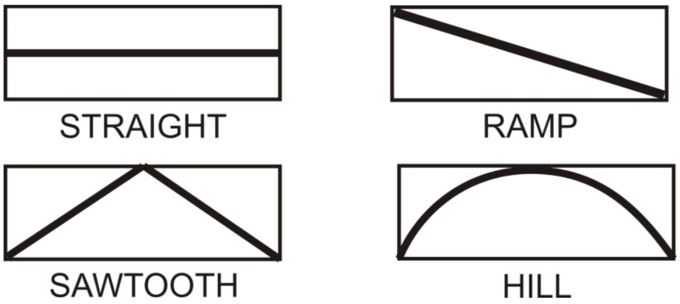

FIGURE 5: Iridium wire profile in front of the slit

Setting the wire "visible" width as 10 mm and maximum height to 2 mm, we can calculate, the approximate values of the lengths of the four profiles shown in Fig. 5:

a) Straight profile: 10 mm long;

b) Ramp profile: given a right triangle, base 10 mm and height of 2 mm, we get a result of 10.198 mm in length, a difference of 1.98% compared to the ideal profile;

c) Sawtooth profile: considering an isosceles triangle of base 10 and height 2 mm, we obtain a result of 10.77 mm, a difference of 7.7% compared to the ideal profile;

d) Hill profile, considering the following sinusoidal function:

x=t

$y = \frac{\pi}{5}\sin t$ $\quad t \in [0, \pi]$, to calculate the length of the wire we get the following line integral:

$\int_0^{\pi} \sqrt{1 + \frac{\pi^2 \cos^2 t}{25}}\, dt$, through the software Calculus Tools, we got the result 3.43, as the interval between 0 and π is equivalent to the interval between 0 and 10 mm, we obtain the length of the wire as 10.92 mm, a difference of 9.2% compared to the ideal profile.

In the examples presented profiles we obtained a variation of wire length ranging from 1.98% to 9.2%, values that influence too much the end result of iridium-192 wire quality control. Therefore, it is necessary to establish measures to restrict this type of variation. By continuing to use the same system of pulleys employing the method push-pull wire is necessary that before the measurements, the wire loses its wavy shape, and also should avoid creasing. New projects of traction, should aim to keep the wire as taut as possible in front of the slit, using guide pipe with an internal diameter smaller, or stretch the wire through the clamps that attach at their ends. Thus, it is possible minimize the effect, that the geometry of the source causes the reading, and thus improve the quality control of the iridium-192 wire used in LDR brachytherapy.

4. CONCLUSION

The current method of quality control of the iridium-192 wire, used in LDR brachytherapy has systematic errors, that directly influence the final result of the wire accordance. These errors can be minimized, by procedures that allow the wire stays as straight as possible in front of the slit, without deviation, folds or sinusoids. Innovative projects about traction, should aim at the wire stays as taut as possible in front of the slit.

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