A PORTABLE, SINGLE-PHOTOTUBE LIQUID SCINTILLATION SYSTEM WITH AUTOMATIC SAMPLE CHANGING

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ABSTRACT. A majority of modern liquid scintillation counting systems are comprised of a coincidence detector unit with two 50-mm-diameter photomultiplier tubes (PMT) and an automatic sample changer that holds 100 to several hundred 20-mL vials. This arrangement emerged over 40 yr ago. Yet, smaller, simpler, and lighter automatic systems would be useful in cases when a compact, transportable system is needed or when only a small number of samples need to be measured. To explore the potential for such systems, we built a prototype carousel sample changer that incorporates a 28-mm-diameter vertical PMT to consecutively view the bottom of 12 vials on the carousel. This vial/PMT geometry, especially suitable for 1- to 5-mL samples, allows the use of sample holders of a variety of sizes and shapes to suit different applications.

INTRODUCTION

The basic features of present-day automatic liquid scintillation (LS) counting systems were established by manufacturers in the 1960s: two 50-mm-diameter photomultiplier tubes (PMT) coincidence detector system, 20-mL sample vials, and an automatic sample changing capacity of tens and later hundreds of samples. In the 1970s, when the disposal of used scintillator became a serious concern, minivials (7 mL) were introduced. These systems were designed mainly for biomedical research, where the measurement of a large number of samples containing a variety of isotopes was necessary. These systems have since been significantly improved and have gradually developed to a high technical standard, both mechanically and electronically. They have also been made available by manufacturers at affordable prices. Yet a smaller, simpler, and lighter automatic sample changer would be more suitable where the number of samples is low, when long counting times are needed, or when a transportable system with low power requirements is needed. To explore such possibilities, we created and tested a simple prototype carousel sample changer based on our experience with a single-PMT automatic sample changer used for radon measurements (Theodórsson and Gudjonsson 2002). In doing so, we focused on applications where the background count rate is of secondary importance, and therefore no lead shield is needed.

EXPERIMENTAL

Automatic Sample Changer and Detector Unit

To make the LS system as simple as possible, we chose the carousel type of sample changer and used a single-PMT detector (Figure 1), a setup that is similar to our radon LS system (Theodórsson and Gudjonsson 2002). A vertical PMT (Hamamatsu R6094, 28 mm diameter) faces the bottom of the vial, and there is an air gap of ~2 mm between the vial and the PMT. The system has no lead shield, weighs less than 3 kg, and has a capacity of 12 samples.

The counting system is enclosed by a light-excluding wooden box, 21 × 26 × 20 cm (Figure 2). A fixed plate inside the box holds the sample-changing unit. The circular carousel plate, made of 10-mm-thick plastic, is its central part. This plate is held by a steel axis fastened to a ball bearing (on the fixed plate) and is coupled to an electric motor. The plate must be able to accommodate sample vials of different shapes and materials. There are 12 circular holes in the plate for special vial holders that fit into the holes and can be adapted to the size and shape of each type of vial. It would

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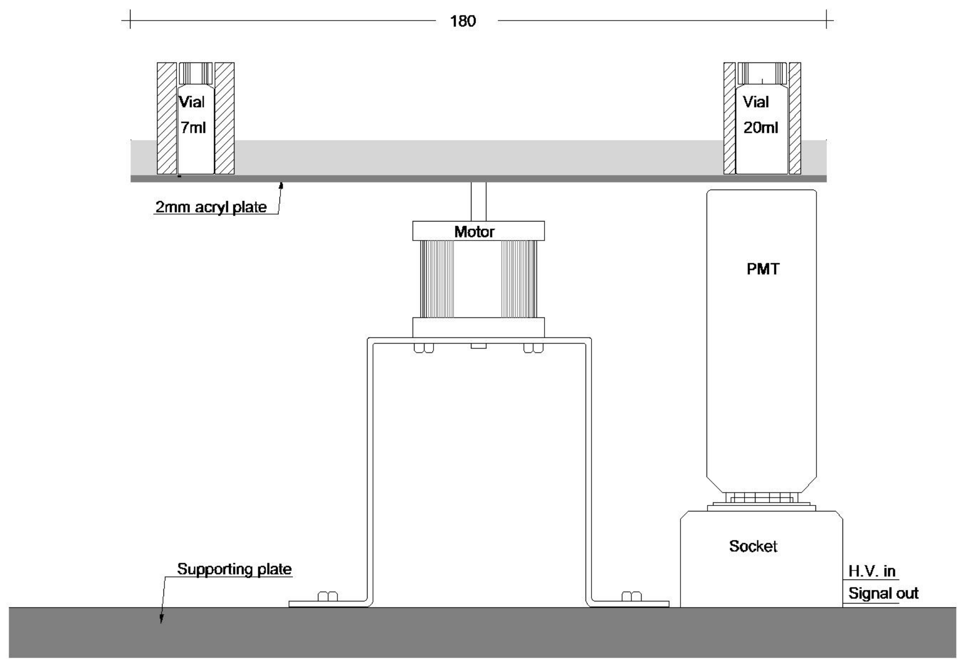

Figure 1 Schematic diagram of sample changer

therefore be easy to adapt the system to accommodate special vials that a new application may require. The carousel plate could also be made to fit vials of only one type, eliminating the need for holders. In addition, changing a carousel plate would be simple. A roller on the arm of a microswitch, fastened to the fixed plate, senses the counting positions of the carousel plate, where the roller rests in 1 of 12 recesses in the edge of the plate. When samples are changed, the motor stops when the roller meets the next recess. Before the lid of the box is opened for changing samples, a lock must be disabled, which switches off the high voltage and protects the PMT.

