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H. T. FRIIS ET AL

2,406,364

OSCILLATION GENERATOR

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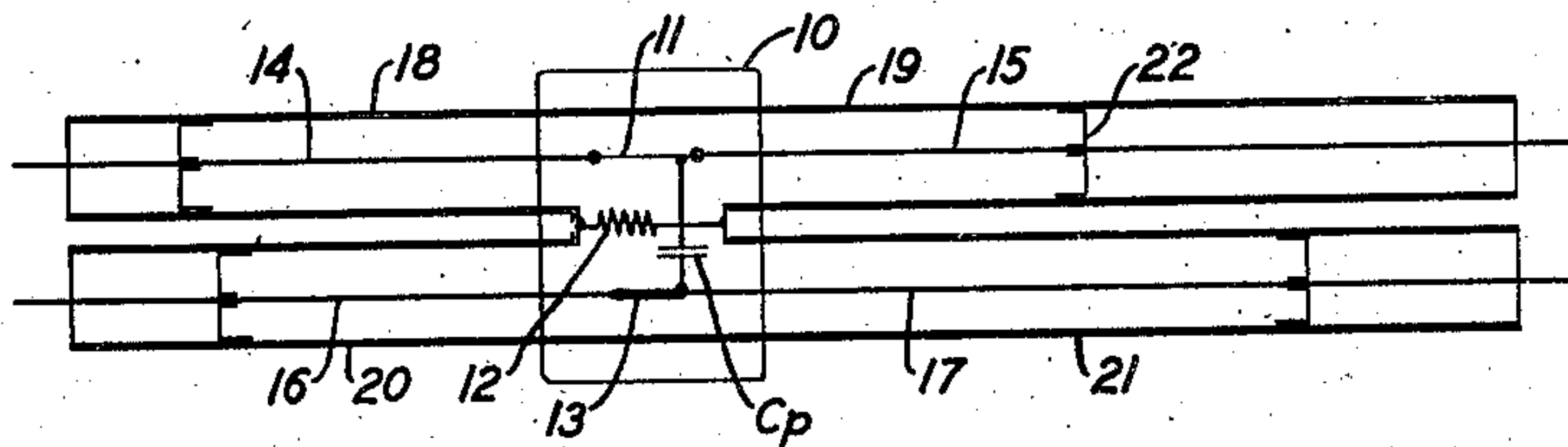


