PROJECT AND ASSEMBLY OF A BETA RADIATION MEASUREMENT SYSTEM

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ABSTRACT

Beta radiation detection systems are used in different fields, such as: environment, industry, medicine and radiation protection. In the project and assembly of beta radiation detection system, the thickness of the plastic scintillator detector is determined by the range of the largest charged particle energy to be observed [1]. The scintillator detectors can be made with a larger thickness, when interesting in the gamma radiation detection, or when this does not constitute a problem for the measurement being carried out. In this study, a measurement system using a 3mm plastic scintillator was assembled. This detector dimension provides an efficient detection for beta radiation and practically no interference from the laboratory background radiation. An approximate 43% efficiency was obtained for the ^{204}Tl source and 83% for the ^{90}Sr/^{90}Y source, geometry 4π. The assembled system was evaluated measuring the beta radiation absorption in paper samples of different superficial densities. For the beta radiation emitting sources used, the following mass absorption coefficient values were obtained: a) for the ^{204}Tl (23.1 ± 1.3 cm^2 x g^{-1}) and b) for the ^{90}Sr/^{90}Y (7.3 ± 0.4 cm^{2}xg^{-1}). A limitation found for the environmental measurement application was the high rate of background radiation, around 20 counts per second. With the use of an anti-coincidence system is obtained a background of at the most 2 counts per second.

Key Words: beta, detector, anti-coincidence, low background

I. INTRODUCTION

In this article the study and the assembly of a measurement system for beta radiation detection is presented. Systems of beta radiation measurements are necessary once several radioactive beta-emitting substances, such as plutonium, cesium, strontium, iodine, and tritium, may impose health risks. Those substances are biologically significant. Biological significance is a result of a combination of high decay energy, biogeochemical availability and efficient energy transfer to biological systems [2]. These elements are always produced during nuclear accidents and in industrial processes worked with nuclear materials.

The Environmental Council Hoosier [3] exposed a process developed by the company Selentec Environmental Technologies, for remotion of Sr-90 and Cs-137 from milk produced in Ukraine, an area affected by Chernobyl accident.

Sr-90 and the Cs-137 are very dangerous for health in situations where bioconcentration occurs, for example in cow milk. Sr-90 resembles Calcium, in the way it incorporates in the organism, mainly in bones and teeth. In the cited region, it is bioconcentrated in the cows milk and tissues. Cs-137 is chemically similar to potassium and it occurs in high level concentration, but Sr-90 dominates the interest [3]. The detection of these radionuclides is necessary, once their ingestion cause damage to the health.

Beta radiation detection systems used in environmental measurements need to have minimum background counts. The combination of a plastic scintillator detector with a NaI(Tl) is particularly satisfactory for this purpose [4].

Beta radiation detection systems are also used in non-destructive analysis (NDA), without necessity of extracting samples of the analyzed material or provoking interference in the productive process [5]. The combination of the beta radiation with a plastic scintillator detector is particularly satisfactory for this purpose.

The transmission of radiation through the material has been used with success to gauge densities of metal layers, recipients fuel level, fuel density, and in two phases analysis of systems [6, 7].

The superficial density (mass for area unit) given in mg/cm^2 or in g/m2 [8,9], is very important in pulp and paper Industry. The superficial density influences several paper properties, such as: thickness, opacity, and action during printing and in the operation of powder printing. When analyzing the economical aspects of the printed product, the importance of the superficial density increases, because the paper is marketed by weight and the printed product by printed area [9].

II. MATERIALS AND METHODS

The plastic scintillator detector used in beta measurements system assembly was produced in the "Centro de Tecnologia das Radiações do IPEN-CNEN/SP" laboratories, as described by Hamada and col. [10]. The dimensions of the scintillator plastic detector used are 50mm diameter and 3mm thickness. Figure 1 shows the detector, the photomultiplier and the photomultiplier base.

The plastic scintillator was used with the main detector and a NaI(Tl) detector of 2x2 inches was used with the secondary detector.

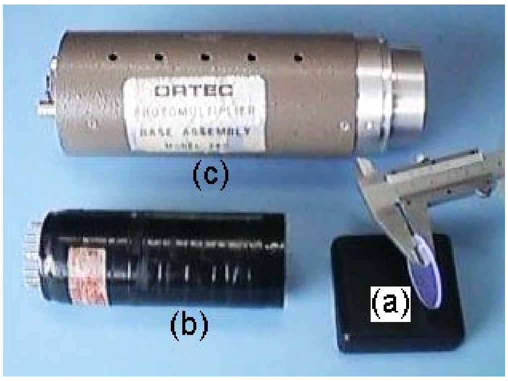

Figure 1 - (a) Scintillator plastic detector, (b) Photomultiplier e (c) Photomultiplier base.