When low-activity samples requiring long counting times are measured, a modified version of the sample changer would be more suitable, e.g. a changer holding 4 vials, shielded by 5 cm of lead, with a total weight of 120 kg.

Electronics

The automatic sample changer unit has been tested both with available electronic units and with the prototype of a new dedicated microprocessorized unit (µPU) that is still in development. This unit is comprised of: 1) a stabilized high-voltage supply, set by a 10-turn potentiometer; 2) a linear amplifier; 3) a multichannel pulse-height analyzer; and 4) a microprocessor unit that controls all operations. Typical current consumption of the µPU is 0.2 Amp at 16 V DC, so it can run for more than a week from an accumulator weighing ~10 kg. To initiate counting, a PC computer is connected to the µPU. Counting conditions for each measurement run are provided to the computer using a special program that queries the user for the identification of the counting run, the number of samples to be counted, the identification of each sample, the number of counting sequences, and the counting time.

Figure 2 Photograph of the automatic sample changer

The information is stored and transferred to the µPU and counting then starts under the control of the unit alone, freeing the computer for other uses. The sample spectra are stored in the internal memory of the µPU, as well as the number of pulses in 6 preset pulse-height windows calculated from the spectra. At the end of the counting run, the PC is reconnected to the µPU for retrieval and processing of the counting data.

When ^{222}Rn is measured, the µPU has the ability to register separately the ^{214}Po alpha pulses in the ^{222}Rn decay chain through pulse-time analysis (Theodórsson and Gudjonsson 2002). This feature results in a background count rate of 3 counts per hour for 15 mL of scintillator with an unshielded detector, with 91% ^{214}Po detection efficiency.

Sample Holders

The vial/PMT geometry allows for a wide range of size and shape of vials. Today, samples with scintillator volume above 10 mL are rarely used, so we have focused on small samples of <5 mL. The vial geometry is matched to the 28-mm-diameter PMT cathode. There is presently a limited choice of suitable commercially made vials, so we have also tested some specially made or modified vials.

An important parameter of each vial/PMT geometry is its light collection efficiency, as an increase in this parameter allows one to attain higher counting efficiency for low-energy radionuclides and quenched samples. As a relative measure of this parameter for each vial, we use the channel number of the Compton edge of an external ^{137}Cs source, measured at fixed high voltage, using toluene with 1.7% butyl-PB as scintillator. The results are shown in Figure 3.

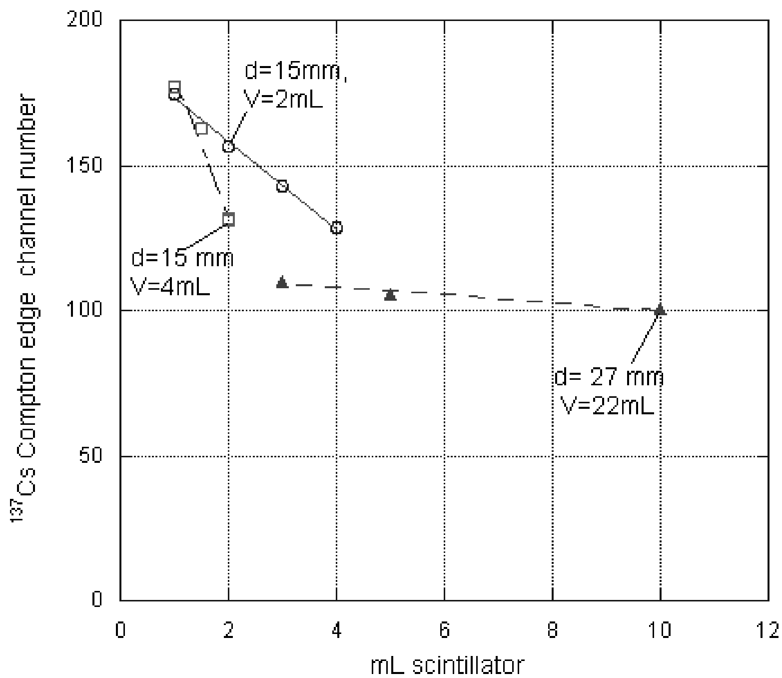

Figure 3 Relative pulse size for different vials, as measured by the Compton edge of a ^{137}Cs spectrum. Their diameter and volume are shown on the figure.

CONCLUSION

There is a need for smaller and simpler automatic LS counting systems than those presently available. To explore possibilities for such systems, a simple LS counter using a single-PMT detector unit and automatic changing of 12 samples has been built and tested. The results of testing the prototype of the system with different vials described here are promising. The next phase of this project is to test the system in a variety of applications.

REFERENCES

Theodórsson P, Gudjonsson GI. 2002. A simple and sensitive liquid scintillation counting system for continuous monitoring of radon in water. In: Möbius S, Schönhofer F, Noakes JE, editors. *LSC 2001, Advances in Liquid Scintillation Spectrometry.* p 249–52.