Sept. 16, 1947. R. L. HARVEY 2,427,498

FREQUENCY STABILIZED OSCILLATOR

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Fig. 1

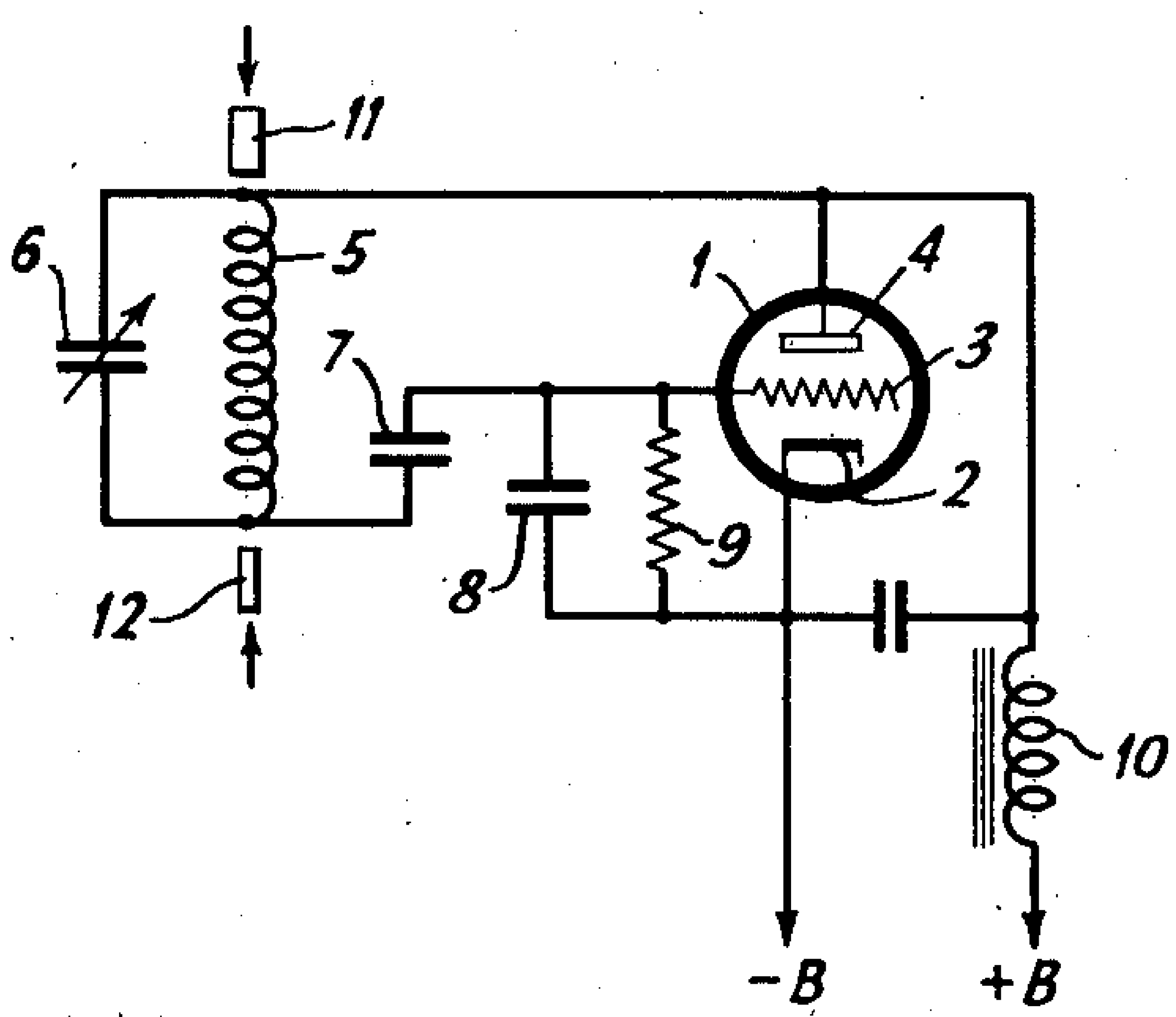

Fig. 2

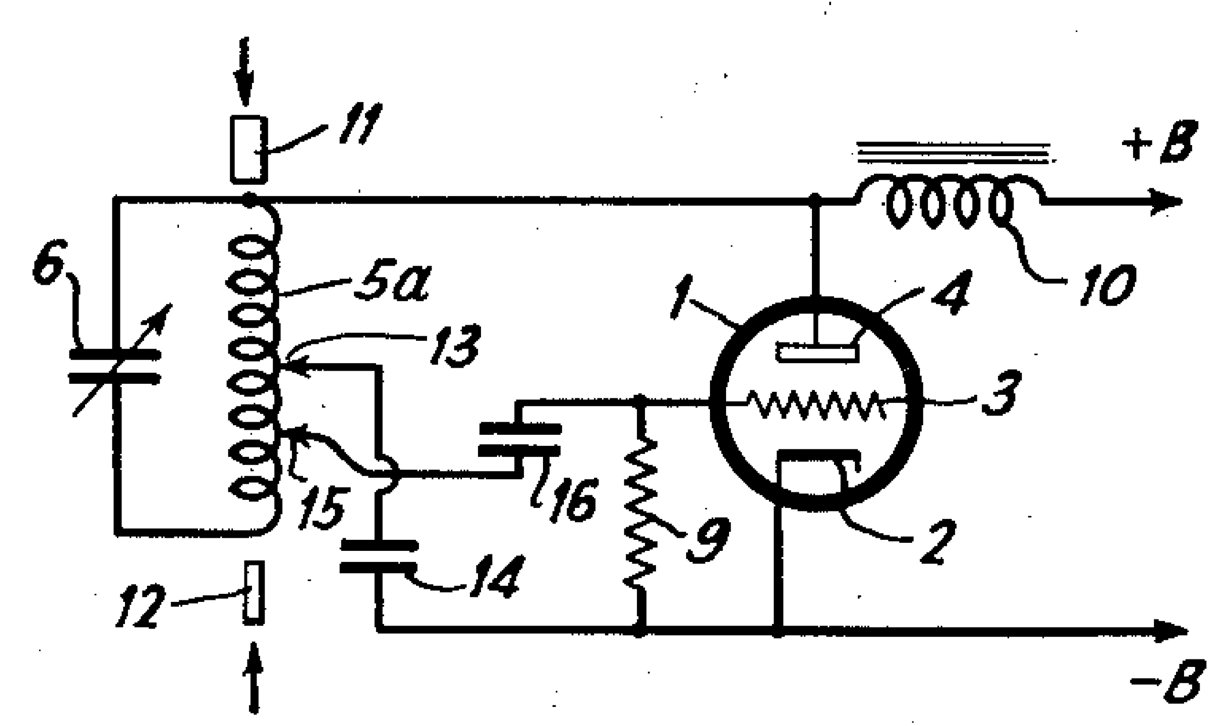

Fig. 3

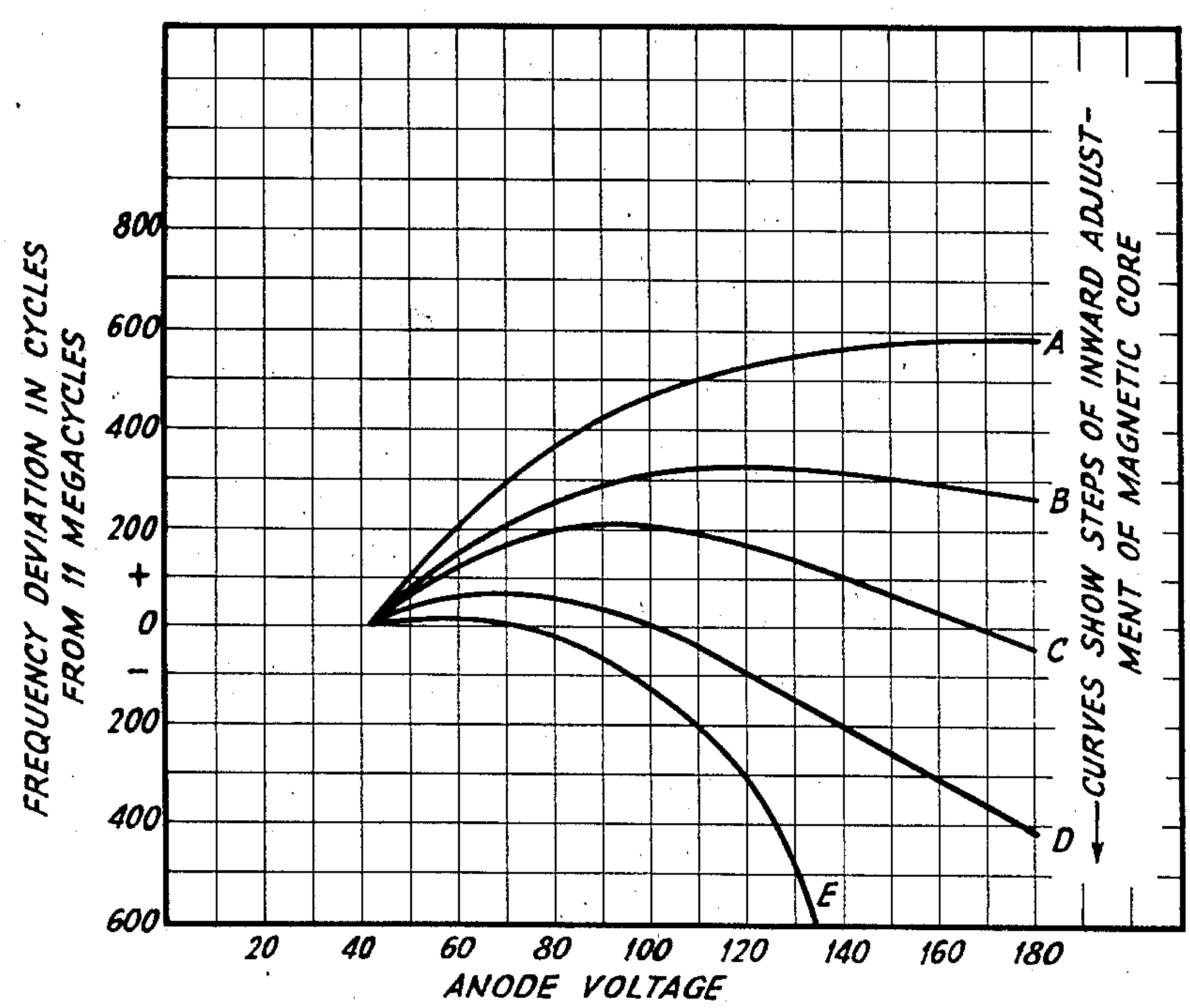

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Fig. 4

