Aug. 2, 1938.

A. W. LADNER

2,125,507

MAGNETRON MODULATION SYSTEM

Filed June 7, 1934

3 Sheets-Sheet 1

Fig. 1

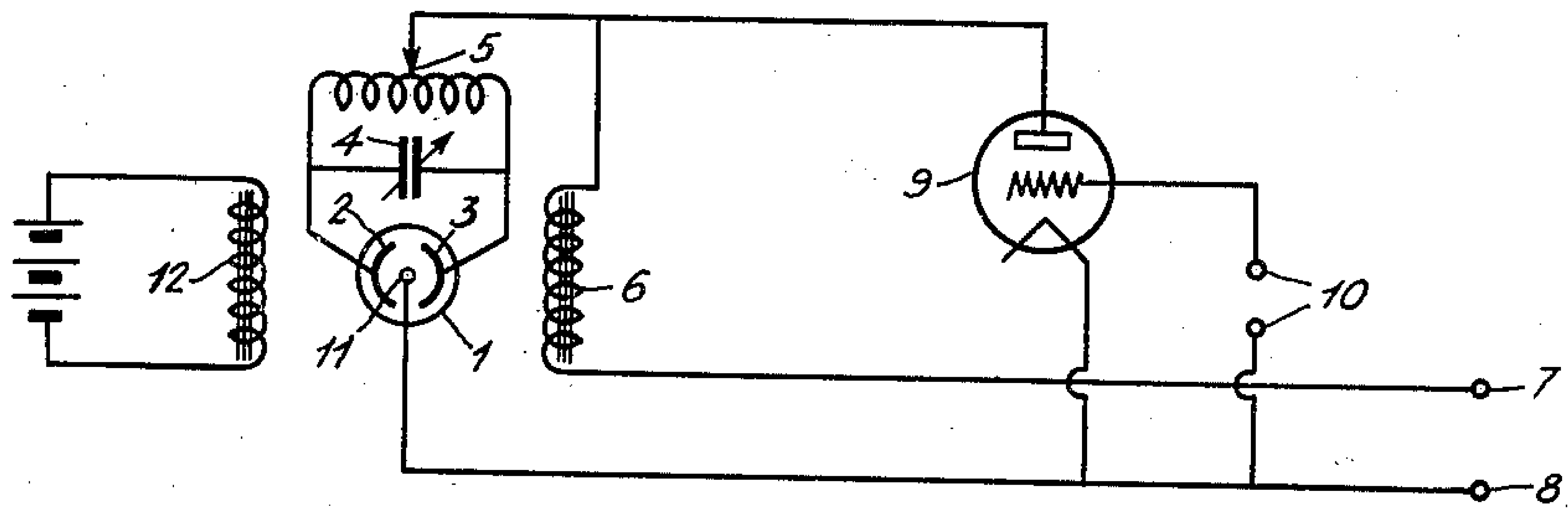


Fig. 2

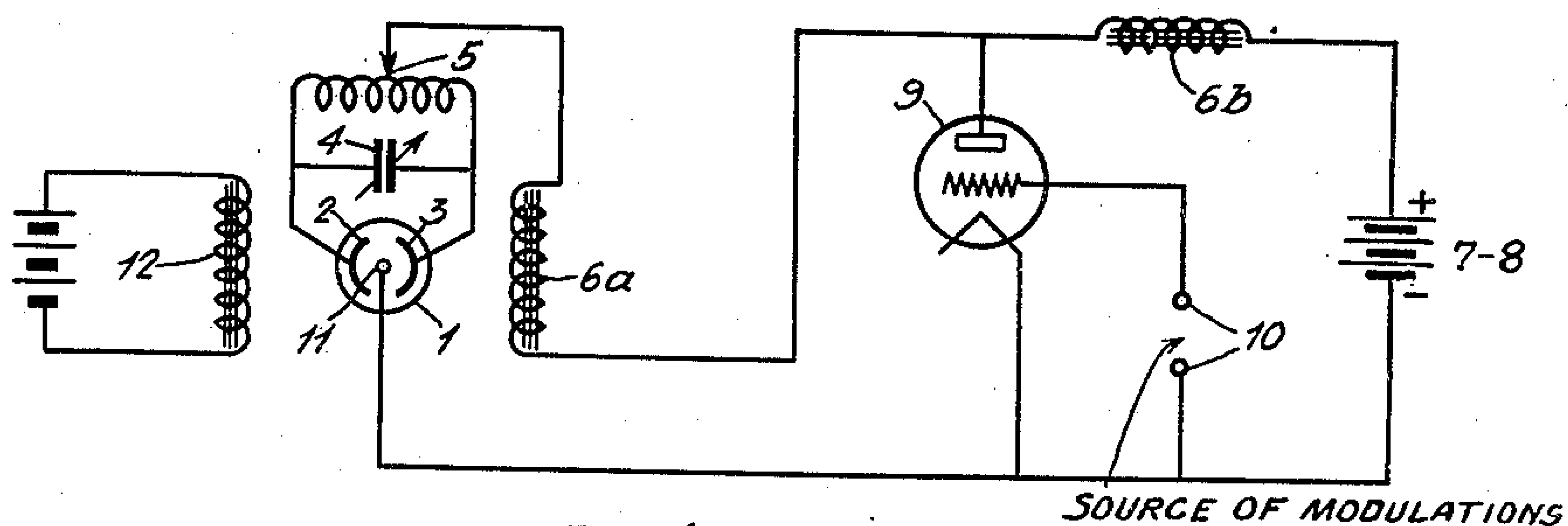
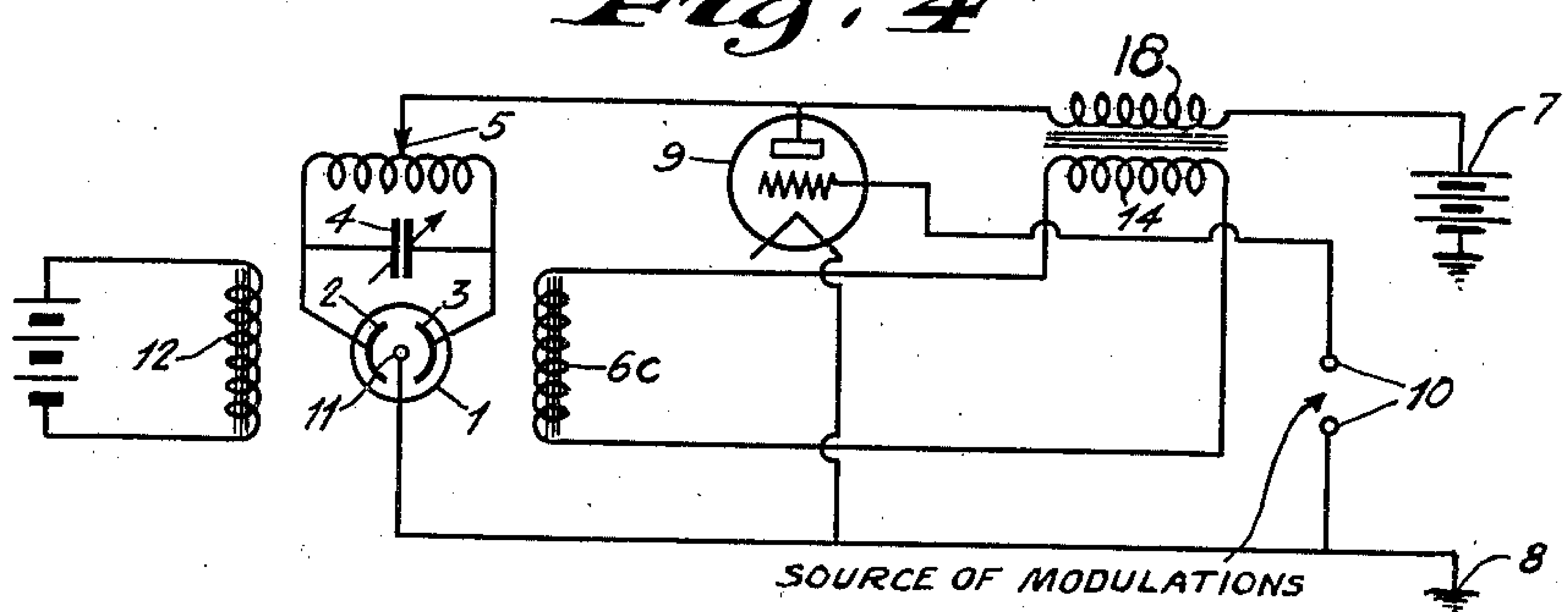


