Jan. 18, 1949. J. W. McNALL 2,459,283

POSITIVE GRID OSCILLATOR

Filed April 13, 1944. 2 Sheets-Sheet 1

Fig. 1.

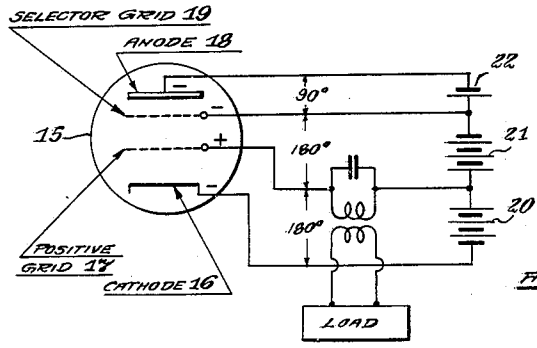


Fig. 2.

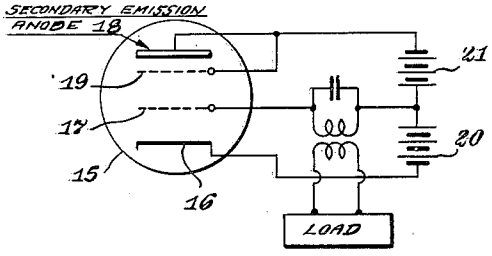


Fig. 3.

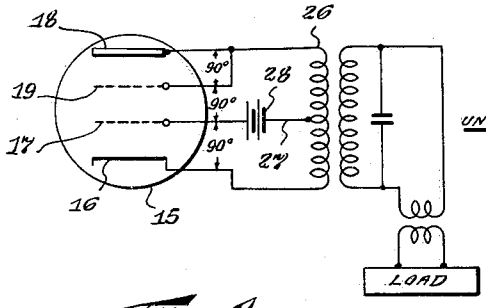


Fig. 4.

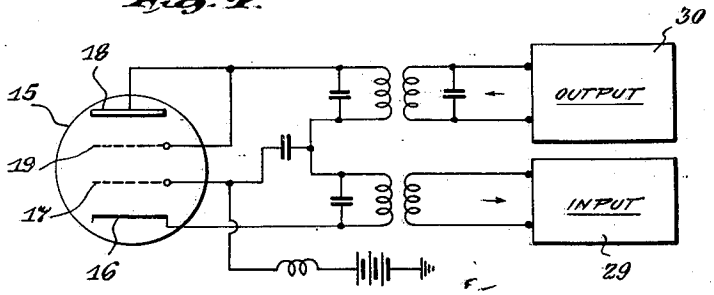


Fig. 5a.

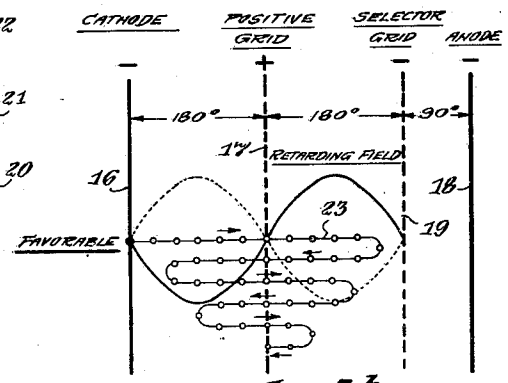


Fig. 5b.

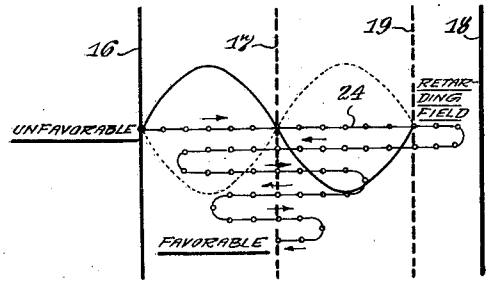
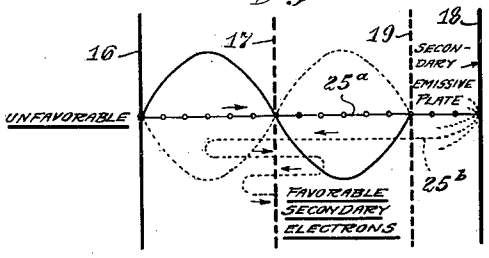


Fig. 5c.