The plastic scintillator was coupled to a RCA photomultiplier unit model 8575 with silicon grease of 1McStokes, in agreement with the analysis done by Hamada and col. [11].

In order to obtain a minimum background, an anti-coincidence unit was used. For the anti-coincidence measurements the plastic scintillator as main detector and NaI(Tl) as secondary detector were used. The measurements system is presented in the Figure 2.

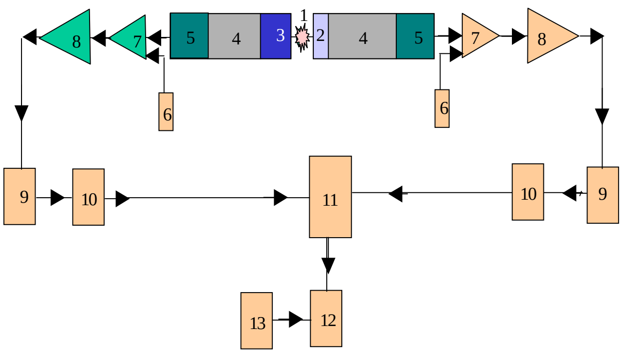

Figure 2 – Scheme of the assembling detectors and associated electronics - (1) Beta source, (2) Plastic scintillator, (3) NaI(Tl), (4) Photomultiplier (5) Photomultiplier base, (6) High voltage power supply, (7) Preamplifier, (8) Amplifier, (9) Single channel analyzer, (9), (10) Gate & delay generator, (11) Fast coincidence unit, (12) Counter, (13) Timer.

For the measurement system operation test, was simulated the method applied to quality control in the Industry of Pulp and Paper was simulated to evaluate the superficial density (g/m^2) of the paper, this system use a more simple electronics and is presented in Figure 3.

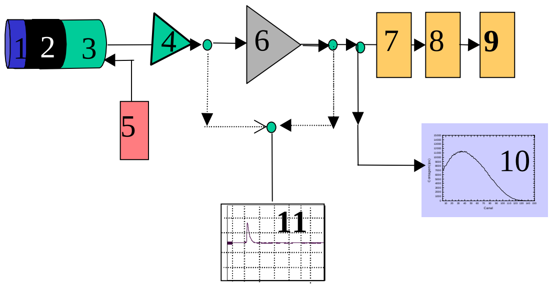

Figure 3 – Scheme of the assembling detector and associated electronics - (1) Detector, (2) Photomultiplier, (3) Photomultiplier base, (4) Preamplifier, (5) High voltage power supply, (6) Amplifier, (7) Single channel analyzer, (8) Timer, (9) Counter, (10) Multichannel analyzer, (11) Oscilloscope.

Measurements. The operation condition and the performance of the gauge system were verified obtaining the beta spectrum of the used radioactive sources, and using the χ^2 test and the Gauss curve (68%) [4]. In order to accomplish the superficial density measurements, paper samples were positioned between the radioactive source and the detector. In this study paper samples of different superficial densities were used. In order to obtain a minimum background value for the beta measurements, anti-coincidence between the plastic scintillator detector and the NaI(Tl) detector signals was carried out.

III. RESULTS

Results. Beta spectra of the sources $^{90}Sr/^{90}Y$ and ^{204}Tl are presented in the figures 4 and 5. It was observed that the spectra shown are continuous in energy as beta spectra described in the literature [4, 6, 7].

