The Anode to Accelerating Electrode Space in Thermionic Valves*

By J. H. Owen Harries

PART I

1. Introduction.

If the length from the anode to the cathode in thermionic valves could be greatly increased without increasing the voltage to current ratios above the values found in short streams (*e.g.* in triodes and diodes), many advantages would result. Some of these advantages appear to have been fairly well known for many years (Bib. Nos. 1 and 2), but no method of gaining this end appears to have been published. The advantages might be expected to include the prevention of the retrograde passage of secondary electrons from the anode, and a substantial reduction in interelectrode capacities. Of the multitudinous publications on electron jet frequency multipliers (*e.g.* Bib. Nos. 3, 4, 5, 6, 7, 8, 9, 10 and 11) there are few indeed which fail to call attention to the desirability of using long streams, so that the sensitivity to deflection may be reasonably great, but such long streams invariably possessed an impracticably high voltage to current ratio.

2. The Two Principal Parts of a Valve

Valves of the kind considered in this paper may be thought of as consisting of two parts, the cathode space, from the cathode to the first accelerating electrode, and the anode space, from the first accelerating electrode to the anode (Fig. 1). The physical relationships of the cathode space have been analysed to a satisfactory degree of accuracy (Bib. 12). The only information the author was able to find about the anode space (where the electrons have an initial energy which is as high or higher than that corresponding to the potential of the anode) is concerned with the production of jets of electrons, having very high voltage to current ratios, as in oscillographs; and, with respect to short stream tetrodes and pentodes, statements that the anode must be placed close to the accelerating electrode to produce a practicably large current, at a sufficiently low voltage. The familiar dynatron characteristic will then appear due to the retrograde passage of secondary electrons. "The maximum current which can flow to the plate gets less as the distance between the grid and plate is increased," is a typical quotation from conclusions, based upon the classical solutions of the basic differential equations only, and arrived at from an analytical consideration of the anode space.

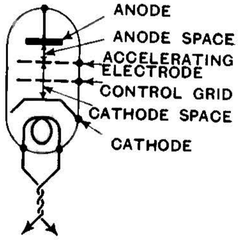

Fig. 1.—*The anode and cathode space of a valve.*

3. Method of Attack on the Problem

An examination of the problem indicated that there was little hope of arriving at the necessary information about the anode space by endeavouring to obtain a complete solution of the basic differential equations. (Bib. No. 12).

Mathematical analysis is a process of producing on paper, by a special notation, a working model of a particular part of the universe which it is desired to study. When a correctly carried out mathematical analysis fails, it is because insufficient data has been provided from which to build the model. It is then necessary to make a physical model, in the form of experimental apparatus, and to obtain the missing information from that. The difficulty with experimental apparatus lies in the fact that it is necessary that the physical model be so designed that other effects than those which it is actually required to study are negligible, and that those it is required to study are readily observable.

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4. Sliding Anode Tubes

Fig. 2 illustrates the type of valve finally employed as an experimental model to investigate the problem and to obtain the data for mathematical analysis. The anode is arranged to slide in guides, and its position is adjusted by tilting and tapping the tube. This rather crude method was the only one found to be successful in practice.

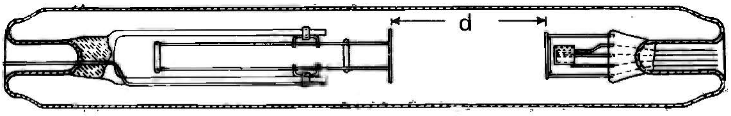


Fig. 2.—*A type of movable anode discharge tube used experimentally to determine the characteristics of the anode space.*

The essential features of the sliding anode tubes are as follows :—

(*a*) A focused cathode of ample emission.

(*b*) An accelerating electrode close enough to the cathode to obtain a space current of at least 5 to 10 mA. at not less than 200 volts or so. (To complete the investigations sliding anode valves having more than one accelerating electrode are necessary.)

(*c*) A mesh formation of the accelerating electrode so that it does not intercept more than a very small part of the total space current. (An important part of the work was the realisation of the fact that such mesh electrodes may be made to give entirely satisfactory results in the production of an electron jet. Prior "electron gun" accelerating electrodes are no good for solving the problem. Their focusing action is unnecessary. They intercept almost all the space current, or only produce a very low space current, and therefore make the anode current too small to be of use.)

(*d*) An anode which is readily and accurately adjustable in position from about 0.25 cm. to 7 cm. from the nearest accelerating electrode. The anode must be of reasonable area, and have a positive electrical contact to the external circuits.

5. Electrical Characteristics of Sliding Anode Tube

Fig. 3 shows the anode current/anode voltage characteristics for various distances, in centimetres, between the anode and accelerating electrode of a typical sliding anode tube.

