Secondary Electron Emission from Solid Metal Surfaces. By C. F. SHARMAN, Ph.D., King's College.

[*Received* 29 January, *read* 11 March 1929.]

I. A considerable amount of experimental work has been done in recent years on the properties of the electrons which leave a metal surface when it is bombarded by an incident beam of electrons. Farnsworth*, who first studied the energy distribution of the secondary beam systematically, showed that it is made up of two groups. The first has the same energy as the primary beam and may be regarded as consisting of reflected primary electrons; and the second has for the most part a very small energy, of the order of a few volts, and contains the true secondaries derived from the metal. The present writer in a preliminary note† has described some measurements of the differential energy distribution by means of the magnetic spectrum method. Owing to an inadequate technique those experiments are considered to be valid only in the upper half of the energy range, where the form of the distribution has several features of particular interest when the mechanism of secondary emission and of electron reflection are considered. In this note, the author called attention to the peculiar depression in the curve immediately preceding the "reflected" peak. It was impossible then to insist on the *reality* of such an effect, owing to the probable presence of an *instrumental* cause (which was given there as the explanation). That it is real, however, has been demonstrated in a striking manner by Whiddington and Brown‡, who have succeeded in recording electrons as slow as 100 volts photographically on a specially sensitised film. The appearance on their photographs of a region of low intensity separating the sharp "reflected" line from the background of secondary emission confirms the form of the distribution first found electrically. The author has measured up a film (kindly sent him by Prof. Whiddington) on a photometer, and finds excellent agreement between the two curves over a range of 20 volts below the primary energy.

Figure 1 shows a set of experimental numbers plotted for a copper target and a primary energy of 240 volts, in the neighbourhood of the energy of the primary beam. A reasonable explanation of the depression is suggested by the broken line in the figure; namely, that the measured distribution is the result of superposing the almost homogeneous "reflected" electron distribution on the

* H. E. Farnsworth, *Phys. Rev.* xxv (1925), p. 41.
† C. F. Sharman, *Proc. Camb. Phil. Soc.* xxiii (1927), p. 523.
‡ Whiddington and Brown, *Nature*, cxix (1927), p. 427.

https://doi.org/10.1017/S0305004100018776 Published online by Cambridge University Press

upper energy limit of the secondary group. This requires that the number of true secondaries, which is tending asymptotically to zero with increasing energy, suddenly decreases to zero within a range of a few volts at the primary energy. Such behaviour agrees well with the distribution obtained from a simple collision theory of secondary emission to be given later.

Much of the recent experimental work on electron reflection has been an endeavour to correlate it with the reflection of radiation in the case of metallic crystals. In spite of current interpretations

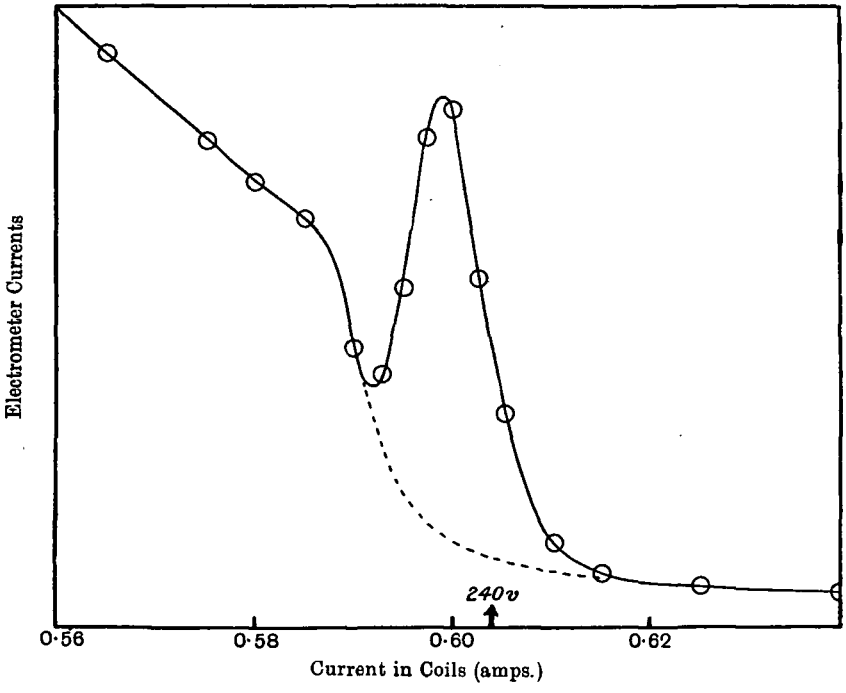


Fig. 1.

on the wave mechanics, a discussion of the mechanism of electron reflection in terms of particle electrons is not entirely useless at the present stage.

Before considering in detail the collisions made by the primary electron, some interesting features of the process of reflection may be noticed from general considerations of the possible energy interchanges. From the conservation of energy and momentum, it follows that the maximum interchange of energy between a moving particle of mass m and a stationary one of mass M is $4Mm/(m+M)^2$ times

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the energy of the moving particle; hence an electron can only lose an appreciable part of its energy by elastic collision, *if it collides with another electron.* Thus we see that only members of the primary beam which pass back again through the surface without suffering a close collision with a free electron of the metal will appear in the class of elastically reflected primaries.