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Fig. 6.

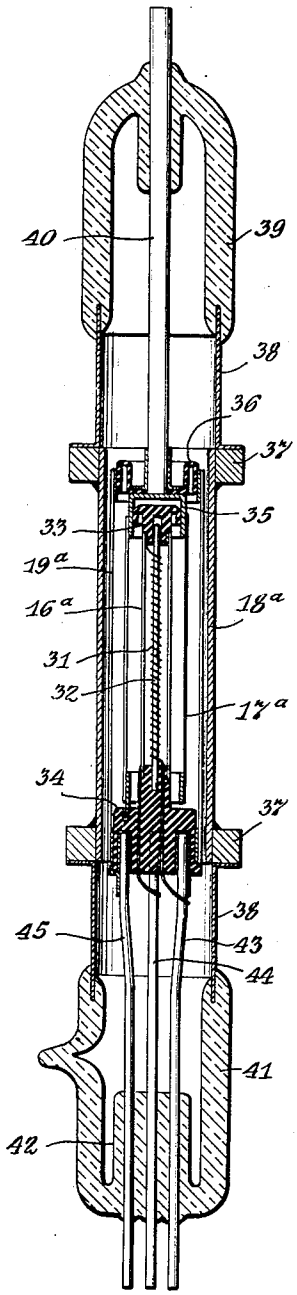


Fig. 7.

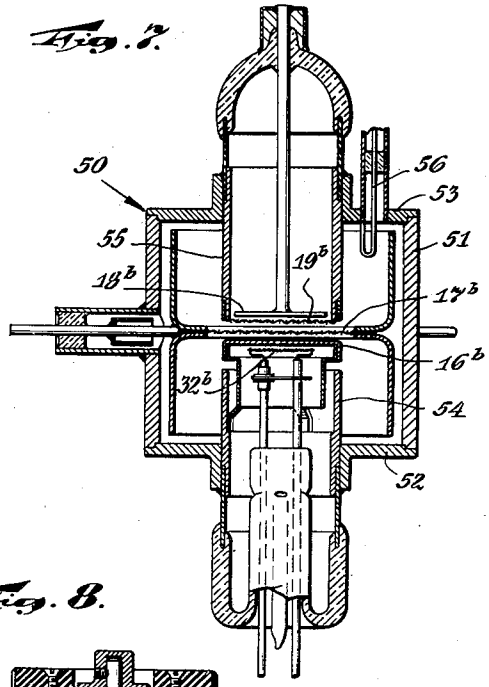
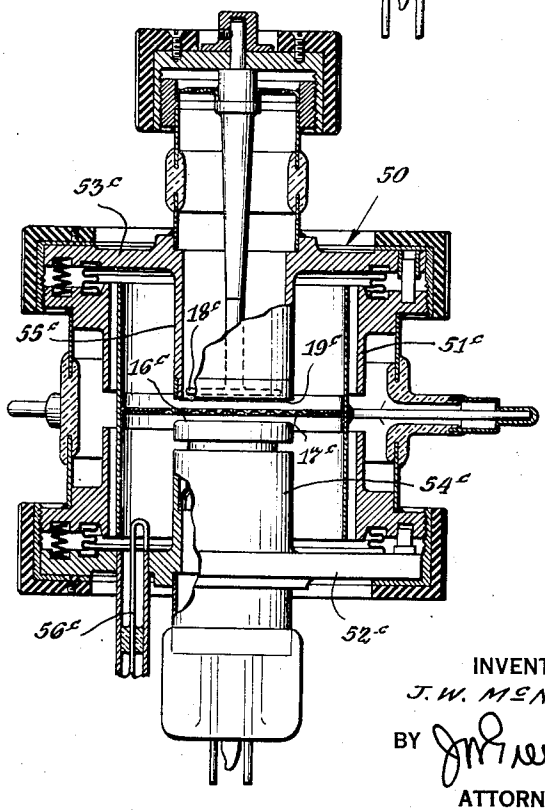


Fig. 8.



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POSITIVE GRID OSCILLATOR

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Application April 13, 1944, Serial No. 530,889

11 Claims. (Cl. 315—5)

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This invention relates to positive-grid oscillators, also known as retarding field oscillators for the reason that the grid is biased more positive than the anode and a retarding field to electron flow is thereby provided.

