

Sept. 13, 1938.

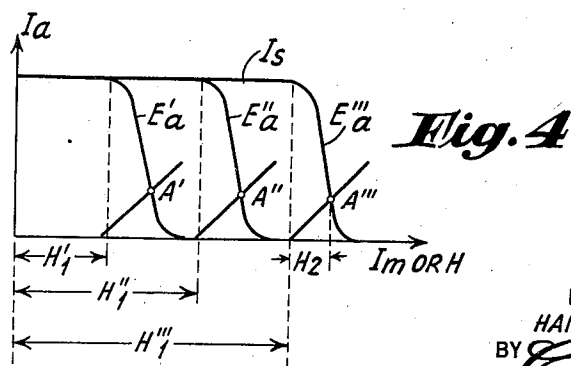
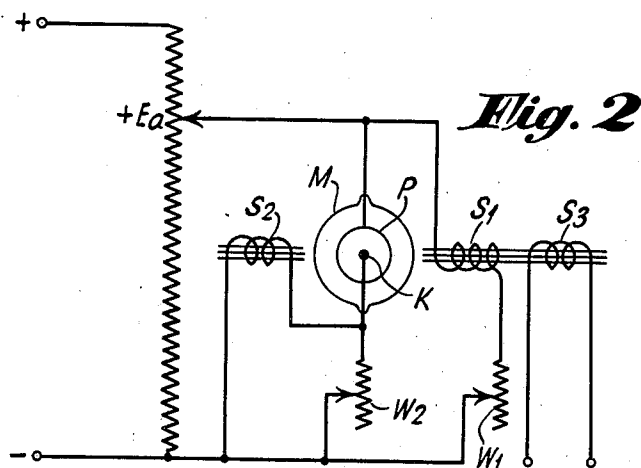
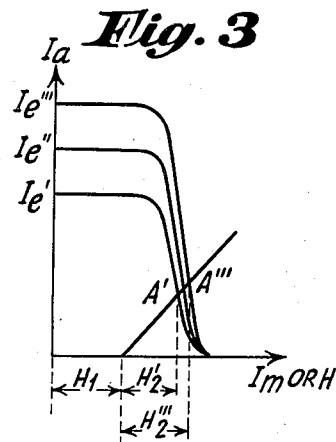
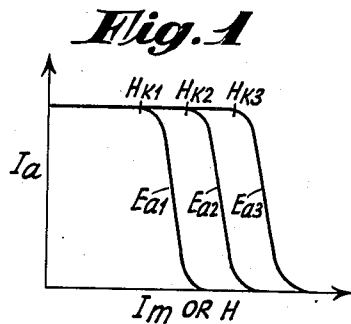
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MAGNETRON

Filed July 1, 1937

2 Sheets-Sheet 1



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MAGNETRON

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Fig. 5

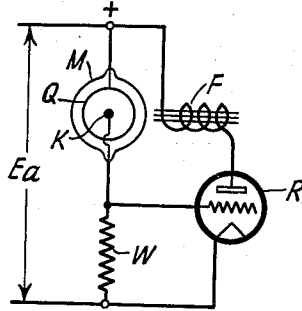


Fig. 6

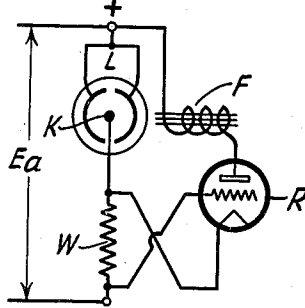


Fig. 7

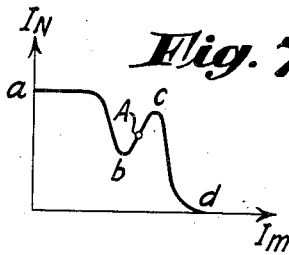
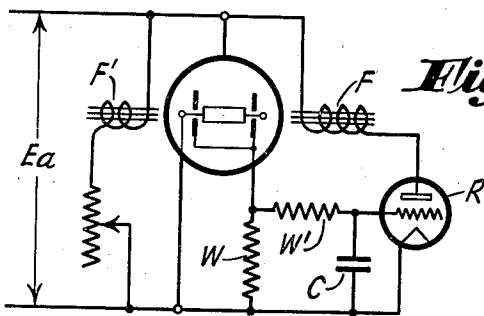


Fig. 8



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2,130,132

MAGNETRON

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5 Claims. (Cl. 250-27)

My invention relates to electron discharge de-
vices, more particularly to such devices employ-
ing a magnetic field for influencing the movement
of the electrons within the device.

