

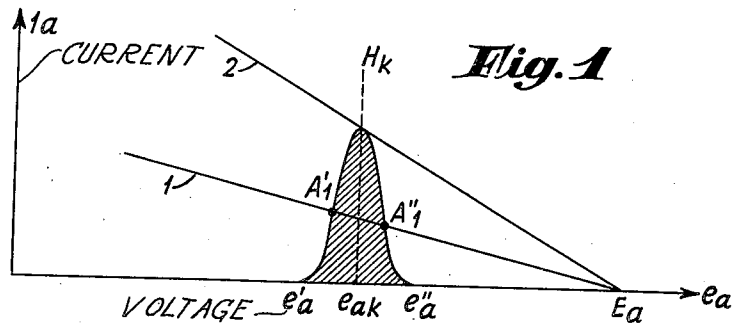
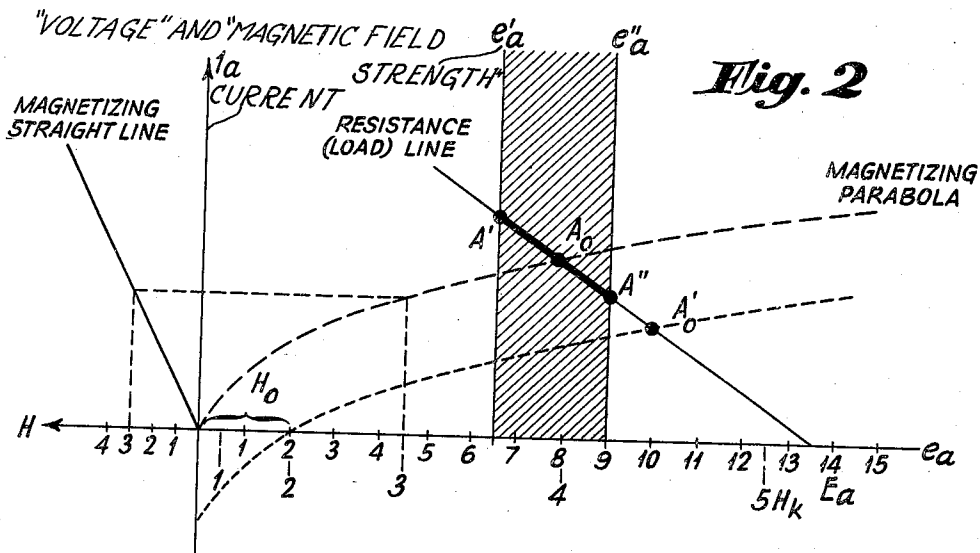
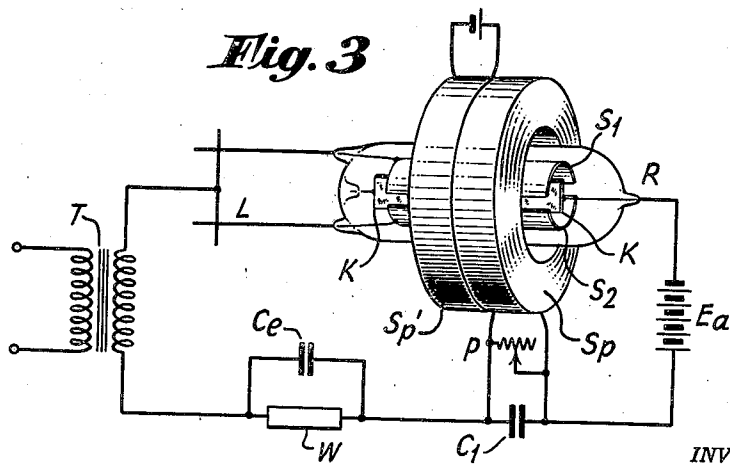
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MAGNETRON

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MAGNETRON

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3 Claims. (Cl. 250-27)

My invention relates to electron discharge de-
vices utilizing the phenomena of secondary emis-
sion and magnetic control and sometimes referred
to as an electron multiplier. The present appli-
cation describes and claims an improvement over
my invention described and claimed in my appli-
cation Serial No. 133,316, filed March 27, 1937,
Patent No. 2,171,212, dated August 29, 1939 and
assigned to the same assignee as the present
application.