Background for the present invention is given in a simple treatise on "Positive Grid or Retarding Field Oscillators" by Robert I. Sarbacher and William A. Edson in "Electronics" for August, 1943, vol. 16, No. 8, page 108 et seq. In brief, that article explains for a simple case that by substantial equality of cathode to grid and grid to anode spacing, proper grid bias and cathode and anode voltages, the transit time of an electron from the cathode to the grid and from the grid to the anode can be made to correspond to a half cycle of the generated frequency.

Explanation of the operation is given first by considering motion of an electron in phase with the oscillating field, that is, an electron which leaves the cathode at the instant that the oscillating potenial on the grid is zero but increasing from zero to a positive value. The electron thus traverses a more than normal accelerating field as it proceeds toward the grid, arriving there with a higher velocity (more energy) than it would have in the absence of the oscillating field. As the electron passes through the grid, the cycle of oscillation of the field has progressed to a change of polarity, so that the electron passing through the grid now traverses a less-than-normal retarding field, arriving at the plate with an energy including that which it has absorbed from the oscillating field during the whole cycle. This represents energy lost, as the electron merely gives up the energy to the anode in the form of heat, and is therefore referred to as an unfavorable electron with regard to the operation of the device.

Useful energy in the operation of the prior art positive grid oscillator is obtained by electrons which leave the cathode 180° (a half cycle) later than the one referred to above, and are referred to as favorable electrons. A favorable electron passes through an accelerating field which is less than normal due to the negative R. F. potential on the grid, and therefore gives up energy to the oscillating field and passes through the grid with less than normal energy. As before, by virtue of the oscillation cycle reversal, the electron enters between grid and anode as that field becomes progressively retarding, and the electron continues to give up energy to the oscillating field. Since the electron has given up energy to the field throughout its travel, it has less

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than normal energy as it approaches the anode and does not reach the anode, but stops and reverses its course, returning toward the positive grid. As the electron came to rest, however, and was reversing its course, the oscillating field between plate and grid also changed polarity so that the electron again encounters a less-than-normal accelerating field. The electron accordingly continues to be a favorable one, giving up energy to the oscillating field. It may again pass through the grid and continue contributing to the oscillating field, again reversing and repeating the procedure until it finally strikes the grid and is lost for further useful purpose.

It is axiomatic that more energy must be imparted to the oscillating field by the favorable electrons than is absorbed from the field by the unfavorable ones for the oscillating field to be self sustaining, so that efficiency is increased by increasing the favorable electrons or by decreasing the unfavorable ones. In practice, a beneficial proportion has been obtained by employing emission maintained temperature limited rather than space charge limited. This, however, prevents increasing the input power or current, and prior art retarding grid oscillators have a low efficiency and a low power operating range.

In its general aspects, the present invention proposes improved efficiency and higher input power for positive grid oscillators.

Likewise, generally considered, an object of the invention is to overcome deficiencies of prior art positive grid oscillators.

More specifically, an object of the present invention is to increase the proportion of favorable electrons functioning in a positive grid oscillator.

Another object of the invention is to convert unfavorable electrons to be favorable.

Yet another object of the invention is to free secondary electrons in phase with favorable primary electrons.

Further object of the invention is to enable a positive grid oscillator to handle much larger peak powers than heretofore and to operate at higher power by use of larger currents.

Still further objects of the invention will appear to those skilled in the art as the description progresses, both by direct recitation thereof and by implication from the context.

Referring to the accompanying drawings in which like numerals of reference indicate similar parts throughout the several views:

Figures 1 to 4 are conventional showings of

electron devices and circuits embodying my invention;

Figures 5^a, 5^b and 5^c are diagrammatic showings of electron action in the oscillator of the present invention; and

Figures 6 to 8 are longitudinal sectional views of several oscillator tubes wherein my invention is employed.