At short distances the familiar dynatron characteristic appears. As the distance is increased, the anode voltage E_b at which substantial saturation of the anode current occurs shifts to the left until it reaches a minimum, and the dynatron characteristic disappears. As the distance is still further increased, E_b becomes greater once more. That the retrograde passage of secondary radiation disappears at extreme distances is not surprising, but the fact that the primary saturated anode current is independent of the distance, and that the saturation voltage is very low at not very long distances immediately outside the dynatron distance, is remarkable. At extremely long distances a peculiar phenomenon appears. Almost no anode current (except that due to stray unfocused electrons) flows until the anode voltage has risen considerably above zero. At a certain anode voltage E_b, however, the anode current suddenly rises to a saturated value, and remains at substantially this value independently of how much further the anode voltage is raised. The accelerating grid current has a characteristic which is the reverse of this, *i.e.* virtually all the space current goes to the accelerating grid until E_b is reached, when it drops to a steady value, which is about one-sixth of the anode current in the case of the tube illustrated in Fig. 2.

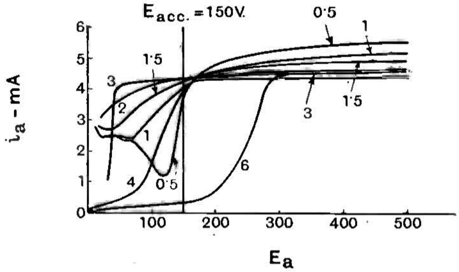


Fig. 3.—*Anode voltage/anode current characteristics of the valve illustrated in Fig. 2.*

An important characteristic of the tube is the "distance curve," connecting the distance *d*, between the anode and the accelerating electrode, and the anode saturation voltage E_b. It is illustrated in Fig. 4.

Further measurements show the effect upon the position of the minimum in the distance curve of changing the accelerating voltage. The distance curve remains about the same, as regards the position of the minimum, because lowering the voltage of a single accelerating electrode decreases the current and the potential gradient simultaneously.

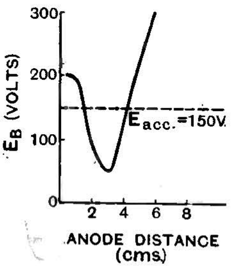


Fig. 4.—*The distance curve. The critical distance is that at which the curve is at its minimum.*

The anode distance at which the distance curve is at a minimum has been christened the "critical anode distance" (Bib. No. 13). The trough of the distance curve is quite flat and if an anode is placed at the precise minimum, accidental or manufacturing variations in its position will make little difference to the characteristics. A tetrode valve made with its anode at this critical distance has a characteristic curve free of the effects of the retrograde passage of secondary radiation. Provided that the accelerating electrode substantially shields the anode from the cathode space, then at low screen voltages the critical-distance valve has an extremely high anode differential resistance R_a, *i.e.* the slopes of the E_a/i_a curves are very small. The fact that there is always a certain amount of slope is because it is impossible completely to separate the cathode and anode spaces, and principally because secondary radiation from the surface of the accelerating electrode adds to the anode current. This latter addition is a constant fraction of the anode current. Therefore, the slope increases with anode current.

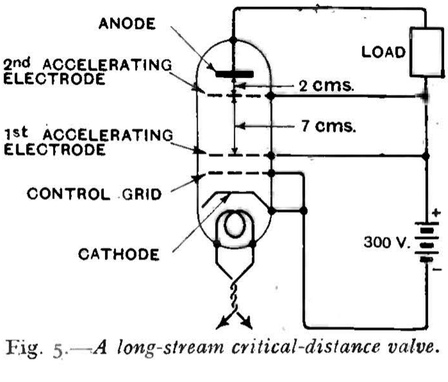


Fig. 5.—*A long-stream critical-distance valve.*

A wide choice of forms of characteristic, particularly as regards the anode differential resistance, is found according to whether the anode is at one side or the other of the minimum of the distance curve. To the left a low anode differential resistance is produced, and to the right a higher value.

6. A "Long-Stream" Valve

The original problem was solved by the results of the above experiments. For instance, Fig. 5 shows a long-stream valve diagrammatically. The control grid and cathode are close together. The first accelerating electrode is near to these two. The second accelerating electrode is spaced from the first by a distance of about 7 cm., which is just not too long to cause the stream across the gap to lose saturation at the working accelerating electrode potential. This space will be operating under the conditions of the curve 6 in Fig. 3. The distance between the second accelerating electrode and the anode will be the critical distance, of, say, 2 cm. The anode voltage/anode current characteristics of a critical distance type of valve are shown in Fig. 6, and they will be recognised as satisfactory from the power efficiency and amplification standpoint. The breakdown voltage at the critical anode distance is less, for instance, than the corresponding saturation voltage of an ordinary short-stream pentode.

