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ELECTRON DISCHARGE TUBE
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Fig. 1

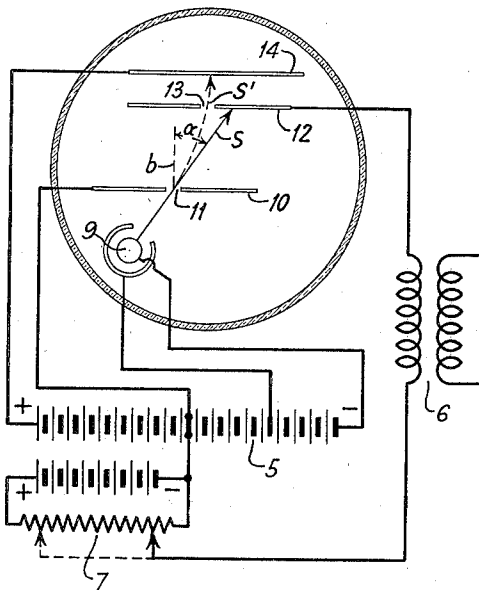


Fig. 2

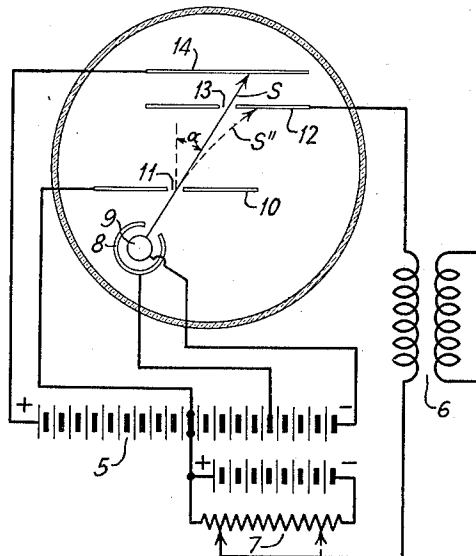


Fig. 3

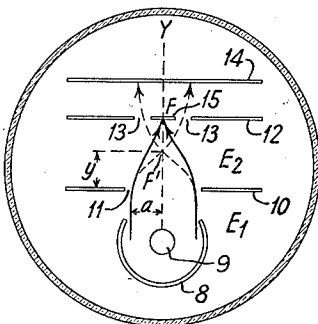
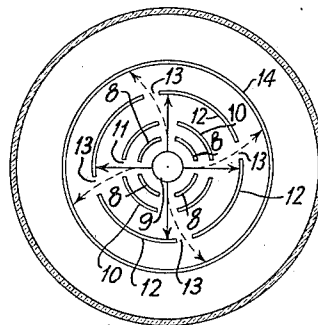


Fig. 4



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ELECTRON DISCHARGE TUBE

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7 Claims. (Cl. 250—155)

This invention relates to electron discharge devices, and more particularly to thermionic tubes in which the electrodes are arranged to provide a negative resistance in the tube.

It has been known in the prior art for a long time how to produce statically negative resistance in amplifier tubes. The feasible constructions and methods known for this purpose in the prior art depend on secondary emission phenomena or on feed-back circuits. Certain disadvantages are inherent in these methods; the devices are, for instance, not constant with respect to time, or require circuit elements disposed outside the tube. The prior art has further proposed to generate a negative internal resistance in specially constructed tubes in which there is disposed behind a perforated anode through which current may pass at least one further output electrode and to retard the current passed by the perforated anode to produce an electron space charge collected between the anode and output electrode, the current being distributed between these two electrodes according to the primary current intensities as well as the anode potential. Accordingly, the appearance of the negative inner resistance between cathode and anode is dependent on slow if not fully retarded electrons.