Fig. 4



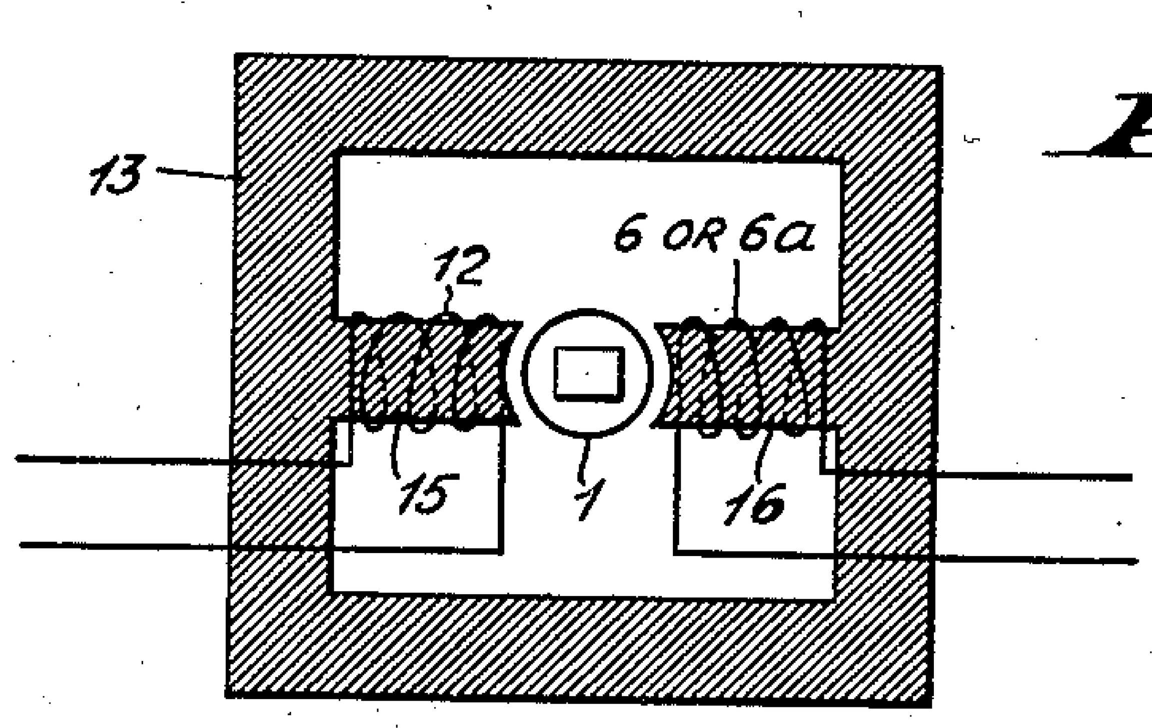


Fig. 3

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