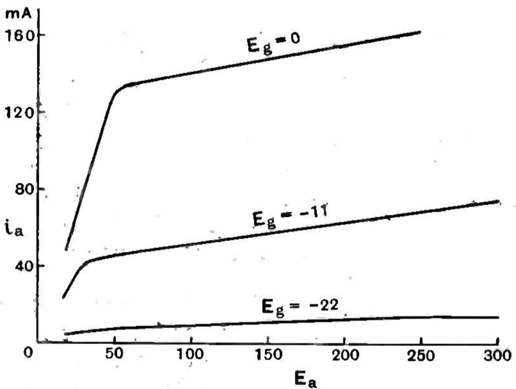


Fig. 6.—*Electrical characteristics of the type of valve illustrated in Fig. 5.*

Of course, additional accelerating electrodes may be used in this manner to lengthen the stream still further. These, being well spaced from the preceding electrode, will be found to intercept very little of the total space current.

Thus it is possible to design a type of long-stream valve which has characteristics the excellence of which, from a power handling or amplification standpoint, is unaffected by extreme length between cathode and anode.

7. Analysis

Having obtained these results from experimental models, it was possible to produce an analytical interpretation of the phenomena.

It may be shown that both the cathode and anode spaces may respectively be represented by a diagram such as Fig. 7, where electrons are emitted from a cathode *K* and tend therefore to travel to a positive anode *A* across a distance *x*. The plane of the accelerating electrode is considered as a cathode with respect to the anode, the potential difference between them being the difference between the accelerating voltage E_{acc} and the anode voltage E_a. The only difference between the anode and cathode spaces, from the analytical standpoint, is the difference in the values and distributions of initial velocities of the emitted electrons.

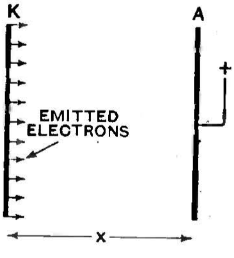


Fig. 7.—*The cathode and anode of a high vacuum discharge tube.*

Fig. 8 illustrates the general form of the potential gradients between any cathode and any anode in a vacuum. *OE* represents the plane of the cathode and *DC* represents the plane of the anode. *V* is the potential of a point *x* distance from the cathode. The magnitude of the initial velocities may be represented on the same scale from *O* downwards.

Applying this diagram to the cathode space we may indicate the maximum emission velocity by v_0 and assume that a continuous spectrum of initial velocities extended from v_0 to zero, *i.e.* over the interval v_0 to *O* in Fig. 8. Only those electrons, the initial energy of which is greater than the negative potential dip *AB* or *A'B'* or *A''B''* (which decreases as the anode voltage is raised from E_{a1} through E_{a2} to E_{a3}) can pass to the anode.

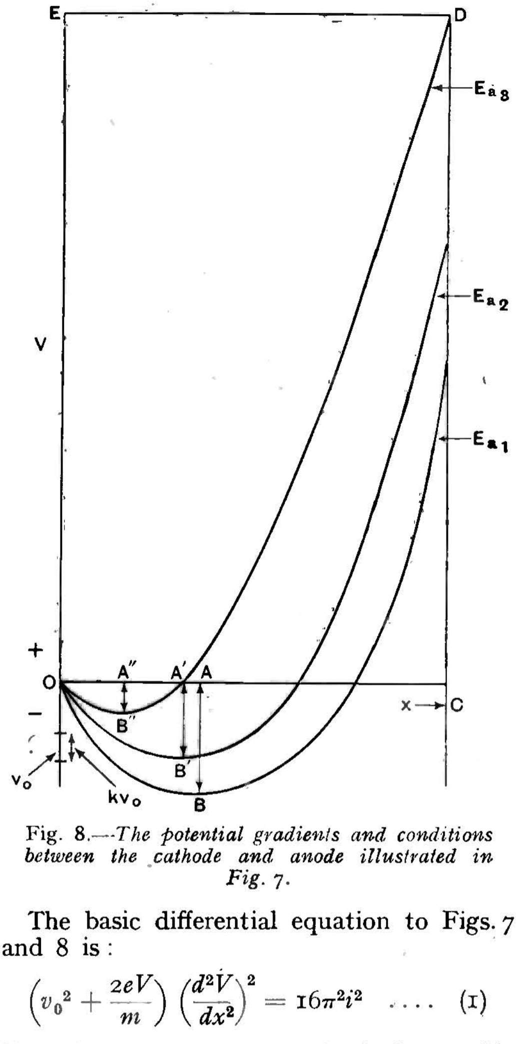


Fig. 8.—*The potential gradients and conditions between the cathode and anode illustrated in Fig. 7.*

The basic differential equation to Figs. 7 and 8 is:

$$\left(v_0^2 + \frac{2eV}{m}\right)\left(\frac{d^2V}{dx^2}\right)^2 = 16\pi^2 i^2 \quad \ldots \quad (1)$$

There is no complete general solution to this as far as the author is aware. A specific solution to the case just explained, where the initial energies extend over a continuous spectrum the maximum value of which is very small compared with the potential of the anode, is the familiar Langmuir 3/2 law. The conditions corresponding to the anode space cannot, however, have initial velocities which fulfil these conditions. If the accelerating electrode were a perfect uni-potential plane, then all the electrons issuing into the anode space would have one single velocity. A consideration of Fig. 8 will show that the E_a/i_a characteristic corresponding to the single velocity case is illustrated in Fig. 9, curve *GADE*.