The invention has as its object to provide electrode arrangements whereby statically negative resistances may be generated by controlling the distribution between two electrodes of a current of fast electrons and in particular accomplishes this distribution in such a way as to result in stable characteristics easily reproducible. The invention may be practically embodied in a device so constructed that an electron beam emerging from an auxiliary electrode suffers a change in direction due to an increase or decrease in potential of a supplementary electrode, and, as a further result, the current flowing to this supplementary or output electrode is decreased with increase in said potential, or increased with decrease in said potential. This relation between current and potential of the supplementary or output electrode is an indication of the fact that the discharge path terminating at this electrode has a negative resistance. The characteristic from which this internal resistance may be read off can be plotted point by point so that the designation as static negative resistances is justified.

The principle of the invention may best be understood by reference to some practical embodiments diagrammatically shown in the accompanying drawing, in which Figures 1 and 2 show electrode arrangements of much the same type;

Figure 3 an arrangement utilizing the electron lens effect of diaphragm electrodes; and Figure 4 a cylindrical form of the embodiment of Figure 1.

The devices shown in the drawing comprise in general the usual highly evacuated envelope which encloses the electrodes. A source of potential, such as a battery 5, is connected to a cathode or electron source and to an array of anodes which are at successively greater distances from the cathode and are at positive potentials with reference to the cathode. A load circuit 6 is connected to one of these anodes, which constitutes a main anode or output electrode. The potential of the main anode may be varied, as by some means such as diagrammatically indicated at 7. The electron source, which preferably produces an electron beam of predetermined cross-section, may, for example, comprise a beam-forming or focusing electrode 8 having in one side a beam-forming slit and surrounding a thermionic cathode 9, although it is obvious that any source of electrons such as a thermionic, gaseous, or photocathode may be used, and the beam may be formed in various ways as, for example by Wehnelt cylinders or by focusing diaphragms.

The form of device shown in Figures 1 and 2 comprises, in addition to the electron source, an auxiliary anode electrode 10, preferably a diaphragm with a slot or aperture 11, a main anode or output electrode 12 which is also a diaphragm with a slot or aperture 13, and a further auxiliary anode or pickup electrode 14, preferably imperforate, all three anode electrodes having impressed upon them a potential positive with reference to the cathode. In Figure 1 the aperture 13 of the diaphragm electrode 12 is out of alignment with the cathode and with aperture 11 of electrode 10, hence a straight beam from the cathode passing through aperture 11 will miss the aperture 13 of the main anode, as the apertures are staggered with reference to the path of the quiescent or undeflected beam. The electron beam S passes through the aperture 11 and through the electrostatic field between the electrodes 10 and 13 emerging from the electrode 10 with an angle of inclination α to the direction of the lines of force of the electrostatic field, the lines of force being, as indicated by dotted line b, at right angles to the auxiliary electrode surface. Assuming that the space between electrodes 10 and 12 has no field, that is, the two electrodes have the same potential, the electron beam between these two electrodes has a rectilinear course, misses the aperture 13 and falls

wholly upon anode or output electrode 12. If now the potential u_2 of anode 12 is increased, electron beam S receives in the now existing accelerating field an additional component of motion in a direction at right angles to main anode 12. The electron beam no longer travels rectilinearly in the same space between electrodes 10 and 12, but describes a parabolic path S', passes in part or in whole through the diaphragm opening 13 and is finally caught by auxiliary electrode 14. Obviously, the output current i_2 flowing to main anode 12 has become smaller in spite of the increase of main anode potential u_2 , that is

$$\frac{\partial u_2}{\partial i_2} < 0.$$

This means, however, that the alternating current resistance of the discharge path ending at main anode 12 is negative. It is evident that by suitable choice of the electron beam cross-section and form of diaphragm anode 12, any desired relation, among others a linear relation between anode potential and anode current may be established, and that likewise the sensitiveness of control and with it also the magnitude of the negative internal resistance may be influenced by the choice of the electrode distances (in particular between 10 and 12) as well as of the angle of beam inclination α .