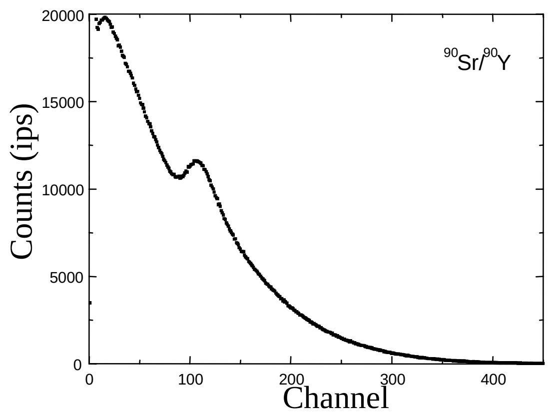

Figure 4 – Beta spectrum $^{90}Sr/^{90}Y$ source

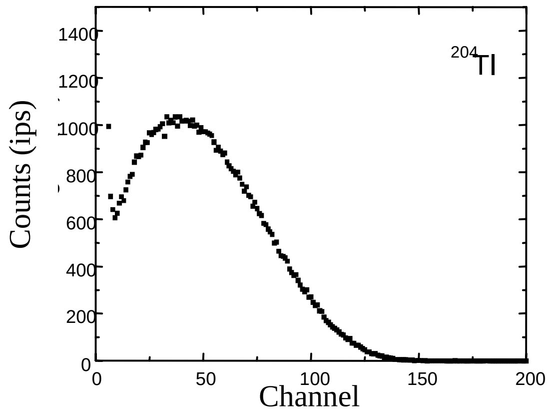

Figure 5 – Beta spectrum ^{204}Tl source

Fit curve region of the beta radiation absorption in a material is approximately exponential, so it could be written as: $N = N_0 e^{-\mu \cdot x}$, where N_0 is the number of beta particles incident per second in a material layer of thickness x. N is the emergent number of beta particles per second, and μ_0 is the absorption coefficient. It is a particular characteristic of the incident beta particles group. This coefficient is almost always independent of the target material, if x is measured in units of g/cm^2 and consequently μ_0 in units of cm^2/g. The half-thickness $d_{1/2}$ is the material thickness necessary to reduce N_0 to $N_0/2$, permitting the direct acquisition of μ, since $d_{1/2} = \dfrac{\ln 2}{\mu}$, [12].

In the Figure 6, the superficial density versus the counting curve is presented, using a ^{204}Tl source. An exponential equation was used for these data, obtaining an absorption coefficient μ (in m^2/g) for the analyzed samples of μ = 0.00231±0.00011 (m^2/g). Thus, the adjusted exponential equation is given by:

$$N = 4442 + e^{-0.00231 \cdot X}$$

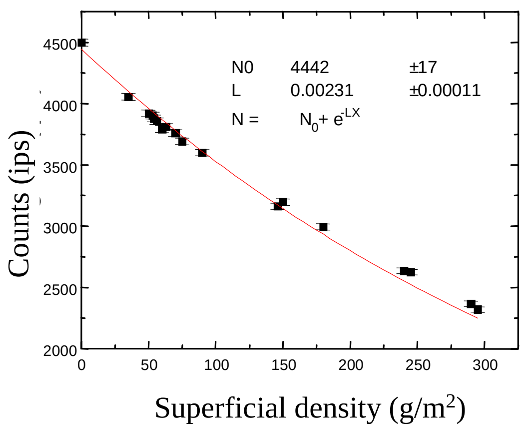

Figure 6 – Counts versus superficial densities, using ^{204}Tl source. The dots in the graph represent experimental values with the counting error bar.

In the Figure 7 the superficial density versus the counting curve is presented, using a $^{90}Sr/^{90}Y$ source. An exponential equation was used for these data, obtaining an absorption coefficient μ (in m^2/g) for the analyzed samples of μ = 0.00073±0.00004 (m^2/g). Thus, the adjusted exponential equation is given by:

$$N = 12663 + e^{-0.00073\cdot X}$$

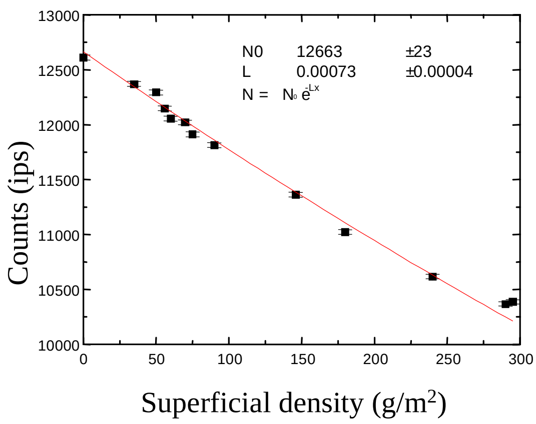

Figure 7 – Counts versus superficial densities, using $^{90}Sr/^{90}Y$ source. The dots in the graph represent experimental values with the counting error bar.

The μ values were obtained in m^2/g since the Pulp and Paper Industry uses g/m^2 as superficial density measure unit.

With the values μ determined for the ^{204}Tl and $^{90}Sr/^{90}Y$ sources, $d_{1/2}$ was calculated in mg/cm2, to compare with the literature values [8]. The Table 1 shows the comparison between the values obtained in this work and those published.

Table 1 – Comparison of determined values with those in the literature

Radioisotope	Half-thickness mg/cm^2 (This work)	Half-thickness mg/cm^2 (Published) [7]
^{204}Tl	30.0 ± 1.3	28.5
$^{90}Sr/^{90}Y$	94.95 ± 5.2	90

Anti-Coincidence. For the anti-coincidence measurements, the main detector output signal (plastic scintillator) enters the coincidence connector and the output signal of the secondary detector [NaI(Tl)] enters the anti-coincidence connector, in the fast coincidence unit. When there is coincidence of the signals the anti-coincidence inhibits the output signal. When there is not coincidence of the signs the output of the main detector is measured.

