A ROOM TEMPERATURE LIQUID SCINTILLATION COUNTER

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THERE are a number of disadvantages to the use of refrigeration to reduce thermal noise in a liquid scintillation counter. Of these, the inconvenience of manipulating samples is perhaps the most obvious. An important consideration in some laboratories is the space occupied by the refrigeration equipment. In our experience the most serious drawback is the spurious counts arising from the operation of relays in the temperature control system.

Thus, for a variety of reasons, we thought a liquid scintillation counter requiring no refrigeration would be more desirable. Successful operation of a single-channel radiocarbon age dating counter at room temperature as described by PRINGLE[1] gave added impetus to the development of such an instrument. As a result of this effort we have constructed a liquid scintillation counter which has proven satisfactory for counting both C^{14} and tritium.

Our detector consists of a piece of 6 in. iron pipe supporting a 2 in. lead shield and containing the photomultiplier with associated circuitry. The iron liner in the lead shield is of special importance since its purpose is to attenuate radiation arising in the lead itself. This optical system is not the best. It was designed for the use of 3 dram vials as sample containers because they are cheap and disposable. It turns out that this disposability is their only virtue. The bottoms are not flat and can trap air bubbles in the optical sealing liquid if extraordinary care is not taken. A mathematical analysis of our counting errors points to the vials as principal offenders. We ran a few series of counts paying particular attention to thorough wetting of the vials and exclusion of air bubbles. This reduced the error to a value comparable to the normal statistical counting error.

The amplifier is located as close as possible to the photomultiplier in order to keep the primary signal lead short. This signal goes directly to the first stage of the amplifier. We have found that a cathode-follower preamplifier can often introduce enough noise to completely swamp the feeble signals produced by weak beta emitters.

The signal is taken from the tenth dynode. This pulse is positive and gives more gain in the first stage than a negative one. Also it seems to have less noise associated with it. The low-value load and grid resistors have been used, not to provide a short coupling time constant, but merely to hold down resistor noise. This first stage is a cascode, chosen because it provides as much gain as a pentode at about the same noise level as a triode. Also for gain vs. noise it seems to be a bit better than the long-tailed pair of cathode-coupled

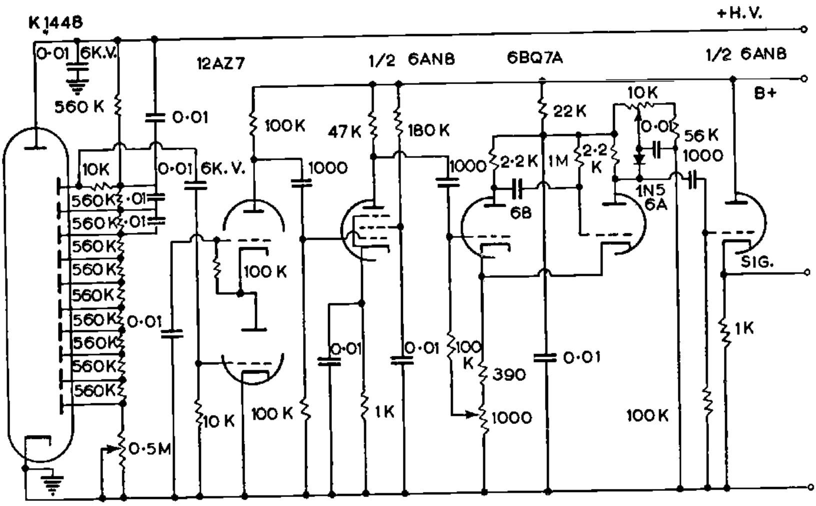

Fig. 1.

first stage. For those who like to be particular about pulse shape the top grid of the cascode is available for feedback. The second stage is a conventional pentode except for the rather long coupling-time constants. The glow-transfer scaler used prefers its pulses long, so the pulse-stretching was done at a point where it could realize the most gain. Pulse pile-up often encountered in a slow amplifier is a minor problem here because we never operate at very high count rates. The overall gain from the tenth dynode to the plate of the pentode is about 4000.

The Schmitt trigger is used as the pulse height discriminator. Its trigger level is adjustable by the bias control. The height of the pulse at its output plate is clipped to 5 V by the low-value plate resistor and the decoupling network. This clipping produces a large negative overshoot, of course, which is removed by the diode and bypassed to ground. The result is a nice square pulse 5 V high and 5 μsec wide with rise and decay times of 0.1 μsec. This passes unchanged through the cathode follower to the scaler.

This counter was first built with both upper and lower gates. However, the noise contribution from high energy sources seemed to be small in comparison with thermal noise. By cutting out the upper gate it was possible to eliminate four tubes. The Schmitt discriminator was used in preference to biased diodes because it was believed that it would give sharper discrimination against thermal noise and might make it possible for us to count tritium.

Using PBD (2-phenyl-5-(4-biphenylyl)-1,3,4 oxadiazole) at a concentration of 6 g/l. and POPOP at a concentration of 100 mg/l. our counting efficiency for carbon-14 is 66% with a background of 43 counts/min. Argon bubbling to remove dissolved oxygen raises this to 73% at the same background. Our tritium data are more recent and less well finalized, but with the same scintillant solution it appears that we can count tritium at 25% efficiency with a background of 140 counts/min. This is without oxygen removal. The improvement of the photomultiplier with use that we reported earlier[2] is also evident here. At the time we put this counter into service (February 1957) the tritium efficiency was 5% at the same background.

The long-term stability of this counter seems to be quite good. Daily background counts over a 30 day period show a random spread of ± 3 counts/min out of 45, when the instrument is adjusted for C^{14} counting. For any one day the spread is ± 1 counts/min. It seems to be quite free of spurious counts arising from the operation of switches and relays in the counting room.

The counter has good concentration sensitivity as well as efficiency. Thus, since we can determine 10 counts/min on a 2 g sample, this corresponds to about 14 disintegrations/min which is $14/2.2 \times 10^6 = 6 \times 10^{-6}$ μc per 2 g sample or 3×10^{-12} c carbon-14/g. This is a very satisfactory sensitivity and we have found the instrument particularly useful in the low activity region.

REFERENCES

[1] PRINGLE, TURCHINETZ and FUNT. *Rev. Sci. Instrum.* **26**, 859–865, (1955).
[2] T. S. HODGSON and B. E. GORDON. *Nucleonics* **14**, 64 (1956).

PART III

CHEMISTRY OF THE COUNTING SAMPLE

(Round Table Discussion)