

Feb. 10, 1948.

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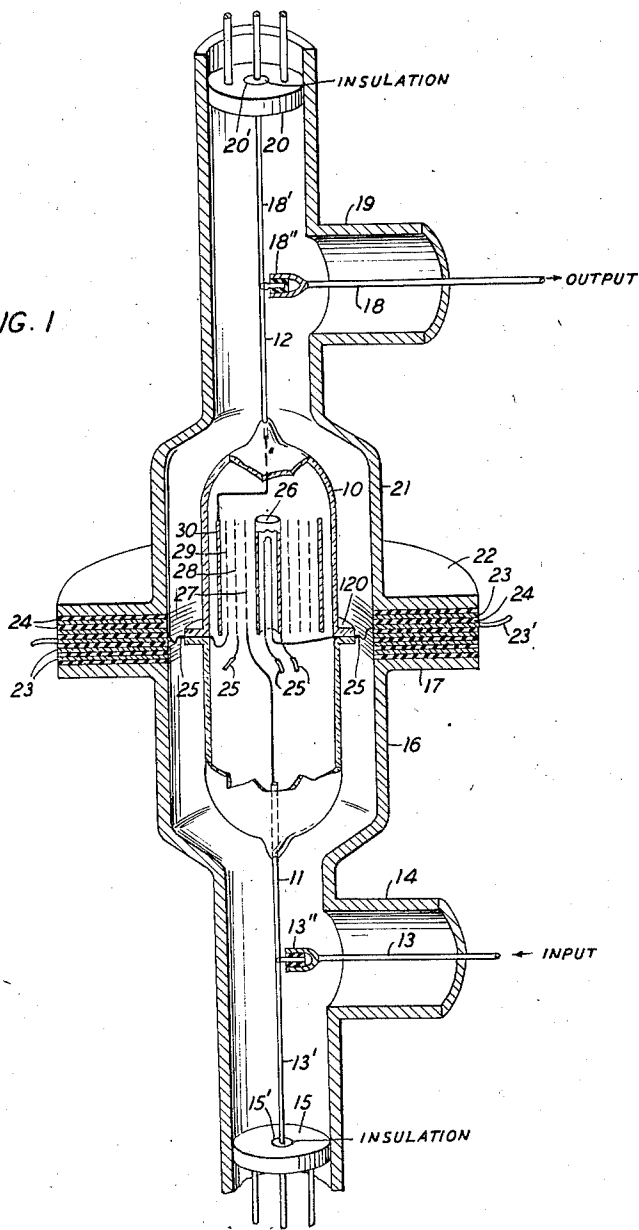
2,435,585

HIGH-FREQUENCY RELAY EMPLOYING AN ELECTRON DISCHARGE DEVICE

Filed Dec. 20, 1941

5 Sheets-Sheet 1

FIG. 1



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FIG. 2

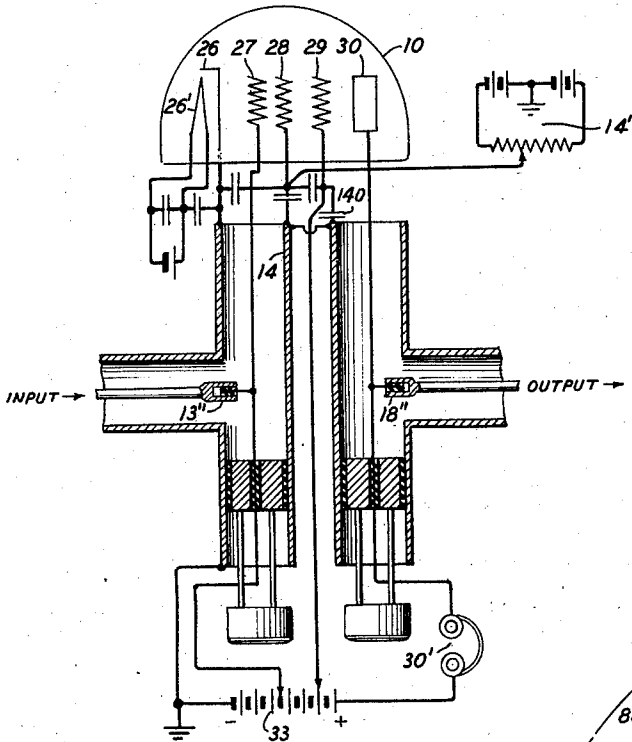
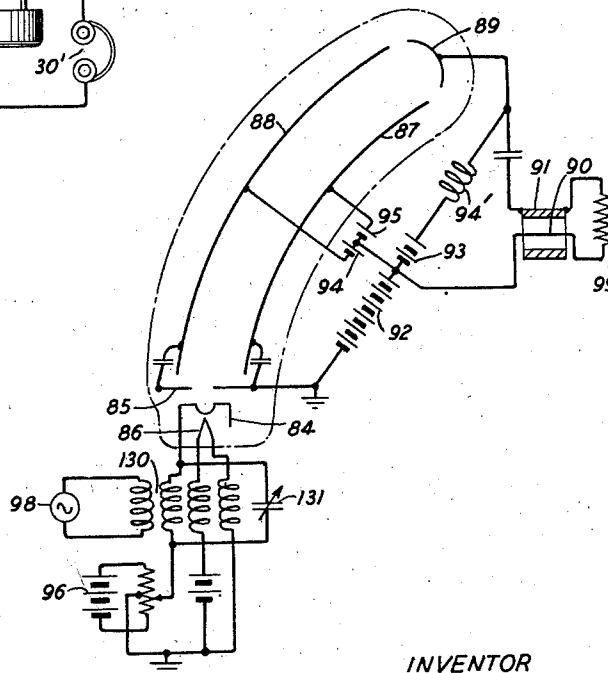