Fig. 1a

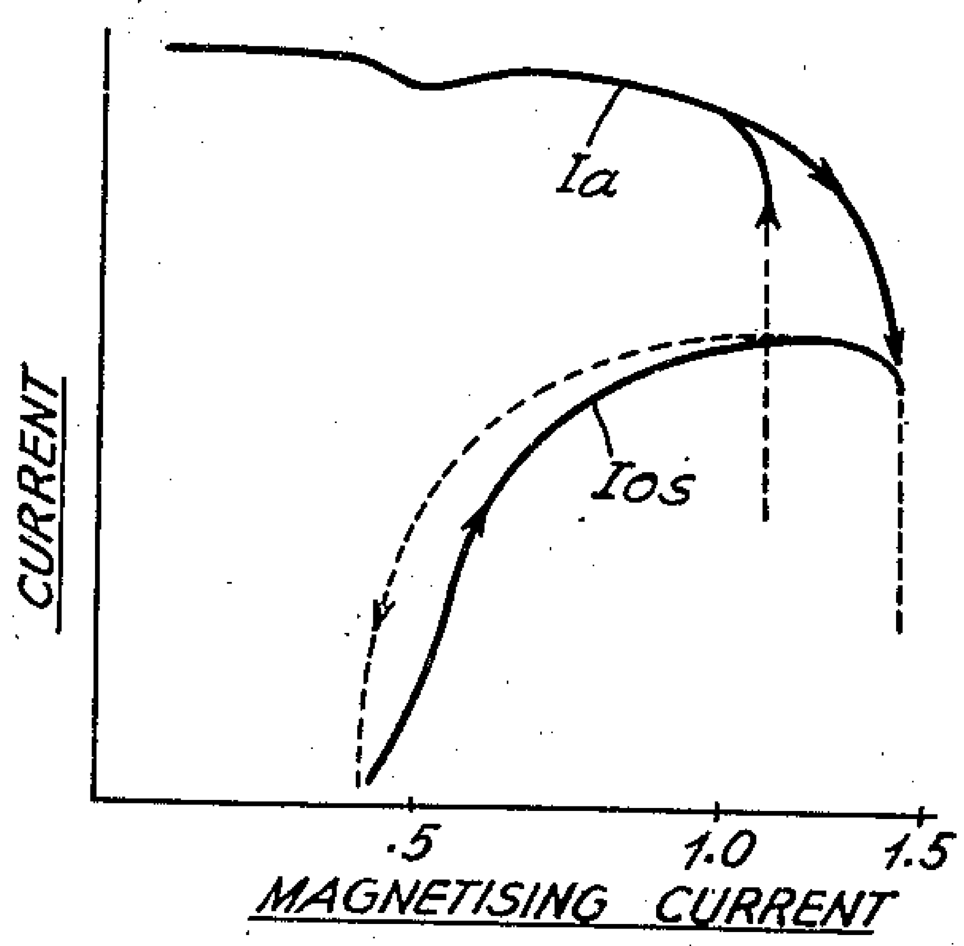


Fig. 1b

