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ELECTRON DISCHARGE TUBES

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FIG.1.

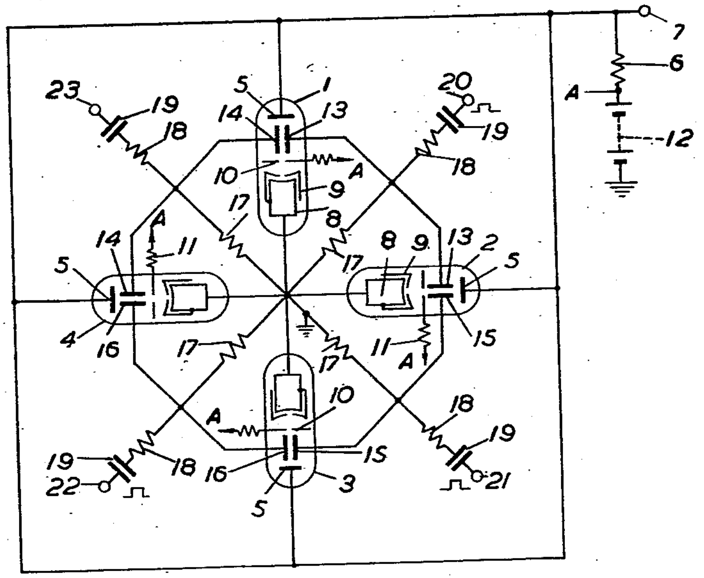
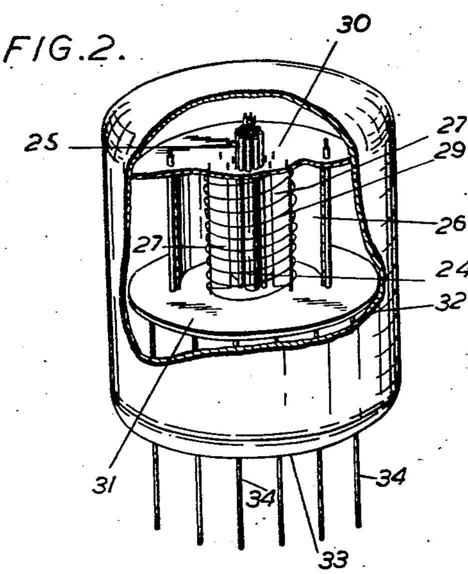


FIG.2.



Inventor
A. H. W. BECK -
A. D. BRISBANE
By Philip M. Bolton
Attorney

FIG. 3.

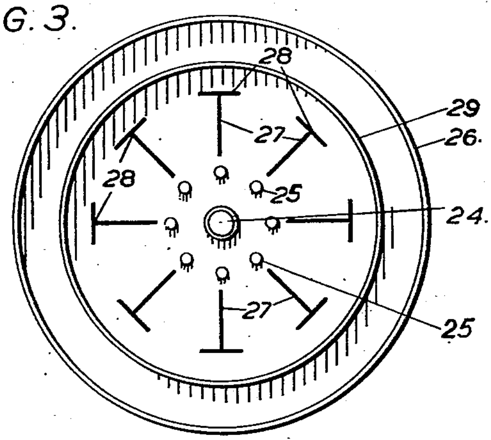
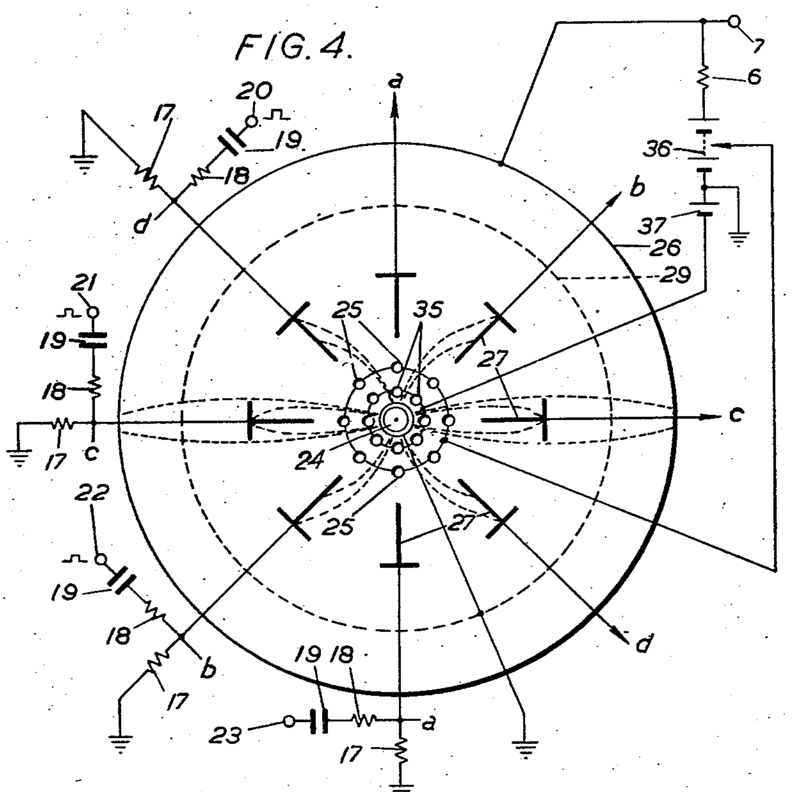


FIG. 4.



Inventor
A. H. W. BECK -
A. D. BRISBANE
By Philip M. Bolton
Attorney

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ELECTRON DISCHARGE TUBES

Arnold Hugh William Beck and Alan Douglas Brisbane, Aldwych, England, assignors to International Standard Electric Corporation, New York, N. Y.