FIG. 9



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FIG. 3

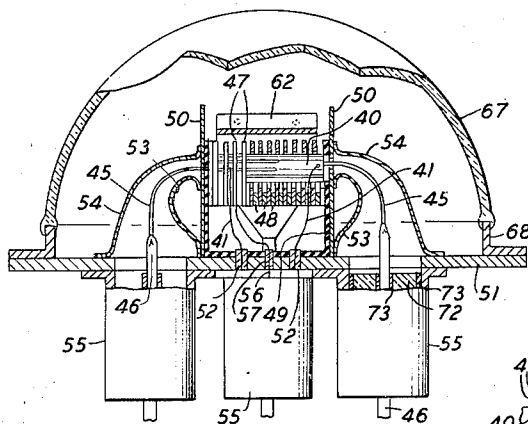


FIG. 5

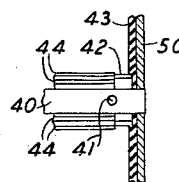
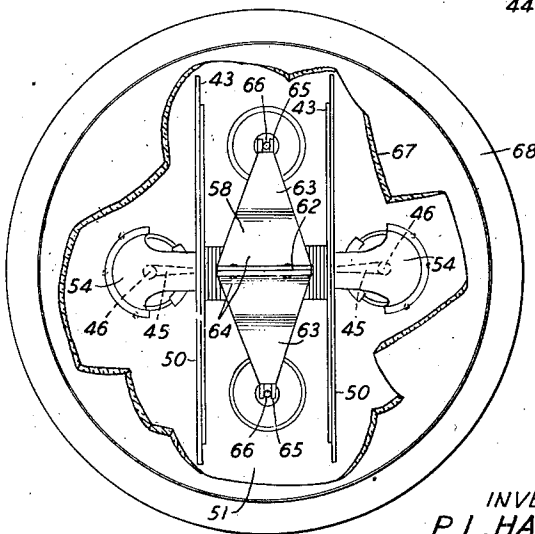