Similar observations apply to the electrode arrangement shown in Figure 2, in which the same elements have the same designations as in Figure 1, but the openings 11 and 13 are in alignment with the cathode and with the path of the undeflected electron beam. The electron beam S passing through the diaphragm opening 11 of the auxiliary electrode 10 passes, if the space between electrodes 10 and 12 is without any field, through diaphragm opening 13 of anode 12 and reaches auxiliary electrode 14. Accordingly, the current i_2 flowing to main anode 12 is zero or at least very small. If, however, anode potential u_2 is decreased, the electron beam deviates from its straight path and follows the curved path S'', anode 12 now catching all or a greater portion of the electrons in the beam. The relation

$$\frac{\partial u_2}{\partial u_1} < 0$$

is valid also in this case, that is, the internal resistance of the discharge path ending at anode 12 is negative.

Figure 3 illustrates an electrode arrangement of somewhat different type in which the auxiliary electrode 10 provided with an aperture 11 and the further imperforate auxiliary electrode 14, of Figures 1 and 2 are used, in conjunction with a main anode or output electrode 12 on which a negative resistance is to be produced which has across its aperture a conductive bridge 15 which is part of the main anode. The conductive bridge 15 in the axis of symmetry Y of an undeflected beam from the cathode and also in alignment with the cathode and the aperture 11 of the electrode 10. Let the potentials of these two electrodes 10 and 12 be designated respectively, u_1 , u_2 , while E_1 means the field intensity in front of electrode 10 and E_2 the field intensity in the space in front of electrode 12. Let it now be assumed that an electron beam, directed at right angles to electrode 10 passes through diaphragm 10 along this course the electrons are subject to deflections which are greater the greater the distance a of the electron in the surface of electrode 10 from

axis of symmetry Y. The angle of deflection β is given by following relation:

$$\beta = \frac{a(E_2 - E_1)}{2u_1}$$

The electrons describe parabolic paths in the space between electrodes 10 and 12, said paths intersecting on the axis of symmetry Y. The distance of the point of intersection from electrode 10 amounts to (assuming that $E_2 > E_1$):

$$y = u_1 \frac{3E_2 - 2E_1}{(E_2 - E_1)^2}$$

Thus all electrons of the beam unite at a point disposed on the axis of symmetry Y which point may be called the focal point. It varies its position, as may be seen from last formula, as a function of the field intensity E_2 and accordingly also of the anode potential u_2 . Let it be first assumed that potentials u_1 , u_2 or field intensities E_1 , E_2 are chosen in such manner that the focal point F is located on the center bridge or pickup surface 15 of electrode 12. If now anode potential u_2 is increased, the focal point moves towards electrode 10 and assumes for instance position F'. As may be seen from the drawing, the electron paths intersect at a point in front of electrode 12, a part of the electrons therefore passing through the opening 13 in diaphragm 12, which may be assumed to be annular and impinging on the electrode 14 located in the rear. It is quite obvious that the current i_2 flowing to output electrode 12 is decreased by the assumed increase of potential u_2 on that electrode, and that thus the internal resistance of the discharge path terminating at electrode 12 is again negative. The particular feature of the embodiment according to Figure 3 is the utilization of the lens or focusing effects of diaphragms with respect to the electron beam passing through them.

In the embodiments described above, only one pair of openings was considered for each of electrodes 10 and 12. The number of openings may, however, be increased at will and electrodes 10 and 12 be given a mesh or grid-like form, resulting in a construction of the electrode assembly such as has often been used in the prior art of tube construction, and the effects produced by means of a single pair of coordinated openings may thereby be multiplied. The described arrangements are based on an electron beam or a pencil discharge of definite cross-section, but the definition of the beam cross-section can, of course, also be accomplished by the diaphragm provided by electrode 10, so that an electron source may be used of the type common in amplifier tubes. The previously described multiple arrangement may also be applied to electrodes in form of concentric cylinders and axial hot filament, or a correspondingly formed indirectly heated cathode.