The present invention has for its principal ob-
ject circuit arrangements, the purpose of which
are to stabilize as far as possible the operating
point of a magnetron, i. e., a tube having a hot-
cathode in which the electron movements are in-
fluenced by a magnetic field, and also to render
such a tube independent of and unaffected by
accidental fluctuations of operating conditions
such as the anode potential, tube heating, etc.

The novel features which I believe to be char-
acteristic of my invention are set forth with par-
ticularity in the appended claims, but the inven-
tion itself will best be understood by reference to
the following description taken in connection with
the accompanying drawings in which Figure 1 is
a graph showing the characteristics of a device
of the type under consideration, Figure 2 shows a
discharge device and circuit made according to
my invention, Figures 3 and 4 are graphs of the
operating characteristics of the discharge device
and circuit shown in Figure 2, Figure 5 shows a
modification of a discharge device and circuit
made according to my invention, Figure 6 shows
a discharge device and circuit particularly suit-
able for a transmitter and made according to my
invention, Figure 7 shows the characteristic of a
discharge device used as an oscillator, and Figure
8 shows another circuit arrangement and dis-
charge device made according to my invention.

It is known in the prior art that the anode cur-
rent of a simple two-electrode tube or diode if
traversed by a magnetic flux, suddenly droops as
soon as a certain critical magnetic field intensity
 H_k has been attained (see Figure 1). Plotting
the anode current I_a against the current I_m , there
result the well known magnetron characteristics.
The latter are shifted in a way as shown in Fig-
ure 1 for various parameters, i. e., anode poten-
tials E_a . The critical field intensity H_k becomes
so much greater, the higher E_a because the deflec-
tion of electrons of higher velocity requires
stronger magnetic forces. In this simple form,
the magnetron is adapted to widely varying pur-
poses, for instance, for the generation, amplifica-
tion, and reception of electrical oscillations.

Now, such a comparatively steep drop of the
magnetron characteristics requires an extremely
careful and delicate adjustment of the neutral
or quiescent operating point to suit various prac-
tical objects. For reception of electrical waves,
the working point must be chosen in the upper or

lower knee of the magnetron characteristic, in
order to amplify or produce oscillations in the
linear part thereof. In order that the adjustment
of the operating point once chosen may be sta-
bilized and preserved for fairly prolonged periods
of operation, exactly stable and constant working
conditions are required, above all, constant heat-
ing, a constant anode potential, and a constant
magnetic field, inasmuch as even the slightest
fluctuations of the three factors referred to im-
mediately cause a shift of the working point
through the drooping part of the magnetron char-
acteristic and thus render the magnetron inop-
erative.

In order that a certain improvement may be
insured in this regard, that is to say, in order
to make the working adjustment of a magnetron
less affected by and liable to disturbing variations
of the three factors above enumerated, one plan
would be to utilize the anode current for exciting
the magnetic field. This could be accomplish-
able by causing the same to traverse the field
windings or else by deriving the exciting current
from the anode potential. In both these methods,
the magnetic field intensity would be raised when-
ever the heating or the anode voltage increases,
and this would counteract a rise of current in
the magnetron occasioned by both changes by
virtue of the fact that the operating point upon
the new magnetron characteristic is shifted down-
wards again. In this manner, undesirable fluc-
tuations of the working conditions are capable of
being compensated only to a certain degree, in
fact, the compensatory action is not adequate
to insure stabilization that will satisfy all practi-
cal requirements.

Now, it is here where the present invention pro-
vides a substantial improvement in that the field
excitation is made to be a function both of the
discharge current as well as of the anode po-
tential, with the consequence that a compound
effect is obtained. To this end, the field winding
of the exciting magnet for the tube M, having
cathode K and anode P as shown in Figure 2,
is divided into two solenoids or coils S_1 and S_2 .
Of these the latter is included in the circuit of
the magnetron tube and is traversed by the anode
current I_a or a current proportional to the anode
current, while the former S_1 is fed directly from
the anode potential source of supply E_a . In
order that the working points may be chosen
most favorably, and in order that the compound
or combination action may be divided in a defi-
nite manner between the two coils, regulating re-
sistances W_1 and W_2 are provided. These may

be connected either in parallel or in series with the field coils according to the practical requirements. In order that, moreover, the operating point where the compound windings start to become operative may be determined, there could further be provided a third magnetic field component which is independent of the operating conditions of the magnetron. For this object, either the core of the exciting magnet is made permanently magnetic, or else a third field coil S_3 is provided which is fed with an energizing current which is independent of E_a and I_a .