FIG. 4



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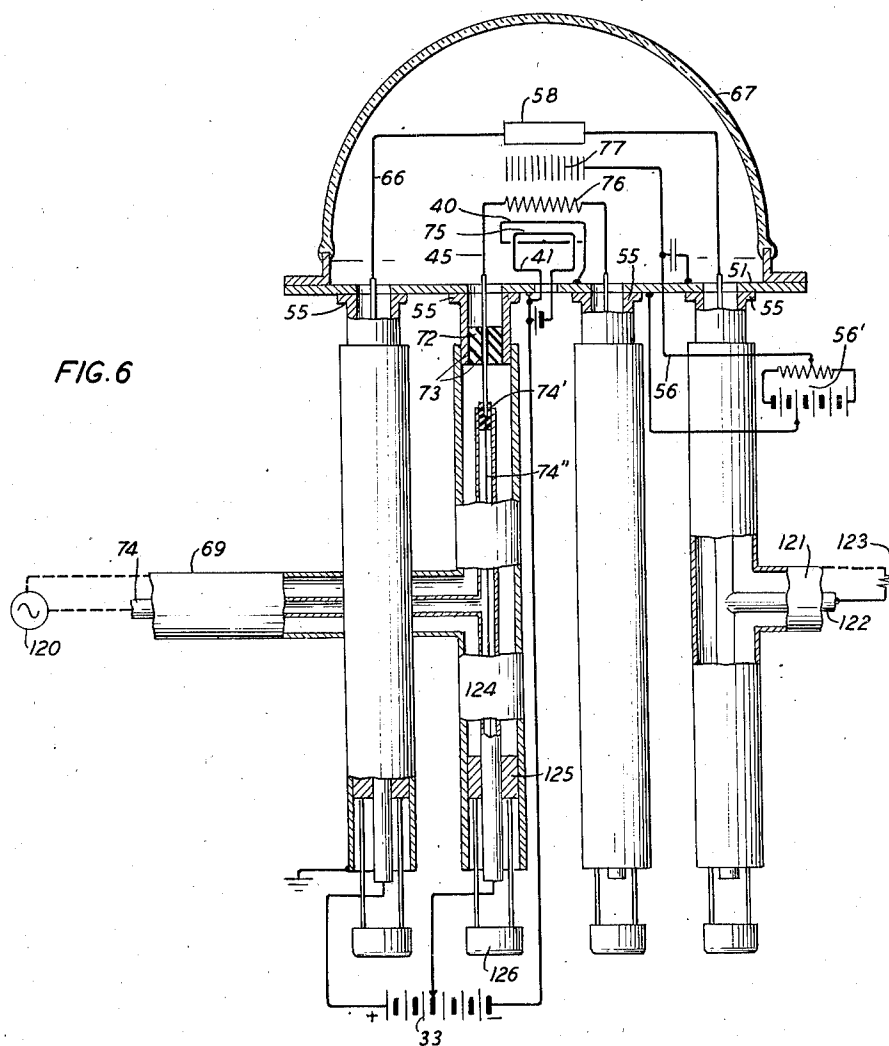
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FIG. 7