Consider the metal divided into monatomic layers parallel to the surface. Let p be the probability that a primary electron of a given energy will emerge on the incidence side of any layer with an energy loss smaller than some preassigned value, and let P be the probability that it will pass through the layer under the same conditions. Then the expectations of "reflected" electrons arising from successive layers, due to a homogeneous beam of N primaries, are

$$Np,\ NpP^2,\ NpP^4,\ NpP^6, \text{ etc.}$$

Hence the total reflected intensity is

$$Np\,(1 + P^2 + P^4 + P^6 + \ldots),$$

or

$$Np/(1 - P^2).$$

Since both P and p are small, this is very nearly equal to Np, which is the effect from the surface monatomic layer only. It thus appears, *a priori*, that electron reflection is a pure surface phenomenon.

In the above argument, it has been assumed that the metal is homogeneous right up to the surface; but if this were the case we should expect a continuous and gradual falling off on the low energy side of the reflected peak in the distribution curve. Experiment shows an intensity corresponding to zero energy loss many times greater than that corresponding to finite but small energy losses. In order to account for this discontinuity it seems necessary to introduce into the mechanism of the process a region at the surface where there are no free electrons capable of exchanging energy with the primary beam. We might imagine, for instance, that there is a surface layer of atoms whose external electron structure approaches that of an isolated gaseous atom of the metal, and that with such systems an electron can make elastic collisions. Electron reflection thus becomes a problem of single scattering, if this layer is sufficiently thin. The ordinary result for single scattering under an inverse square law of force may be written

$$n = \frac{\pi Z^2 q^4}{4E^2}\,\tau\mu \cot \tfrac{1}{2}\phi,$$

where n is the probability of deflection of a primary electron through an angle greater than ϕ, Z is the effective nuclear charge, τ is the number of monatomic layers in the scattering sheet and μ is the number of atoms per unit area of each layer.

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Putting $\phi = \pi/2$, we have for the total reflected intensity

$$n = \pi Z^2 q^4 \tau \mu / 4E^2.$$

This result indicates that the reflected intensity should be inversely proportional to the square of the primary energy. As far as the experiments go they seem to show an inverse first power variation; but a discrepancy of this sort might be expected if Z is a function of E.

Applying the last equation to the case of a 100 volt primary beam reflected from a copper surface, and giving n its approximate experimental value of 2 $^{\circ}/_{\circ}$, we find

$$Z^2 \tau = 10.$$

Assuming that on the average Z is slightly greater than unity, the thickness of the reflecting layer appears to lie between one and ten atoms.

Experimental information concerning the constituents and their arrangement at the surface of a metal is extremely meagre, and it is mostly derived from the results of bombarding the surfaces with particles of very low penetrating power, such as positive ions or slow electrons. Two observations may be quoted here which confirm the assumptions in the foregoing argument. Oliphant* has recently shown, in some very careful experiments, that gas-free metal surfaces when bombarded with positive ions of a few hundred volts energy give a negligible secondary electronic emission. He also estimates that for positive potassium ions "a surface four atoms thick appears to behave as if the underlying metal did not exist." For rubidium the limit is seven atoms. Interpreting these thicknesses as the ranges of the ions in the surface matter, the experiments of Oliphant also seem to require a surface layer, of about ten atoms thickness, devoid of free electrons.

Baum† and Hippel‡ have established the fact that, in a discharge tube, atoms of metal which are "sputtered" from the cathode are uncharged. This result, again, favours the idea of an "unionised" layer covering the, presumably, ionised interior.

II. Before discussing the mechanism of delta ray or true secondary emission, reference must be made to an ingenious attempt by Kapitza§ to calculate the total secondary effect. He considers that the incident electron loses all its energy to the electrons of the metal at a point in the surface. The dissipation of this energy radially through the metal is calculated by means of the general conductivity relation; and from the known thermal properties of the metal in mass, the temperature after time t at a point a distance

* Oliphant, *Proc. Camb. Phil. Soc.* xxiv (1928), p. 451
† Baum, *Zeit. für Phys.* xl, 9 (1927), p. 686.
‡ Hippel, *Ann. der Phys.* lxxx, 7 (1926), p. 672.
§ Kapitza, *Phil. Mag.* xlv (1923), p. 989.

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r from the point of impact of the primary can be found. By means of the Richardson equation Kapitza then calculates the total thermionic emission by integrating over the whole surface and all time. The result obtained gave fair agreement with the experimental results then available. As the author points out, although this theory is useful in linking up several well-known properties of metallic surfaces, it cannot be expected to describe with any degree of accuracy the process of delta radiation. In view of several objections which can be brought against *any* purely statistical treatment of the problem, it was thought advisable to work out a simple case from the dynamics of electronic collisions. This simple collision argument probably satisfies the conditions no better than the statistical one of Kapitza, but it was hoped that it would throw some light on the energy distribution curves, particularly in the region of the primary energy.

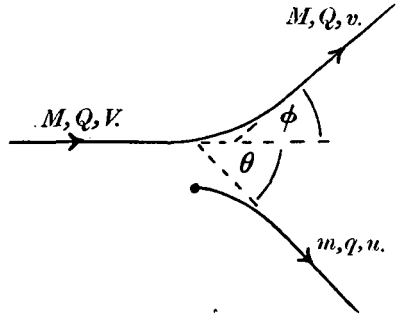


Fig. 2.