An oscillator embodying the present invention may be designated by well-known symbols of the art, as in Figures 1 to 4, as an evacuated envelope **15** containing a source of primary electrons, indicated as a cathode **16** therein, spaced from which is a usual control or positive grid **17** and beyond which is an electrode designated anode or electron pulling electrode **18**. Oscillators of the prior art have contained these three electrodes, namely, cathode, grid and anode, with a spacing proportioned to transit time of electrons for taking advantage of preponderance of energy of favorable electrons over unfavorable ones for maintaining oscillations. The effect, as explained more fully in the above-identified article in "Electronics," depends upon the electrode dimensions or spacing and voltages at which they are operated, and suffers from both structural and operational limitations which results in low efficiency.

According to the present invention, the anode electrode of the prior art is replaced by an electrode here designated as a selector grid **19**, and an electrode herein designated the anode or electron pulling electrode **18** is provided beyond the said selector grid. Anode-replacing or selector grid **19**, maintained at a negative potential corresponding to use of negative potential on the anode of the prior art, acts, as in the prior art, as an anode for electrons which leave the cathode in favorable phase relation. Electrode referred to as anode or electron pulling electrode **18** herein, is spaced a predetermined distance beyond the selector grid **19** and functions as an anode or electron pulling electrode for electrons which emanate from the cathode in unfavorable phase relation and converts them to favorable electrons. By this construction, the initially favorable electrons remain favorable and the unfavorable electrons become favorable. Efficiency is thereby greatly increased, not only by presence of the increased number of favorable electrons, but also by the elimination of the cancelling effect of unfavorable electrons upon favorable ones.

Described more in detail, Figure 1 represents an oscillator wherein cathode **16** and positive or control grid **17** have the usual spaced relationship and potentials of cathode and grid as generally employed in positive grid oscillators. Selector grid **19** has usual spacing and approximate potential generally characteristic of the usual anode of a positive grid oscillator. These two spacings are commonly equal, and in relation to electron transit time and phase, are spaced such a distance that an electron leaving the cathode at a definite phase time reaches the positive or control grid when the phase is advanced 180° and continuing therethrough arrives at the selector grid when the phase has advanced another 180°. An electron passing through the selector grid approaches the electron pulling electrode **18**, and its position is such that the electron reaches the electron pulling electrode when the phase has further advanced an amount of 90° or quarter cycle transit time. The selector grid is preferably at or approximately at cathode potential,

whereas the anode is at a potential sufficiently negative with respect to the cathode or to the selector grid to repel electrons which enter the anode-selector grid region. D. C. potential is applied from a source, such as battery **20**, between cathode and control grid **17**, and a like but opposite potential is applied between control grid and selector grid from a source such as battery **21**. A somewhat more negative D. C. potential is applied to the anode from a suitable source, such as battery **22** if so desired.

Operation of the oscillator shown in Figure 1 is indicated in connection with diagrams of Figures 5^a and 5^b. Referring first to Figure 5^a, an electron which leaves the cathode **16** at a favorable instant gives up energy to the oscillating field for the two half cycles while in transit from the cathode to the vicinity of the selector grid. Due to the fact that these favorable electrons have lost some of their energy in transit to the retarding field, they are repelled by the selector grid **19** which acts as a virtual anode for those electrons. The action is repetitious, so the electrons oscillate back and forth through the positive grid **17** giving up energy to the retarding field. The oscillating path of the favorable electron is indicated by line **23**.

Next, referring to Figure 5^b, an electron which leaves the cathode at an unfavorable instant absorbs energy from the oscillating field for the initial two half cycles of transit, arriving at the selector grid **19** with a velocity determined by the amount of energy it has absorbed. This added velocity results in the electron continuing through or past the selector grid into the retarding field between the selector grid **19** and electron pulling electrode **18**, which slows the electron until it comes to rest before arriving at and in the vicinity of the electron pulling electrode. Due to the D. C. field, the electron thereupon reverses in direction and is accelerated back toward the selector grid, to again pass through that grid. Of course some electrons will strike the said selector grid, and are lost for further use, but consideration is here given to the majority which pass through the selector grid on the return path, and which are by far the larger number of electrons because of the open nature and the focusing action of the electric field existing in the neighborhood of the selector grid. Since the electron pulling electrode is situated at electron travel distance from the selector grid agreeing with substantially 90° phase cycle shift, the round trip transit of the electron in the region between selector grid and electron pulling electrode occupies a flight time of substantially 180° phase shift. Accordingly, the electron returns and passes through the selector grid 180° later than on its forward flight, and due to the 180° delay, is then a favorable electron in the region between the cathode and selector grid and acts as the above-described favorable electrons, oscillating back and forth through control grid **17** giving up energy to the retarding field. Path of this initially unfavorable and ultimately favorable electron is indicated by the line **24** in Fig. 5^b. It is now apparent that I have provided means for increasing the ratio of the number of favorable half cycle electron transits to the number of unfavorable ones, and accordingly obtain a corresponding increase in efficiency of oscillation.