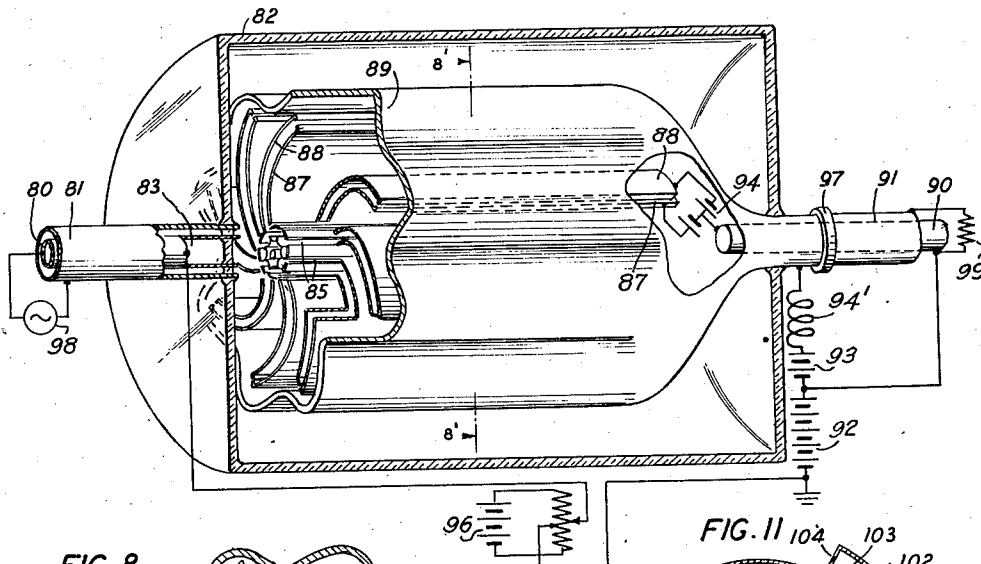


FIG. 8

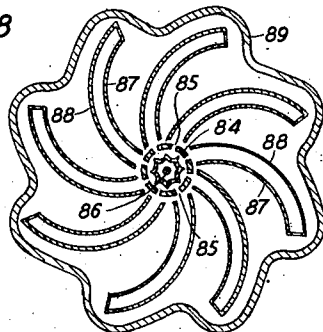


FIG. 11

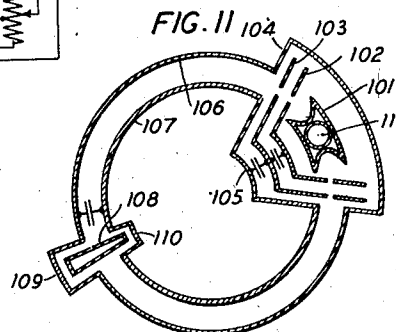
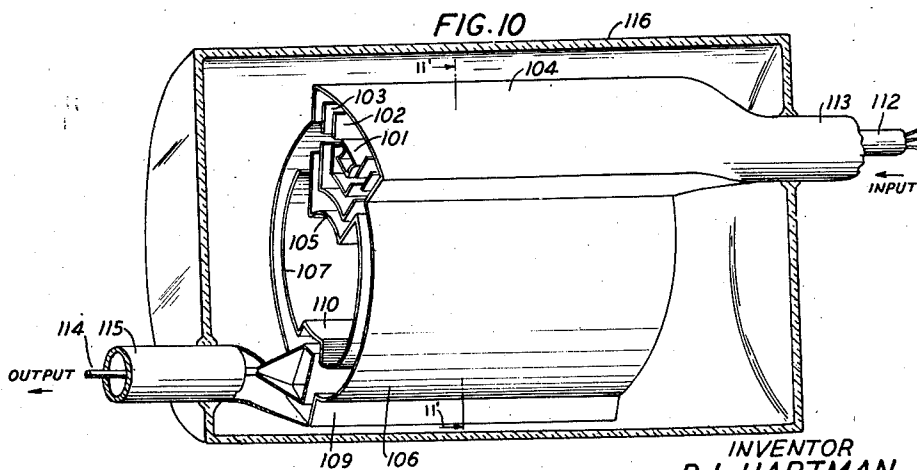


FIG. 10



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2,435,585

HIGH-FREQUENCY RELAY EMPLOYING AN ELECTRON DISCHARGE DEVICE

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Application December 20, 1941, Serial No. 423,788

4 Claims. (Cl. 315—39)

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This invention relates to systems employing electron discharge devices and particularly to the design and operation of such systems for use at ultra-high frequencies.

An object of the invention is to extend to still higher frequencies the usefulness of electron discharge devices designed for high frequency operation, by using specially adapted connecting circuits and modes of operation.

A feature of the invention is the use of coaxial transmission lines for input and output connections to the electrodes of the electron discharge device in a number of arrangements particularly adapted for operation in a wide range of frequencies including the centimeter wave-length range.

Another feature is the use of a reflecting or retarding potential to effect a process of velocity sorting of the electrons in a velocity varied electron stream employing electrode structures of more or less conventional type.

Other objects and features are brought out in the following description with reference to the accompanying drawings, while the scope of the invention is defined in the appended claims.

In the drawings:

Fig. 1 is a perspective view, partly broken away, of an embodiment of the invention employing a double-ended vacuum tube electron discharge device enclosed in a coaxial transmission line system;

Fig. 2 is a schematic diagram of suitable circuit connections for the arrangement of Fig. 1;

Fig. 3 is an elevational view of another form of a vacuum tube suitable for use with the invention;

Fig. 4 is a partial plan view of the structure illustrated in Fig. 3;

Fig. 5 is a fragmentary view showing details of construction of the structure illustrated in Figs. 3 and 4;

Fig. 6 shows, partly in section and partly schematically, an amplifying system employing the electron discharge device of Figs. 3, 4 and 5;

Fig. 7 is a perspective view, partly broken away, of another embodiment of the invention;

Fig. 8 is a cross-sectional view of a portion of the structure of Fig. 7;

Fig. 9 is a schematic diagram of circuit connections for the arrangement of Figs. 7 and 8;

Fig. 10 is a perspective view, partly broken away, of still another embodiment; and

Fig. 11 is a cross-sectional view of a portion of the structure of Fig. 10.

Referring to Fig. 1, 10 represents the envelope

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of an electron discharge device or vacuum tube designed for high frequency operation, having a central flange 120 and having grid and plate leads 11 and 12, respectively, coming out from opposite ends in known manner for the purpose of reducing the interelectrode capacity. The tube may, for example, be of the type disclosed in United States Patent 2,017,549, issued October 15, 1935, to B. Salzberg. An input coaxial line with an inner conductor 13, 13' and an outer conductor 14 is provided having a tuning stub terminated by a conductive piston 15 carrying a bushing 15' to insulate it from the inner conductor portion 13' and arranged for axial adjustment. The bushing 15' may be of mica or other suitable insulating material. The piston 15 forms a short-circuiting termination for the stub line at high frequency and may be provided with any suitable mechanical means for its manipulation. The conductor 13 is connected through an insulating joint or blocking condenser structure 13'' with conductor 13' and the latter conductor is conductively connected with the lead 11. The sheath 14 has an enlarged end 16 surrounding the lower part of the envelope 10 and terminating in a flange 17. A similar coaxial line is provided for the output circuit with inner conductors 18, 18' and a sheath 19. The line has a tuning stub with an adjustable piston 20 having an insulating bushing 20' surrounding the conductor 18'. The inner conductor 18 is connected to the conductor 18' through a blocking condenser 18'' and the conductor 18' is conductively connected with the lead 12. The sheath 19 has an enlarged portion 21 terminating in a flange 22 opposite the flange 17 of the input line. Between the flanges 17 and 22 are clamped a plurality of conductive rings or apertured plates 23 separated by insulating layers 24. There are a plurality of leads 25 protruding from the flange 120 of the envelope 10 which serve for connections to a filament, a cathode and one or more auxiliary grids within the envelope. Each lead 25 is connected to a different plate 23 and thereby to a terminal or lug 23' attached to the plate. The assembly 23, 24, together with the flanges 17 and 22, forms a stack or plurality of by-pass condensers effectively connecting together the filament, cathode and auxiliary grids for high frequency currents and rendering these electrodes essentially equipotential.