FIG. 1

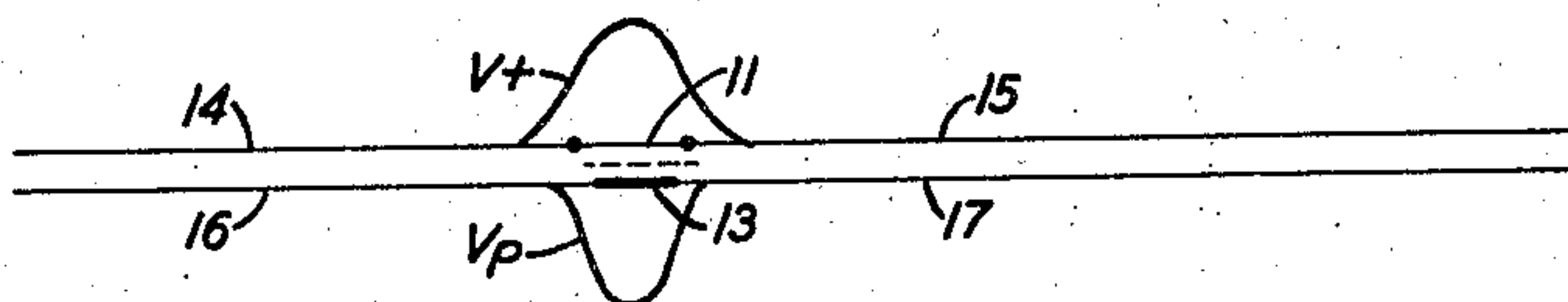


FIG. 2