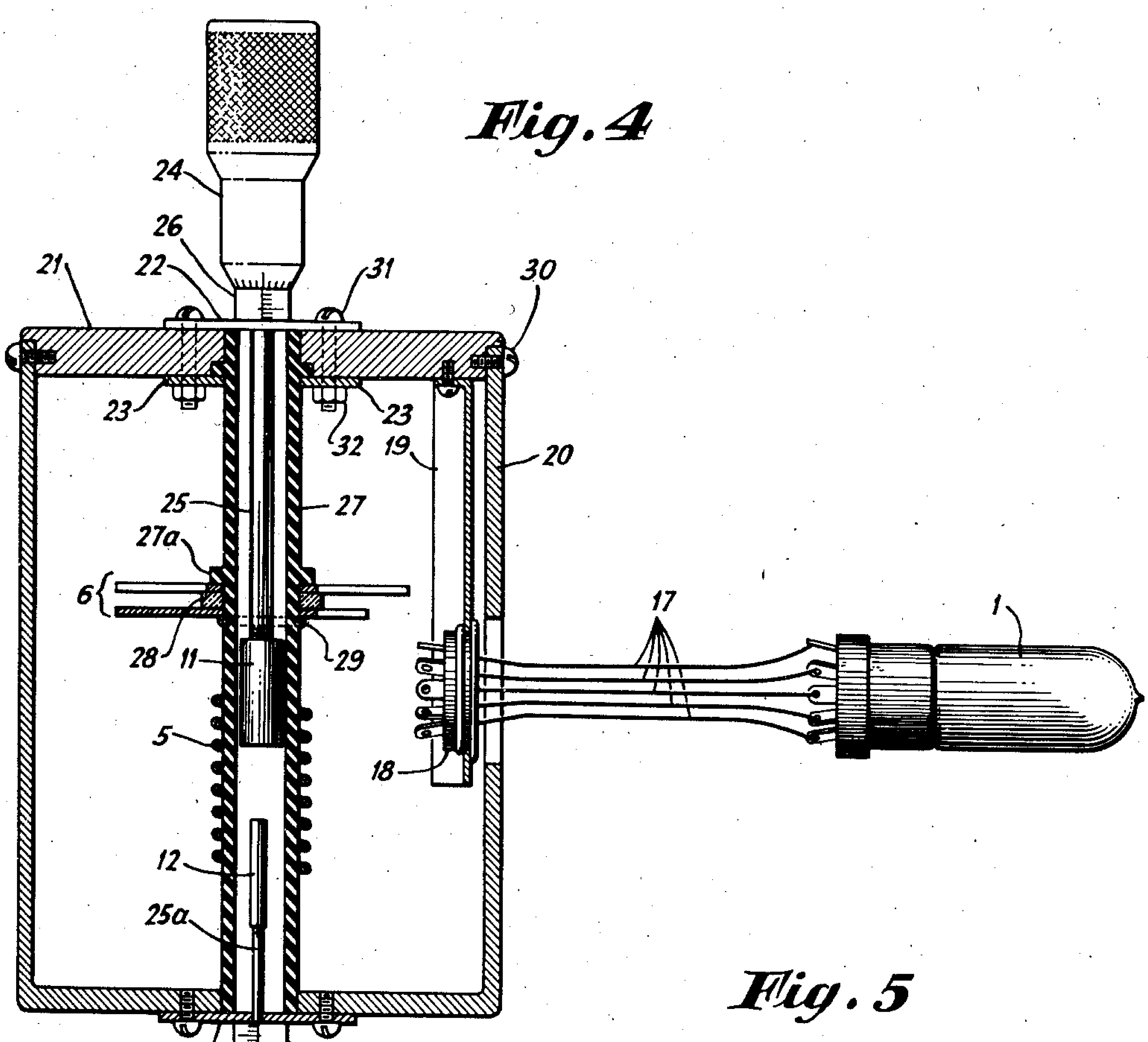
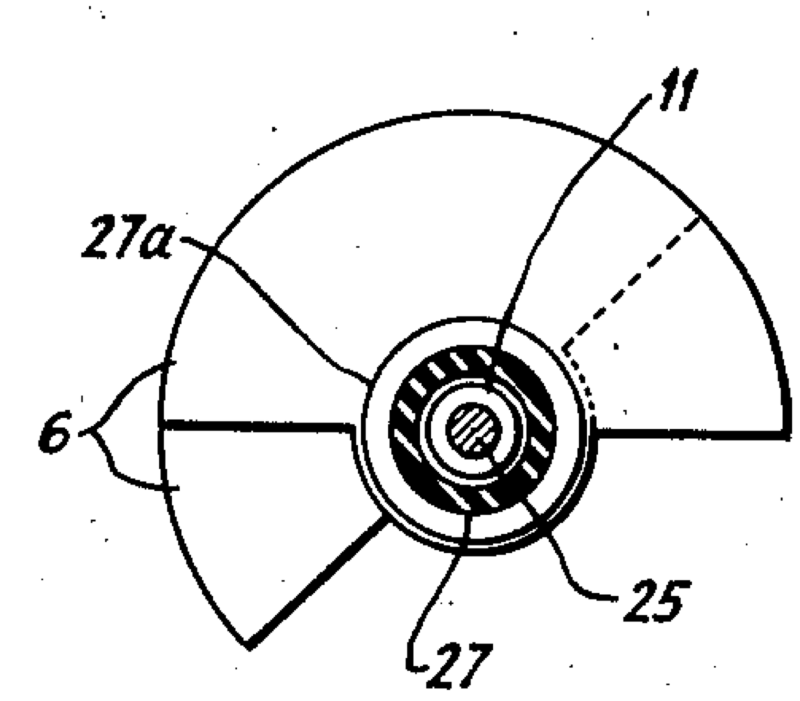


Fig. 5



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Patented Sept. 16, 1947 2,427,498

UNITED STATES PATENT OFFICE

2,427,498

FREQUENCY STABILIZED OSCILLATOR

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Application September 27, 1943, Serial No. 503,962

4 Claims. (Cl. 250—36)

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This invention relates to oscillation generators and has for its principal object to provide an electron oscillator which is tunable over a wide range of frequencies and which is adapted for operation at a stabilized frequency.

My invention is the outgrowth of certain research work which was undertaken with the object of providing a generator the frequency stability of which would be maintained within .02% under practical operations conditions, the use of quartz crystals being purposely avoided in order to cover the required tuning range.