The operation of this compound excitation is explained in more detail by reference to Figures 3 and 4. First solenoid S_2 , which is dependent upon the anode current, will be examined. Figure 3 shows two distinct magnetron characteristics which distinguish themselves by different emission currents $I_e' - I_e''$ as parameters, and which, in the presence of constant anode potential are obtainable most simply by adjustment of the cathode heating. Coil S_1 thus furnishes a constant magnetic field component H_1 which fixes on the abscissa axis a definite starting point for the action of S_2 . The field component furnished from S_2 is proportional to the product of number of turns and current, hence, it may be represented in the diagram by a straight line which has an angle of inclination or slope corresponding to the number of turns and which starts at the end of H_1 . If both coils S_1 and S_2 comprise the same number of turns, then in lieu of the magnetic field intensity, the magnetizing current may be plotted on the abscissa axis seeing that the other magnetic conditions are identical for the two solenoids. It can be seen from the diagram that the straight magnetizing line for emission current I_e' intersects the corresponding magnetron characteristic at the working point A' which on changing to characteristic I_e'' is shifted but very little to A'' .

In order to appraise the effect of the second magnetic field component H_1 due to the anode potential when the same is variable, it is necessary to revert to the family of curves already shown in Figure 1, that is to say, to different magnetron characteristics, with constant saturation current I_s and anode potentials E_a' to E_a'' as parameters, this family of curves being shown once more in Figure 4. In order to facilitate an examination and to render the situation as lucid as possible, the case shall be assumed where the field component H_1 is equal to the critical magnetic field intensity H_k . Inasmuch as the magnetron characteristics experience a parallel shift proportional to E_a , i. e., when E_a is raised, and since then also H_1 grows in direct proportion to E_a , this implies that the ends of the various field components H_1' to H_1'' will always lie upon the abscissa axis at a point where the anode current begins to droop. Now, from these points must be plotted the straight field lines characterizing winding S_2 , for a constant angle of inclination or slope, and these will intersect the various magnetron characteristics at operating points A' to A'' . It will be seen that it is thus feasible to fix all of the working points at a definite point of the magnetron characteristic.

The compound winding of a magnetron field magnet is useful not only when the magnetron is doing transmitter work where inadvertent and unintended fluctuations of the operating conditions tending to impair the efficiency must be compensated, but also where the magnetron operates as a receiver for ultra-short waves. In

this case, as is known from the art, the operating point must be fixed at the lower or upper knee or bend of the characteristic, although the working conditions, for other reasons, must be capable of wide variation. For it will be understood that maximum sensitivity of reception, for magnetron type receivers, will in the first place be realized when the electron transit times (electron oscillation periods) inside the tube are tuned to the incoming signal wave, and, in the second place, when the receiver is close to the self-oscillating point, a point which may most easily be attained by variation of the heating of the tube. In this instance, tuning of the anode voltage and regulation of regeneration through heating may be insured without it being necessary to pay particular attention to the stabilization of the proper operating point seeing that this is secured by the action of the compound winding.

What is also to be noted is that the effect of the compound winding should affect only slow variations, but should not affect variations due to the demodulation or modulation currents. Since here mostly relatively high frequencies are involved, the desired state will alone be insured, to a certain degree, even by the inductance of the windings S_1 and S_2 ; otherwise the time-constant must be correspondingly raised by connecting in parallel sufficiently large capacitors.

Another improvement of the working conditions is obtained by regulating the exciting current for the magnetic field through a control tube with the anode current. By the amplifying action peculiar to the control tube particularly precise stabilization is insurable.