Consider first the energy transfer which takes place when an electron with energy E collides with a stationary electron. With the notation shown in the figure, the perpendicular distance from the initial position of the stationary electron to the line of approach of the moving one is given by the relation

$$p = \tan\theta \,.\, (1/M + 1/m)\, qQ/V^2 \quad \ldots\ldots\ldots\ldots\ldots (1).$$

In the present case we have

$$Q = q, \text{ and } M = m,$$

so that (1) reduces to

$$p = \tan\theta \,.\, q^2/E \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2).$$

From the energy and momentum relations it can be easily shown that, in this case of equal masses and charges,

$$\theta + \phi = \pi/2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3),$$

and

$$\cos\phi = v/V = (E-e)^{\frac{1}{2}}/E^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots (4).$$

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From (2), (3) and (4) it appears that

$$p^2 = q^4(E-e)/(E^2e) \quad \ldots\ldots\ldots\ldots\ldots\ldots(5).$$

Now suppose that a beam of N primary electrons is incident normally on a layer of electron "gas" of thickness dl and of density γ electrons per c.c.; and let the energy of the primary beam be large compared with the energy of thermal agitation of the "gas." Assuming that the layer is so thin that no primary electron sustains more than one appreciable energy loss, the distribution of energy among the secondary electrons can be calculated from equation (5). Thus, the number n of secondaries with energies greater than e will be the number of electrons of the "gas" originally to be found in N cylinders of height dl and radius p; that is

$$n = N\gamma\pi p^2 dl.$$

Substituting for p^2 from (5),

$$n = N\pi\gamma dl\, q^4(E-e)/(E^2e) \quad \ldots\ldots\ldots\ldots\ldots\ldots(6).$$

Treating e as the independent variable and differentiating,

$$dn = \frac{N\pi\gamma dl\, q^4}{E} de/e^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots(7),$$

where dn is the number of secondary electrons produced in the layer in the energy range e to $e+de$. This relation states that the differential energy distribution is inverse square in form and that

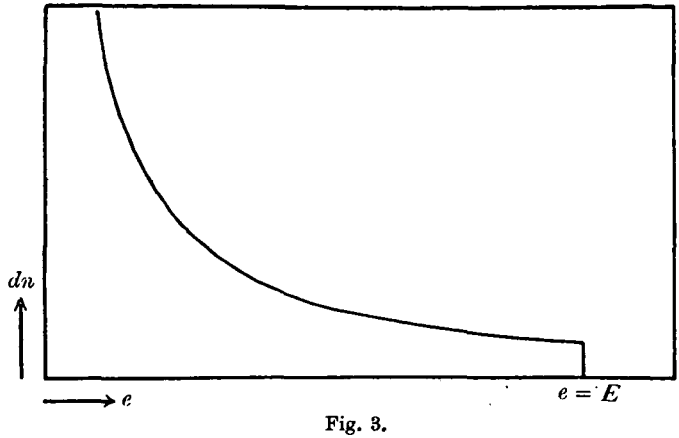


Fig. 3.

each ordinate is inversely proportional to the primary energy, in the range $0 < e < E$; for $e > E$, dn is everywhere zero (see Figure 3).

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In applying this result to the problem in hand, it is necessary to consider the conditions under which the excitation of delta rays takes place.

(*a*) The effect of collisions with atoms will be neglected since there are good reasons to believe that at low energies all but an inappreciable number of such impacts are elastic; hence the distribution of *energy* amongst the excited secondaries should not be affected by the presence of the atoms. We should expect them, however, to produce an almost random directional distribution; this has been found by Becker*, and is obviously consistent with the observation of Campbell† that the "incidence" and the "emergence" delta radiations excited by alpha rays in thin foils are very accurately equal in total intensity.

(*b*) As the primary beam passes into the metal, the number of its members decreases by "reflection," its average energy decreases and it becomes heterogeneous as regards energy. It is necessary to consider the effect of these three factors on the form of the distribution function. The distribution of energy amongst the secondaries excited in the first monatomic layer by a primary electron designated by the suffix "*a*" can be represented by

$$dn_{1a} = \frac{K}{E_{1a}} j_{1a} \frac{de}{e^2},$$

where $K = \pi . \gamma dl . q^4$ from equation (7) above, E_{1a} is the incident energy of the electron "*a*," and j_{1a} is a factor which is unity or zero according as e is less than or greater than E_{1a}. The factor j in fact makes the distribution function zero for energies greater than the energy with which the primary was incident on the layer under consideration. Now let suffixes "*b*," "*c*," etc. represent other primary electrons, and let the successive monatomic layers be indicated by 1, 2, 3, etc. Then if dn_1, dn_2, dn_3, etc. are total numbers of secondaries from the layers 1, 2, 3, etc. in the energy range e to $e + de$,

$$dn_1 = K \frac{de}{e^2} (j_{1a}/E_{1a} + j_{1b}/E_{1b} + j_{1c}/E_{1c} \ldots),$$

$$dn_2 = K \frac{de}{e^2} (j_{2a}/E_{2a} + j_{2b}/E_{2b} + j_{2c}/E_{2c} \ldots),$$

$$dn_3 = K \frac{de}{e^2} (j_{3a}/E_{3a} + j_{3b}/E_{3b} + j_{3c}/E_{3c} \ldots).$$

This array of terms has the following properties:

(1) For a homogeneous primary beam

$$E_{1a} = E_{1b} = E_{1c} = \text{etc.}$$

* A. Becker, *Ann. der Phys.* LXXVIII (1925), p. 253.
† N. Campbell, *Phil. Mag.* XXIII (1912), p. 46.