Fig. 2 shows in schematic form the arrangement of Fig. 1 and associated circuits. The envelope 10 is assumed to contain a cathode 25, a heater 26', a plurality of grids 27, 28 and 29 and an anode 30. The input coaxial line is con-

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nected between the grid 27 and the cathode 26, to the former through the blocking condenser 13". One terminal of the output coaxial line is connected to the anode 30 through the blocking condenser 13" and the other through a blocking condenser 140 to the grid 29. The tube is energized by a source of direct electromotive force shown as a battery 33 impressed between the cathode 26 and the anode 30. The grids 27 and 29 are connected to intermediate points of the source 33, the grid 29 being at the higher potential. The graduated potential differences impressed upon the electrodes 26, 27, 29 and 30 by the source 33 serve to accelerate electrons leaving the cathode 26 and to form them into an electron beam falling upon the anode 30. A reflecting or retarding voltage is impressed upon the grid 28 by connecting it, for example, to a potentiometer 14'. The reflecting or retarding field of the electrode 28 serves to effect a velocity sorting of the electrons in the beam. Electrons arriving in the neighborhood of electrode 28 with sufficient velocity will continue on to the anode 30. Other electrons, having smaller velocities will be drawn to the grid 29, and others slower still will be turned back toward the cathode and may be collected by the grid 27.

In the operation of the system of Fig. 2, a high frequency input wave is applied to the grid 27 by means of the input coaxial line, which impresses a velocity variation upon the electrons as they pass between the cathode 26 and the grid 27. Consequently, some of the electrons gain velocity in sufficient amount to penetrate the retarding field and reach the anode 30, thereby constituting an output current. By proper choice of the spacing between the grid 27 and cathode 26 and between the grids 27 and 28 and by proper adjustment of the potentials, the electron transit time may be adjusted, for example, in terms of the periodic cycle of the impressed wave, to one-half cycle between the cathode 26 and the grid 27 and one-quarter cycle between the grids 27 and 28. It is desirable to make the transit time between grids 27 and 28 somewhat different from that between the first two electrodes in order to suppress electron oscillations of the type present in oscillators of the Barkhausen type. An electron executing that type of oscillation will tend to swing in an excursion symmetrical with respect to grid 27 which will take it beyond grid 28 into the strong accelerating fields of grid 29 and anode 30, to be drawn to the anode. With suitable arrangements a good velocity variation is effected as the electrons move from the cathode to the grid 27 and velocity sorting occurs between the grids 27 and 29. The electrons passing grid 29 are then accelerated toward the anode 30.

The system of Figs. 1 and 2 may be adjusted for operation either as an amplifier, an oscillator or a detector. By using a retarding potential such that substantially all the electrons are turned back in the absence of any high frequency excitations, the system acts as a detector, responding to changes in the amplitude of an impressed high frequency wave. When using the system as a detector the output circuit may be tuned to the input frequency to take advantage of regenerative amplification and the detected output may be received in a suitable device such as a telephone receiver 39.

Amplification is secured when the retarding potential is adjusted to reduce the current, preferably to substantially half of its maximum value,

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in the absence of excitation. With this adjustment the output current will be capable of following the wave form of the impressed wave. To operate the system as an oscillator, feedback coupling may be provided between the output and the input in any suitable manner. Lesser amounts of feedback, insufficient to cause self-oscillations may, of course, be employed to increase the efficiency of a detector, the device operating regeneratively as above-mentioned.