As indicated heretofore, it is a desideratum of the invention to increase the proportion of favorable electrons. In addition to accomplishment of this object by conversion of unafvorable

electrons to favorable ones, a further multiplication may be effected by employment of secondary emission. Exemplary of this feature, electron pulling electrode 18 of Fig. 1 may be composed of material having a relatively high secondary electron emission ratio. In order that the primary electrons shall travel to the electron pulling electrode or anode for releasing the secondary electrons, the potential of the anode is preferably at or near the potential of the selector grid 19. Thus the extra potential applied by battery 22 in Fig. 1 will be reduced, reversed or eliminated where secondary emission is desired, and exemplary of the total absence of potential difference, the showing of Figure 2 indicates the selector grid and anode as at the same potential, but spaced, as before, an electron transit distance apart affording approximately a quarter cycle phase shift, or more accurately, to provide a round trip transit time from and back to the selector grid of substantially 180°.

With regard to the assembly wherein the electron pulling electrode or anode is emissive of secondary electrons and considering electrons leaving the cathode at favorable moments, the operation is identical with that given above in connection with Figures 1 and 5a. For electrons leaving the cathode 19 at unfavorable moments, operation is analogous to that given above for unfavorable electrons, differing in that the primary electrons reach the electron pulling electrode or anode and in that secondary electrons make the return passage and in greater number than primary electrons. Operation of the oscillator of either Figure 1 or Figure 2 when utilizing secondary emission from the electron pulling electrode or anode is shown in Figure 5c.

Referring more especially to Figure 5c, an electron which leaves the cathode 16 at an unfavorable moment absorbs energy as described above from the oscillating field during the initial two half cycles in transit from cathode 16 to selector grid 19. Considering only electrons which pass through the grids, the primary electron from the cathode is accelerated by the absorbed energy from the oscillating field and strikes the electron pulling electrode or anode 18. Upon impact with the electron pulling electrode or anode, the primary electron releases a plurality of secondary electrons, which, due to the D. C. field, travel to and through the selector grid, where they find themselves in a favorable phase because the oscillating field has advanced 180° since the time the unfavorable primary electron passed through the selector grid. The secondary electrons are then favorable electrons and act as above described, oscillating back and forth through control grid 17 giving up energy to the retarding field. Path of the unfavorable primary electron is indicated in Figure 5c by solid line 25a and path of one of the secondary electrons is indicated by dotted line 25b. As there are many secondary electrons to each primary electron, it will now be apparent that a corresponding increase in efficiency of oscillation is obtained.

The foregoing examples of the invention in Figures 1 and 2 as applied respectively to derivation of increase energy from either primary electrons or from primary and secondary electrons have been made upon a consideration of oscillating potential on the control grid. The invention is equally applicable with the control grid constant or grounded and the cathode and anode, either or both, electrically oscillating. One specific example is indicated in Figure 3 wherein the secondary emission type of electron pulling electrode or anode of Fig. 2 has arbitrarily been selected, but it is to be understood electron pulling electrode structure and bias of Fig. 1 is equally applicable. In Fig. 3, by connecting the electron pulling electrode 18 and cathode 16 to opposite ends of the transformer secondary 26, the oscillating potential thereon rocks back and forth, the control grid 17 being neutral as to oscillating potential in view of center tap 27 to the said secondary 26. Positive D. C. potential is supplied to said control grid 17 by suitable source, such as battery 28. Spacing from cathode 16 to control grid 17 and from control grid 17 to selector grid 19 is now made 90° transit time distance, whereas spacing from selector grid 19 to electron pulling electrode 18 remains at 90° transit time spacing as before. Thus, as before, unfavorable electrons are impelled with their absorbed energy through the selector grid substantially 180° out of phase with the favorable ones, and those primary electrons in traversing the approximate 90° spacing to the electron pulling electrode there producing secondary electrons which retrace that distance, make a round trip distance of substantially 180° as before and thereby enter the field from selector grid to control grid in phase with the favorable electrons.