Because the accelerating electrode consists of spaced wires which are in the neighbourhood of a fairly dense space charge, and quite possibly also in the neighbourhood of earthed or negatively charged metal, the potential of the equivalent cathode falls between the wires, and the initial energies will therefore vary from a value tending to equal the potential of the accelerating electrode, down to a minimum. The resulting emission spectrum extending from v_0 a short distance towards zero is indicated by kv_0' in Fig. 8. The rise in anode current at saturation point will no longer be infinitely steep. The result is shown by curve *GABE* in Fig. 9.

(Later in this paper it will be shown that the production of as sharp a knee as possible to the characteristics in the anode space is desirable in the design of valves. To attain this sharp knee, it is necessary to have as nearly as possible a single value of initial energy, and therefore to have as little reduction in potential as possible in the neighbourhood of the positive grid immediately preceding the anode.

The above reasoning has neglected the effect of diffusion due to uneven emission from the accelerating electrode. It will be equivalent to having a number of ideal single velocity valves in parallel having slightly different initial energies of emission. The result will be to round the curves at *A* and *B* in Fig. 9. Such diffusion may be neglected without much error when the anode distance is considerable, because the small change of potential gradient due to diffusion will be negligible compared with the large negative dip produced due to the space charge and the long distance.

In Fig. 9 the dotted curve *FHDE* represents the result to be expected at a short anode distance in the absence of diffusion (and secondary radiation), and with an initial velocity v_0 of one value only. In the presence of varying initial velocities and of diffusions, the curve will be changed to dotted curve *GIDE*.

These results take no account of the emission of secondary electrons. The similarity of the general form of curve *GABE* with curve 6, Fig. 3, can, however, be noted. The curve marked for 3 cm. distance in Fig. 3 will be seen to approximate very closely to that in Fig. 9 at *GIDE*.

To obtain a complete solution of (1) is not of great practical importance. Partial solutions showing the positions of the potential minimum and so relating i_a and V, etc., may be found. The saturation current i_0 is equal to the current to the accelerating electrode flowing in the cathode space, less that portion intercepted by the accelerating electrode. Thus i_0 is entirely independent of anode distance d or anode potential above saturation. This is an important confirmation of the practical results of Fig. 3. (If the screening effect of the accelerating electrode is small the current will be added to by the anode field extending to the cathode space, but this effect is subsidiary and usually negligible.)

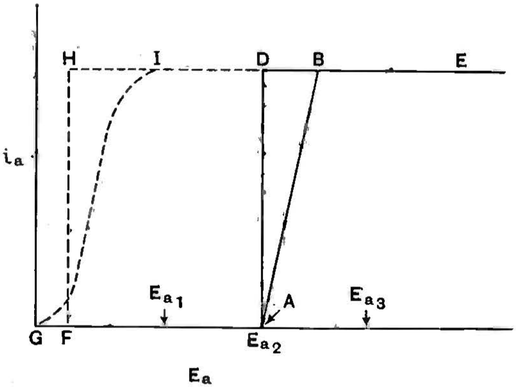


Fig. 9.—*Theoretically deduced anode voltage/anode current characteristics for the anode space.*

8. The Effect of Secondary Electron Emission

Consider the effect of the emission of secondary electrons from any metal. (Bib. 14, 15, 16 and 17). Fig. 10 is reproduced from Farnsworth (Bib. Nos. 14, 15, 16) and shows that the bulk of secondary electron emission consists of a spectrum which is almost entirely of much lower velocity electrons than the velocity of impact giving rise to the emission. (Emission and reflection are considered as the same thing for the purpose of this analysis.) The primary velocity of impact is indicated at v_p. I_s/I_p is the ratio between secondary and primary electrons. v_s is the velocity of secondary emission.

Consider first the effect of secondary emission from the accelerating electrode on the characteristics of the anode space. The result will be that secondary electrons will enter the anode space, and will have a spectrum of initial energy extending from a value tending to be equal to that of the potential of the accelerating electrode, and continuing down to zero. The result may be referred to Fig. 8 by imagining that the initial spectrum of width kv_0' extends from v_0 down to zero. Fig. 11 *OGE* and *BCD* shows *GIDE* and *GABE* Fig. 8 redrawn to suit these circumstances. The slope of the characteristics above the saturation point has been increased and the secondary electrons of low velocity have rounded the knees of both the characteristics for short and for long distances. This makes these characteristics a closer approximation to those experimentally determined and shown in Fig. 3. Stray electrons and diffusion will tend to produce the departure from zero current shown by the line *OE*.