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(2) The sequences

$$\begin{array}{llll} E_{1a}, & E_{2a}, & E_{3a}, & \text{etc.} \\ E_{1b}, & E_{2b}, & E_{3b}, & \text{etc.} \\ E_{1c}, & E_{2c}, & E_{3c}, & \text{etc.} \\ & \text{etc.}, & \text{etc.} & \end{array}$$

all decrease monotonically.

(3) In the lower rows, terms disappear for all values of e when E becomes zero. There is also a less important disappearance all through the table due to reflection. It is at once evident that this complete annihilation of a term *has no effect on the form of the resultant distribution function.*

Thus we see that at the moment of excitation the secondaries throughout the metal have a simple inverse square distribution in any range of e where all the j's are unity. For small values of e, all the j's will be unity, except a few in the lower rows, which will not contribute greatly to the emission. As e increases some of the j's pass over from unity to zero, thus disturbing the inverse square distribution.

If any trace of the simple energy distribution with which the secondaries appear to be excited is to be found in the actual secondary emission, we must look for it in the middle and lower energy ranges. The effect just considered would make the actual distribution curve fall below the inverse square curve as we proceed to higher energies.

(*c*) Beside the so-called "reflected" primaries, there will be emitted primaries which have lost various amounts of energy. These will appear in the distribution curve superimposed on the secondary distribution, and so will give rise to another deviation from the inverse square curve, opposed in sign to the disturbance considered above.

(*d*) Owing to the small but finite thermal energies of the free electrons of the metal, Figure 3 cannot be expected to represent the form of the energy distribution of the excited secondaries in the region of very low energies. Still less can it be applied to that of the emitted secondaries, since their passage through the surface is certain to introduce a further modification in the case of the slower electrons. These effects, however, should not alter the form of the curve above about 10 volts.

III. In the present experiments the principle of the magnetic spectrum was used, as in those described in a previous paper, but here attention was focussed on the low energy group. It was necessary to eliminate any possibility of distortion of the distribution curves by absorption of the slower electrons in the residual gas. All other requirements were subordinated to the necessity of obtaining the

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best possible vacuum*. With this end in view the essential part of the apparatus was made small enough to be enclosed in a glass tube, all electrical connections being made by means of metallic seals through the glass. This tube and its contents could be outgassed by baking in a small electric furnace which was made to fit in between the Helmholtz coils producing the magnetic field. As a preliminary treatment, the tube was baked at 400° C. for 8 hours with the pumps working; during the whole of this time gas was given off from the metal parts, out of screw-holes, etc, the rate of evolution becoming very small at the end. Before any experiment this was repeated for 2 hours, the traps being heated to about 400° C. at the same time. Then the temperature of the tube was lowered to 300° C. for an hour, after which liquid air was applied to the traps and the tube was allowed to cool. The fore-pump (rotary Gaede) was shut off by a tap and any gas evolved after this stage was pumped into a McLeod gauge. From the known "speed" of the pumps the residual pressure in the tube was estimated† to be certainly as low as 10^{-6} mm. of mercury.

Since the whole path of the secondaries must be enclosed in a metal box for the sake of electrostatic screening, and since all the material of the apparatus must be non-magnetic in order that the small magnetic fields used may be accurately calculated, the contents of the tube were constructed entirely of aluminium, with

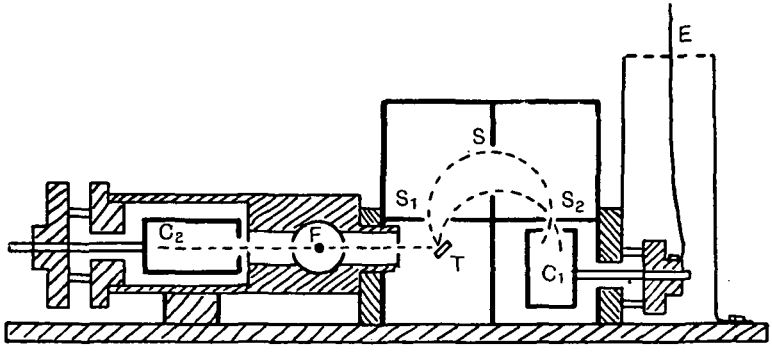


Fig. 4.

the exception of the small screws which were of molybdenum. Figure 4 is a diagrammatic representation of this part of the arrangement.

The helical tungsten filament *F* was adjusted to be coaxial with the cylindrical shield around it. The thermions from this

* It should be mentioned that these experiments were done in 1925–26.

† R. J. Clark, *Proc. Camb. Phil. Soc.* (1927), xxiii (1927), pp. 953–6.

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were accelerated by charging it to a negative potential, and they then passed through two exactly similar slits on opposite sides of the cylinder. One beam entered the Faraday cylinder C_2 and the other impinged on the target T placed at an angle of 45° with the direction of the primary beam. The two beams were defined by slit systems which were as nearly identical as they could be made, and it was assumed that the current measured by the cylinder C_2 was equal to the primary current to the target. The deflection chamber was cubic in form and the slit system S_1SSSS_2 slid in grooves in the sides of it. After passing through S_1SSSS_2 the secondary electrons from the target focussed into the Faraday cylinder C_1, and were measured by the rate of charge of a sensitive Dolezalek electrometer. The whole arrangement was built on a single base plate which was earthed. Both Faraday cylinders, the filament and the target were supported and insulated from the outer case by small glass stalks. The outside glass surface which insulated the electrometer lead was surrounded by an earthed brass tube fitted with an air-tight ebonite plug and provided inside with a pocket containing phosphorus pentoxide. Thus the glass surface was thoroughly dried, and, being well annealed also, very little trouble was experienced with the insulation. Guard-rings of thin copper wire were bound tightly round the tube so as to prevent leakage from the charged filament electrodes to the measuring instruments.