Tracing the unfavorable electron more minutely, it will be observed that it leaves the cathode at a moment when the oscillating potential is increasing from 0 at the cathode to −90° when the electron reaches control grid 17. The electron is speeded by that repelling potential, absorbs energy to do so, and is therefore unfavorable. As the electron passes into the field between the grids, the oscillating potential on the selector grid is at its maximum positive potential which reduces the retarding field. In traversing this less-than-normal retarding field, the electron absorbs energy from the oscillations, arriving at the selector grid as the oscillating potential on the said selector grid decreases to zero, but the electron having acquired energy, will continue to the electron pulling electrode or anode and there release secondary electrons. The secondary electrons are attracted by the control grid, the D. C. field of which sufficiently penetrates the selector grid and proceeds on what is here referred to as the return path. The forward and return path transit time of electron travel between selector grid and electron pulling electrode consumes substantially 180° phase shift of the oscillating period so that the entry of the secondary electrons into the selector grid-control grid region is at a time when the selector grid begins to be affected by an increase of the oscillating positive potential, which algebraically decreases effect of the positive D. C. potential and creates thereby a less-than-normal accelerating field. The electron loses speed, thereby giving part of its energy to the oscillating field, passes to the region between the control grid and cathode where it is again in a retarding field, is turned back and oscillates back and forth through the control grid as in the cases previously described. Conversion and use of originally unfavorable electrons is accordingly accomplished in the several embodiments illustrated and referred to or described above.

While emphasis of adaptation of the invention as an oscillator only may have been implied by the extended description above based on the simplicity of explanation achieved by consideration in that connection, it is to be understood the in-

vention is applicable in more general usage, for instance as an amplifier. Thus in Figure 4 is illustrated an input oscillating means or circuit **29** within the oscillating period of the above-described oscillator for supplying the oscillation potential of the oscillator. This is then amplified by the oscillator and passes for useful purpose to an output circuit or means **30**. The particular oscillator shown in Fig. 4 is one having an electron pulling electrode or anode **18** emissive of secondary electrons and spacing of the several electrodes therein is, as in Fig. 4, electron transit time distance of 90° from each to the next.

Observation is made that whereas the oscillator described in the "Electronics" article must of necessity operate with the cathode non-space charge limited, the present invention is not so restricted but may function either space charge or emission limited, because the unfavorable electrons as described herein ultimately become favorable electrons.

In addition to increase of efficiency and effectiveness of an oscillator obtained by the improvements above described, it is also a feature of the invention to enable use of higher currents and of higher voltages both for taking advantage of these higher currents and for increasing power. I propose to pulse the grid voltage, thus increasing the non-space charge limited currents, and to use a considerably higher potential than heretofore found possible in positive grid oscillators, thus allowing the oscillator to handle much larger peak powers for the same amount of electrode heating. Pulsing the grid voltage will not only allow much larger peak voltages to be used for the same average power but will result in a considerably, and desirably, shorter wave length of radiation for a given tube structure.

Positive grid oscillators may be made in accordance with my invention with various physical arrangement of tube parts, and my conception contemplates use of coaxial electrodes as illustrated in Figure 6, or hollow body resonant structures of which Figures 7 and 8 are illustrative. In Figures 6 and 8 all electrodes are insulated from each other for applying any desired potential to any electrode, whereas in Figure 7 the cathode and selector grid are necessarily at a common potential. Figure 8 furthermore shows tuning adjustment for cathode, electron pulling electrode and selector grid with respect to the control grid. In Figures 6 and 7 the electrodes are in predetermined fixed position so that tuning is by adjustment of applied potentials.