In the magnetron described in my co-pending
application identified above the electrons which
carry the electron current are produced by sec-
ondary emission of cold cathodes. When switch-
ing in the electrical fields, at first only a few
electrons, for instance photo-electrons, leave the
cathode and after describing a circular course
they impinge on the second cathode coating.
By means of a special construction of the oscil-
latory tube in conjunction with ultra-high fre-
quency resonance systems care is taken that the
electrons retain a sufficient residual velocity
when impinging on the second cathode so that
a large number of secondary electrons are re-
leased from the cathode coating. The secondary
electrons produced in great numbers by the im-
pinging first primary electrons, now leave the
second cathode coating in the reverse direction,
and return to the first cathode coating after de-
scribing their own circular course. At this cath-
ode coating secondary electrons are produced
anew, and the entire performance repeats itself.
Through alternative building up of the secondary
emission from the two cathode coatings the
emission and the plate current will be gradually
built up. In fact, this building up is limited only
by the yield of the coatings having secondary
emission, since in view of the impulse like emis-
sion, space charges which fill in only a small
part of the electrode space play only a minor
role.

In view of the fact that in the interest of an
intensive building up of oscillations, it is aimed
at imparting to the cathode coatings a possibly
high yield in order that they deliver in the form
of secondary electrons an amount equal 10 to 20
times the number of primary electrons impinging
on said coatings, danger exists that the emis-
sion will be driven in this manner to a higher
intensity than the tube can withstand from the
point of view of heat. Under these conditions
any practical operation is of course out of the
question, and measures must be resorted to which
prevent the emission current from growing be-
yond the allowable value.

The object of the present invention is to sub-
stantially eliminate an uncontrollable building
up of the emission, since at a high yield of the
cathode coating capable of secondary emission,
the plate current may increase beyond the allow-
able load limit thereby destroying the tube.

The novel features which I believe to be char-
acteristic of my invention are set forth with
particularity in the appended claims, but the
invention itself will best be understood by ref-
erence to the following description taken in con-
nection with the accompanying drawing in which
Figure 1 is a graph showing operating charac-
teristics of a tube made according to my co-
pending application identified above, Figure 2 is
a like graph showing further operating charac-
teristics under other conditions, and Figure 3
is a perspective of a tube and a diagram of a
circuit made according to my invention.

In the tube arrangements operating with sec-
ondary emission such as have hitherto been
known, the danger of unduly high currents was
avoided simply by the insertion of an ohmic pro-
tecting resistor in the plate circuit of the tube.
Such series resistor although limiting the emis-
sion current to a certain degree, however, renders
on the other hand the operating conditions of
the tube inexact and unstable as can be seen
from the diagram of Figure 1 showing the elec-
trical conditions.

The diagram reveals the action of an ohmic
resistor placed ahead of the secondary emission
magnetron of the type described in my co-pend-
ing application. The abscissa indicates the plate
potential e_a of the tube, and the ordinate shows
the plate current i_a . It is at first assumed
that certain operating conditions are adjusted to,
i. e. the magnetic field is assumed to have the
value H_k and the tuning of the generator circuit
is maintained on the wavelength determined by
the equation $\lambda_0 = 10,650/H_k$. Furthermore, a lim-
ited yield of the cathode coatings having sec-
ondary emission is presupposed. A building-up
of the emission and plate current is then in the
beginning possible only at or near the critical
plate potential e_{ak} determined by the known
magnetron formula

$$H_k = \frac{6.72}{r_a} \sqrt{e_{ak}}$$

where r_a is the radius of the anode plates and
 e_{ak} is the potential between the anode and cath-
ode. If in starting from zero, the plate poten-
tial e_a is gradually increased then the plate
current i_a begins at a certain voltage value

e_a' , and attains its maximum at the critical condition e_{ak} corresponding with the formula and with which also the optimum of the generation of oscillation coincides, and at a further increase of e_a the plate current decreases again down to zero at e_a'' . In contrast to the known glow cathode magnetron arrangements, the current-voltage line of the secondary emission magnetron has a pattern similar to a resonance curve as emphasized by the shaded surface in Figure 1.

The action of a protective resistor having a value W and starting from a fixed voltage point namely from the feed voltage E_a can be shown in the diagram in the form of a straight resistance line. This resistance line must originate in the voltage point E_a on the abscissa, and is to indicate the value of the plate potential in relation to i_a and reduced by the voltage drop $i_a W$. The resistance line is determined by the equation:

$$e_a = E_a - W i_a$$

and its inclination towards the abscissa is $di_a/de_a = 1/W$. In Figure 1 two resistance lines 1 and 2 are shown for different resistance values W but starting from the same voltage point E_a . If a variable series resistor is chosen, the resistance line can be turned about the turning point E_a . But if at constant W the fed voltage E_a is changed the resistance line will thereby be displaced parallel to itself.