It is another object of my invention to provide means and a method of stabilizing the frequency of an oscillator against supply voltage variations and against changes in the circuit parameters due to aging and other factors.

As is well known, there is a considerable frequency drift in oscillators which is most pronounced during the warm-up period. Frequency drift is also attributable to mechanical expansion, distortion, or buckling of the tube elements and secondary emission from the bulb and the mica parts within the tube. While some of these factors are not easily compensated, I have found that there is a great advantage to be derived from the use of cores in the inductive elements of the tuned circuit. Preferably, I employ two such cores, one being made of copper, and the other of a material generally known as "magnetite." Powdered iron or magnetite cores are well known in the art, but I have discovered what are believed to be novel methods of using them to compensate for frequency drift caused by changes in the circuit parameters, due, among other factors, to variations in the supply voltage.

My invention will now be described in more detail, reference being made to the accompanying drawings, in which:

Fig. 1 shows diagrammatically a conventional Colpitts oscillator circuit arrangement employing adjustable cores in association with the tuned inductance of the circuit;

Fig. 2 shows a circuit diagram similar to that of Fig. 1 but following the teachings of Hartley;

Fig. 3 shows graphically the correlation between anode voltage variations and frequency derivations, the several curves being plotted under different conditions of adjustment of a magnetic core within the tuning coil;

Fig. 4 shows a cross-sectional view through the tuned circuit and mounting therefor in an oscillator, certain features of my invention being therein detailed; and

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Fig. 5 shows an outline of the tuning condenser plates.

Referring first to Fig. 1, I show a conventional Colpitts oscillator circuit arrangement which is one of two alternative circuits preferably employed in carrying out my invention. This circuit includes an electron discharge tube **1** having a cathode **2**, a grid **3**, and an anode **4**. A source of direct current operating potential indicated by —B and +B terminals is connected between the cathode **2** and the anode **4**. A tuned circuit comprising an inductance **5** and adjustable capacitor **6** is directly connected at one terminal to the anode **4**. The other terminal is coupled to the grid **3** by way of capacitor **7**. Capacitor **8** intercouples grid **3** and cathode **2**. A grid leak resistor **9** is in shunt with capacitor **8**. The positive terminal of the direct current source is connected to the anode **4** through a choke **10**.

Fig. 1, as a circuit arrangement, is not claimed to be novel, except for the fact that I have provided a novel frequency stabilizing means comprising adjustable copper and magnetite cores and a combination of the same. One of these cores **11** is preferably made of copper while the other core **12** is preferably made of comminuted iron, or particles of magnetic material known in the art as "magnetite" and held together by means of a binder. The method of adjusting these cores **11** and **12** for the purpose of gaining frequency stability within a given range of anode voltages while tuning the tank circuit to a desired frequency will be hereinafter set forth in more detail.

The circuit arrangement of Fig. 2 is substantially a Hartley oscillator. It may employ the same tube **1** as shown in Fig. 1, this tube having the same electrodes **2**, **3**, and **4** as shown in Fig. 1. The principal difference between the Hartley oscillator and the Colpitts oscillator, as is well known, resides in the use by the Hartley oscillator of a tapped inductance in place of series capacitance for deriving a suitably phased feedback potential. Somewhere near the mid-point of the inductance **5**a a tap **13** is provided for coupling across capacitor **14** to the cathode **2**. Another tap **15** on the inductance **5**a is used for coupling the inductance across capacitor **16** to the grid **3**. In the particular embodiment of the circuit which I have used for working in a band of frequencies adjacent to **11** megacycles, the inductance **5**a consisted of four turns from the anode end down to tap **13**, two turns between taps

13 and 15 and two more turns from tap 15 to the lower end of the coil.

Fig. 4 shows mechanical details of construction of the oscillator which I preferably use. In order to avoid frequency drift and heating of the component circuit parts, the tube 1 is preferably mounted at the end of wire rods 17, about 3″ long and having pins (not shown) adapted for insertion in a conventional tube socket 18. Socket 18 is supported by a bracket 19 within a cup-shaped housing 20, the latter being of metal in order to provide suitable shielding.