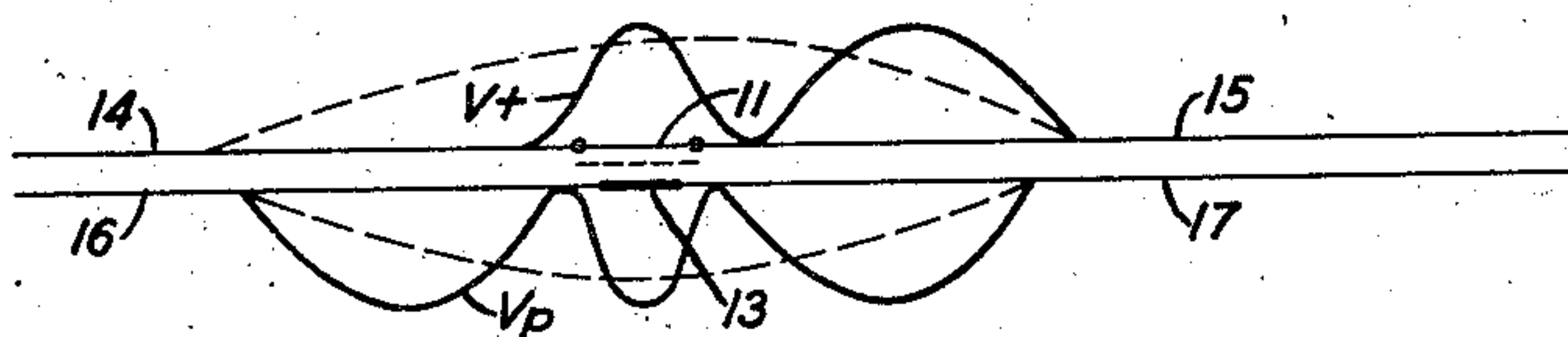


FIG. 3

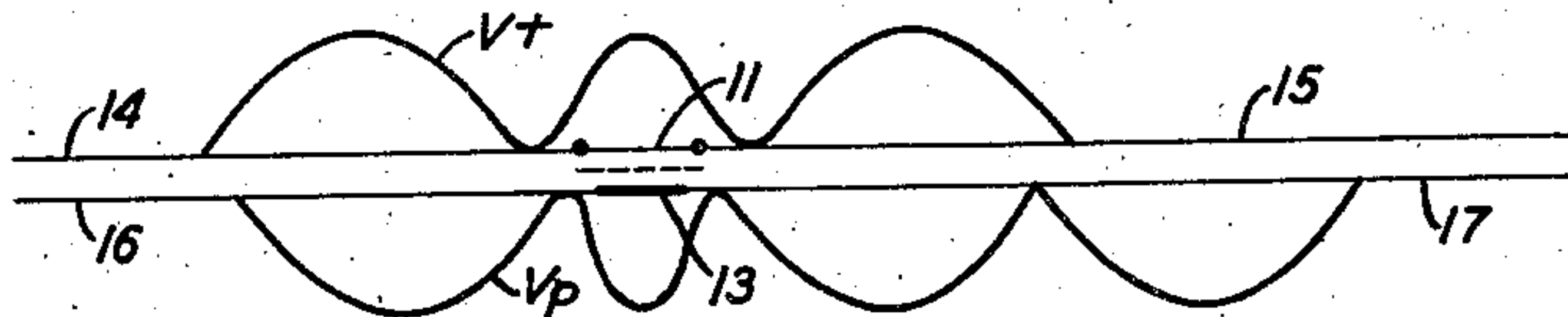


