A NOTE ON END EFFECTS IN ELECTRON DRIFT TUBE EXPERIMENTS

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Abstract

Experiments to test the influence of end effects on electron drift velocity measurements by the Bradbury–Nielsen time-of-flight method are described. A comparison of data taken at drift distances of 5, 10, and 50 cm in hydrogen and 5 and 10 cm in helium shows that over the E/N and pressure ranges investigated the results are independent of drift distance and that it is justifiable to consider this distance as that between the mid planes of the grids which terminate the drift chamber.

The analysis of electron transport coefficient data to obtain scattering cross sections as a function of electron energy depends for its success on the availability of data of high precision (Crompton 1969; Bederson and Kieffer 1971). The transport coefficient that is subject to the least experimental error is the drift velocity, and Crompton *et al.* (1970) have claimed that measurements by the Bradbury–Nielsen method of the electron drift velocity in helium have an absolute error of less than 1%. One of the assumptions made in assessing the error was that the effective drift length could be taken as the geometric distance between the mid planes of the grids used to gate the electron current. However, there are a number of effects, which we shall generally term "end effects", which can cause the effective drift distance to differ from the geometric distance, and these include contact potential differences between shutters, surface layer effects (at the top shutter), diffusive effects, the variation of shutter transmission with electron energy, the change in mean energy as the swarm of electrons traverses a shutter, and field distortion due to the sinusoidal potential applied to the shutter wires. A discussion of these effects has been given by Elford (1972).

By suitable choices of experimental parameters it is possible to reduce end effects to an insignificant level over a wide range of values of E/N in most gases (E being the electric field strength and N the gas number density), although there are certain values of E/N where some of these effects cannot be completely ignored. The influence of contact potential differences and surface layer effects can be reduced by using large applied potential differences across the drift chamber, while diffusive effects and the consequences of change in mean energy can be minimized by using high gas densities. The presence of field distortion due to potentials applied to the shutter wires can be detected by varying the magnitude of the sinusoidal potential. However, despite the choice of parameters and experimental checks there is no certainty that all

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end effects have been accounted for and the only rigorous test is to show that the electron drift velocity is independent of the length of the drift chamber. In view of the significance of the precision of drift velocity data in obtaining precise cross sections, it is appropriate that such a test should be made. Data have therefore been assembled for two gases, hydrogen and helium, and for experimental tubes of different drift length.

TABLE 1

MEASURED DRIFT VELOCITIES W OF ELECTRONS IN HYDROGEN AND HELIUM AT 293 K AS FUNCTIONS OF DRIFT LENGTH L

(a) Drift Velocities in Hydrogen

L (cm)	p (torr)	W (10^5 cm s^{-1}) $E/N = 0\cdot152$	$0\cdot213$	$0\cdot304$ Td
5·084	400	1·879	2·431	3·137
10·195	300	—	—	3·139
	400	1·881	2·431	—
50·000	100	—	—	3·139
	150	—	2·433	—
	200	1·881	—	—

(b) Drift Velocities in Helium

L (cm)	p (torr)	W (10^5 cm s^{-1}) $E/N = 0\cdot0303$	$0\cdot0607$	$0\cdot1214$	$0\cdot1517$	$0\cdot2124$	$0\cdot2428$	$0\cdot303$ Td
5·006	500	0·638	—	1·619	—	—	2·372	—
9·991	200	—	1·054	—	1·842	2·125	2·377	2·671
	500	0·638	1·054	1·622	—	—	—	—
10·000	200	—	1·055	—	1·840	2·213	—	2·669
	500	—	1·053	—	—	—	—	—

The collected data for hydrogen are shown in Table 1(*a*), where the drift velocities W are listed as functions of E/N and gas pressure p for tubes of three different drift lengths L, these lengths being the geometrical distances between the mid planes of the grids. The tube with $L = 5\cdot084$ cm is the one described by Elford (1971; Fig. 1, system B without guard rings R1, R2, and R3), that with $L = 10\cdot195$ cm is system B of Elford (1971), and that with $L = 50\cdot000$ cm is the tube employed by Crompton and Elford (1973). The data in Table 1(*a*) do not include corrections for diffusive effects. If, from Lowke (1962), it is assumed that the error so introduced is of the order of $3(D_L/\mu)/V$, where D_L is the longitudinal diffusion coefficient, μ the electron mobility, and V the potential difference across the drift chamber, then the largest correction to any of the values of W is less than $0\cdot1\%$. It can be seen from Table 1(*a*) that with the exception of only one entry the data at each value of E/N agree to within $0\cdot1\%$.

The data for helium are shown in Table 1(*b*). The drift tubes with $L = 5\cdot006$, $9\cdot991$, and $10\cdot000$ cm are respectively those described by Crompton *et al.* (1968), Crompton *et al.* (1967), and Crompton *et al.* (1970). The tube of Crompton *et al.*

(1967) was specifically designed to have a highly uniform electric field while that of Crompton *et al.* (1970) is known to have a small, and it is believed insignificant, degree of field distortion in the vicinity of the grids. As for the hydrogen data, no allowance has been made for diffusive effects in the values of Table 1(*b*), but an assumed correction of $3(D_L/\mu)/V$ leads to a maximum adjustment to the data of less than $0\cdot1\%$. An inspection of Table 1(*b*) shows that the data from the three tubes agree at any value of E/N to within $0\cdot2\%$.

From the above comparisons we may conclude that in the Bradbury–Nielsen method there is no significant dependence (to within $0\cdot2\%$) of the electron drift velocity on the drift chamber length over the range of values of L and E/N considered and therefore that the effective drift length is the geometrical length as previously defined.

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