A head 21 is provided for the cup-shaped shield member 20 and may be secured thereto in any convenient manner, such as by means of screws 30. This head supports the bracket 19 and also a tubular member 27 made of insulating material on which the condenser plates 6 and the inductance coil 5 are mounted. The lower end of the insulating tube 27 is slipped into a hole in the bottom of the cup 20 when assembling. For convenience in assembling, the insulating tube 27 is seated in the head 21 before insertion into the cup-shield and is secured by means of washers 22 and 23 which are clamped together by means of screws 31 and nuts 32 on the two sides respectively of the head member 21. The members 23 are half-washers each, since their inner circumference is too small to go over a shoulder portion 27*a* on the insulating tube 27. This shoulder is provided for holding the condenser plates 6 in place. A spacing washer 28 of insulating material holds the two condenser plates suitably spaced apart. A retaining ring 29 of resilient material fits into a groove in the insulating tube 27. This construction facilitates the necessary tuning adjustment of the condenser plates 6 since either of these plates may be rotated with respect to the other. Their semicircular outline is shown in Fig. 5 and provides for varying the condenser plate areas which may be mutually opposed.

The tuning inductance 5 is wound on the lower portion of the insulating tube 27. The connections between the terminals of the inductance coil and the respective plates may be made in any convenient manner. These connections are not, therefore, shown in Fig. 4 nor are the connections indicated to the terminals of the socket 18, since they would unduly complicate the drawing. Reference is made to Figs. 1 and 2, however, for two alternative circuit arrangements.

Secured to the washer plates 22 at the two ends of the assembly are stationary micrometer sleeves 26. These sleeves fit into micrometer heads 24 and the latter are provided with rotatable shafts 25 and 25*a*. The sleeves 26 may be threaded either externally or internally. Mating threads are, therefore, provided either internally of the micrometer heads 24 or externally of the shafts 25, 25*a*. The screw threads are not shown because concealed within the heads 24. On the end of shaft 25 is mounted a copper core 11, while on the end of shaft 25*a* is mounted a magnetite core 12.

The stationary sleeves 26 are axially graduated while the knobs 24 are graduated around the circumferences of their bevelled ends. Each of the knobs may be turned to any desired point for raising or lowering the core members 11 and 12 respectively. The graduations of the elements 24 and 26 enable the adjustment of these core members to be made within an accuracy of .001″.

Referring now to Fig. 3, there is therein shown a family of curves representing frequency deviations from a normal tuning of an oscillator at 11 megacycles when the anode voltage is varied within certain limits. Different curves A to E inclusive are plotted to show the effect of inserting the magnetite core by successive steps into the magnetic field of the tuning inductance 5. Such steps are arbitrarily chosen for the sake of illustration. The curve A represents a minimum practical limit of insertion of the magnetite core within the inductance, and curve E represents an approach to a maximum practical limit of insertion of the core. The adjustment of the copper core 11 is used primarily for tuning purposes.

The frequency deviations from 11 megacycles (an operating frequency chosen merely for purposes of illustration) are shown by the vertical scale at the left of the chart. The horizontal scale represents variations in anode voltage. It should be noted that when the magnetite core adjustment is made according to curve A, there is very little frequency variation within a range of 160 to 180 volts. A frequency variation when the core is adjusted as in accordance with curve B is very slight within the range of 90 to 160 volts. Curve C shows a minimum frequency variation within the voltage range of 80 to 110 volts. If it is desired to operate within an anode voltage between 60 to 80, then the core adjustment is preferably made according to curve D, and an even lower voltage without serious frequency variation is practical if the core adjustment is in accordance with curve E.

From the foregoing description of the chart of Fig. 3, it will be clear that considerable frequency stability and freedom from frequency drift is obtainable by means of the magnetite core adjustment for working in different anode voltage ranges. Furthermore, to compensate for the change in frequency attributable to the adjustment of the magnetite core 12, the copper bore 11 may be adjusted to restore the tank circuit to the required normal frequency.

It has been found in practice that frequency deviation due to changes in the filament voltage are very slight in comparison with frequency deviation attributable to anode voltage variations. Accordingly, I have not herein shown the effects of filament voltage variations. It is well, however, to recognize that such effects exist in a minor degree but they are not so serious but that they may be neglected in view of the compensation provided by the core members 11 and 12 and the adjusting means therefor.