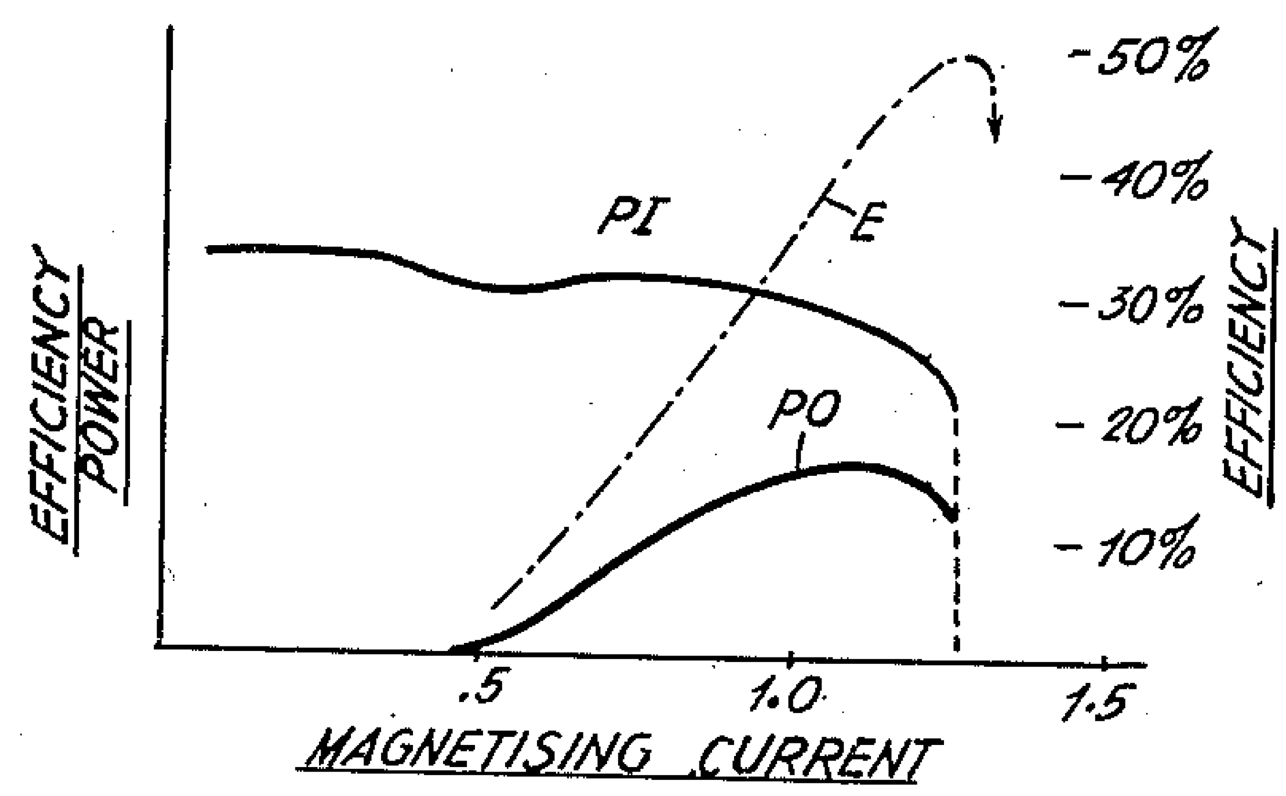
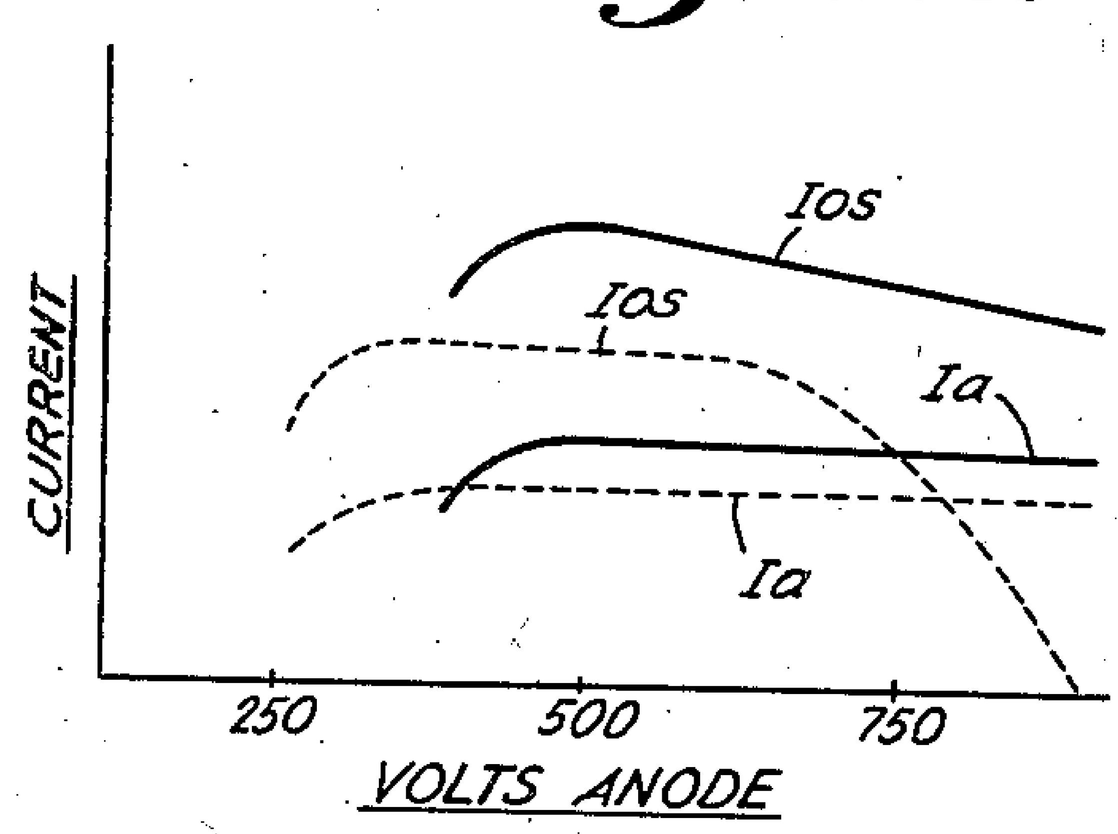
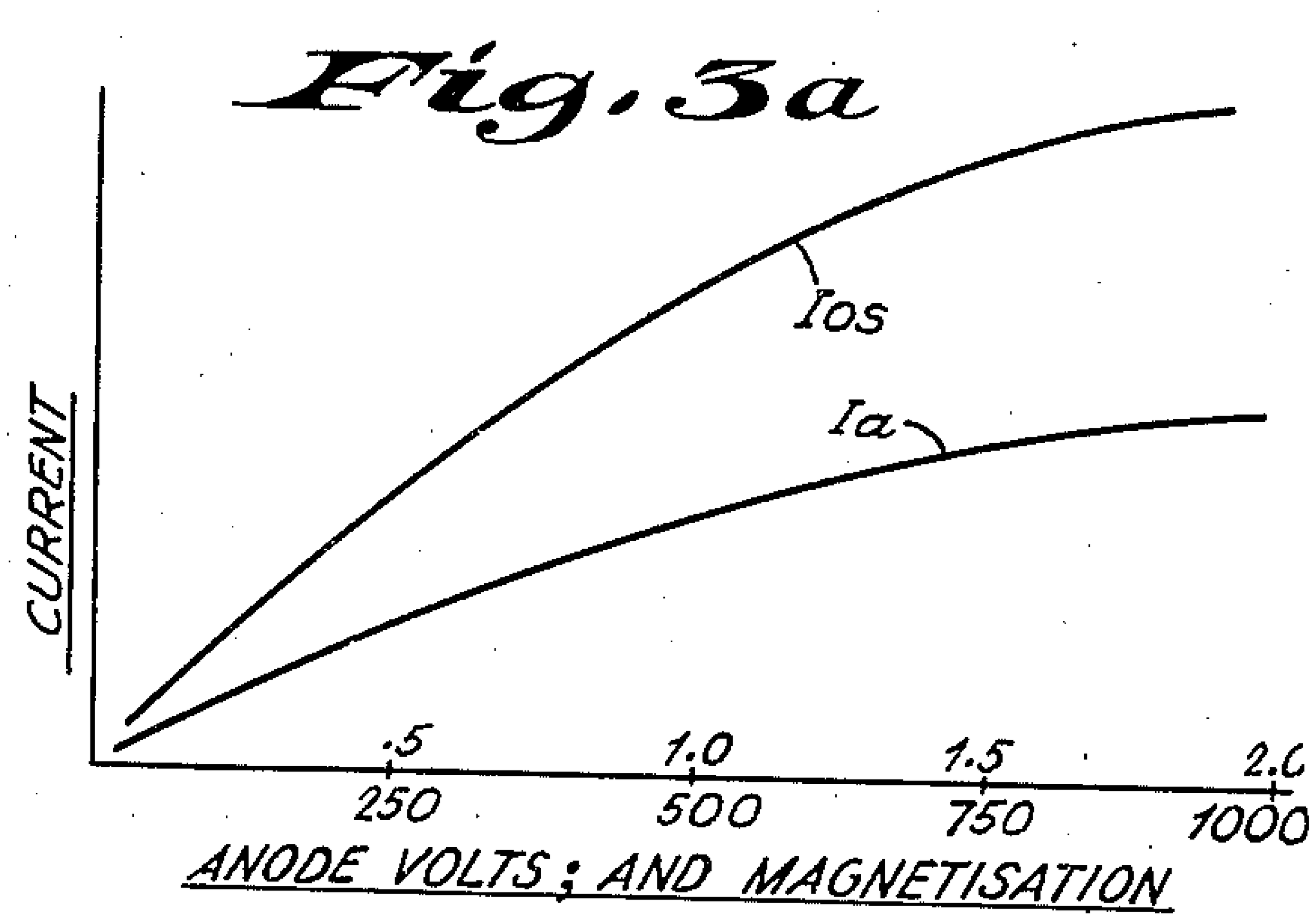
