[Radiocarbon, Vol 25, No. 2, 1983, P 577-580]

AN EVALUATION OF SHIELDING CHARACTERISTICS APPLICABLE TO MINI-GAS PROPORTIONAL-COUNTER-BASED ^{14}C DATING SYSTEMS

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ABSTRACT. A mini-gas-proportional counter prototype of 10ml capacity (at NTP) was constructed of oxygen-free Finnish copper. The counter tube will be one of 16 equivalent tubes of a small-sample gas counting system, which is equipped with passive graded shield made of lead, cadmium, and copper and a dual active anticoincidence shield, consisting of an external cosmic gas-proportional and an internal plastic scintillation guard. The aim of this study was to evaluate the parameters leading to the design of a cost-effective and compact shielding package for mini-counters.

INTRODUCTION

A joint project was initiated in February 1982 between the Australian National University, Wallac Oy, and University of Turku to design a commercially viable multiple, gas-proportional β-counting system capable of ^{14}C age resolution of small samples, ie, 10 to 100mg of elemental carbon. The heart of the device will be 16 10ml capacity gas counters capable of operation at pressures from 1 to 10atm (abs). Flexibility will be achieved by loading each detector with a separate sample (parallel mode) or by loading the same sample into several counters (serial mode). It was estimated that the precision of a mini-gas counter in determination of the age of a sample would approach that of a good liquid scintillation counter (Polach et al, 1982). A predecessor of the proposed microprocessor-controlled instrument was constructed for tritium counting (Soini and Kojola, 1977).

SHIELDING CONCEPT

The passive shield consists of 600kg of low activity lead distributed asymmetrically around the sample counter: a maximum thickness of 20cm above, 12cm underneath, and 7cm in the side-walls of the cylindrical counting cavity (fig 1). An excentrically hollow cylindrical plastic scintillator (NE 102) is

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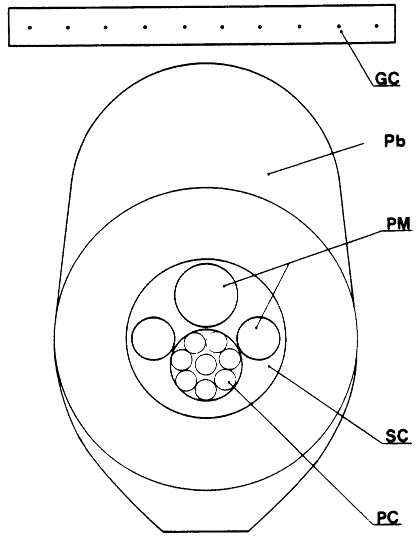

Fig 1. A cross-sectional view of the multicounter shield consisting of: gas-proportional flow counter (GC), massive asymmetric lead shield (Pb), photomultipliers (PM) facing plastic scintillator (SC) and sample gas-proportional counters (PC). The copper and cadmium layers as described in the text are not shown.

viewed with 6 photomultiplier tubes (3 on each end) and is surrounded by 3mm of copper. The inner wall of the plastic container is made of 1.5mm thick cadmium and a copper cylinder with a wall thickness of 5mm. The photomultipliers viewing the plastic scintillator are in anticoincidence with the sample counters, and the upper guard counter, which is a flat multiwire gas-proportional flow counter. The concept and reasons leading to the adoption of this shielding design will be described elsewhere.

SAMPLE COUNTER

The experimental counter (fig 2) was made of Finnish oxygen-free copper with nylon end-plugs and viton O-rings. The inner diameter of the counter tube is 13mm and its wall thickness is 1.5mm. The anode is a 10mm gold-coated tungsten wire. The voltage plateau, using pure CH_4, extends over a range of 1kV with a slope of 1%/100 V. The capacity of the counter is 10ml at STP. The tube is designed to withhold pressures of 4ATM and future design modifications will ensure that a pressure is expected to lie within 4 to 7ATM. Selection of materials was governed by the need to achieve a very low background signal within the ^{14}C β-energy region.

https://doi.org/10.1017/S0033822200005889 Published online by Cambridge University Press

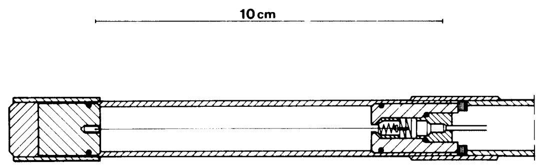

Fig 2. The prototype proportional gas counter. In this version the gas is admitted to and evacuated through the spring cavity, the gas capillary serving as the HV lead at the same time.

Good counters currently achieve a contemporary carbon-to-background count rate ratio of 8 (Harbottle, Sayre, and Stoenner, 1979). Based on this, our design goals at 7ATM are to achieve a modern count rate of ca 0.5cpm (≅720 counts per day) and background of ca 0.06cpm (≅90 counts per day).

TEST DATA

Background tests were carried out in Turku using the shielding described in figure 1 and at AERE, Harwell, using the iron/sodium iodide shielding as described by Otlet et al (1983). Results are given in table 1. A number of automatic on-line controls, as well as pre- and post-counting protocols can be instituted (Currie et al, 1983). These will deal with such parameters as counting gas purity, HV setting, detector long-term stability, detection of spurious (non-Poisson) signals, electronic system instability and environmental factors.

TABLE 1. Sample counter background

		CPM
Outside the lead shield		35
Inside the lead shield		7.8
Inside the lead shield + flat guard on top	*	5.5
Inside the lead shield + plastic scintillator	*	0.35
Inside the lead shield + plastic scintillator + flat guard on top	*	0.20
Old iron + borated paraffin + NaI(Tl) guard	**	0.06

* 50μs anticoincidence resolving time
** 114 hr count at Harwell (80 counts per day)

CONCLUSION

The performance of our sample gas-proportional counter at Harwell shows that it was possible to build an all-metal (copper) detector that meets our requirements. The increase in background, as observed when the same counter is located within our double anti-coincidence graded shield, located in Turku,

https://doi.org/10.1017/S0033822200005889 Published online by Cambridge University Press

is due to a number of factors. The most significant possibly are environmental gamma radiation and difference in attenuation of environmental gammas between plastic (Turku) and sodium iodide (Harwell) active coincidence guards. An experiment is planned late this year (1982) at the Harwell location, which will yield data to answer the above questions.

ACKNOWLEDGMENTS

This work was supported by a research grant from the Australian National University, Canberra, Australia, and Wallac Oy, Turku, Finland. Their support is gratefully acknowledged.

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