In accordance with the magnetic field H_k and the associated resonance wave λ_0 , the plate current resonance curve exists at a certain plate potential e_{ak} . The working points may then be placed at the two intersection points A_1' and A_1'' of the straight resistance line 1 with the current resonance curve. When the high frequency oscillation performance is influenced in any manner, for instance by withdrawing of energy, the current resonance curve which is very closely related to the ultra high frequency building up performances becomes flattened out, and the two working points A_1' and A_1'' move towards each other on the resistance line until finally only a single working point is left over. The same conditions prevail when at a fixed current resonance curve, the resistance of the line 2 is correspondingly so chosen that the resonance curve just forms a tangent in the point A_2 . At this working point at the slightest flattening out of the resonance curve the oscillations break off immediately, because the current maximum falls below the straight resistance line, and the building up can no longer set in by itself. Therefore this adjusting which is extremely critical is entirely useless for practical purposes.

The conditions become still worse when disregarding the limitation as regards the yield of the cathode coatings having secondary emission on which Figure 1 is based, and which would in practice be desirable in connection with the above viewpoints. In this case, the current resonance curve assumes the form shown in Figure 2, i. e. at a certain voltage value e_a' , the oscillations and therewith also the plate current increase in a jump and build themselves up immediately to very high values reaching far beyond the load capacity of the tube, so that therefore they can no longer be measured. The same also holds true as regards the potential value e_a'' . The resistance line now passes through the shaded current region between e_a' and e_a'' , and cuts off the area lying above. Thus there remains as the only possible part of the resistance line useful for the

adjustment of the operation, the part between the limit points A' and A'' , on which the actual working point may move back and forth in accordance with the conditions of building up and the load conditions. It can thus be seen that the insertion of a series resistor as protection means actually limits the load of the tube and protects the tube against the danger of destruction, but the instabilities therewith encountered represent a serious disadvantage in the practical operation since the movement of the working point always entails greater or lesser variations in the frequency and intensity.

In order to eliminate these instabilities, a third parameter is introduced into the arrangement and plays a decisive role in determining the operating conditions. There serves as a parameter in accordance with the invention, an auxiliary magnetic field permeating the tube and which is coupled with the building up and emission performances. This field is produced entirely or in part by a field coil through which the plate current of the secondary emission tube passes. An arrangement set up on the basis of the principle of the invention is represented in Figure 3. Here the magnetron tube R is provided with the cold flat cathode K having both sides covered with substance emitting secondary electrons, the said sides being positioned in the center of an anode cylinder divided into the two segments S_1 and S_2 . Both segments are connected to the lecher line L whose resonance potentials control the electron current. The anode circuit contains the magnetizing coil Sp concentrically surrounding the tube, and the protective resistor W . Both are bridged by condensers C_1 and C_2 in order to avoid low frequency disturbance oscillations.

In order better to visualize the functioning and action of the new stabilization method, the diagram according to Figure 2 is completed by the introduction of the "magnetizing characteristic" which like the straight resistance line, represents the magnetic field intensity H produced by the coil Sp and its relationship to the plate current i_a . It is obvious that the magnetic field must be proportional to the magnetizing current i_a , i. e. $H = K i_a$ whereby the proportionality factor K contains the magnetic data of the coil Sp such as the number of turns, and the cross section, as well as eventually also the magnetic resistance of an existing iron core. The magnetizing line resulting from any factor K is shown in Figure 2 extending towards the left from the zero point of the coordinates. The magnetic field produced by the currents i_a in the ordinate can be read at the abscissa.

Now in order to couple this straight magnetizing line with the straight resistance line, and to project it into the current voltage diagram, above the abscissa scale for e_a the associated scale of the magnetic field for H is shown. As stated above, both values are connected with each other through the critical magnetron formula

$$H k^2 = k e_a$$

and therefore a quadratic division will be obtained for H when the voltage scale is divided in a linear fashion. Above this quadratic scale for H , the magnetizing characteristic forms no longer a straight line but a parabola, such as shown in dotted lines in Figure 2. The parabola intersects the straight resistance line in the point A_0 and this is the only possible point to which the generator can adjust itself in the operating state, when the above critical magnetron

formula holds true. Otherwise a different law is to be relied upon when transforming the scale for the magnetic field. The ultra high frequency potentials produced at the anode segments may cause considerable deviations compared with the magnetron laws for the static case, which for the sake of simplification have herein not been considered since they have principally no bearing on the principle of the invention.