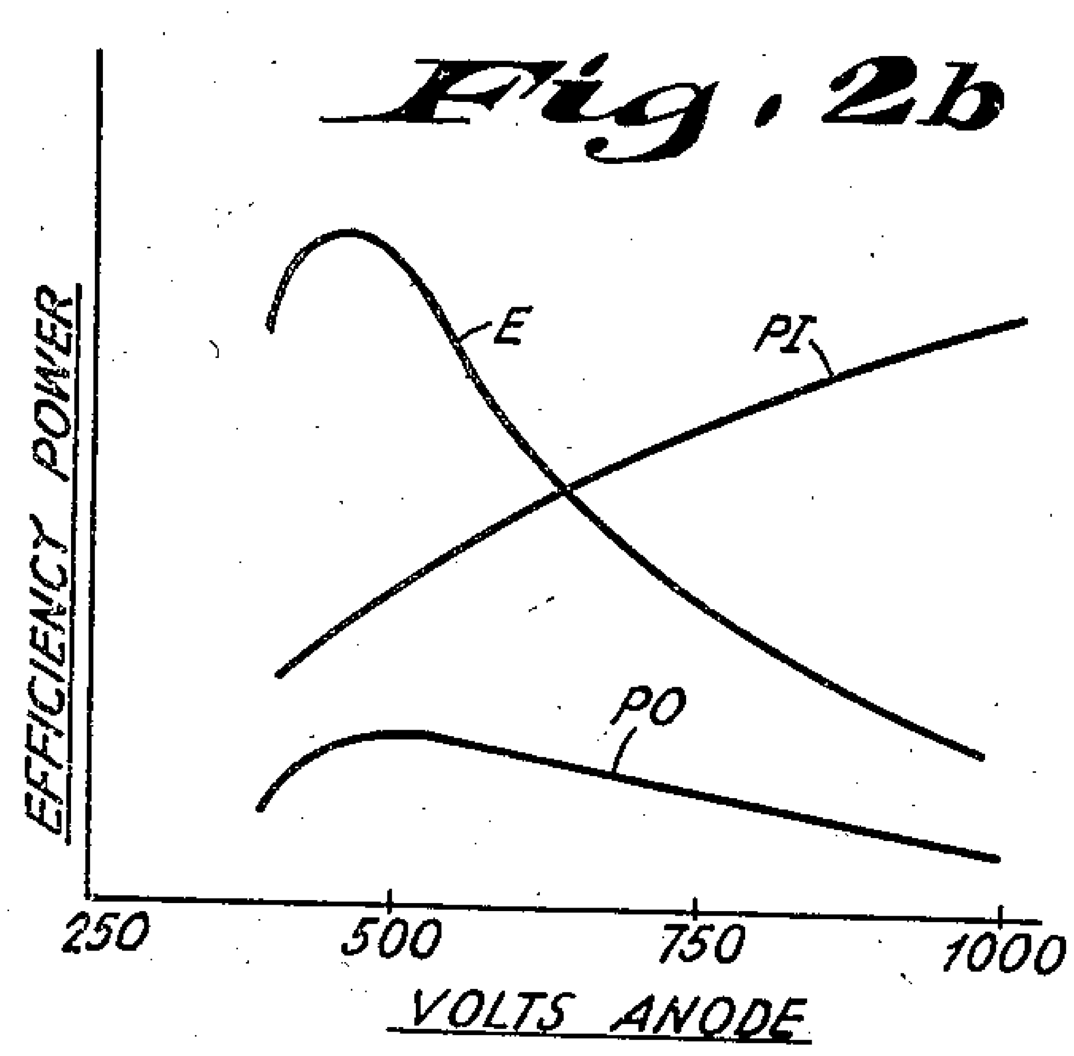
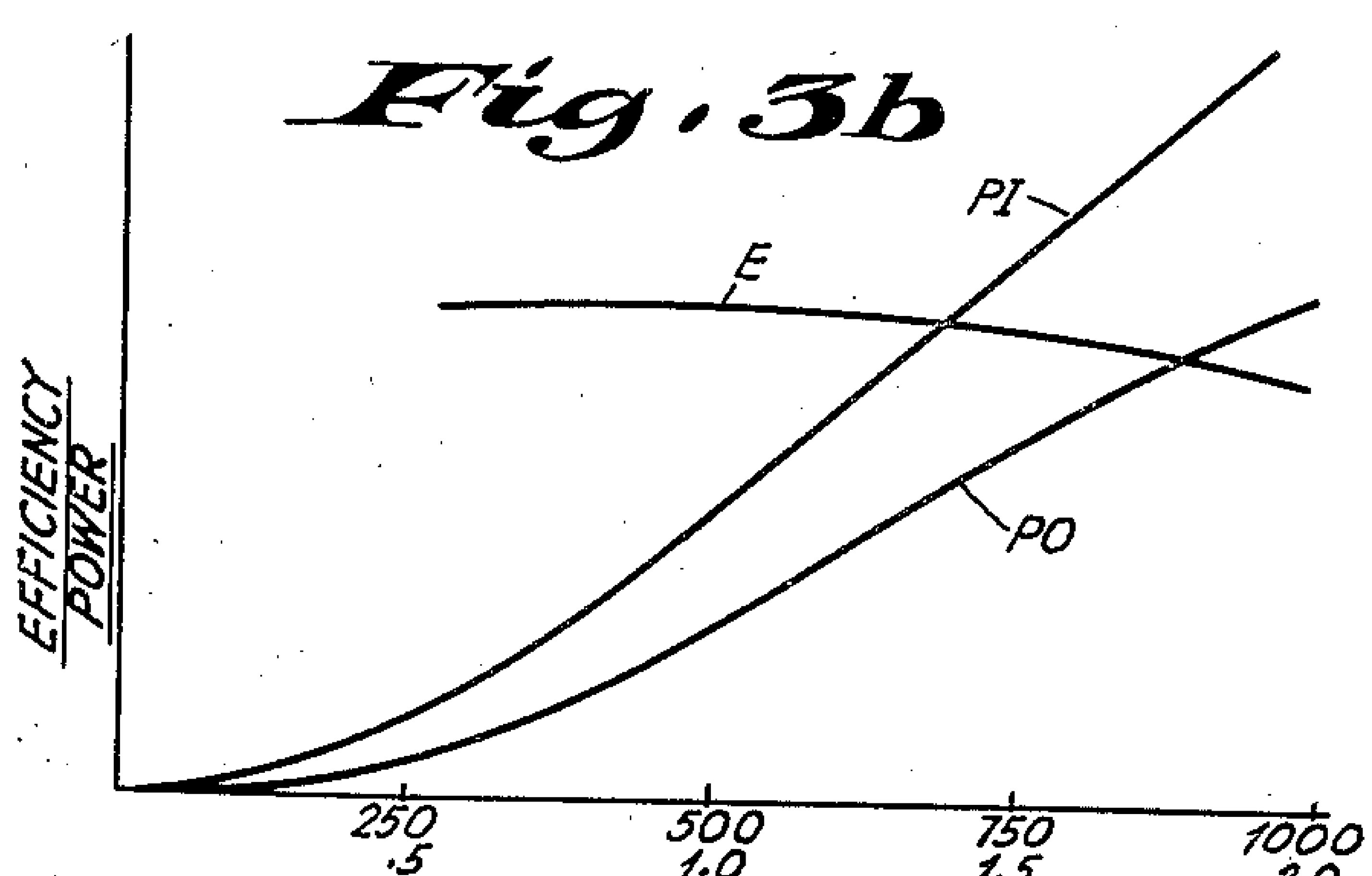