As was pointed out in a previous paper, the experimental readings must be divided by the corresponding energy, or the square of the magnetic field, to give the energy distribution. It is obvious, then, that in the case of the small energies an accurate knowledge of the intensity of the magnetic field is essential. For this reason the tube was set up as far from large masses of iron and magnetic instruments as possible and the earth's horizontal component was measured in terms of current in the Helmholtz coils used to bend the secondary beam. As before, the vertical component due to the earth was neutralised although its effect was six times smaller than previously.

The experimental procedure was similar, except that readings of the primary current were taken for every setting of the magnetic field. This was necessary, because in this apparatus the length of the path of the primary beam was comparable with that of the secondary, so that the primary was appreciably deflected; which caused the primary current to decrease slightly as the magnetic intensity was increased. The measured secondary currents were then divided by the corresponding primary current readings. Owing to this variation of the primary beam, the distribution curve could not be extended over so large a range as previously, and therefore the observations were restricted to the slow delta-ray group for which the apparatus was designed.

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The results for a polished copper target and a primary energy of 400 volts are shown in the form of an energy distribution curve in Figure 5. The circles are the experimental points, and the full curve is drawn through them.

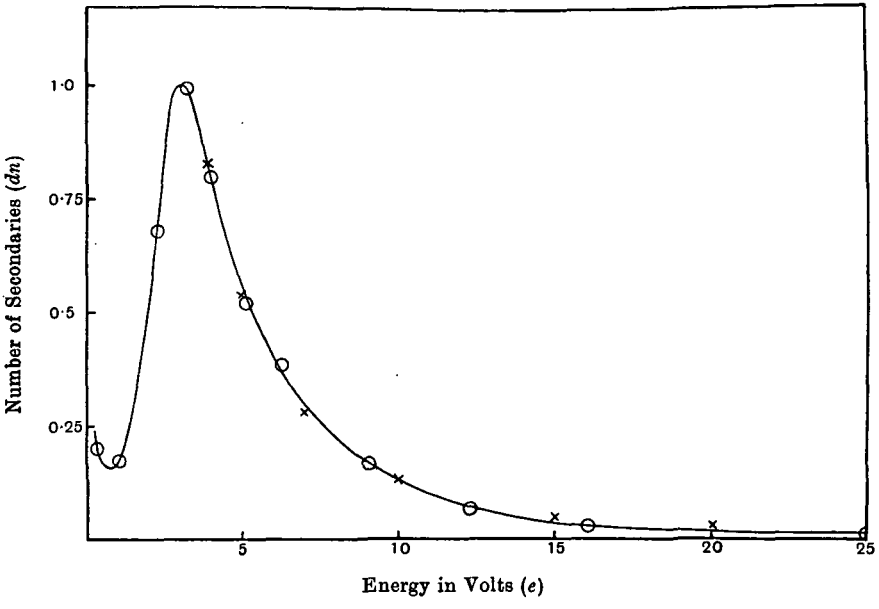


Fig. 5.

The following results emerge from a study of a series of distributions similar to Figure 5 taken under various conditions.

(*a*) Its general form is like those obtained previously, the chief difference being the position of the maximum. In the case illustrated it occurs at 3·0 volts, which agrees well with the approximate position found by Becker for a smoked target.

(*b*) The rapid rise of the curve near the origin probably has no physical significance; it is due to the small but finite currents obtained in this region, being divided by the square of a very small magnetic intensity. The distribution by this method is not reliable so close to the origin.

(*c*) A series of measurements was made for a number of different primary energies. The position and height of the maximum were both found to vary with the energy of the primary beam, as the following table shows:

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Primary Energy. Volts	Position of maximum. Volts	Relative intensities
200	4·07	0·32
400	3·10	0·60
600	2·58	0·78
800	2·24	0·94
1000	2·10	1·00

These numbers are plotted in Figure 6, which shows that the intensity curve appears to pass through the origin (as would be expected), and that both tend to become constant at high primary energies.

