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FAST COUNTING WITH THE SCINTILLATION DETECTOR

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Abstract

Experience with the 56 AVP Mullard and 9594 E.M.I. photomultipliers is described. Harwell 2000 series amplifiers and scalers giving a 10 nsec. double pulse resolution were used. Problems associated with ion counting with the scintillation detector at count rates above $3\ 10^6$ counts/sec. are discussed.

Pulse counting methods for ion detection in isotopic analysis have been used for some time now both with Allen electron multipliers (1) (2) and scintillation detectors (' Fig. 1 shows the detector used for these experiments, which has been in use with 10 Mcs. electronics for three years on one of our analytical instruments. The incident ion beam is shown impinging on the polished target which is at a potential of 30 kV. The secondar electrons are accelerated on to the plastic phosphor and the light signal is then detecte by the photomultiplier. As the phosphor is sealed in the vacuum wall it is possible to remove the normal multiplier, the E.M.I. 6097 which has a transit time spread of 12 nsec and replace it with a fast photomultiplier. The phosphor is Nuclear Entèrprises NE 102 which has a decay time of 3 nsec.

The usual pulse height distribution is shown in the histogram in Fig. 2 and it is clear that with a discriminator setting which almost eliminates the small noise pulses, very high efficiency of ion detection is obtainable. The smooth curve shows the pulse distribution obtained from an electron multiplier. Fast counting has obvious advantages for large ratio measurement when in order to have reasonable statistics of the small beam the main beam must be as high as possible. Also precise measurement of smaller ratios is easier with fast counting as the analysis time can be reduced. We have used the internal standard method of Dietz, Pachucki & Land to show that quite high precisio is attainable for low level uranium measurement. This work has emphasized the value of being able to count the principal isotope as fast as possible to reduce the time for the analysis. We found that it was possible to obtain very nearly the theoretical precision at 0.1% levels when measuring natural uranium with 10^{-7} gm. samples (5). It is easy to show that if the maximum count rate is limited to 2.10^5 counts/sec. the analysis time ca be long. Four peaks were measured with a peak switching technique 235, 238, 233, and 23 and the final ratio was computed as (235/238)/(233/236). With natural uranium 235/238 - 0.0072, the maximum count rate for 235 is 1.4×10^3 counts/sec. and as the theoretical precision is:

$$\sqrt{\frac{1}{n_{238}} + \frac{1}{n_{235}} + \frac{1}{n_{233}} + \frac{1}{n_{236}}} \times 100\%$$

for 0.1% precision the analysis time must be greater than 3×10^3 sec. For this type of measurement it is worthwhile to extend the counting system to use 100 Mcs. electronics.

The complete system is shown in Fig. 3. The 100 Mcs. 2068 prescaler and tunnel diode discriminator and 2117 scaler are in the Harwell 2000 series (6). With a 10 nsec. clip line to produce a bipolar pulse the double pulse resolution of the whole system from the multiplier output using equal height pulses was found to be 12 nsec.

Although one can achieve a very high system gain with no additional amplifier it is not possible to make use of this when counting fast as the integrated output currents become high enough to cause trouble. With 10^9 gain of the phosphor multiplier system and 10^7 counts/sec. the output current is $1.6 \times 10^{-19} \times 10^7 \times 8 \times 10^9$ amps = 13 mA. Not only is this current comparable with the tube chain current, so making special stabilization of the later stages necessary, but it also gives rise to non-linearity due to space charge effects. This can be reduced by increasing the interdynode voltages progressively towards the anode, but the possibility of damage to the dynode surfaces remains, and the manufacturers recommend a maximum current of ½ of 1 mA in any case. The total power dissipation on the anode is also limited (ca. ½ watt), and this clearly limits the product of current and the final dynode voltage (e.g. at 600 volts I max < 1 mA). There is always the possibility of an accidental excessive count rate when 'tuning up' a spectrometer, and this must not be allowed to damage the tube. For various reasons, then it is advisable to use a pulse amplifier after the photomultiplier, and for this work two 250 Mcs. distributed amplifiers were used with a gain of 10 each, and the tube gain was set at approximately 10^6. It was found for both tubes that the multiplier was highly sensitive to stray magnetic fields and a tight fitting mumetal screen was required.

56 AVP

At first the tube was wired as shown in Fig. 4 with 0.1 μF condensers on the last three dynodes. With this arrangement it was discovered that bad ringing occurred and in our early attempts the counting losses increased much more than expected above 3×10^6 counts/sec. Finally all the condensers were removed and the ringing was much reduced.

If the removal of the condensers produces any effect it should be to reduce the size of the larger pulses which is not serious for our scaling application. The focussing potentials are adjusted to give the best signal. The pulse rise time and width when counting uranium ions with 1.5 kV on the tube and an amplifier gain of 100 are indicated in the Table as obtained from a Hewlett Packard 185 B sampling oscilloscope. The tube characteristics are also given. The pulse height distribution follows the curve given earlier with few small and large pulses, and any ringing is small.