Fig. 2a









ANODE VOLTS; AND MAGNETISATION

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Fig. 5

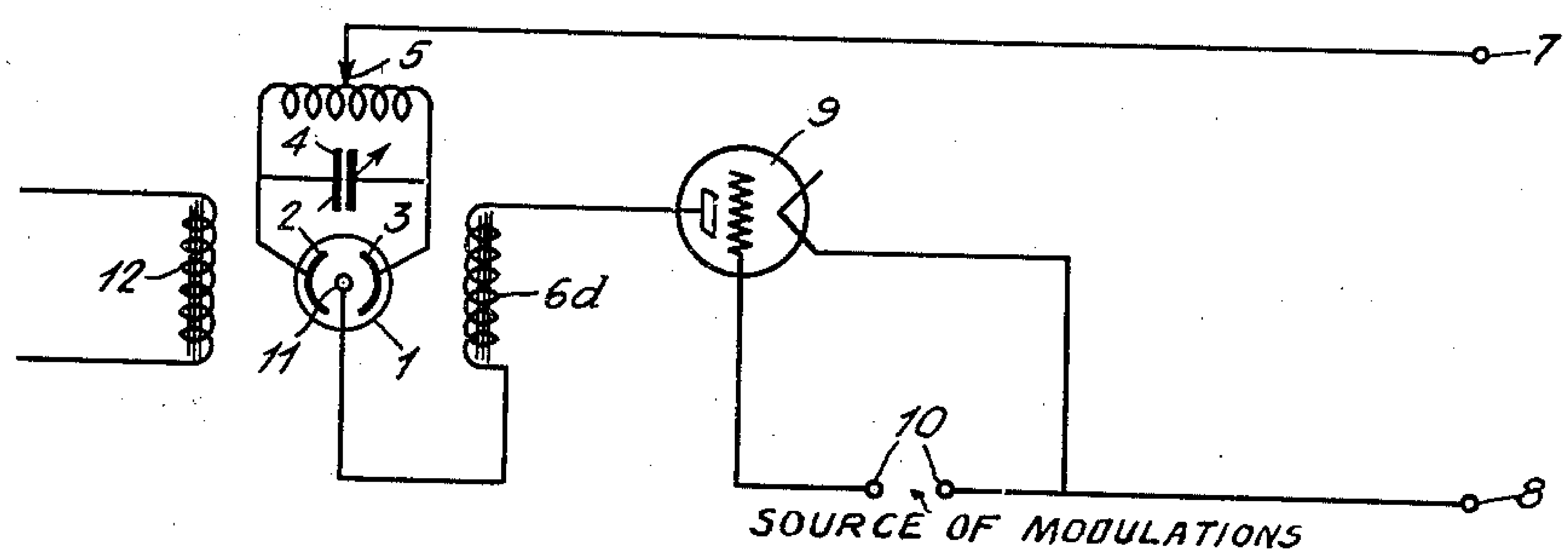
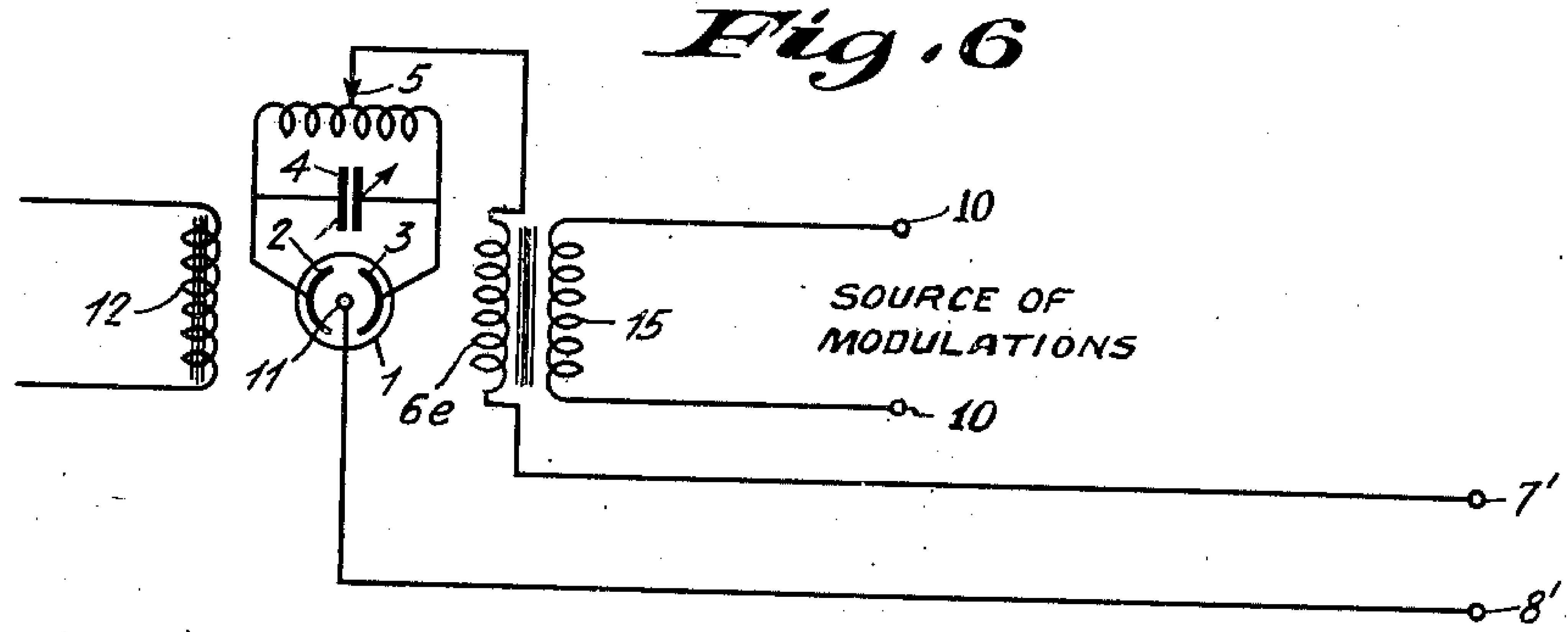


