A PROPORTIONAL COUNTER WITH GRID CONTROL*

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Introduction

Where accurate energy loss measurements are to be attempted, counter proportionality must be preserved over the entire active length of the anode wire. This may be endangered by attachment to electronegative impurities in the counter gas ; or by the counter end effect, which causes a serious loss of gas amplification at the wire terminations (Curran, Angus, and Cockroft 1949 ; Rossi and Staub 1949).

The end effect may be considerably reduced either by using large length/diameter ratios (Curran, Cockroft, and Insch 1950), when the contribution of a given end effect may be made small ; or by some improvement in the design of the wire terminating system. Two common methods are to use either an earthed guard tube (Curran, Angus, and Cockroft 1949), insulated from the centre wire, or an effective thickening of the centre wire itself (Coon and Nobles 1947). If the latter system is used, the terminating rod diameter must be chosen so that the gas amplification at its surface will be negligible compared with that along the wire. A recent technique (Curran and Cockroft 1951), ideally suited to short counters, employs field adjusting tubes located at each end of the counter, and these limit electron collection to a region free from end effects.

An alternative method of eliminating end effect is advanced, in which a grid system of fine wires completely surrounds the anode wire, as in Figure 1. Since the effective counter diameter is now reduced to that of the grid system, a large length/diameter ratio will be obtained, while the full counter diameter is still available for electron collection.

The Gridded Counter

Construction.—The proportional counter, shown sectionally in Figure 1, was designed for a cosmic ray shower experiment, in which a large collection volume was required together with rapid electron collection. In order to test the field configuration, a double scale model of the grid and anode structure was submerged in an electrolytic tank and a three-dimensional field plot taken, particular attention being given to the region near the wire termination. It was found that the lines of force became radial within 3 mm from the end of each guard

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tube, indicating constancy of gas amplification over all but 6 mm of the 56·8 cm effective wire length.

The counter wall was rolled from 0·006 in. tinplate to minimize transition effects, and the joins within α-particle range of the collection volume soldered with pure tin instead of ordinary lead solder, which is badly contaminated (Bearden 1933). Accurately machined " Micalex " insulators carried the 24 stainless steel grid wires, and located the anode wire on the axis of the grid system to within 0·001 in. The central wire was made of spring steel, examined microscopically for defects, and reduced to a constant diameter of $0\cdot0225 \pm 0\cdot0001$ in. over its entire length. This was the greatest diameter for an operating potential below 3 kV, and permitted a more accurate wire treatment. Removable end pieces carried the anode and grid assemblies, and were screwed tightly into place prior to outgassing, after which the O-ring seals were inserted to make the counter vacuum tight. A filling tap is provided which is vacuum

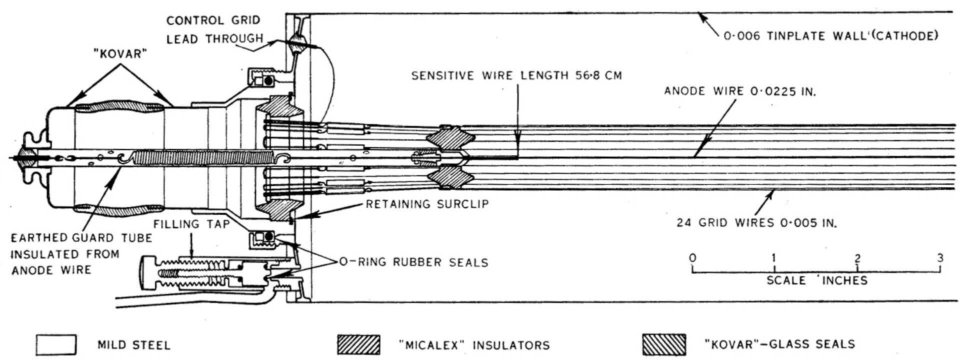

Fig. 1.—Sectional diagram of gridded proportional counter. Gas filling consists of 5 cm methane+argon to 81 cm Hg. Gas amplification is 400 for anode-grid voltage of 3 kV and anode-cathode voltage of 5 kV.

tight when closed, or when opened to the filling system. Gravitational sag is made the same in each wire by adjusting the tension with springs. The counter is enclosed in a thin metal shield to reduce radio-frequency interference, and to provide a safety precaution because of the high voltage present on the cathode.

For a gas amplification of 400, the grid is maintained at —3 kV with respect to the centre wire, and the cathode or case at —5 kV, allowing 2 kV for electron collection. The anode and guard rings are, of course, at earth potential.