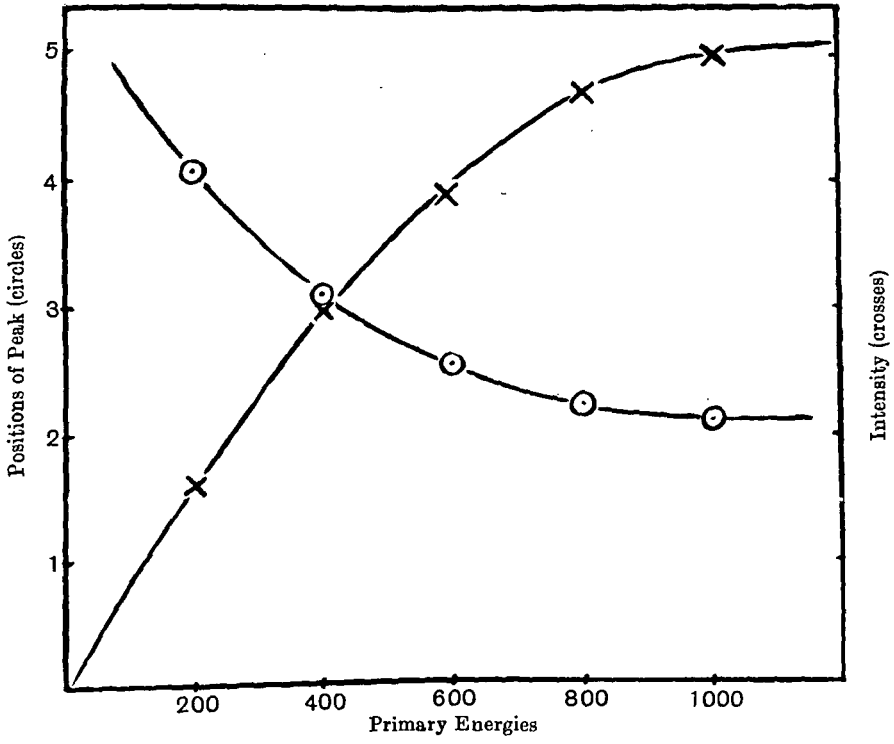


Fig. 6.

It should be noticed that this result is in complete discordance with similar measurements made by the author using a differential modification of the ordinary retarding potential method*, where

* Sharman, *Proc. Camb. Phil. Soc.* XXIII (1927), p. 923.

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the position of the peak appeared to be quite independent of the primary energy. Other investigators have assumed from retarding potential measurements that the energy of the secondaries is independent of that of the primaries, but that method is scarcely capable of detecting the small variation found here.

(*d*) The falling off on the low energy side is still very sudden and still suggests some instrumental cause, such as the accumulation of space or surface charges in the deflection chamber. In this connection a series of experiments was done using different primary intensities, other conditions being maintained constant. The results are shown in Figure 7. The position of the maximum is

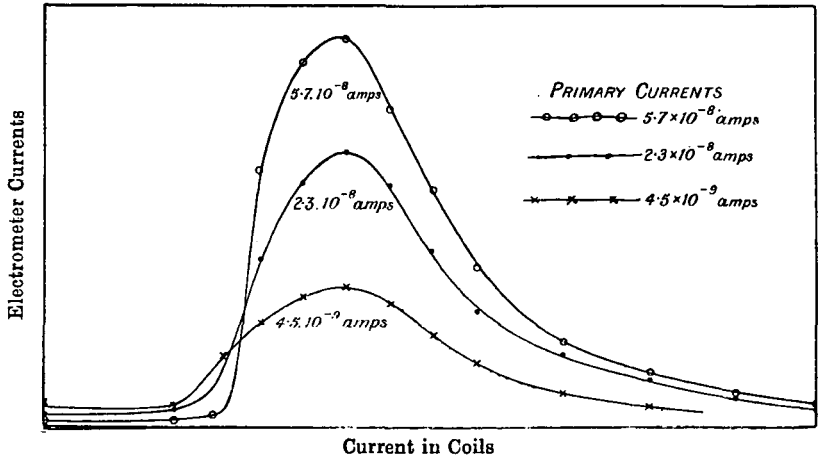


Fig. 7.

unaffected by the variation of primary intensity; but the crossing over of the curves in the neighbourhood of 2 volts shows that a high current density produces an exaggerated scarcity of secondaries of low energy. This is probably due to the edges of the slit getting charged by the intense beam of electrons falling on them, the plane of the slit thus becoming a surface of minimum potential and preventing the passage of electrons of energy smaller than that which corresponds to this potential. The curves of Figure 7, by extrapolation to zero primary intensity, lead one to imagine that the true distribution decreases still more gradually on the low energy side and passes through the origin.

(*e*) The crosses in Figure 5 represent an attempt to fit an inverse square distribution to the observed one. Although not a very good test, it shows that this simple law is at least an approximation to the truth.

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IV. In Section II the conclusion was reached that although secondary emission is a complicated phenomenon involving many monatomic layers, yet some trace of the energy distribution from each single layer might be expected to be found in the lower half of the energy range. If the differential distribution due to a primary beam of energy E be represented by

$$dn = K\,de/Ee^2,$$

then the current measured by the retarding potential method for a potential corresponding to the energy e is

$$q\int_0^N dn = Kq\int_e^E de/Ee^2,$$

or

$$Nq = i = \frac{Kq}{E}\left(\frac{1}{e}-\frac{1}{E}\right) = \frac{Kq}{E^2}\left(\frac{E-e}{e}\right).$$

Hence we should expect a linear relation between the quantity $(E-e)/i$ and the applied potential e. This relation was used to test the application of the inverse square distribution. The experimental procedure was similar to that usually employed in retarding potential measurements.

The primary beam was generated in the water-cooled brass tube A by accelerating the thermions from the filament through a parallel wire grid. The beam was defined by the brass nozzle which projected into the glass bulb B. The target was supported from the other side of the bulb and was adjusted to be at the centre. The inner surface of the bulb was heavily silvered and acted as a collector for the secondaries from the target, electrical connection with the external apparatus being made through two platinum seals PP. Electrical continuity between these seals and the silver surface was verified by measuring the resistance between the two seals. All joints were of hard wax, and the one between the brass tube and the glassware was made directly on to the water jacket since it was fairly near the filament.