FIG. 4

FIG. 5

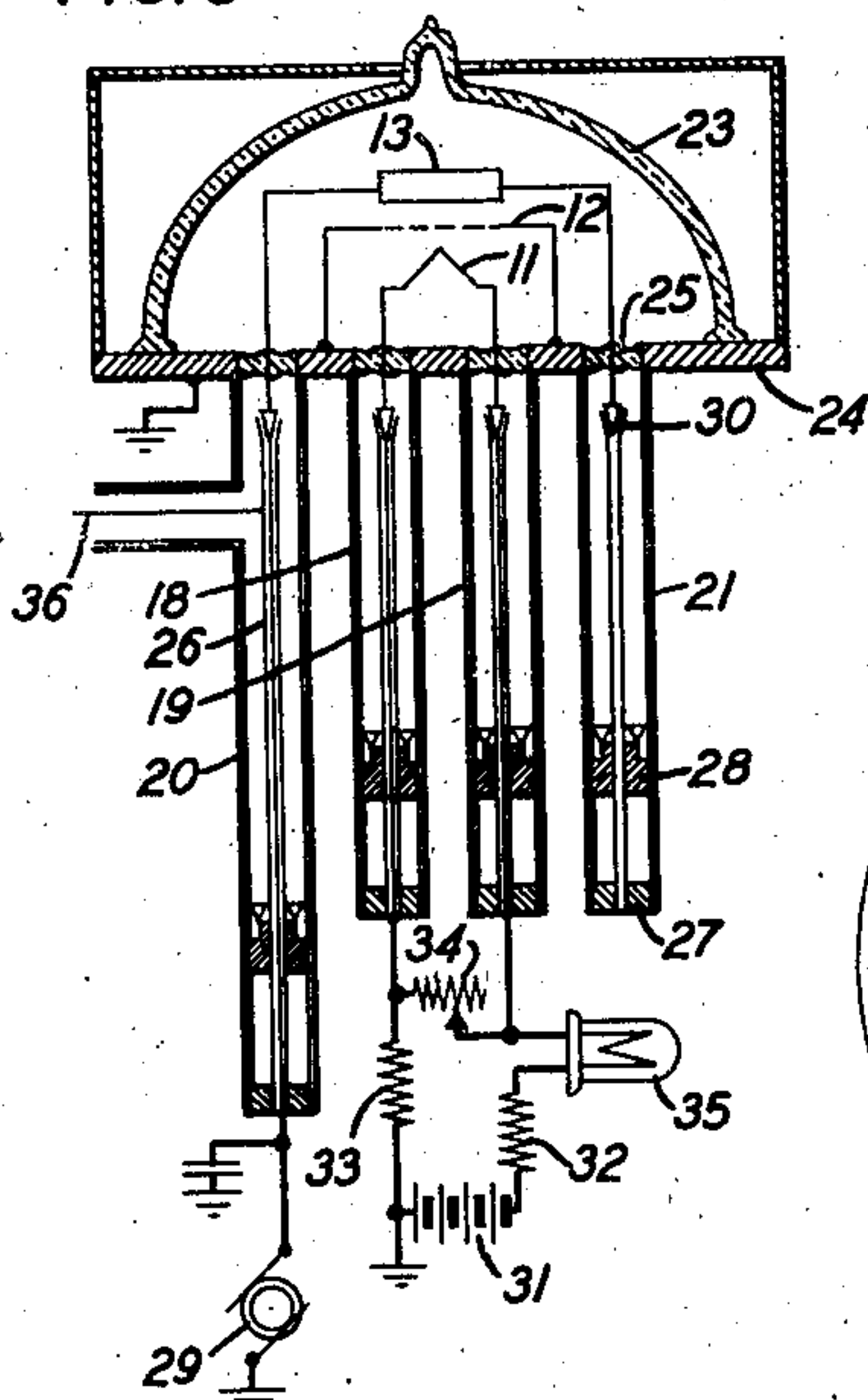


FIG. 6