The discriminator curve for uranium is shown in Fig. 5 and a plateau is observed. The noise is less than one count per second at the operating position, but if a 1 cm diameter photocathode becomes available rather than the present 5 cm diameter the noise should be considerably reduced.

Counting losses were measured mass spectrometrically by analysing NBS 1% uranium, 235/238 = 0.01013. The observed ratio is increased at higher count rates principally because of the losses of the mass 238 signal. A plot of observed 238 against expected 238 is shown in Fig. 6. The curve (Run 1) now follows that predicted for 15 nsec. deadtime up to 5×10^6 counts/sec. and thereafter becomes unstable, rising rapidly to about twice this figure. This effect can be pushed to a higher count rate by reducing the tube supply voltage but this soon moves the operating point off the end of the plateau. Small additional pulses can be seen on the oscilloscope while in the unstable mode but it is not clear what process is involved. It was found possible to raise the threshold of instability to above 1.2×10^7 counts/sec. by putting 47 pf condensers back in the dashed positions on the dynode chain (Run 2). It is thus possible to count to 1.2×10^7 counts/sec. when required with approximately 1.3% error in the corrected count rate due to uncertainty in deadtime or 1.0×10^6 counts/sec. with 0.1% error.

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This tube gave similar results to the 56 AVP but a rather longer output pulse was observed. A similar unstable condition was observed at high count rate, but at a lower rate than with the 56 AVP.

Full intercomparison cannot be given because the number of tubes examined so far is small and some of these were damaged by using too high output currents.

References

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Table 1

Manufacturer's Data		Mullard 56 AVP	E.M.I. 9594
No. of stages		14	14
Overall maximum volts (kV)		2.5	2.[illegible]
Gain		10^8	10^8
Maximum anode current (mA)		2	1
Maximum anode dissipation (W)		1.0	0.5
Transit time spread (rise time, nsec.)		2	2.[illegible]
Pulse width at half height (nsec.)		2	ca. 4
Observed - Scintillation Detector			
Rise time (nsec.)	(Without amplifier)	3	5
	(With amplifier)	7	7
Pulse width at half height, (nsec.)	(Without amplifier)	4	6
	(With amplifier)	7	7

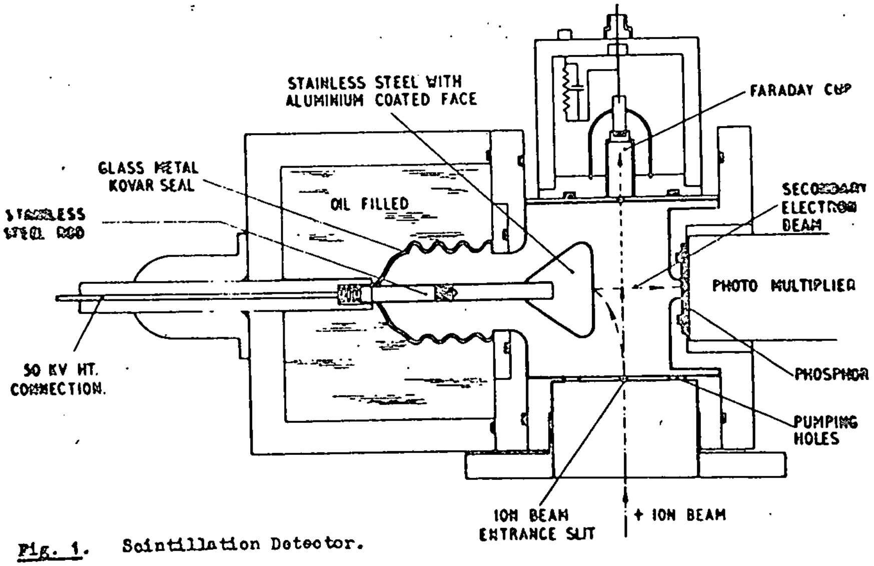
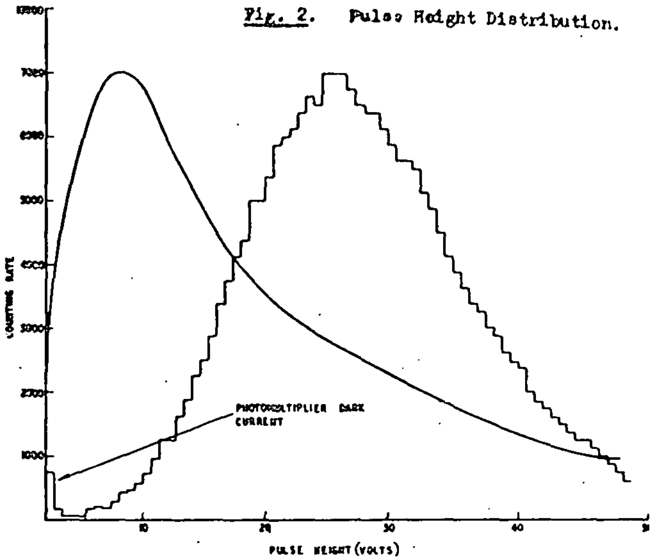


Fig. 1. Scintillation Detector.