The target and the tube surrounding the filament were earthed, the latter through a milliammeter. The middle of the filament was charged to a constant negative potential, and a tapping of the same battery carried the collecting surface to a smaller negative potential which could be varied. The galvanometer had a sensitivity of 3.10^{-10} amp. per division, and was carefully insulated.

The total filament emission was maintained constant and readings of current to the collector were taken for a series of retarding potentials (read off the voltmeter V). Figure 9 (1) shows the actual observations of a run taken for a primary energy of

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200 volts, in the range 0 to 40 volts where we might reasonably expect an indication of an inverse square energy distribution.

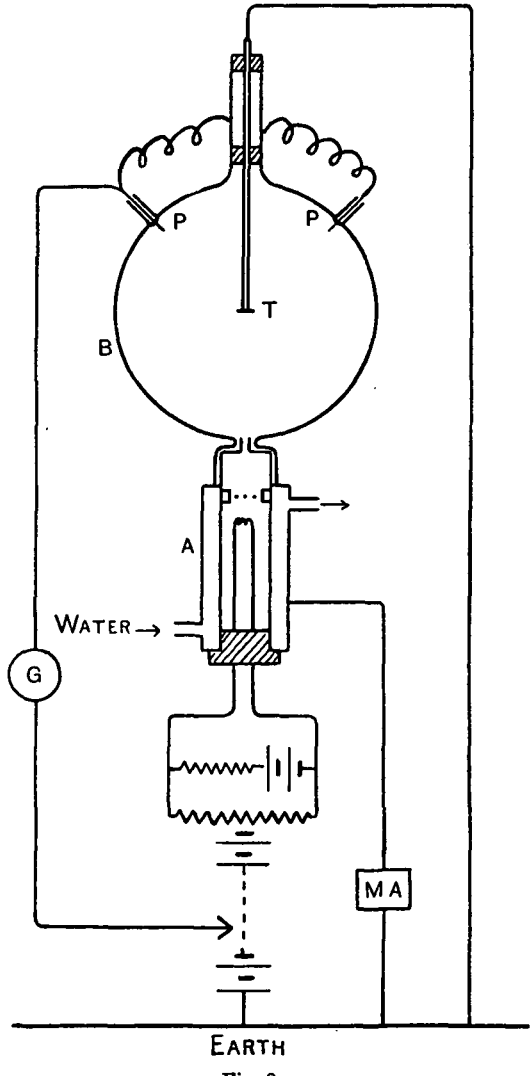


Fig. 8.

In the same figure (2) is also plotted the quantity $(E-e)/i$ as ordinate. It appears that in this range there is very strong evidence for the existence of the above simple distribution.

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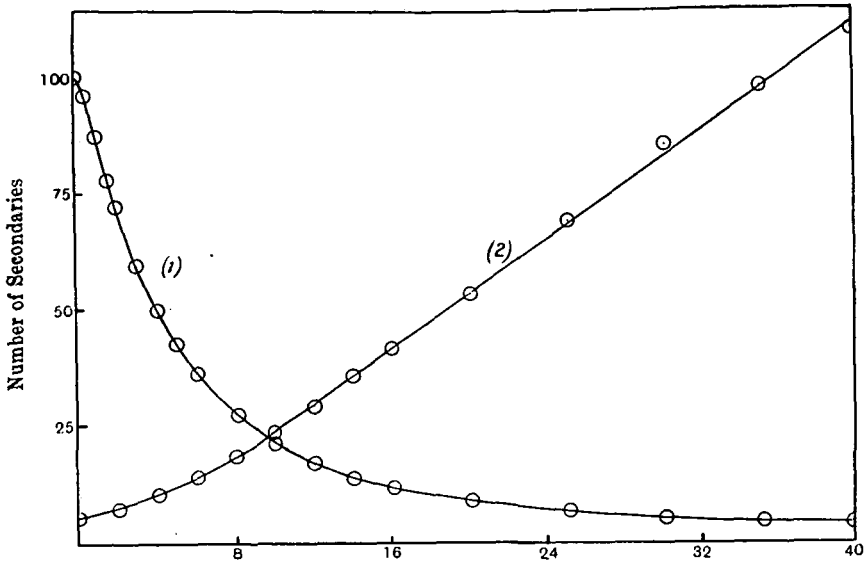


Fig. 9.

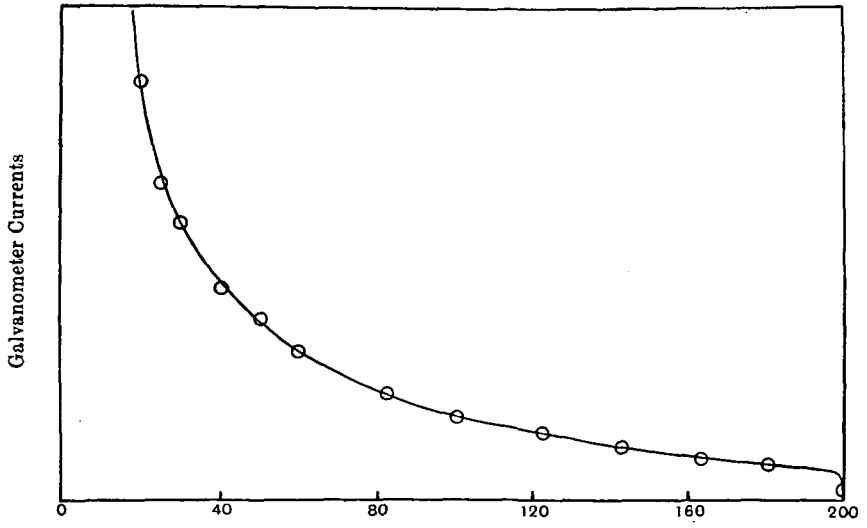


Fig. 10.