The presence of secondary radiation from the accelerating electrode constitutes a limitation in the design of screened valves. If a very effective positive electrostatic screen grid, having a close mesh, is used, the anode differential A.C. resistance R_a will fall and the knees of the E_a/i_a curves become rounded to an undesirable extent. This is the reason why many short-spaced screened tetrodes have a very low value of R_a under working conditions. As secondary radiation is drawn from the positive grid, the total positive grid current is reduced. This result will be at the expense of the anode differential resistance, which will fall. This agrees with common experience in the design of screened tetrodes of the dynatron type in which the anode field is extremely strong. The reduction in R_a under these circumstances is sometimes accepted as a penalty inseparable from adequate screening between the anode and cathode spaces in such tetrodes. A very good positive electrostatic screen will have a large number of positive wires. Unless a great deal of secondary radiation is drawn from this positive grid, the screen current will be impracticably high; whereas by drawing sufficient secondary electrons away it may actually be made negative.

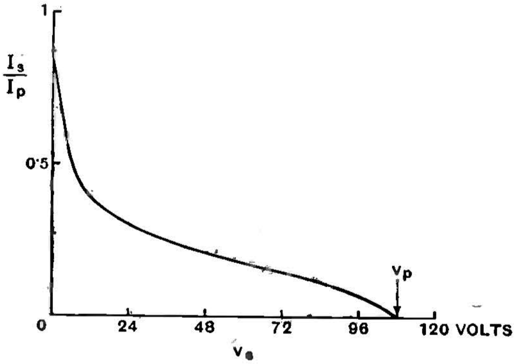


Fig. 10.—*Velocity spectrum of emission of secondary electrons from nickel. The primary velocity of impact is indicated at* v_p. I_s/I_p *is the ratio between secondary and primary electrons.* v_s *is the velocity of secondary emission.*

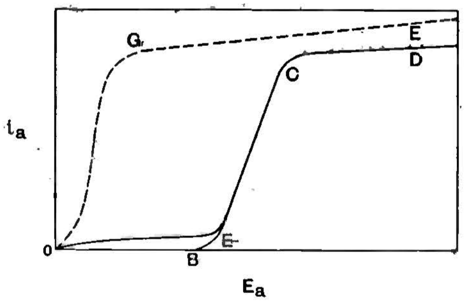


Fig. 11.—*Theoretically deduced anode voltage/anode current curves showing the effects of secondary radiation from an accelerating electrode to an anode.*

The emission of secondary electrons from the anode, as well as from the accelerating electrode, tends to reduce the value of V in the neighbourhood of the anode and alters the potential gradient from the theoretical shape in the absence of secondary radiation. At values of E_a greater than the accelerating voltage E_{acc}, the only result of this is to reduce the effective anode potential acting in the plane of the accelerating electrode or equivalent cathode. Provided E_{acc} is sufficiently great for the secondary emission to be produced from the anode when the anode potential is less than that of the accelerating electrode, then, when it is less, the emission will tend to travel back to the accelerating electrode, and will do so unless the negative space charge potential dip between the two electrodes is sufficient to prevent this.

(9) The Theory of the Critical Distance

The minimum found in the distance curve (Fig. 4) may be explained as follows. Since the velocities of almost all secondary electrons are less than the velocity corresponding to the anode potential, and therefore less under these conditions than the velocity of the primary electrons issuing from the plane of the accelerating electrode, it is possible to find a value of potential gradient sufficient to prevent the retrograde passage of secondary electrons when E_a is less than E_{acc}, but which is not sufficiently great at anode voltages in excess of a small value, to prevent the passage of primary electrons. From the preceding analysis, the negative potential gradient in a given tube is proportional to the spacing between the anode and accelerating electrode. Therefore, this explains the fact that the experiments with a sliding anode tube resulted in finding a " critical anode distance " at which the retrograde passage of secondary radiation is prevented and yet, at this distance, anode current saturation occurs at an anode voltage E_b considerably less than that of the accelerating voltage.