Fig. 6



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MAGNETRON MODULATION SYSTEM

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Application June 7, 1934, Serial No. 729,382
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5 Claims. (Cl. 179—171)

This invention relates to oscillation generating arrangements including magnetrons and has for its principal object to provide an improved arrangement whereby efficient and "deep" modulation of the oscillations generated by a magnetron may be obtained.

According to the main feature of this invention modulation of an oscillation generator comprising a magnetron is effected by simultaneously varying the magnetic field of said magnetron and also the anode potential thereof.

It is, of course, known per se to modulate a magnetron oscillation generator by varying the anode potential thereof and it is also known per se to modulate a magnetron oscillation generator by varying the magnetic field thereof but the use, according to this invention, of the two methods in combination avoids serious disadvantages which are present when either of the two methods known per se is employed separately.

In order that the advantages and nature of the invention may be the better understood, reference will be made in the following description to the accompanying drawings in which

Figures 1, 2, 4, 5 and 6 show, with slight variations, typical circuit diagrams for a magnetron discharge tube in combination with modulating means having the novel features of the invention;

Fig. 3 shows an embodiment of means for producing a magnetic influence upon the electron discharge in the tube; and

Figs. 1*a*, 1*b*, 2*a*, 2*b*, 3*a* and 3*b* are characteristic performance curves for certain embodiments of a magnetron discharge tube and of my invention.

Consideration will first be given to the well known case of a magnetron having a split anode arrangement and in which modulation is effected by varying the magnetic field. The curves shown in Figs. 1*a* and 1*b* of the drawings are typical of the results obtained with such an arrangement. In Fig. 1*a* the curve I_{os} is a curve of high frequency current (ordinates) plotted against magnetizing current (abscissae), while the curve I_a is a curve of direct current feed (ordinates) plotted against magnetizing current (abscissae). In Fig. 1*b* the abscissae are again variations of magnetizing current, but the curve PI is a curve of power input, the broken line curve E is a curve of efficiency and the curve PO is a curve of power output. The curves of Figs. 1*a* and 1*b* were obtained with a magnetron oscillator operating on a wave length of three metres with a fixed anode voltage, modulation being effected by varying the magnetic field, i. e., the magnetizing current. From these curves the following results appear:

(1) Modulation of the magnetic field does not give linear modulation of the high frequency output current since the curve I_{os} is not a straight line and has no substantially rectilinear portion.

(2) There is a marked hysteresis effect when the magnetic field is reduced to zero and then brought up again (this is indicated in the usual conventional manner in Fig. 1*a* by the dotted line curves and arrow heads).

(3) Although the efficiency at one point of working is high it is at other points extremely low. Therefore, although modulation by varying the magnetizing current does cause a change in high frequency output, there is also a substantial change in efficiency and accordingly the dead loss through the magnetron is increased as the output falls. It follows, therefore, that modulation by this method can only be accomplished where the magnetron is operated in such circumstances that its average condition of working is greatly under its maximum output condition, and its average efficiency greatly less than its maximum efficiency.

Figs. 2*a* and 2*b* of the drawings show corresponding curves for the case where modulation is effected by varying the anode voltage, the magnetizing current being maintained constant. In the curves of Figs. 2*a* and 2*b* the references I_{os}, I_a, E, PI and PO have the same meaning as in Figs. 1*a* and 1*b*, but the abscissae in Figs. 2*a* and 2*b* are values of anode potential, the magnetizing current being kept constant for any particular curve. In Fig. 2*a* the full line curves are those obtained when the magnetizing current is set to the best value for a particular voltage and it will be seen that when this is done the curves are characterized by discontinuity when the anode voltage is reduced (by modulation) and by very small change of output when the anode voltage is increased (by modulation) although the input remains high. Thus the efficiency is high near the point of discontinuity and falls rapidly as the anode voltage is raised, and it is only possible to obtain shallow modulation. The dotted curves of Fig. 2*a* are shown for the case where the magnetizing current is reduced to a lower value than the best value, resulting in a reduction of output and a lowering of efficiency. As will be apparent from the curves, it is now possible with the lower magnetization, to obtain a greater range of output variation by varying the anode voltage but the efficiency is extremely low. The results represented graphically in Figs. 2*a* and 2*b* may be summarized by the statement that when anode voltage modulation alone is employed the choice is between "shallow" modulation at a somewhat low efficency, or "deep" modulaton at a very low efficiency, and a low average output.

Figs. 3*a* and 3*b* of the drawings show graphically the results obtained by employing, in accordance with this invention, both anode voltage modulation and magnetizing current modulation simultaneously. As will be apparent from Figs. 3*a* and 3*b* the input and output vary together and therefore at all points the magnetron is operating at a relatively high efficiency and in consequence with low dead loss. It would further appear that the present invention enables very deep and linear modulation to be effected, probably up to 100%, although the obtaining of rectilinearity of modulation at the top of the modulation curve will be dependent upon whether the filament of the magnetron is capable of giving the necessary emission.

The invention may be carried into practice in many different ways, some of which are illustrated in the accompanying drawings. For example, in one circuit arrangement in accordance with the invention and shown in Fig. 1, a split anode magnetron 1 has two anode portions 2, 3 connected to the opposite ends of a tuned circuit 4, the center point 5 of which is connected through a choke 6 to the positive terminal 7 of a source (not shown) of anode potential having a negative terminal 8. Modulation by the well known choke method is employed, the anode cathode space of a modulating valve 9 to whose grid circuit the modulating potentials are applied at 10 being connected between the center point 5 of the tuned circuit 4 and the cathode 11 of the magnetron, i. e. to the terminal 8. The choke 6 may be arranged to constitute or form part of the magnetization system of the magnetron (if its inductance be high) and thus both anode voltage modulation and magnetizing current modulation may be effected simultaneously. If, however, the magnetization system of the magnetron be of low inductance, its magnetizing winding will still be included (as shown at 6*a* of Fig. 2) in the anode supply circuit for the magnetron, but it will be necessary to provide a separate high inductance choke 6*b* in series with the magnetization winding 6*a*, the anode of the modulator valve 9 being connected to the junction of 6*a* and 6*b*, all as shown in Fig. 2.