Figs. 3, 4, 5, and 6 illustrate another form of electron discharge device which is particularly well adapted for use in systems according to the present invention. The discharge device is of the type more fully described, and claimed *per se*, in my copending application Serial No. 395,948, filed May 31, 1941, Patent No. 2,403,444, July 9, 1946, assigned to the assignee of the present application. The discharge device comprises an indirectly heated equipotential cathode including a cylindrical metallic sleeve 40 fitted in apertures in a pair of shield plates 50 and coated on its outer surface with a thermionic material, the sleeve enclosing a heater filament 75, shown schematically in Fig. 6. Heating current may be supplied to the filament 75 through conductors 41 extending through apertures in the sleeve 40, as shown in Fig. 5, and through the base plate 51, the conductors 41 being sealed to the base plate by insulating beads 52. The cathode is encompassed by a cage type control grid 76 coaxial therewith, the grid comprising a pair of metallic collars 42 fitted in depressions or apertures in thin insulating plates 43, for example of mica, secured to the shield plates 50, and a plurality of equally spaced parallel wires 44 secured at their ends to the collars 42. The control grid 76 is provided at opposite ends with tapering, strip leading-in conductors 45 which extend midway between a pair of shields 53 and 54 and are connected to conductors 46 joined to two eyelets 55.

The control grid is encompassed in turn by a screen grid 77 which comprises a plurality of metallic laminations 47 apertured adjacent one end to provide circular openings coaxial with the control grid and maintained in parallel relation by metallic spacers 48. The screen grid 77 abuts the insulating members 43 and is seated upon a thin insulating member 49, such as a mica plate, upon the base plate 51, so that the screen is at radio frequency cathode or ground potential. Direct current connection to the screen grid may be established through a leading-in conductor 56 extending through the base plate 51 and hermetically sealed thereto by an insulating bead 57.

Mounted in cooperative relation with the cathode 40 and control grid 76 is an anode, designated generally by the reference numeral 58, composed of two similar halves having joined flanges 62, laterally extending generally triangular portions 63, and intermediate arcuate portions 64 which together define a substantially semicircular electron receiving portion uniformly spaced from and parallel to the cathode and control grid. The laterally extending portions 63 are provided at their outer ends with sockets 65 in which leading-in conductors 66 are secured.

The enclosure of the electron discharge device is completed by an air-tight member 67, which may be of glass, hermetically sealed at its edge to a flanged metallic ring 68, the flange of which is hermetically joined, as by welding, to the base plate 51. The base plate 51 has joined thereto a total of four metallic eyelets 55 through which

pass certain of the leading-in conductors for the electrodes of the device.

Fig. 6 shows, partly in section and partly schematically, the device of Figs. 3, 4 and 5 connected in an amplifying system. A source 120 of waves to be amplified, for example, ultra-high frequency waves, is connected between the outer conductor 69 and inner conductor 74 of a coaxial line serving as the input line. Another coaxial line serving as the output line with an outer conductor 121 and an inner conductor 122 is connected to a utilization device of any suitable kind, represented here by a resistor 123. The input line has a tuning stub 124 in which is fitted a piston 125 of annular form adjustable axially by any suitable means and manipulated, for example, by a knob 126. The grid leading-in conductor 45 is taken out through a quartz insulator 72 in one of the eyelets 55, the insulator being sealed to the conductor 45 and to the eyelet by quantities of silver 73. The fabrication of the seal is described in more detail in my copending application, supra. The conductor 45 is insulated from the inner conductor 74 by a collar 74', which may be of mica, for example. The conductor 45 continues inside the conductor 74 in the form of an insulated wire 74'' and emerges at the end of the tuning stub where it connects to a suitable tap on the battery 33.

The opposite end of the control grid is connected to the inner conductor of a tuning coaxial line through another of the eyelets 55. Similar tuning coaxial lines are provided at both ends of the anode 58, one of which contains an insulated lead connecting the anode to positive terminal of the battery 33. The other anode tuning line connects with the resistor 123. The lead 56 from the screen grid 77 connects to a variable point of a potentiometer 55' by means of which the screen grid potential may be adjusted to a small positive or negative value suitable for best operation.

In accordance with one mode of operation of the system of Fig. 6, the individual electrons emerging from the cathode 40 are variously accelerated by the impressed alternating field between the cathode and the control grid according to the phase of the field to which they are exposed. The slower electrons are turned back by the screen grid which is at substantially the cathode potential. The faster electrons are drawn to the anode. As in the case of the system of Figs. 1 and 2, amplification is best obtained by an adjustment of the biasing potentials such that about half the maximum current reaches the anode in the absence of impressed alternating input potentials. Then the input wave will cause fluctuations above and below the initial anode current to produce a replica in the anode circuit.