Gas Filling.—The counter was outgassed for several days, at 160 °C during the day ; and left under static vacuum at room temperature overnight. When the vacuum remained better than 0·001 mm Hg for 24 hr, the counter was filled. Of the counter fillings tried, the most successful proved to be a mixture of Arc-argon and 6 per cent. commercial methane, dried with phosphorus pentoxide. Drift velocity data for these gases are available (English and Hanna 1953) ; the most important impurity being 0·2 per cent. oxygen in the Arc-argon.

The question of electron attachment to the oxygen impurity due to its known electronegative nature (Wilkinson 1950) may now be investigated by means of the control grid, since the grid conveniently partitions the counter into two sections; one being a high field region inside the grid wires which is most unfavourable for electron attachment, and the other being the large volume outside the grid system where attachment may occur. The latter occurs on forward collection where electrons liberated anywhere within the counter travel to the centre wire; whereas the former applies on reverse collection where a reverse field prevents electrons released outside the grid system from making any contribution.

A molybdenum filter on an X-ray tube concentrates the transmission radiation at its K absorption edge, providing a sufficiently homogeneous calibrating source to check the pulse distribution widths for both forward and reverse collection. These are shown in Figure 2 (*a*), the one for reverse collection being

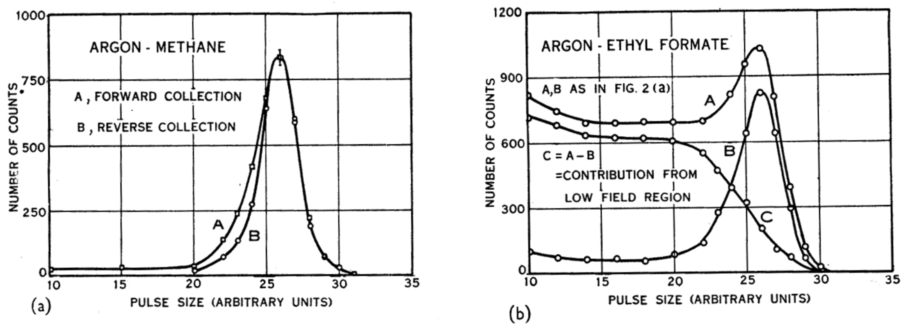

Fig. 2 (*a*).—Experimental pulse distributions obtained with transmission X-radiation through 0·017 in. of molybdenum, for a proportional counter filling mixture of unpurified commercial methane and Arc-argon. Percentage width at half height for *A* is 13 per cent. and for *B* 12 per cent.

Fig. 2 (*b*).—Pulse distributions for a filling mixture of 6 per cent. ethyl formate with Arc-argon. Distribution width for the high field region inside the grid wires, *B* is 14 per cent. *A* represents the distribution from the entire volume and *C*, the contribution from the low field region outside the grid, has no peak, indicating a very high attachment rate.

12 per cent. width at half height, and for forward collection 13 per cent. This discrepancy in widths could be accounted for by the increased attachment outside the grid system, although this is by no means certain since some increase in width is to be expected from the X-rays which eject photoelectrons from the counter wall.

Two other counter fillings had previously been tried, one being Arc-argon with 6 per cent. ethylene. After working well for some time, it quickly deteriorated and produced a white deposit, presumably of some ethylene polymer, over the anode wire. The second filling contained 6 per cent. ethyl formate as quenching agent, and gave evidence of overwhelming attachment despite intense efforts to purify the liquid by distillation and outgassing at low temperature. The only conclusion possible was that ethyl formate is itself slightly electronegative. This effect has not been observed with Geiger counters, possibly since they operate at a higher value of X/p than that outside the control grid system but comparable with that inside it, where X is the field strength in volt/cm and p the pressure in mm of Hg. The experimental pulse distributions for argon with ethyl formate are shown in Figure 2 (*b*), in which curve *B* is the contribution from inside the grid wires. Here the low distribution width provides evidence for only a small amount of attachment. In contrast to this, the distribution *C* obtained from the lower field region outside the grid wires exhibits no peak at all, and is indicative of an enormous attachment rate. The possibility of the collection field straddling an attachment peak may be discounted, since the field strength increases continuously, changing by an order of magnitude between cathode and grid.