In Figs. 1 to 6 inclusive, 12 represents the usual polarizing winding of the magnetron. In practice the iron core of the magnetizing winding (6 or 6*a* as the case may be) is arranged to influence the magnetron and a convenient practical design is shown as in Fig. 3, and consists of an iron core 13 having a rectangular "window" with a pair of pole pieces 15, 16 projecting from opposite sides of the window towards one another and separated by a relatively small gap in which the magnetron 1 is inserted. On the pole pieces 15 and 16 is wound the polarizing winding 12 (if necessary) and the magnetizing winding 6 or 6*a*, the former coil (if provided) being, of course, energized to a desired degree from any convenient direct current source, e. g., the anode potential source at 7, 8.

In a modification shown in Fig. 4 and which has the advantage of improved flexibility of design since it does not require the winding of the magnetron field core to be such as to have to take a predetermined current value, a winding 18 in the common part of the anode circuits of the magnetron and of the valve 9 constitutes the primary of a transformer whose secondary 14 is connected across the magnetizing winding 6*c* of the magnetron, the polarizing winding 12 being adjusted to set the field to the mean value.

The invention can also be carried into practice with the employment of series modulation. In one arrangement of this kind, shown in Fig. 5, the positive terminal 7 of the anode source is connected to a center tap 5 upon a tuned circuit 4 whose ends are connected each to one of the anode portions 2 or 3 of the split anode of the magnetron 1, and the cathode 11 of the magnetron is connected through the magnetizing winding 6*d* of the said magnetron and thence through the anode cathode space of a modulating valve 9 to earth and terminal 8. In this embodiment a low inductance magnetizing winding would be employed.

In a slight modification (not illustrated) of the last mentioned arrangement, the magnetizing winding is not connected directly in series with the modulating valve and the magnetron but is energized from the secondary of a transformer whose primary is connected in series with the said modulating valve and the said magnetron.

In a further modification shown in Fig. 6 and in which direct anode modulation is effected, a center tapping 5 upon a tuned circuit 4 connected between the anodes 2, 3 of a split anode magnetron 1 is connected through the secondary 6*e* of a transformer to the positive terminal 7' of a source of anode potential and modulating potentials are applied at 10 to the primary 15 of this transformer. The secondary 6*e* of the transformer also constitutes or forms part of the magnetizing winding of the magnetron. In a slight modification of this last mentioned arrangement the secondary of the transformer does not constitute part of the magnetizing winding of the magnetron but a separate magnetizing winding in series with the primary of the transformer is employed.

Although in all the arrangements illustrated in the drawings a polarizing winding 12 is provided in order to enable the core of the magnetizing system of the magnetron to be set to its correct magnetic adjustment, this winding is theoretically not a necessity, though in practice it will almost always be required.

It will be appreciated that in order to obtain simultaneous modulation of anode voltage and magnetization, it may be necessary to provide in any of the described embodiments, means for controlling or determining the phase of the magnetization changes relative to the anode voltage changes. Any means known per se may be provided for this purpose, e. g., chokes or resistances in series or capacities in shunt may be included in the magnetization circuit or in the main feed (anode) circuit, or both, as may be required.

What is claimed is:

1. In a system of the class described, a magnetron oscillator device having split anodes and a cathode, means including a magnetizing coil for producing a magnetic field within which said device is to operate, a source of direct current potential for activating said magnetizing coil and also the electrodes of said magnetron, an impedance in series with and of greater inductive value than said magnetizing coil, both the impedance and the magnetizing coil constituting

part of an anode potential supply lead for said magnetron device, and an electron discharge device having an input circuit connected to a source of modulations and an output circuit connected between the cathode of said magnetron and a point in said anode potential supply lead intermediate said impedance and said magnetizing coil.

2. In a modulator system, a magnetron having split anodes and a cathode, an anode potential supply circuit including output leads for said magnetron, a transformer having its primary winding included in one of said output leads, a magnetizing coil within the magnetic field in which said magnetron is disposed, said coil being in circuit with the secondary winding of said transformer, and an electron discharge tube having its input circuit connected to a source of modulations and its output circuit in shunt between the cathode of said magnetron and a point on one of said anode potential supply leads intermediate said transformer and the anodes.

3. In a modulator system, a magnetron discharge tube having a cathode and divided anodes, a direct current potential source connected between said cathode and said anodes, a frequency-determining circuit interconnecting said divided anodes, a magnetic field coil for controlling the lines of magnetic force within said tube, and a modulation circuit including an electron discharge tube having its space discharge path in a circuit between the cathode of said magnetron and a nodal point on said frequency-determining circuit, the last said circuit including also a portion at least of said magnetic field coil and constituting shunting means for varying the direct current anode potentials which are supplied to said magnetron discharge tube and also to said magnetic field coil.

4. In a modulator system, a magnetron discharge tube having a cathode and segmented anodes, a frequency determining circuit interconnecting said segmented anodes, a direct current potential source connected between said cathode and a point on said frequency determining circuit, a magnetic field coil for controlling the lines of magnetic force within said tube, and a modulation circuit including an electron discharge tube having its space discharge path in shunt with the circuit which includes said magnetron discharge tube and said frequency determining circuit, said modulation circuit being arranged to simultaneously vary the potentials applied respectively to the electrodes of said magnetron discharge tube and to said magnetic field coil.

5. In a modulator system, a magnetron discharge tube having a cathode and divided anodes, a direct current potential source connected between said cathode and said anodes, a frequency-determining circuit interconnecting said divided anodes, a magnetic field coil for controlling the lines of magnetic force within said tube, and a modulation circuit including an electron discharge tube having an input circuit under control of a source of modulating energy and a space current path constituting shunting means for varying the direct current potentials which are supplied to said magnetron discharge tube anodes through said frequency-determining circuit, and to said field coil.

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