The resolving time of the anti-coincidence were adjusted of 2.0 μs. When the secondary detector pulse arises before the main detector pulse in the 0.0s – 2.0μs range, there is not output signal. The Figure 8 shows the output signals of the plastic scintillator and NaI(Tl) detectors after passing to the electronics system, difference between the signals rise is 2.0μs. The range of the anti-coincidence is exhibited in the figures 8 and 9. The Figure 10 shows one situation where anti-coincidence does not occur, so there is output signal.

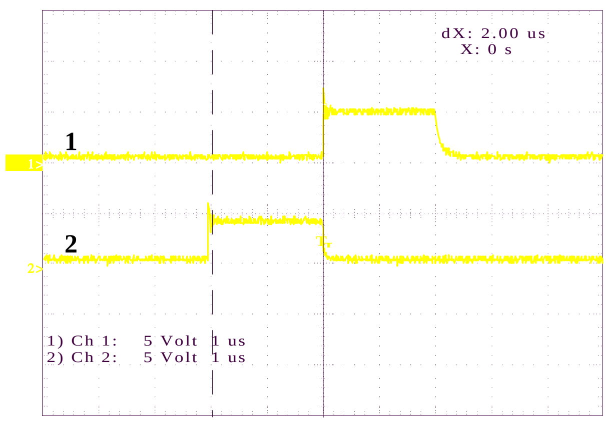

Figure 8 – Input signals in anti-coincidence unit. (1) Plastic scintillator, (2) NaI(Tl). No output signal.

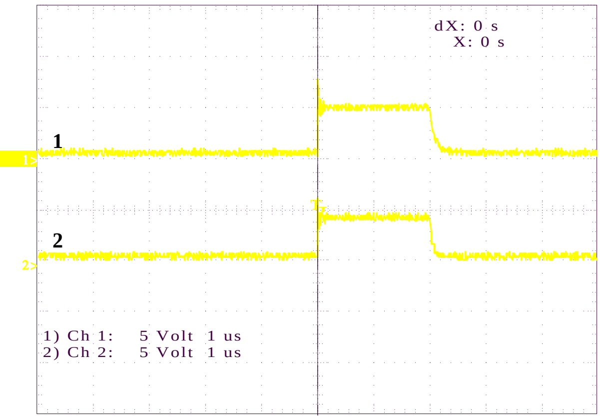

Figure 9 – Input signals in anti-coincidence unit. (1) Plastic scintillator, (2) NaI(Tl). No output signal

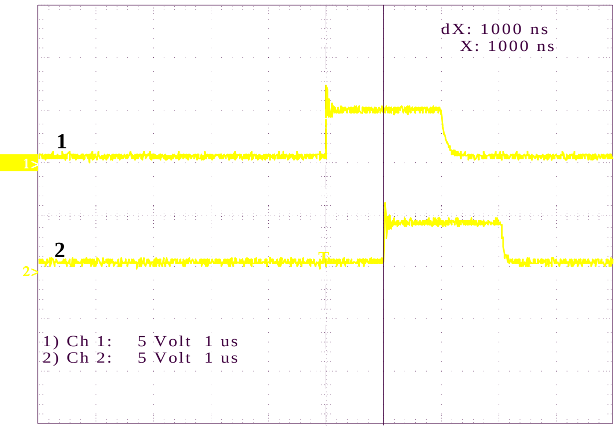

Figure 10 – Input signals in anti-coincidence unit. (1) Plastic scintillator, (2) NaI(Tl). There is output signal.

The background measurement reached maximum 2.0 counts per second.

With the anti-coincidence unit, the efficiency obtained for the gauge system using a $^{90}Sr/^{90}Y$ Source was of 34,6% for geometry 2π.

IV. CONCLUSION

From the obtained data for μ, $d_{1/2}$ and beta sources spectra, for the BG and efficiency of measurement for the small activity of a $^{90}Sr/^{90}Y$ source, this system proved to be running accordingly and these data are in agreement with the literature.

ACKNOWLEDGEMENT

The authors thank the Reactor Board and the Nuclear Engineering Center of the IPEN-CNEN/SP for the use of the Nuclear Experiments Laboratory, where the experiments were carried out. We also thank the Center of Radiation Technology, for the plastic scintillator detector used. We thank the University Cruzeiro do Sul (UNICSUL) and the CNPq for the financial support.

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