Obviously the operating conditions must be so chosen that the intersection point A_0 is in the center between e_a' and e_a'' , since it is in this place that optimum conditions can be expected. To this end, on the one hand, the ultra high frequency tuning is available, and on the other hand, if a certain wave is to be produced, the adjusting can be carried out by means of E , E_a or H . When changing W the resistance line turns about the E_a -point, while it is placed parallel to itself when E_a is changed. An analogous parallel displacement can also be obtained with the magnetizing parabola, in that an additional component H_0 is superimposed on the magnetic field produced by i_a , said component may be obtained for instance by an auxiliary winding Sp' in Figure 3 fed with direct current, or by a permanent magnet. The additional field causes a parallel displacement of the magnetizing parabola in the i_a -axis such as shown for instance by the parabola drawn in dotted lines in Figure 2. In the case represented, the straight resistance line is intersected in the point A_0' outside the range of oscillation in which no building up is possible. In order to turn the parabola about the zero point of the coordinates, simply the proportionality factor K is to be changed such as can be done for instance by means of a variable parallel resistor P .

The example of the circuit herein given and the operating conditions herein discussed in connection with said circuit may suffice for the elucidation of the principle of the invention, which in practice affords numerous variations and modifications. It should furthermore be mentioned that by introducing sufficiently large time constants in the current control and voltage control, for instance by using sufficiently large condensers C_1 and C_2 , such a high inertia can be imparted to the stabilization that it can no longer compensate for rapid fluctuations. In this connection a practical requirement is seen for instance if the transmitter by superimposing speech potentials on the working potential e_a for instance, is to be modulated eventually by means of the transformer T in Figure 3. If the modulation periods are essentially greater than the time constants of the control performance, the transmitter can be fully controlled if adjusted to a suitable working point.

The operation of the tube is stabilized by bringing about an equilibrium between the secondary electrons produced at the cathode and the electrons received by the anodes. In order to bring about this equilibrium the resistance W and the magnetic coil Sp are relied upon. If for any reason, the discharge current increases, the effective accelerating voltage e_a at the anode segments will decrease as a result of the voltage drop in the resistance W . At the same time, there is an in-

crease in the strength of the magnetic field which is produced by the winding Sp by the increased discharge current flowing through the winding. The effect of the strengthened magnetic field is to decrease the orbits of the electrons so that fewer electrons are taken from the discharge and sent to the anode. At the same time, the decreased anode voltage causes fewer electrons to be received by the anode segments. These actions have a compensating effect on the current through the output circuit connected to the anode segments. However, any strong tendency for a too great reduction in the discharge current due to the decreased anode voltage is compensated for by an increase in the number of secondary electrons produced by the electrons confined to the discharge space, and thus more electrons become available to increase the discharge current. All these factors help in stabilizing the anode currents when balanced against each other.

What I claim as new is—

1. An electron discharge device having an envelope containing a straight cathode coated with material for emitting electrons, and an anode surrounding said cathode for receiving electrons from said cathode, means for producing a magnetic field parallel to said cathode and anode and of sufficient strength to cause electrons to impinge on the cathode to release secondary electrons and an output circuit including a source of anode potential connected to the anode of said electron discharge device, and means including a resistance for varying the anode potential and means including an electromagnetic coil for varying the strength of the magnetic field and the rate of secondary emission.

2. An electron discharge device comprising an envelope containing a straight cathode coated with material for emitting electrons and a pair of coaxial anode segments surrounding said cathode for receiving electrons from said cathode, a coil surrounding said electron discharge device for producing a magnetic field parallel to said cathode and anode segments and of sufficient strength to cause electrons to impinge on the cathode to release secondary electrons, a load circuit connected to the anode of said electron discharge device and including a resistor and a second electromagnetic coil surrounding said electron discharge device for varying the intensity of the magnetic field and the rate of secondary emission.

3. An electron discharge device comprising an envelope containing a straight cold cathode coated with electron emitting material and a pair of coaxial segments surrounding said cathode for receiving electrons from said cathode, a coil surrounding said electron discharge device for producing a magnetic field parallel to said cathode and anode segments and of sufficient strength to cause electrons to impinge on the cathode to release secondary electrons, a load circuit connected to the anode of said electron discharge device and including a resistor and a second electromagnetic coil surrounding said electron discharge device for varying the strength of the magnetic field and the rate of secondary emission.

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