In accordance with another mode of operation of the system of Fig. 6, the retarding potential upon the screen grid may be reduced enough to permit substantially all the emitted electrons to proceed to the anode. In this case a drifting action is effected in which the faster electrons overtake the slower ones to form groups or bunches of electrons which give rise to a pulsating anode current. Either mode of operation is facilitated by the parallel plate construction of the screen grid.

Fig. 7 shows an arrangement operating on the principle of electron velocity filtering, and suitable for insertion between tuned coaxial trans-

mission lines. An input section of line with an inner conductor 80 and an outer conductor 81 is shown entering an insulating evacuated envelope 82 through suitable seals. The inner conductor 80 is preferably hollow, at least at the end within the envelope and merges into a fluted cathode 84 shown more clearly in Fig. 8, in cross section viewed from the line 8' in Fig. 7. A section of the outer conductor 81 within the envelope and opposite the cathode 84 is provided with a plurality of axial slots 85, one opposite the center of each concave portion of the cathode. An insulated heating element 86 is supported in an axial position within the cathode 84 in any suitable manner and the ends of the element 86 are brought out through the conductors 80, 81 and through the envelope 82 in any suitable manner, not shown, the connections to the element 86 being insulated from the conductors 80, 81.

Opposite each of the slots 85 is suitably mounted a pair of curved substantially parallel plates 87, 88, which may be of circular cylindrical shape and preferably have a mean circular arc of approximately 127 degrees.

The assembly of plates 87, 88 is enclosed in a hollow conductive corrugated tube 89 as shown, the outer opening between each individual pair of plates 87, 88 being close to one of the corrugations in the tube 89.

At the end of the envelope 82 opposite the input transmission line 80, 81 there is sealed an output coaxial transmission line with inner conductor 90 and outer conductor 91. The inner conductor 90 terminates inside the envelope 82 where it is conductively connected to the assembly comprising the plurality of plates 87, 88 through biasing means as hereinafter more fully described. The outer conductor 91 flares to merge with the tube 89 but is insulated therefrom by a suitable coupling section 97.

In the operation of the system of Figs. 7 and 8 the element 86, when heated, serves to heat the cathode 84 and by virtue of the shape of the fluted surface of the cathode 84 a sheet of electrons is emitted and focussed to pass through the slot 85, there being a sheet of electrons for each slot 85.

The operation of the various elements of the tube will be more readily understood from Fig. 9 which is a schematic diagram including the connecting circuits. The anode element 89 is placed at a relatively high positive potential with respect to the cathode 84 by means of the combined voltages of batteries 92, 93, and 96 preferably through an inductive element 94', which latter, at ultra-high frequencies, may comprise merely the inductance of a short length of lead. The plates 87, 88 are biased to slightly different potentials with respect to the junction point between the batteries 92 and 93 by means of batteries 94 and 95, respectively, or by other suitable means. The potential difference between the cathode 84 and the grid 85 is adjusted to a small positive or negative value by means of a potentiometer across the battery 96. It will be understood that any or all of the batteries shown may be replaced by any suitable sources of direct electromotive force. Electrodes 85, 87 and 88 are preferably connected together for high frequencies by means of built-in by-pass condensers.

A high frequency wave to be amplified may be impressed upon the input transmission line 80, 81 by a suitable source 98 and the output transmission line may be connected with a load represented by a resistor 99. The input line and the

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associated cathode and heater leads are represented in Fig. 9 by an equivalent transformer 130 tuned by a condenser 131. The source 98 will set up a pulsating potential difference between the cathode 84 and the grid 85 thereby impressing a succession of velocity variations upon the electrons in the stream emerging from the cathode. Depending upon the fixed potential difference between the plates 87 and 88 the electrons will follow various curved paths in the space between the plates under the influence of the transverse electric field therebetween. Within a certain narrow range of velocities all the electrons entering the space between the plates with such velocities will emerge at the far end without striking either of the plates and be drawn to the anode 89. Electrons having velocities below the critical range will strike the plate 87 and electrons having velocities greater will strike the plate 88. Hence, if the system is adjusted so that the potential differences impressed by the input waves are such as to vary the electron velocities through the critical range, the electron current to the anode 89 will be varied, thereby generating a high frequency current in the output circuit. It will be evident that the high frequency component of the output current will be transmitted to the load 99 through the output transmission line 90, 91. It will be evident that the system may be adjusted to give either one or two output pulses for each cycle of the input wave, thereby giving either amplification or frequency doubling, the latter adjustment being similar to the adjustment for a detector.