It will be appreciated by those skilled in the art that in an oscillator the tube characteristics are mainly responsible for instability of the frequency. The changes in the input and output resistances, however, increase the difficulty of maintaining stability. A change in these resistances caused by variations in plate voltage or cathode emission will shift the phase of the regenerated oscillation. This calls for compensating phase shift in the resonant circuit. The use of copper and magnetite cores in association with the inductance of the resonant circuit, I have found to be very advantageous in that the compensation so provided is such as to shift the frequency of the resonant circuit oppositely to the frequency drift produced by the input and output circuit resistances and by other tube variables, especially during voltage changes of the supply source.

Another factor entering into the frequency stability problem is the change of capacity between the tube elements with temperature changes and electron flow in the tube. These changes directly affect the frequency to which the resonant circuit is tuned.

For best results in carrying out my invention, I have found that the Q of the resonant circuit should be made as high as practical. If a Hartley oscillator is used, the taps 13 and 15 should be adjusted along the inductance 5a at points suitable for maintaining the feedback as small as is consistent with dependable operation. I have found that a grid circuit load of 500 ohms and a plate circuit load of 2,000 ohms is satisfactory. I have also found that loose coupling between the tube and the resonant circuit reduces frequency drift during the tube warm-up period. Low anode voltage also reduces the frequency drift during tube warm-up.

The value of the grid leak resistance 9 is not critical. A value of 12,000 ohms has been found satisfactory when using tubes of types known as RCA 955 and RCA 604.

A utilization circuit may be coupled to the oscillator either inductively or capacitively. Preferably, a buffer tube is used in order that the load may have a minimum effect on the oscillator frequency. The maximum allowable voltage delivered to the buffer grid circuit depends on the anode voltage in the oscillator. With a high anode voltage, the output delivered to the grid of a buffer stage may be of the order of 1 volt.

Numerous modifications of my invention will suggest themselves to those skilled in the art, but they should be understood to be comprehended within the scope of the invention.

I claim:

1. An oscillation generator having a metallic housing, a tank circuit mounted within the housing, said tank circuit comprising parallel-tuned inductive and capacitive elements, a tubular support of insulating material for both elements of said tank circuit, a tube socket mounted within said housing, a discharge tube positioned externally of said housing for producing oscillations, the prongs of said tube having individual connections extending to the terminals of said socket, thereby to minimize the heating effects of said tube upon the contents of said housing, a copper cylinder having a tuning function supplemental to that of the capacitive elements in said tank circuit, frequency stabilizing means including a core member containing magnetic particles, both said copper cylinder and said core member being adjustably disposed within said tubular support, and means external to said housing for independently varying the positions of said cylinder and core member along the axis of said inductive element.

2. A generator according to claim 1 wherein the last said means includes micrometer heads axially disposed at the two ends of said tubular support.

3. An oscillator comprising an electron discharge tube having at least a cathode, an anode and a control grid, means including a tank circuit coupled to the tube electrodes for determining the frequency of the oscillations generated, said tank circuit having a capacitor in parallel with an inductive helix, a copper core member and a magnetic core member adjustably positioned along the axis of said helix, a resistor connected between the control grid and the cathode, a capacitor coupling said control grid to a suitable point on the helix of said tank circuit, a source of operating potential applied between the cathode and anode, an inductive impedance connected between the positive terminal of said source and the anode, the ohmic value of said impedance and the terminal voltage of said source being suitably chosen to obtain a normal anode voltage, compensating means operable by suitably positioning said magnetic core within the field of said helix so that the curve of frequency deviation with respect to anode voltage variation is substantially flat at the normal anode voltage, and further compensating means operable by suitably positioning the copper core member so as to obtain the desired tuning of the oscillator while operating at normal anode voltage.

4. An oscillator for generating oscillations of substantially constant frequency despite changes over a limited range in the applied anode voltage, comprising an electron discharge device having an anode, a cathode and a control grid, a tank circuit having inductance and capacity connected to said anode, cathode and control grid, said tank circuit serving to determine the frequency of oscillations generated, the inductance of said tank circuit being established by a coil having independently adjustable copper and magnetic core members positioned therein and movable along the longitudinal axis of said coil, a circuit for subjecting said control grid to a suitable operating potential with respect to said cathode, interconnections between said anode, cathode and control grid whereby oscillations are regeneratively set-up at a frequency determined by the resonant characteristic of said tank circuit, and a circuit for subjecting said anode to an operating voltage of suitably positive value with respect to said cathode, the position of said magnetic core within said coil being so chosen as to minimize frequency variations due to changes in the anode voltage, and said copper core being so positioned as to effectively tune said system at the desired operating frequency.

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