Figure 5 shows a circuit scheme comprising a control tube in which due regard has been given to the magnetron tube itself, whereas all circuit elements serving for amplification or oscillation have been omitted for the sake of greater clarity of illustration because these details are in no casual relationship to the invention. Referring to Figure 5, M denotes the magnetron tube in the plate or anode circuit of which is included the resistance W between the cathode K and the negative pole of the anode voltage source of supply E_a . R designates the regulator tube controlling the magnetic field whose plate current flows through winding F of the field magnet. For energizing the tube including the magnetic winding F the anode potential E_a may be employed. In this manner linking of the field excitation and the anode potential E_a is directly obtained. Another relation with the magnetron current is assured through the resistance W which furnishes the grid voltage for the regulator or control tube R . For instance, if the anode potential grows, this results in an increase both of the magnetron current I_a as well as of the anode current of tube R and the magnetizing current I_m , with the result that the working point of the magnetron characteristic is shifted in downward direction with a tendency to restore the original state. Moreover, the increase in the current in the magnetron through the intermediary of resistance W renders the grid of the control tube more positive and the magnetic field is still further reinforced. The total ensuing stabilizing and regulator action is extremely efficient. The action of the regulator tube R will be of a corresponding nature whenever the current variations of the magnetron are ascribable to fluctuations in the heating or emission or RF actions no matter of what origin or nature. For in all instances, the action of the magnetic field will coun-

teract variations of current in the magnetron by causing a corresponding shift of the working point.

However, the regulator effect hereinbefore described will operate in phase, in other words, in the sense of stabilization, only as long as the static magnetron characteristics are uniform. This is not always the case, indeed, the most serious distortions will arise when the magnetron serves as a wave generator for ultra-short waves either with a cylindrical anode closed upon itself or with an anode cylinder split two or more times into a corresponding number of segments.

Such a magnetron transmitter comprising an oscillatory system *L* interposed between the anode segments is illustrated in Figure 6. As a consequence of the dynamic electron transmits or oscillations which are occasioned by the action of the radial anode field and the transverse magnetic field, and which will come to be in resonance with the radio frequency potentials arising between the anode segments, the static I_a — I_m characteristics of the entire oscillator are not smooth curves or uniform but have dips in the curves, and these tend to turn the stabilizing steps and means hereinbefore disclosed into the opposite; in other words, the adjustment of the working point is rendered unstable rather than stable. Under this condition, the use of a distinct regulator or control tube affords a simple chance to reverse the phase of regulation by the magnetron current simply by transposing the connecting leads between the regulating resistance *W* and grid and filament of tube *R* in a way as indicated in Figure 6. If, then, the working point experiences a shift as a result, say, of radio frequency tuning or energy-abstraction actions, for instance, in the direction of growing magnetron current, the grid of the regulator tube will become more negative, and the magnetic field is weakened. If, then, the static magnetron characteristic as a consequence assumes a shape as shown in Figure 7, the working point may be located upon the rising branch *b*—*c*, and this is advantageous for modulation work. In this case the drooping branches of the graph *a*—*b* and *d*—*c* are unstable so that when connecting the transmitter, the magnetron characteristic will change from *a* through *b* to the working point *A*.

If the magnetron tube is fitted with terminal plates designed to shut the anode cylinder at both ends and which collect the escaping electrons, then also the electronic current flowing to these terminal plates may be utilized at the same time for regulation of the magnetic field. This is accomplished by including resistance *W* not in the anode circuit, but rather in the terminal plate circuit, and by taking the grid potential for the regulator tube therefrom. Also in this instance, by proper choice of the connecting leads of grid and cathode according to Figures 5 and 6 any desired phase may be adjusted for regulation as shown, for instance, in the circuit arrangement Figure 8.

The circuit organizations hereinbefore disclosed stabilize the operating point at arbitrarily adjustable places of the magnetron characteristic, and this is required in a great many practical cases, for example, when the magnetron is to be modulated by variations of the anode potential. Now, in order that stabilization under these circumstances may affect really only the working point and not by chance also the modulation variations (in which latter case they would suppress and wipe out the entire modulator action),

care must be taken so that stabilization occurs with a certain time-constant. In most practical cases, the inductance inherent in the magnetizing winding will introduce an adequate amount of sluggishness in the stabilizer action. However, whenever this should be inadequate, the time-constant may have to be raised by the interposition of sufficiently great resistance-capacity networks or combinations, for instance, in the grid circuit of the regulator tube as indicated in Figure 8, for example, by the provision of *C* and *W'*.