It may be expected that the distribution of space charge will be affected by the relative configurations of the accelerating electrode (or equivalent cathode) and anode, and by the degree or otherwise of focusing of the electron stream, due to the effect of this upon current density and upon diffusion. This is actually found to be the case. For instance, in the sliding anode valve illustrated in Fig. 2 the critical anode distance is about 3 cm. If an ordinary fixed anode valve is constructed having a tubular section anode, a circular cross-section positive grid and a filament cathode within the latter, a very diffuse radially directed stream will be produced in which the current density is low. The critical anode diameter, will then be of the order of, say, 5 to 6 cm. or more. For commercial valves, it is usually necessary so to focus the stream into a jet that the critical anode diameter is very much smaller than this, so as to go into a reasonably compact bulb. Details of the methods of design in this respect are beyond the scope of this paper. Wide bulbs with very large openings to admit a short electrode assembly of considerable diameter are extremely difficult to seal in by machinery.

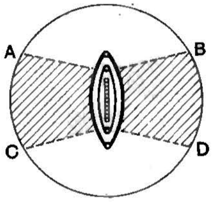


Fig. 12.—*A sectional view of a typical commercial Harries critical-distance valve. The shaded area indicates the approximate path of the discharge.*

Fig. 12 shows a section of a typical tetrode having a focused stream and its anode at the critical anode distance. The stream is confined to the shaded path. Practically the same result is obtained in the absence of those portions of the circular anode from A to B and from C to D.

PART II

1. Ideal Valve Characteristics

Fig. 13 shows the anode voltage/anode current characteristics of an ideal valve. It may be shown that E_b should be as small as possible, and that the slope of the lines from E_b upwards should be constant. The more linear the curves are to the right of the knee and the lower the value of E_b, the lower the distortion.

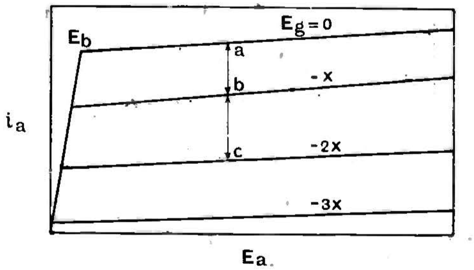
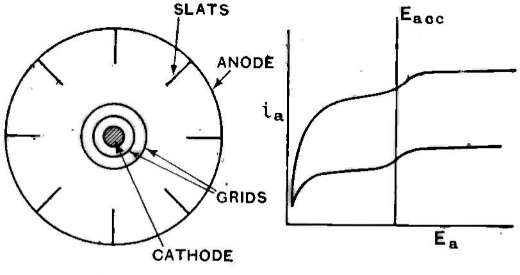


Fig. 13.—*Theoretically perfect anode voltage/anode current characteristics of a multi-grid valve.*

2. Design of the Anode Space and Examples of Valves

Referring back to Figs. 9 and 11 in the previous part of this paper, it will be seen that the characteristics illustrated in Fig. 13 correspond to those referring to valves in which secondary radiation in both directions has been rendered as low as possible, and the screening of the anode from the cathode space is as complete as possible. The effects of diffusion should also be avoided as far as possible by widely spacing the anode, and yet not spacing it so far as to cause E_b to become greater than is desirable in any given circumstances.



(a) (b)

Fig. 14.—(*a*) *A type of anode design intended to prevent the emission of secondary electrons from the anode into the anode space.* (*b*) *The anode voltage/anode current characteristics of this type of valve.*

There are three possible methods of anode space design, as regards that part of the problem having to do with preventing the retrograde passage of secondary radiation :—

1. The prevention of emission of secondary electrons from the anode surface.
2. The prevention of passage of secondary radiation across the anode space.
3. A combination of the above.

So far as the author is aware 1. has never been successful. 2. is very effective, and is exemplified both in the critical-distance valve and in the pentode valve. 3. is also effective, particularly with the critical-distance valve, though usually it is not worth the trouble, because excellent characteristics are obtained by 2. without it.

The prevention of the emission of secondary electrons (method 1) was tried by Hull by chemical treatment of the anode surface (Bib. No. 17). It was only partially successful. Another suggestion which has been carried out in practice is to arrange the anode to have radially directed slats or holes therein. It is intended that primary electrons will travel into the space between the slats, and that secondary electrons will then not readily leave the space between the slats and travel back to the accelerating electrode. Figs. 14*a* and 14*b* show, respectively, the section of a slatted anode, and the type of characteristic usually found with this kind of valve. It is not very satisfactory, because it appears to be quite impossible completely to trap the electrons in the spaces between the slats.

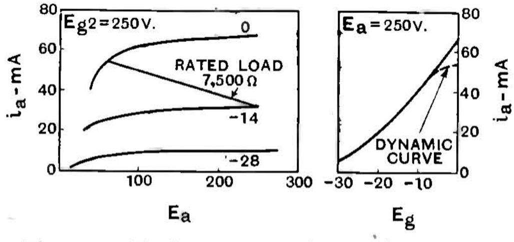


Fig. 15.—*Typical characteristics of a power output receiving valve of the pentode type. Note curved top of the dynamic characteristic producing distortion of a complex input wave.*

Fig. 15 shows the characteristics of a pentode. These have a rounded knee compared with Fig. 13. The reason for this is that the anode of the pentode is immediately preceded by an earthed grid. Electrons in the neighbourhood of the wires of this grid are reduced in velocity, whilst in between the wires the velocity of the stream tends to rise. Thus there is a wide spectrum of initial velocity from zero upwards. The anode is close to the equivalent cathode, causing diffusion effects to become important.