Fig. 2. Pulse Height Distribution.



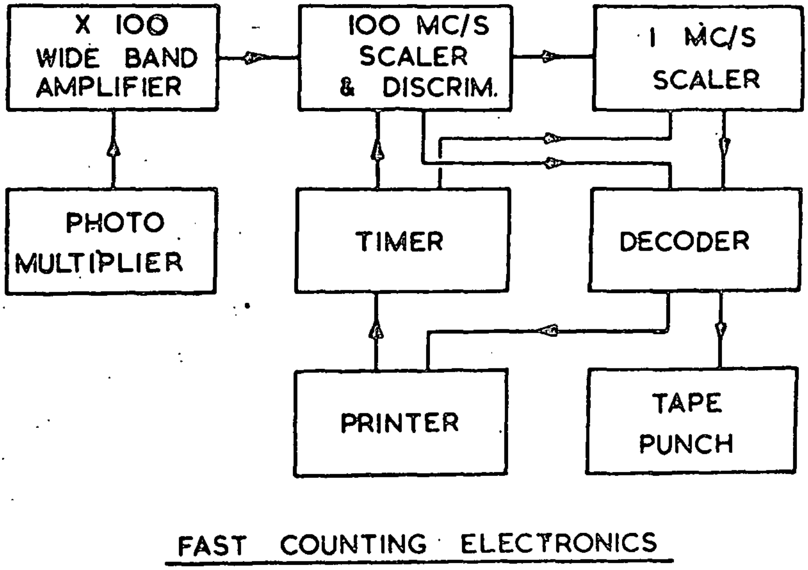


Fig. 3. Fast Counting Electronics.

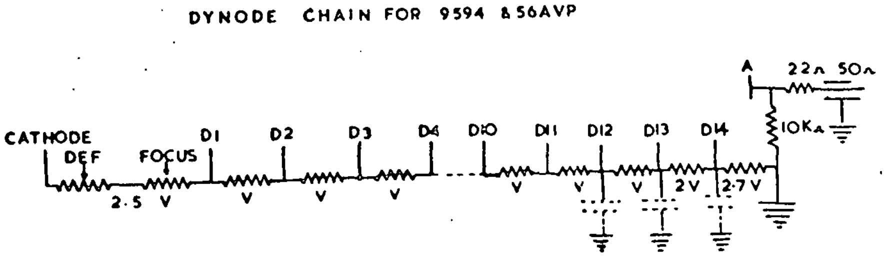


Fig. 4. Photomultiplier Wiring.

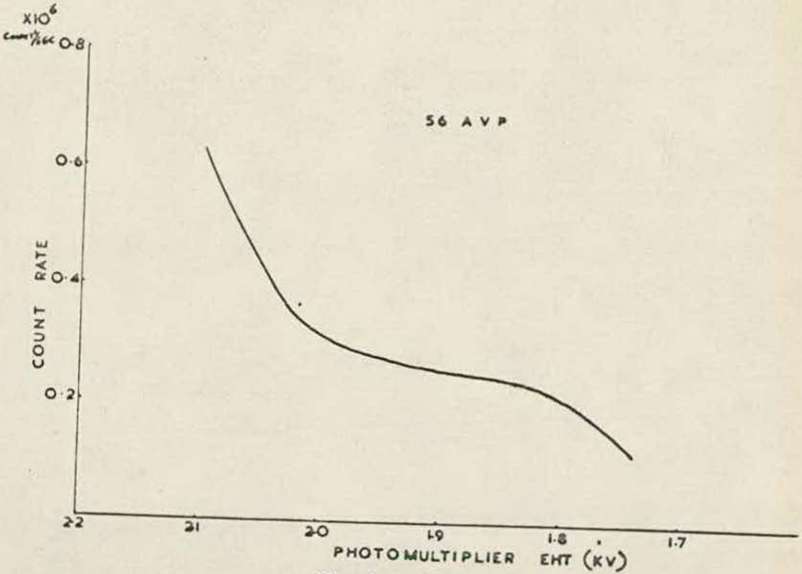


Fig. 5. Discriminator Curve.

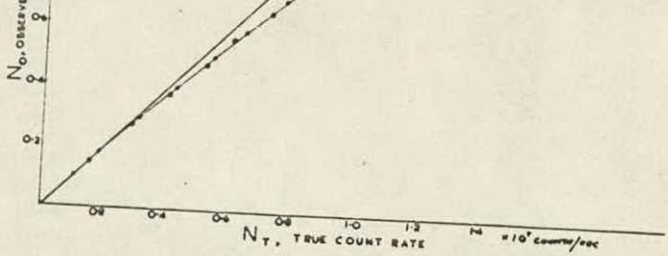


Fig. 6. Counting Losses.