The above described embodiments must not be considered as limiting examples for it is obviously that the man skilled in the art may develop other constructional possibilities on the basis of the described arrangements. Thus, for instance, the arrangements in Figures 1 and 2 are based on a beam which is straight when in quiescent position in the space between electrodes 10 and 12, which presuppose equal potentials at electrodes 10 and 12. Of course a curved electron path of definite curvature may just as well be chosen as the quiescent position, the two previously named electrodes being then impressed with different potentials. In this manner errors in mechanical

adjustment of the electrodes may be equalized by electric means. By the stipulation in accordance with the invention, that the current distribution is obtained with fast electrons, there is available such a choice of the discharge current intensity, as well as of the distances and potentials of the different electrodes, that in that part of the discharge space where the current distribution is effected no space charge choking of the discharge may develop and in particular no minimum of effective potential with zero value.

We claim:

1. A negative resistance electron discharge device comprising a cathode, a beam forming electrode for forming a discharge from said cathode into a rectilinear beam, two equipotential anodes, each having an aperture, mounted parallel to each other at different distances from said cathode with the aperture in the first anode in alignment with the longitudinal axis of the beam and the aperture in the second anode out of alignment with said axis to cause a beam of fast electrons passing from said cathode through the aperture of said first anode to shift the entire beam bodily relative to the aperture in said second anode with changes in potential of said second anode and thereby produce in response to a change in potential of said second anode an inverse change in beam current to said second anode, and a third anode in alignment with the aperture in said second anode.

2. A negative resistance electron discharge device comprising a cathode, a beam forming electrode for forming the discharge from said cathode into a rectilinear beam, a main anode having an aperture, an auxiliary equipotential anode between said cathode and said main anode and having an aperture out of alignment with the aperture in said main anode and said cathode to permit the electron beam from said cathode to emerge from said auxiliary anode into the field between said anodes along a path inclined to the lines of force of said field, the path of the electron beam changing in direction and in relation to said aperture in said main anode as a function of change in potential of said main anode to produce in response to a change in potential of said main anode an inverse change in the amount of current collected from said beam by said main anode, and a third anode overlapping the aperture in said main anode.

3. A negative resistance electron discharge device comprising a cathode, a beam forming electrode for forming a discharge from said cathode into a rectilinear beam, three equipotential anodes at differing distances from said cathode, the second anode being the output anode of the device, the first and second anodes from the cathode each

having an elongated aperture and with the aperture of the second anode out of alignment with the longitudinal axis of said beam to cause an electron beam passing from said cathode through the aperture in the first anode to impinge upon said second anode or to shift bodily along said second anode and pass through the aperture in said second anode to said third anode in accordance with changes in potential on said second anode, and the third anode overlapping the aperture in said second anode.

4. A negative resistance electron discharge device according to claim 3 in which the cathode is out of alignment with the corresponding apertures in said first and second anodes and the electron beam passes through the aperture of the first anode at an acute angle to the perpendicular to the surface of said anode and with equal potentials on the first and second anodes passes through the aperture of the second anode and with decrease of potential of the second anode moves along said second anode and away from said aperture and impinges on said second anode.

5. A negative resistance electron discharge device according to claim 3 in which the cathode is displaced from a perpendicular to the surface of the first anode at the aperture in said anode and electron beam passes through the aperture of the first anode at an acute angle to the perpendicular to the surface of said anode and the second anode is so coordinated with the first anode that equal potentials of said anodes cause the electron beam to impinge on the second anode and an increase of potential of the second anode causes the electron beam to move bodily along said second anode into the aperture of the second anode.

6. A negative resistance electron discharge device according to claim 3 in which the first and second anodes are grid-like and each has a plurality of apertures, each aperture in one anode being coordinated with a corresponding aperture in the other anode, and the cathode is out of alignment with the corresponding apertures in said anodes.

7. A negative resistance electron discharge device according to claim 3 in which the electron beam from the cathode passes through the aperture in the inner anode perpendicular to the first anode and the second anode is so coordinated to the first anode that the anodes act as an electron lens to focus the beam in the space between the two anodes at a focal point dependent upon the potential of the second anode to cause the proportion of the beam passing through the aperture of the second anode to vary with variations in potential of said anode.

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