In order that the automatic stabilizer effect need not be extended so as to include the entire range of the magnetron characteristic, but only the region which is really concerned in such control action, another field winding *F'* could be provided in addition to the field winding *F* fed from the regulator tube *R*, as shown in Figure 8. This second field winding could be directly fed with anode potential E_a as shown in this exemplified embodiment. Other auxiliaries beside resistance *W* designed to adjust the desired stabilizing action and the desired working point are shunt or series resistances connected to *F* or a variable grid bias potential for the regulator tube, though not all of these details are indicated in the circuit diagrams.

It is a known fact that the operation of a magnetron is a function not only of the intensity, but also of the direction of the magnetic field traversing the discharge space. As a general rule, it is advantageous to orientate field so that it presents a small angle of inclination with reference to the axis of the electrode system. This end is accomplished not only by rotation of the magnet or of the tube itself, but it may be effected also by forming the magnetic field of two componental fields presenting a slope with reference to each other, for instance, by placing these field components at right angles to each other, while the intensity thereof is so balanced that the resulting field will have the desired intensity and direction. In order to obtain stabilization of the working point by turning the field, it would be feasible to act by ways and means described, upon the intensity of the field component at approximately right angles to the main field parallel to the axis of the system. Inasmuch as this field component is comparatively feeble it follows that the corresponding exciting current is small. Hence, the regulator action is restricted to circuits with lower loads and the same is practicable by the aid of circuit elements of reduced dimensions. More particularly speaking, a control tube of far lower power may then be utilized.

While I have indicated the preferred embodiments of my invention of which I am now aware and have also indicated only one specific application for which my invention may be employed, it will be apparent that my invention is by no means limited to the exact forms illustrated or the use indicated, but that many variations may be made in the particular structure used and the purpose for which it is employed without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is—

1. An electron discharge device having a straight thermionic cathode and an anode surrounding said cathode, means for producing a magnetic field parallel to and between said cathode and anode, a source of voltage supply connected to said anode, a second electron discharge device having an anode, cathode, and grid, said

means for producing the magnetic field and said second electron discharge device being connected in series across said source of voltage supply, and a resistance connected in series with the first electron discharge device, the grid and cathode of said second electron discharge device being connected across said resistance.

2. An electron discharge device having a straight thermionic cathode and an anode surrounding said cathode, means for producing a magnetic field parallel to and between said cathode and anode, a source of voltage supply connected to said anode, a second electron discharge device having an anode, cathode, and grid, said means for producing the magnetic field and said second electron discharge device being connected in series across said source of voltage supply, and a resistance connected in series with the first electron discharge device, the grid and cathode of said second electron discharge device being connected across said resistance, the grid of said second electron discharge device being connected between the resistance and said first electron discharge device.

3. An electron discharge device having a straight thermionic cathode and an anode surrounding said cathode, means for producing a magnetic field parallel to and between said cathode and anode, a source of voltage supply connected to said anode, a second electron discharge device having an anode, cathode, and grid, the means for producing the magnetic field and said second electron discharge device being connected in series across said source of voltage supply, and a resistance connected in series with the first electron discharge device, the grid and cathode of said second electron discharge device being connected across said resistance, the cathode of the second electron discharge device being con-

nected between the resistance and said first electron discharge device.

4. An electron discharge device having a straight thermionic cathode and an anode surrounding said cathode, an end member at either end of said anode, means for producing a magnetic field parallel to and between said cathode and anode, a source of voltage supply connected to said cathode and anode, a second electron discharge device having a cathode, grid, and anode, the means for producing the magnetic field and said second electron discharge device being connected in series across said source of voltage supply, a resistor connected to said end members and to one side of said source of voltage supply, the grid and cathode of said second electron discharge device being connected across said resistor.

5. An electron discharge device having a straight thermionic cathode and an anode surrounding said cathode, an end member at either end of said anode, means for producing a magnetic field parallel to and between said cathode and anode, a source of voltage supply connected to said cathode and anode, a second electron discharge device having a cathode, grid, and anode, the means for producing the magnetic field and said second electron discharge device being connected in series across said voltage supply, a resistor connected to said end members and to one side of said source of voltage supply, the grid and cathode of said second electron discharge device being connected across said resistor, a second resistor connected between the grid of said second electron discharge device and between the end members and said first resistor, and a condenser connected across the grid and cathode of said second electron discharge device.

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