Oscillator tube of Figure 6 depicts coaxial electrodes comprising a cylindrical cathode **16a** containing a heater **31** therein consisting of a coil carried upon an insulating rod **32**. A spacer **33**, shown of plug type, is provided at and fits into the upper end of the cathode and receives an end of said rod. Another spacer **34** is provided at and fits into the lower end of the cathode and receives the other end of said rod. Both said spacers also make supporting contact with ends of a cylindrical control grid **17a**, the upper end of which is shown having a metallic cap **35** which overlies the end of the spacer as well as a part of the peripheral side of the same. The lower spacer protrudes from the end of the cathode and shoulders outward below the grid cylinder and affords thereat a supporting engagement for the lower end of a cylindrical selector grid **19a**. The upper end of the selector grid is engaged at its inner peripheral margin by a third spacer **36** mounted above the said cap **35**. A cylindrical electron pulling electrode **18a** is coaxially around and spaced from the selector grid. Radial spacing of the cathode to positive grid, control grid to selector grid and selector grid to electron pulling electrode is made in accordance with description given above in the discussion of Figures 1 to 5. Said electron pulling electrode may be reflective or capable of secondary emission likewise in accordance with the foregoing dissertation.

Support of the electrodes and sealing as an evacuated envelope may be accomplished in approved manner. As shown, the anode or electron pulling electrode constitutes part of the envelope wall, and at its ends has rings **37** soldered thereto around, said rings having flanges of metallic collars **38** welded or otherwise secured thereto, the collars projecting as cylindrical continuations of said electron pulling electrode. Said collars are of appropriate material, such as that manufactured in accordance with patent to Howard Scott, No. 2,062,335, and sold in the trade as "Kovar." The upper one of the collars has a glass cap **39** sealed thereto, said cap also being seated at its outer end portion around a lead-in metallic rod support **40** coaxial within the collar and supporting, at its lower end, the metallic cap **35** heretofore described as part of the control grid. The lower collar **38** has a glass cap **41** sealed thereto, this cap being shown with a re-entrant stem **42** therein which seals around lead-in wire supports **43**, **44** and **45**, by which heater current is conducted to the heater and connection afforded for the cathode and selector grid.

Adaptation of the invention to hollow body resonant oscillators is indicated by inclusion herein of structures of that character in the showings of Figs. 7 and 8. Separately considered, Fig. 7 shows a hollow body resonator, the hollow body **50** whereof is all metal, provides a cylindrical wall **51** and end walls **52**, **53**, which respectively provide re-entrant portions **54**, **55** coaxial with the cylindrical wall **51** and directed toward each other but with space between. At the end of and transverse to one re-entrant portion **54** is a cathode **16b** which is caused to emit from heat applied by heater **32b**. Within the other re-entrant portion **55** next the innermost end thereof is an electron pulling electrode or anode **18b** in the form of a flat disc transverse to the said re-entrant portion and parallel to the cathode. At the end of the re-entrant portion containing the electron pulling electrode is a selector grid **19b** parallel to the anode, and between said selector grid and the cathode is a control grid **17b** also parallel to the electron pulling electrode, cathode and selector grid, and insulated from those several electrodes. Spacing of the several electrodes is in accordance with the above description and like operation is obtained, with the resonator supplying the oscillating field and receiving the generated energy which is made available for useful purpose by a loop output **56**.

Description of Figure 8 is a repetition of that just given for Figure 7, and the reference numerals in Figure 8 are accordingly duplicated but with exponent C applied thereto for more ready reference. The showing is here included for indicating the adjustability of electrodes on opposite sides of the control grid for tuning purposes, the structure being more fully described and claimed in a copending application.

I claim:

1. A positive grid oscillator having electrodes in parallelism to each other, said electrodes comprising a cathode, an electron pulling electrode

and two grids therebetween of which one is a control grid adapted to be positive with respect to the cathode and the other is a selector grid, the spacing of said electrodes being related to the electron transit time and oscillating cycle such that round-trip electron transit time from selector grid to electron pulling electrode and back to said selector grid is substantially the same time required for 180° phase shift of the said selector grid.

2. A positive grid oscillator having electrodes in parallelism to each other, said electrodes comprising a cathode, an anode-like electrode and two grids of which one is a control grid adapted to be positive with respect to the cathode and the other a selector grid, the spacing of the selector grid and anode-like electrode being substantially a quarter wave-length distance apart referring to the wave-length of the oscillating cycle of the oscillator.