The arrangement of Figs. 7 and 8 is claimed in my copending application Serial No. 516,290, filed December 30, 1943, assigned to the assignee of the present application.

An alternative arrangement operating on the same principle as the system of Figs. 7, 8 and 9 is shown in Figs. 10 and 11. The arrangement of the elements is seen most readily in Fig. 11, showing a section on the line 11' in Fig. 10. The cathode 101 has but two active surfaces both of which are fluted as are the surfaces of the cathode 84 in Fig. 8. A pair of focussing electrodes 102 and 103 are provided between the cathode 101 and enlargements 104 and 105, respectively, of a pair of concentric cylinders 106, 107. The non-enlarged portions of the cylinders 106, 107 form a pair of arcuate velocity filtering elements, one on either side of the cathode 101. The arc subtended by each filtering element is again preferably approximately 127 degrees. A common anode 108 is provided enclosed by enlargements 109 and 110, respectively, of the cylinders 106 and 107. A heating element 111 is provided within the hollow interior of the cathode 101, the ends of the element 111 being suitably brought out through a hollow inner conductor 112 forming part of an input coaxial line, shown at the right of Fig. 10 and having an outer conductor 113. The inner conductor 112 is conductively connected to the cathode 101. The outer conductor 113 flares to merge into the enlargement 104. The anode 108 merges with the inner conductor 114 of an output coaxial line of which the outer conductor 115 is flared to merge with the enlargement 109. Any suitable means may be provided to support the coaxial lines and the various electrodes and the assembly may be suitably enclosed by a vacuum-tight insulating envelope 116, the latter serving incidentally as a support. For example, the outer conductor 113, enlargement 104, cylinder 106, enlargement 109 and outer conductor 115 may be

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integral and supported by the envelope surrounding the conductor 115 at the left and the conductor 113 at the right. The cathode 101, electrodes 102 and 103, and cylinder 107 may be supported by the conductor 112 properly sealed into the envelope, and the leads from the heater 111, and from the other electrodes comprising members 101, 102, 103, 107 may be brought out through the hollow interior of conductor 112. The anode 108 may be supported by the conductor 114 properly sealed into the envelope. Built-in by-pass condensers are preferably provided connecting elements 102, 103, 105, 106 and 107 together for high frequencies.

In the operation of the system of Figs. 10 and 11, with suitable biasing potentials applied, a sheet of electrons emerges from either side of the cathode 101, passes through the slots in the focussing electrodes 102 and 103 and enters the space between the cylinders 106 and 107. In the critical range of electron velocities the sheet of electrons reaches the anode 108. At other electron velocities the electrons are intercepted by one or the other of the cylinders 106 and 107, as described in connection with Fig. 9.

What is claimed is:

1. A retarding potential system for detecting velocity variations in a stream of negatively charged particles comprising a space discharge device having a pair of grids located one beyond the other in the space intermediate between a cathode and an anode, the first of said grids in order beyond said cathode being adapted to be biased at a positive potential with respect to said cathode and the second of said grids being adapted to be biased in the neighborhood of the cathode potential and thus to provide a retarding electric field, the spacing between said first and second grids being materially less than the spacing between said cathode and said first grid to provide a quarter cycle transit time between said first and second grids, and a half cycle transit time between said cathode and said first grid.

2. A space discharge system comprising a cathode to supply negatively charged particles, an anode, first and second grids arranged in succession in the order named between said cathode and anode, means connected between said cathode and said first grid to bias said first grid at a substantially constant initial positive potential with respect to said cathode, means connected between said cathode and said second grid to bias said second grid at a substantially constant potential in the immediate neighborhood of the cathode potential to provide a retarding potential for negatively charged particles passing said first grid and approaching said second grid, means connected between said cathode and said first grid to velocity vary charged particles in the space between said cathode and said first grid whereby at least a portion of said particles are accelerated and thereby passed beyond said second grid in groups in accordance with the action of the said velocity varying means, and means connected between said second grid and said anode to impress a substantially constant accelerating potential upon said anode with reference to said second grid to accelerate negatively charged particles passing beyond said second grid thereby producing an output current flowing to the anode, the spacing between the cathode and the first grid corresponding to a transit time substantially equal to one-half cycle at the operating frequency to promote efficient velocity variation.

3. The system as in claim 2 in which the spac-

ing between the first and second grids corresponds to a transit time materially shorter than that between the cathode and the first grid.

4. The system as in claim 2 in which the spacing between the first and second grids corresponds to a transit time equal to substantially one-quarter cycle at the operating frequency.

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