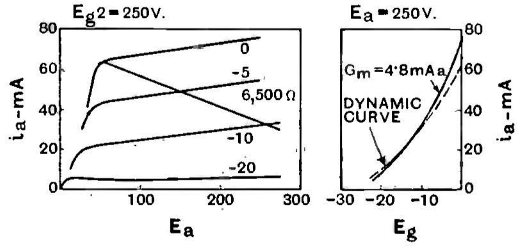


Fig. 16.—*Characteristics of commercial Harries mains type critical-distance valve. Note dynamic characteristic.*

Fig. 16 shows the characteristics of a spaced anode power output valve. This valve has been described elsewhere (Bib. 18). It is found to give a substantially lower distortion level, and greater power output, than the equivalent pentode of Fig. 15. The focusing in this valve has been arranged so that the anode will go inside a reasonable size of bulb. Everything possible is done to remove negative or earthed metal from the neighbourhood of the anode space, and thus, together with the longer anode space, because of the comparatively small width of initial energy spectrum, results in the sharp knee and linear characteristics, shown.

The rounded knees and S shaped dynamic characteristic of the pentode (Fig. 15) is the cause of a very serious type of distortion. This distortion is not indicated by, or proportional to, the amplitudes of second and third harmonic, neglecting phase angle, obtained by conventional distortion measurements with a sine wave input. It may be evaluated by measurements on harmonic distortion using an input consisting of two simultaneously applied waves, simulating the actual conditions of telephony reception. This distortion is absent in the case of the characteristic of Fig. 16. Oscillographic records of complex wave distortion have been published (Bib. No. 19).

During the past few years the author has investigated the effect of the anode critical distance on a large number of control-grid type valves. It is not possible within the space of this paper to give more than two examples, which are of interest as illustrating method 3 of designing the anode space. In Fig. 17 two separate anodes are employed, one on each side of the positive grid, and are spaced from it at the critical distance. The resemblance to Fig. 12 if the portions of the anode from A to B and from C to D are removed will be noted. The earthed plates E_1, E_2 are too far outside the anode field substantially to affect the passage of secondary radiation. The field of these plates is very slight and similar in its action to a suppressor grid. The result is that the knee of the characteristics are in general not quite so sharp as those of a pure spaced anode valve; but the critical distance effect still appears, and the anode is at the critical distance. It is of interest to observe that whenever there is sufficient metal in the accelerating electrode to give a substantially positive field and a "single velocity" emission "sharp knee" effect, then secondary radiation will travel back to the accelerating electrode at small anode spacings and the typical distance curve minimum, or "anode critical-distance effect," will appear.

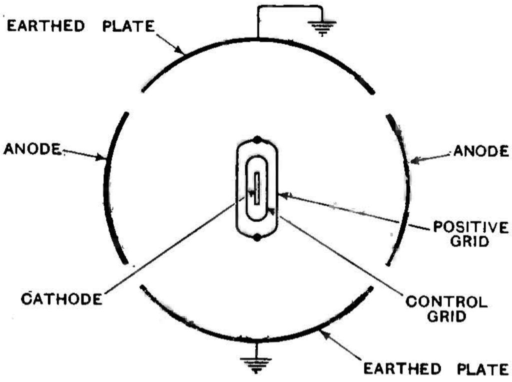


Fig. 17.—*An alternative anode design for a critical distance valve using earthed side plates.*

If a slatted anode is employed at the anode critical distance, the unsatisfactory nature of the characteristic (Fig. 14*b*) at the shorter distance disappears. Provided the slats are fairly deep it is largely immaterial whether the back portion of the anode is present or not.

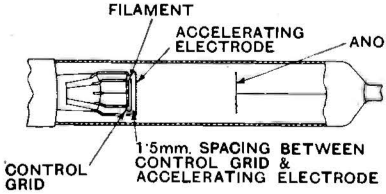


Fig. 18.—*Illustration of a type of low capacity critical distance receiving valve. The capacity can be reduced further by taking the grid lead out at the side of the bulb.*

Extremely low capacity valves may be produced by taking advantage of the long spacings possible. It is not difficult, by means of conventional screened grid constructions, only to screen one electrode, such as the anode, from the control grid; but electrostatic screens, when this is done, increase the capacities to earth. By means of such a construction as that illustrated in Fig. 18 a short wave valve is produced having extremely low capacities, not only from anode to control grid, but also from these electrodes to earth.