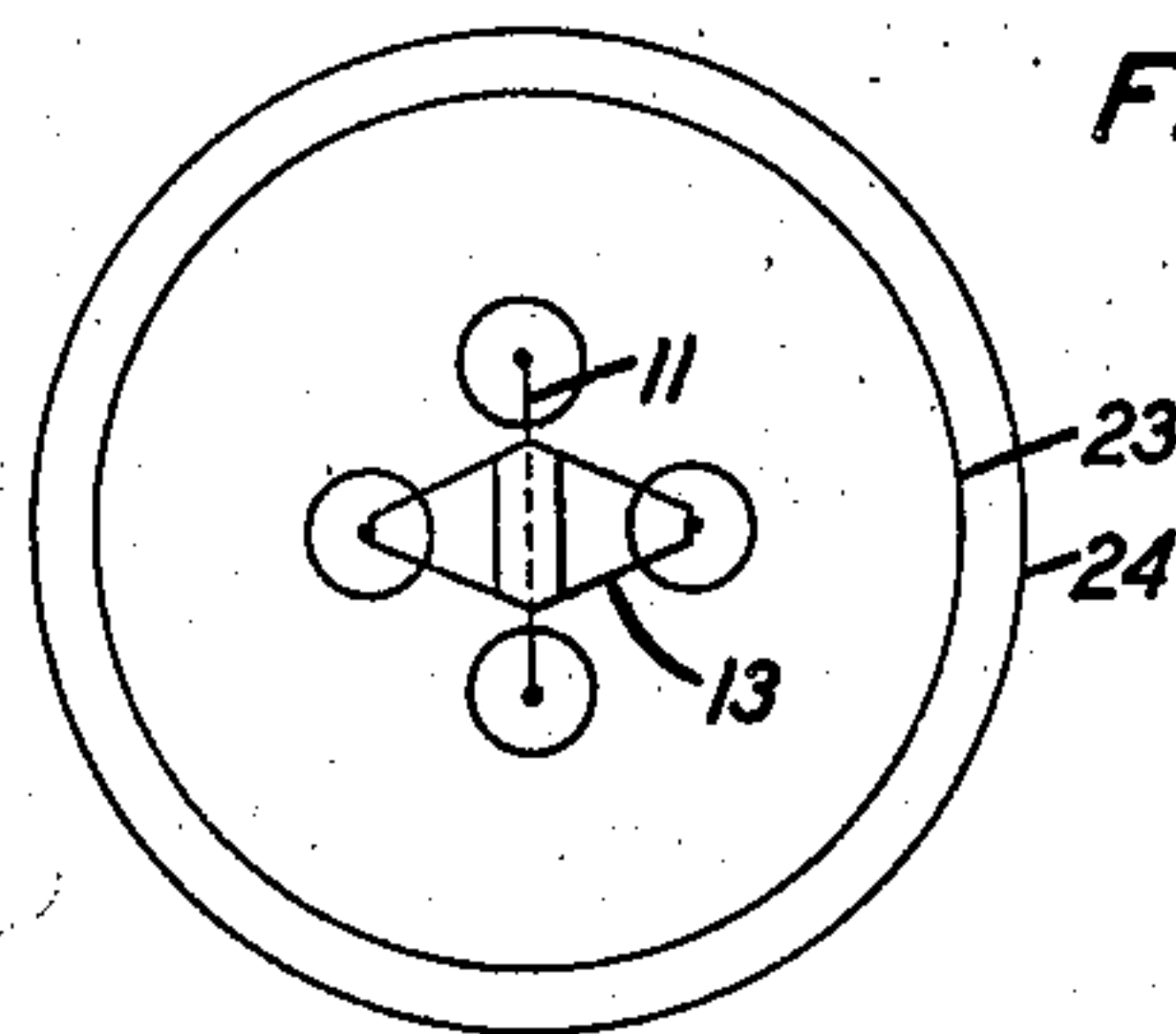
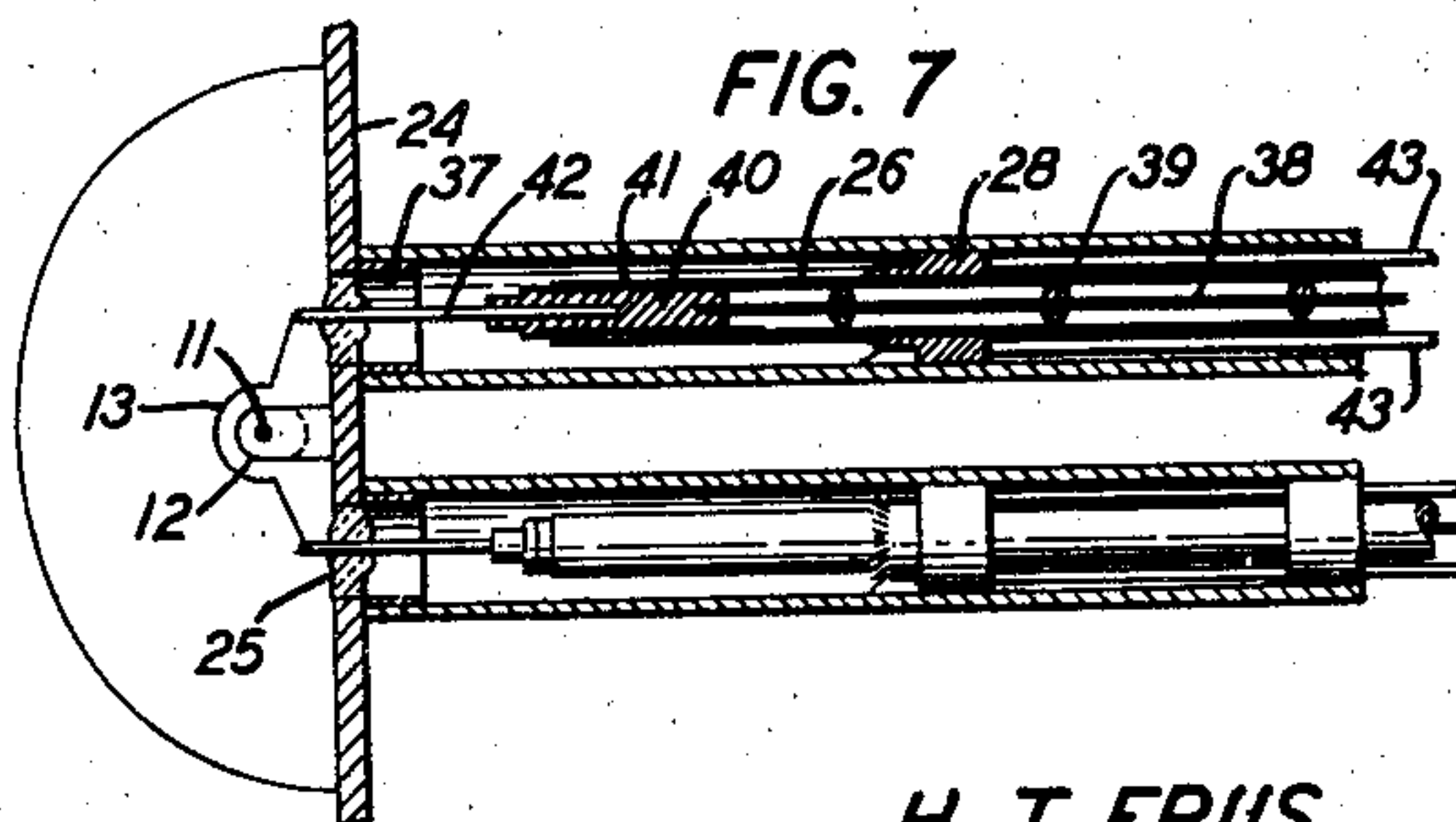