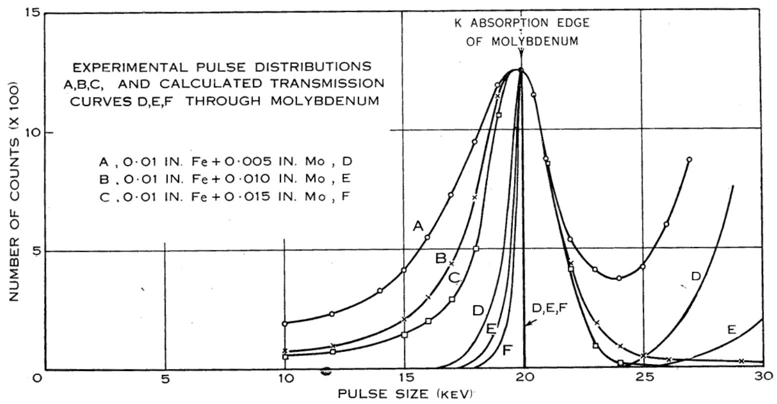

Fig. 3.—Theoretical and experimental curves for transmission X-radiation passing through the counter wall and shield (0·010 in. iron) plus various thicknesses of molybdenum. The energy scale is located by using the 46·7 keV γ-ray line from Ra D+E+F as a pulse size reference.

Calibration with Transmission X-radiation

A method of X-ray calibration with transmission radiation, utilizing the abrupt transmission discontinuity at the K absorption edge, has been found to yield excellent results. White radiation from an X-ray tube falls on a thin sheet of molybdenum, and the emergent radiation is grouped strongly below the K absorption edge at 20·0 keV. The fraction transmitted through various thicknesses of molybdenum, plus the 0·010 in. iron counter wall and shield is shown as a function of energy in Figure 3. As the thickness of molybdenum increases, the transmitted energy band becomes narrower and approaches K_∞, and the maximum thickness of molybdenum usable will then be governed by intensity considerations.

The experimental pulse distributions are also shown in Figure 3, and are accurately located on the energy scale by using the 46·7 keV γ-ray line from Ra D+E+F as an energy reference. The experimental distributions are seen to coincide on the high energy edge; and to exhibit a similar behaviour to the computed curves on the low energy side, which will be emphasized since the counter detection efficiency at 15 KeV is just twice that at 20 keV. There will also be some contribution from fluorescent radiation at the smaller absorber thicknesses, since some higher energy radiation which penetrates the absorber will be accompanied by fluorescent radiation being continuously produced. The experimental peak occurs at 19·9 keV, which is equal to the energy of the absorption edge at 20·0 keV within the experimental error.

While there are objections to this type of calibration in principle, since the calibrating wavelengths are not homogeneous, in practice the width of the experimental pulse distributions is large compared with that of the transmitted energies. One may even assume that the latter are centred at the K absorption edge at 20 keV, the error so incurred being quite unimportant. It must also be emphasized that the calibration distribution width of 12 per cent. obtained with 0·017 in. molybdenum is not the smallest width available using the transmission method, but, when a tungsten anode X-ray tube is operated at 16 kV (r.m.s.) and 0·5 mA, a greater thickness that this will reduce the count rate through the single analyser channel to a value below 30 counts/sec. The homogeneity of the transmitted beam may be further improved by removing the contribution made by transmission fluorescent radiation. This fluorescence is produced by some of the higher energy X-rays which penetrate the absorber, and may be eliminated by a reduction in operating voltage.

The transmission method has several advantages. Firstly, a thin window, in the usual sense, is not necessary, provided that the counter wall itself does not cause too much attenuation. Of course the absorption edge of the wall material (6 keV) must be well below that of the transmitting element (20 keV). As a possible alternative, either some part or all of the counter wall may be constructed from the transmitting element. This can facilitate calibration of high or low pressure counters.

Secondly, since the emerging wavelengths are grouped strongly above the absorption edge, only one material is required for calibration. This contrasts favourably with either fluorescent X-radiation or K-capture calibration techniques, where the radiator or K-capture source emits all the characteristic wavelengths of the element concerned, and to produce a homogeneous beam for calibration we must use a selective filter to remove the Kβ component. Consequently, if a selective filter is used, the number of calibrating energies available will be greatly reduced.

Finally, scattered radiation is completely eliminated since the counter may now be completely shielded with lead except for the transmission window, through which all the detected radiation must pass. The trouble experienced with scattering becomes very serious when fluorescent X-radiation is used for calibration. Here the contribution from scattered radiation makes the distribution peak shift with a change in X-ray tube voltage; even in the position of minimum scattering.

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