3. Screened Voltage Amplifier Valves

As previously pointed out, ordinary dynatron tetrodes, when well screened to give an anode to control grid capacity as low as 0.002 to 0.001$\mu\mu$F, have undesirably low A.C. anode resistances and curved characteristics. A way of overcoming this is by the introduction of a suppressor grid, but the reduction in anode field then causes the screen current to become impracticably great unless the screening is also reduced. Thus, screened pentodes have anode to control grid capacities never less than $0.004\mu\mu$F and usually of about twice or more this value. On the other hand, their anode A.C. resistances are satisfactorily high, namely, about 1,000,000 ohms at 7 mA anode current. A screened critical-distance type valve has been produced with a close mesh screen, having a screen current of the normal value, an anode A.C. resistance of 1,000,000 ohms, and an anode to control grid capacity of as low as $0.001\ \mu\mu$F.

4. Conclusions

From the theoretical considerations outlined in Part I, and from comparative experiments made with some thousands of valves over a period of several years (a few typical results of which are set out in Part II), it is considered that the correct design of the anode space of a multi-grid valve should utilise the anode critical distance and that the design of very long stream valves should be in accordance with the methods of spacing accelerating electrodes described herein.

BIBLIOGRAPHY

1. Gill, *Philosophical Magazine*, May, 1925, pp. 993–1005.
2. Tellegen, *British Patent*, No. 287,985**, 1926.
3. Robert Von Lieben, *German Patent*, No. 179,807.
4. Dieckmann & Glage, *German Patent*, No. 184,710, 1906.
5. Rene Zei, *British Patent*, No. 18,438, 1913.
6. Nasarischwily, *Ann. de Phys.*, 1921, Vol. 64, p. 759.
7. Gebbert, *Jahrboch derdrahtlosen Telegraphie*, 1923, Vol. 22, p. 107.
8. Dieckmann & Glage, *Jahrboch derdrahtlosen Telegraphie*, 1922, Vol. 19, p. 194.
9. Harries, *British Patent*, No. 328,680, 1929.
10. Alfven, *Zeitschr. f. nochf. Tech.*, July, 1934, Vol. 38, pp. 27–29.
11. Dieckmann & Gebbert, *German Patent*, No. 375,808, 10th July, 1921.
12. J. J. Thomson, *Conduction of Electricity Through Gases*, Third Edition, 1928, p. 373.
13. Harries, *British Patents*, 380,429, 385,968, 1931.
14. Farnsworth, *Physical Review*, 1922, Vol. 20, p. 358.
15. Farnsworth, *Physical Review*, 1925, Vol. 25, p. 41.
16. Farnsworth, *Physical Review*, 1926, Vol. 27, p. 413.
17. Hull & Williams, *Physical Review*, 1926, Vol. 27, p. 432.
18. Harries, *Wireless World*, 2nd August, 1935.
19. Bartlett, *Wireless Engineer*, Feruary, 1935, Vol. 12, pp. 70-74.

Osram Valve for Microphone Amplifiers

THE new Osram MH40 valve is similar to the well-known MH4 type, but has several features which particularly adapt it to the early stages of a microphone amplifier. It is an indirectly heated valve with a heater consuming 1.0 ampere at 4.0 volts, and it is fitted with a standard 5-pin base. An automatic bias resistance of 1,000 ohms is recommended, and with its maximum anode potential of 200 volts, the anode current is 2.7 mA. The optimum load resistance is 50,000 ohms and the valve has a mutual conductance of 2.4 mA/V., with an A.C. resistance of 16,700 ohms. These figures are, of course, for 100 volts anode potential and zero grid bias. The interelectrode capacities are given as: grid-anode 7.3 $\mu\mu$F., grid - other electrodes 6.0 $\mu\mu$F., and anode-other electrodes 4.0 $\mu\mu$F.

The particular features claimed for the valve, and the ones which make it so suitable for the early stages of a high-gain amplifier, are the very low degree of microphony and the high insulation of the electrodes. This is accomplished by the use of steatite insulators for the electrode spacers instead of the usual mica separators.

The valve is priced at 50s. and the makers are The General Electric Co., Ltd., of Magnet House, Kingsway, London, W.C.2.

Book Reviews

The Radio Amateur's Handbook, 1936 edition

By the A.R.R.L. Headquarters Staff. 480 pages (including a 96-page catalogue section) approximately 500 diagrams, illustrations and charts. Published by The American Radio Relay League, West Hartford, Conn. U.S.A. Price $1.15 with paper cover, or $2.50 with linen cover, post free.

Probably no reference book contains such a wealth of practical data for the short-waves amateur experimenter as the 1936 edition of The Radio Amateur's Handbook. It has been revised and brought up-to-date and forms a worthy successor to the twelve previous editions. Of the several new chapters