FIG. 7



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2,406,364

OSCILLATION GENERATOR

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4 Claims. (Cl. 250—36)

1

This invention relates to vacuum tube oscillators and more particularly to oscillators for the generation of ultra-high frequency currents for which the corresponding wave-lengths may be comparable to the dimensions of the vacuum tube electrodes and their associated leads.

The principal objects of the invention are to ensure the establishment of the oscillation frequency at a definite desired value and to prevent the generation of oscillations at frequencies other than that desired. Another object is to improve the efficiency of ultra-short wave oscillation of the feedback type.

When the frequency of oscillation corresponds to a wave-length of the order of 10 centimeters it may be found that the distributed inductance and capacity of the vacuum tube electrodes and their lead-in conductors are such that a portion of a standing wave representing a substantial fraction of a wave-length may be set up within the vacuum tube, leaving only a small part of the wave to be established in the conductors external to the tube. This results in a restriction of the range and accuracy of adjustment of the oscillation frequency. Where tuning by Lecher wires or adjustable concentric lines has been used, a common practice has been to extend the lengths of the lines sufficiently to include several half waves at the oscillation frequency. This has the advantages of permitting a wide range of frequency adjustment and, because of the inherently low dissipation of the line structures, of ensuring a high degree of frequency stability. However, such arrangements tend to permit the establishment of oscillations at the lower natural frequencies of the extended lines, with the result that oscillation at the desired harmonic modes can be started and maintained only with difficulty.

In accordance with this invention the above-noted difficulty is avoided by employing the feedback method of oscillation generation using a triode vacuum tube and by tuning two of the interelectrode circuits by means of lines differing in length by a predetermined fraction of a wave-length at the operating frequency. With this arrangement the phase or the magnitude, or both, of the feedback are such at the lower natural resonances of the lines that oscillations cannot be sustained. For the generation of the highest frequency oscillations we find it advantageous to operate the vacuum tube with its control grid at ground potential and to connect the tuning lines to the grid-cathode and grid-plate circuits, respectively. The feedback coupling may be pro-

2

vided by the inherent capacity between the plate and cathode or a supplementary capacity may be provided if necessary.

Other features of the invention are, first, the use of a vacuum tube having its electrodes so disposed and connected that they form, in effect, continuations of the tuning lines and, second, the extension of the tuning lines on both sides of the electrodes. By virtue of these features the creation of voltage antinodes at the centers of the electrodes becomes possible with a resulting substantial increase in the output power.

The nature of the invention will be more fully understood from the detailed description which follows and by reference to the accompanying drawing of which:

Fig. 1 is a simplified schematic of the invention;

Figs. 2 to 4, inclusive, are diagrams illustrative of the operation of the invention;

Fig. 5 is a somewhat simplified showing of a preferred form of the invention; and

Figs. 6 and 7 illustrate mechanical and circuit features of the oscillator of Fig. 5.

Referring to Fig. 1, 10 is a vacuum tube containing a straight filamentary cathode 11, a control grid 12, and an anode 13, disposed in parallel relation to one another. Lead-in wires extend from both ends of the filament and plate through opposite sides of the tube to tuning conductors 14, 15, 16 and 17, which constitute the central conductors of sections of coaxial line elements 18, 19, 20 and 21. Each line section is provided with a sliding short-circuiting bridge such as 22, by means of which its effective length may be varied for tuning purposes. For the sake of simplicity the connections of the energizing sources for the cathode and plate have been omitted from the showing of Fig. 1, but these are shown in Fig. 5. As is usual in the case of feedback oscillators, the plate is positive with respect to the filament and the grid may be at the same direct current potential as the filament or may be given a negative bias. The control grid is connected directly to the outer conductors of the tuning lines all of which may be grounded.

The pair of line sections 18 and 19 together with the filament 11 and grid 12 constitute a single substantially uniform shielded line short-circuited at both ends. Likewise, line sections 20 and 21 together with the plate 13 and the grid constitute a second substantially continuous short-circuited line. The two lines are shielded from each other except for the couplings provided by the direct capacity between the plate

3

and filament of the tube, denoted by C_p in the figure, and by the electron stream. The lines are adjusted so that each is an integral number of half waves in length at the desired oscillation frequency, the lengths differing from each other by one or more half waves. They are also adjusted by positioning the short-circuited ends relatively to the mid-point of the tube electrodes so that voltage antinodes exist at the centers of the plate and filament when standing waves are produced. With these adjustments the system oscillates readily at the desired frequency corresponding to the half wave difference in the lengths of the lines.