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Several curves of this kind were taken ; all were of the same form, but the point of intersection of the linear part with the axis of energy varied in a narrow range on either side of the origin in a manner that could not be accounted for.

In order to discover how the actual distribution departs from the simple theoretical one at energies comparable with the primary energy, the intensity of the primary beam was increased many times and attention was confined to the middle and high energy ranges. In Figure 10, i is plotted against e as before.

In this experiment the reflected electrons must be taken into account since they form an appreciable proportion of the small currents obtained at high energies. Thus, the total current I corresponding to a retarding potential e is given by

$$I = \frac{K}{E^2} q\left(\frac{E-e}{e}\right) + R,$$

where R is the total intensity of the reflected peak. In order to test this relation, Figure 11 has been plotted with $(E-e)/e$ as abscissa and I as ordinate. In the region where the inverse square distribution holds, this should be a straight line cutting the I-axis at the point $I = R$. From the energy scale at the top of the figure it will be noticed that the theory fits the observations fairly well over the lower half of the energy range, but after that the currents fall appreciably below the theoretical distribution. This is exactly the kind of deviation which was expected owing to the slowing down of the primary electrons as they penetrate successive layers of the metal.

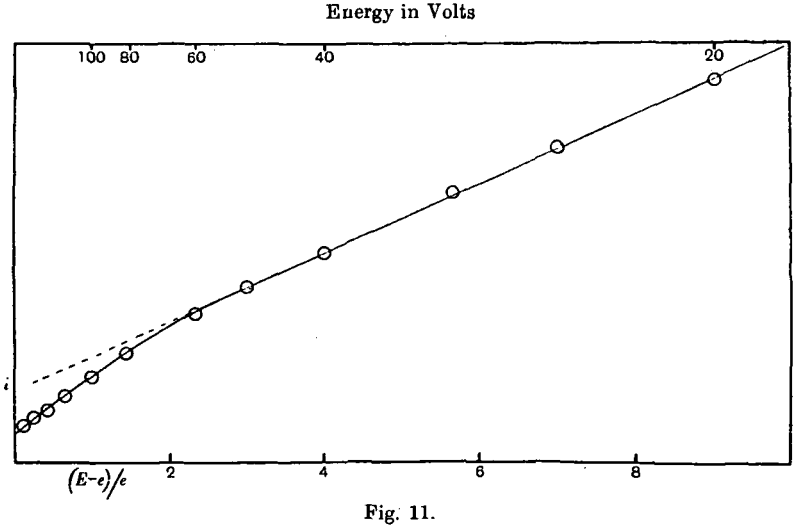


Fig. 11.

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V. The foregoing results may be summarised by representing the energy distribution of the total electronic emission in two parts as in Figure 12.

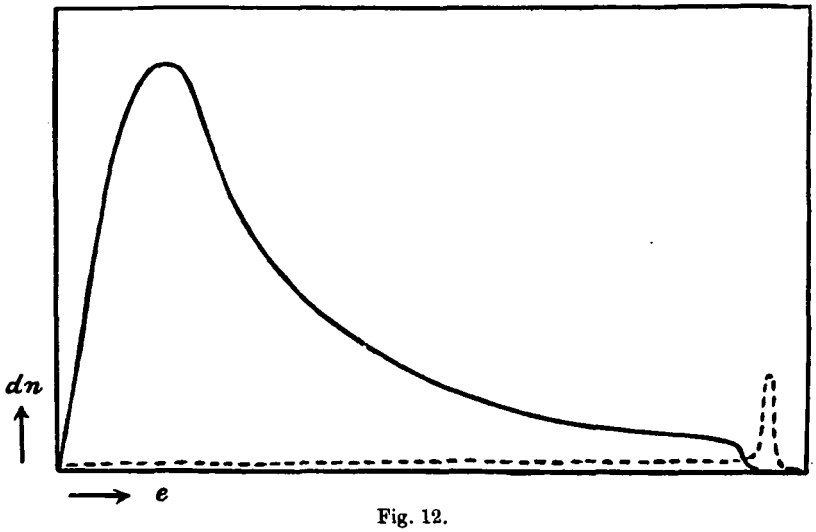


Fig. 12.

The full curve is the distribution of energy amongst those of the emitted electrons which were originally in the metal. At high energies it falls considerably below the inverse square distribution for the reason given in (*b*) of Section II. The broken curve is an attempt to represent the energy distribution of the primary electrons which are reflected from the surface. Apart from the peak, its form is of course purely conjectural (although Figure 1 shows that the intensity of the elastically reflected primaries is many times greater than that of the inelastically reflected background).

The rather complex distribution found experimentally may be regarded as formed by the superposition of these two relatively simple curves.

The author wishes to express his gratitude to Prof. Sir Ernest Rutherford for the interest he has taken in this work; also to the Provost and Fellows of King's College and to the Goldsmith's Company of London for grants which enabled the work to be carried out.

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