3. A positive grid oscillator having electrodes in parallelism to each other, said electrodes comprising successively a cathode, a grid adapted to be positive with respect to the cathode, a selector grid and an electron pulling electrode, the spacing of the selector grid and electron pulling electrode being substantially a quarter wave length distance apart referring to the wave length of the oscillating cycle of the oscillator, and the other electrodes being spaced substantially equal distances apart from each other.

4. A positive grid oscillator having electrodes in parallelism to each other, said electrodes comprising successively a cathode, a grid adapted to be positive with respect to the cathode, a selector grid and an electron pulling electrode, all of said electrodes being spaced from each other a substantially equal distance comprising a predetermined fractional part of a wave length of the wave length of the oscillating cycle of operation of the oscillator.

5. A positive grid oscillator having electrodes in parallelism to each other, said electrodes comprising successively a cathode, a grid adapted to be positive with respect to the cathode, a selector grid and an electron pulling electrode, all of said electrodes being spaced from each other substantially a quarter wave length distance apart referring to the wave length of the oscillating cycle of the oscillator.

6. A positive grid oscillator having electrodes in parallelism to each other, said electrodes comprising successively a cathode, a grid adapted to be positive with respect to the cathode, a selector grid and an electron pulling electrode, the spacing of the selector grid and electron pulling electrode being substantially a quarter wave length distance apart referring to the wave length of the oscillating cycle of the oscillator, and the other electrodes being spaced substantially half wave length distances apart from each other.

7. A positive grid oscillator comprising a cathode, a selector grid spaced in parallelism to said cathode, another grid between said cathode and selector grid constructed and arranged to establish an oscillating field for electrons from said cathode and oscillating the same therein, and another electrode beyond said selector grid having spacing therefrom less than spacing of said cathode from the selector grid and adapted to return electrons to the field between said cathode and selector grid in phase with oscillating electrons in said field.

8. A positive grid oscillator comprising a cathode, a selector grid spaced in parallelism to said cathode, another grid evenly spaced between said cathode and selector grid constructed and arranged to establish an oscillating field for electrons from said cathode and oscillating the same therein, and another electrode beyond said selector grid having spacing therefrom less than spacing of said cathode from the selector grid and adapted to return electrons to the field between said cathode and selector grid in phase with oscillating electrons in said field.

9. A positive grid oscillator comprising a cathode, a control grid adapted to be positive with respect to the cathode, and spaced from the cathode in the direction of normal flow of electrons from the cathode, a selector grid beyond the control grid having substantially an equal spacing therefrom as said spacing of the control grid from the cathode, said cathode and grids being constructed and arranged to establish an oscillating field for the electrons with attendant cycle of phase reversal, said selector grid passing electrons therethrough out of phase with said cycle, and means in the path of travel of and for returning the out-of-phase electrons back through the selector grid in phase with the oscillating cycle.

10. A positive grid oscillator comprising a cathode, a control grid adapted to be positive with respect to the cathode and spaced from the cathode in the direction of normal flow of electrons from the cathode, a selector grid beyond the control grid having substantially an equal spacing therefrom as said spacing of the control grid from the cathode, said cathode and grids being constructed and arranged to establish an oscillating field for the electrons with attendant cycle of phase reversal, said selector grid passing electrons therethrough out of phase with said cycle, and a secondary emission electrode beyond the selector grid for receiving the out-of-phase electrons passing through the selector grid, said secondary emission electrode being productive of secondary electrons and adapted to promulgate said secondary electrons through the selector grid in phase with the said oscillating cycle.

11. A positive grid oscillator having an electron source for promulgation of electrons and having grids spaced therefrom and from each other successively with equal spacing, said grids adapted to have operating voltages and currents applied thereto, a source of pulsed voltage connected with one of said grids for increasing the non-space charge limited currents, and means in the path of and for returning electrons passing through the outer spaced grid into the field of the pulsed voltage.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,844,319	Hatt	Feb. 9, 1932
2,115,866	Lux	May 3, 1938
2,128,232	Dallenbach	Aug. 30, 1938
2,170,219	Seiler	Aug. 22, 1939
2,287,845	Varian et al	June 30, 1942

OTHER REFERENCES

Electrical Engineers Handbook by Pender & McIlwain, 3rd ed., published 1936, by John Wiley and Sons, Inc., New York city. (Copy in Div. 54, U. S. Patent Office.)