The oscillator may be looked upon as a modified form of the well-known Colpitts oscillator, in which the oscillation circuit comprises essentially two capacities interconnecting the grid and cathode and the plate and cathode, respectively, and an inductance connected between the plate and the grid. One of the capacities is provided by the plate to cathode tube capacity C_p and the other by detuning the cathode line 13, 19 to a frequency very slightly below the oscillation frequency so that its effective reactance, measured at the tube electrodes, is capacitive. Correspondingly, the inductive character of the plate to grid impedance may be realized by tuning the plate line 20, 21 to a frequency very slightly greater than the oscillation frequency. This explanation of the character of the circuit is given tentatively in the absence of more exact knowledge of the actions at the extremely high frequencies contemplated.

Some of the various standing wave conditions that may exist in the tuning lines of the oscillator with different adjustments of the short-circuiting bridges are shown in Figs. 2, 3 and 4. In each of these figures the upper and lower horizontal lines represent, respectively, the central conductors of the filament and plate tuning lines. The curves, designated by V_f and V_p , superimposed thereon illustrate the voltage distributions along these lines. The ends of the voltage curves correspond to the positions of the short-circuiting bridges. The shortest possible adjustment of the lines is illustrated by Fig. 2, for which case each line supports only a single half wave. Because of the irregularities of the geometry of the electrode structures the voltage distribution may be expected to differ from the simple sinusoidal form characteristic of a uniform line. With this mode of operation the range of adjustment is limited by the dimensions of the tube and the highest frequencies cannot be produced.

Fig. 3 illustrates one mode of operation in accordance with the invention. The plate line is extended on both sides of the tube sufficiently to accommodate three half waves and the filament line is extended on one side only so that it includes two half waves. If the filament line were extended equally on the other side of the tube, oscillation could take place at a greater wave-length as indicated by the dotted curves, but, with the two lines differing by one-half wave-length, oscillation is possible only at the higher frequency.

For the generation of the highest possible frequencies it is desirable that each of the lines should include at least three half waves, in which case the dimensions of the tube no longer limit the positioning of the short-circuiting bridges. Fig. 4 illustrates the standing wave conditions when the filament line includes three half waves and the plate line includes four.

4

Under this condition the short-circuiting bridges can be kept well clear of the tube structure so that the tuning adjustment is not restricted.

It will be evident that the lines might be extended further to include larger numbers of half waves and that the difference in their lengths could be more than a single half wave, subject to the condition that the difference should not be such as to permit oscillations in a lower frequency mode.

The constructional features of an oscillator embodying the principles of the invention are shown in Figs. 5, 6 and 7. Referring to Fig. 5, the vacuum tube comprises a roughly hemispherical glass envelope 23 sealed to a flat metallic base 24. The grid 12 is mounted directly on the base 24 and is electrically connected thereto. Leads from both ends of filament 11 and plate 13 are brought out through glass seals, such as 25, in holes in the base 24. The four tuning lines 18, 19, 20 and 21 have their outer conductors connected directly to the vacuum tube base 24 and extend perpendicularly thereto. The inner conductors of the lines consist of small diameter tubes such as 26, the outer surfaces of which carry the high frequency currents and through which insulated conductors are threaded for supplying the necessary energizing currents to the plate and filament. These inner tubes are held in place inside the outer conductors by ring supports such as 27 which may be metallic. At their inner ends, the inner tubes are provided with special condenser couplings 30 to the current supply conductors to provide low impedance paths for the high frequency oscillations. These are shown diagrammatically in Fig. 5 and in detail in Fig. 7. Adjustment of the effective lengths of the lines is obtained by means of sliding bridges such as 28 comprising metallic piston members drilled through the center to slide over the inner tubes and provided with a circular comb of flexible contact fingers which make contact with both line conductors. Direct current is supplied to the plate from a source through the inner conductor of line 20. The other terminal of the plate extends into the inner conductor of line 21 but is insulated therefrom by condenser coupling 30. Filament current is supplied from a source 31, grounded at its positive terminal, through conductors threading the inner tubes of lines 18 and 19 and is controlled by a circuit including resistors 32 and 33, potentiometer 34, and ballast lamp 35. These elements also serve to provide a suitable negative bias voltage for the grid, the amount of which may be controlled by the choice of the values of resistors 32 and 33. An output circuit is indicated by a branching concentric line 36 connected to line 20 close to the base of the tube. When this output circuit connection is used the impedance of the connected circuit should be high and preferably should be so tuned as to prevent any substantial effect on the standing wave pattern in the oscillator lines. Other well-known types of coupling may also be used.

As already explained, the showing of Fig. 5 is to some extent diagrammatic. Constructional features of an actual oscillator are shown in Figs. 6 and 7. Fig. 6 shows a plan view of the tube base and electrodes, and Fig. 7 is a sectional view showing the details of the line construction. The tuning lines, instead of being disposed side by side are placed at the four corners of a square as indicated by the four small circles in Fig. 6.

5

The vacuum tube plate 13 has a roof-like form in section and a diamond-shaped plan. The grid has the sectional form of a U-shaped channel and has a multiplicity of narrow transverse slits, not shown, giving it a comb-like structure.

Short tubular elements 37 welded to the tube base plate provide supports for the tuning lines. The lines fit over the supporting elements, good contact and a firm hold being obtained by slitting the ends of the outer conductors axially. Other familiar methods of attachment may, of course, be used. The tube terminals take the form of straight rods coming out through the centers of the line supporting tubes. Their connections to the inner conductors of the tuning lines and the power supply leads are shown in detail in Fig. 7. Plate supply lead 38, passing through the center of the inner conductor and insulated therefrom by glass beads 39 terminates in a tapered circular rod 40 which fits tightly in the end of the inner conductor tube and is insulated therefrom by a layer of mica 41. The end of the rod 40 projects beyond the inner conductor tube and is drilled and slitted axially to receive and make contact with plate terminal 42. The layer of mica between the terminal rod and the tube insulates the direct current supply circuit and at the same time provides a capacitive coupling to the tubular conductor having very low impedance at ultra-high frequencies. The connections to the other terminals of the tube are made in the same way as described above.

For the adjustment of the short-circuiting bridges 28, rods 43 are provided which are connected to the bridges and extend beyond the ends of the tuning lines.

What is claimed is:

6

1. An oscillation generator comprising a vacuum tube having a cathode, an anode and a control grid, a tuning line connected to said anode and said grid and a second tuning line connected to said cathode and said grid, said lines being short-circuited at their ends remote from the vacuum tube electrodes and having unequal lengths differing by an integral number of half wave-lengths at the oscillation frequency, and said electrodes being connected to said lines at points corresponding to voltage loops of the standing waves developed in the lines at the oscillation frequency.

2. An oscillation generator in accordance with claim 1 in which the tuning lines are extended on both sides of the vacuum tube electrodes sufficiently to include on each side at least one half standing wave in addition to the half wave centered about the connection of the electrodes to the lines.

3. An oscillation generator in accordance with claim 1 in which the tuning lines are extended on both sides of the vacuum tube electrodes and in which the electrodes are connected to the line extensions at the opposite ends of their major axes whereby the electrodes are included as portions of the line conductors.

4. An oscillation generator in accordance with claim 1 in which the tuning lines comprise coaxial conductors, the cathode of the vacuum tube being connected to the inner conductor of one of said lines, the anode being connected to the inner conductor of the other line, and the control grid being connected to the outer conductors of both of said lines.

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