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7 Claims. (Cl. 315—21)

The present invention relates to electric current control devices in which a plurality of current paths feeding a common output are controlled by potentials applied to elements associated with the several paths. In particular the invention relates to electric circuit arrangements for recognising the coincidence of several potentials separately applied to the said control elements.

It is frequently required in the electric switching and computing arts that a circuit shall be operated when and only when a number of independent conditions occur simultaneously. To deal with the coincidence of two separately appearing pulses many circuits have previously been proposed using ordinary types of thermionic valves capable of operating at high repetition frequencies. At lower frequencies multi-electrode gas-filled trigger tubes may be used, types of which have more recently been developed for dealing with several coincidences, while multi-coincidence circuits using silicon or germanium rectifiers have also been proposed.. The latter circuits invariably involve considerable power loss in their application and tend either to be limited as regards maximum repetition frequency or are unduly expensive and complicated.

It is an object of the present invention to provide an arrangement in which the coincidence of several independently occurring conditions may give rise to a relatively large output current so as to obtain a power or voltage gain while being capable of operation at very high repetition frequencies.

According to the present invention there is provided an electric current device having a plurality of current paths feeding common output and control terminals each associated with a said path but not directly with all output current flowing in all of said paths when like positive potentials within a given range of potentials are applied to all said terminals, but, when any one said terminal is at a lower potential, the said like potential being applied to the remainder, the output currents in paths both directly and not directly associated with the said terminal are reduced.

In carrying out the invention it is arranged that as the potential applied to one terminal is reduced, the current in the directly associated path is deflected from the output and is made to reduce the effective potentials applied to control elements of other paths from the terminals directly associated with them. The currents in these paths are at least partially deflected from the output and tend in turn to react upon further paths. In a device according to the invention having but four or five separate current paths and a corresponding number of terminals, it is thus possible for the reduction of applied potential at one terminal to react upon all the current paths, but in the case of large numbers of paths and terminals it is not to be expected that the current in a remotely coupled path will be appreciably reduced.

In practice we make use of electron beams to provide the output current and control the current flow along individual electron beam paths by means of potentials applied to control electrodes associated therewith.

According to a further aspect of the invention, therefore, there is provided an electric circuit arrangement comprising means for projecting a plurality of electron beams each towards an anode connected to a common output and means providing an electron gate in the path of each said beam said means including a set of control electrodes such that the closure of any one gate due to the potential of an associated control electrode being lower than that of others of the said set, the potentials of all control electrodes lying within a given range, causes other said gates to be at least partially closed.

Preferred embodiments of the invention utilise a novel type of electron discharge tube and a further feature of the invention is the provision of an electron discharge tube comprising electrode means for projecting a plurality of electron beams along respective paths towards a common anode and a control electrode between each pair of said beams arranged so that when all said control electrodes are at a given low potential all the said beams are each substantially reflected back upon their respective fellows, when all said control electrodes are at a given higher potential all said beams flow to the said anode without substantial interception by any said control electrode, while when any adjacent two said control electrodes are at appreciably different potentials within the range bounded by the said given potentials, the electron beam whose path to the anode lies between them is deflected at least in part onto the control electrode of higher potential, the last mentioned control electrode collecting substantially all the deflected beam when the said different potentials are at the respective limits of the said range.

Using a novel electron discharge tube as specified above the invention provides an electric circuit arrangement comprising beam forming means for projecting a plurality of radial electron beams from a central cathode towards a surrounding anode through a corresponding plurality of electron gates formed by and between adjacent members of a set of control electrodes equally spaced about the said cathode, each said control electrode being connected through a corresponding shunt impedance to the said cathode and through a series impedance to a separate source of positive pulses, the arrangement being such that in the absence of a said pulse on any control electrode the said electron beams are all reflected by the said electron gates, with a positive pulse applied to some, but not all, control electrodes respective electron beams are deflected in their electron gates towards, and are at least in part collected by the control electrodes positively biassed by the said pulses, thus reducing the effective amplitude of the said pulses and still restricting the flow of electron current to the said anode, while with a said positive pulse applied to each control electrode the electron beams pass through their respective electron gates to be collected by the said anode without any substantial interception by any said control electrode.

The invention will be described with reference to the accompanying drawings in which:

Fig. 1 shows a circuit arrangement according to the invention utilising a separate electron discharge tube for each current path;

Fig. 2 shows a view in part section, with some of the electrodes removed to show the construction, of a single tube according to the invention suitable for replacing the several discharge tubes of Fig. 1;

Fig. 3 shows a diagrammatic plan view of the electrode system of Fig. 2, and

Fig. 4 shows a preferred circuit arrangement according to the invention.

Fig. 1 shows four similar electron beam tubes **1**, **2**, **3** and **4** each of whose anodes **5** are connected to a common load resistance 6 and an output terminal 7. Each tube has a conventional electron gun shown as consisting of a cathode 8, focussing cylinder 9 and accelerating electrode 10. The cathodes 8 and focussing cylinders 9 are connected together and to ground. The accelerating electrodes 10 are indicated as being connected through individual series resistors 11 to the point A at the junction of load resistor 6 and a high tension source 12. The other end of the source 12 is grounded. In each tube the beam path to the anode 5 passes between a pair of deflecting plates which are indicated by the reference numerals 13 and 14, 13 and 15, 15 and 16, 16 and 14 respectively.

The deflecting plates having like reference numerals are connected together to ground through resistors each denoted 17 and through series resistors each denoted 18 and D. C. blocking condenser each denoted 19 to respective pulse input terminals. The pulse input terminals associated with deflecting plates 13, 15, 16 and 14, respectively, are identified by the reference numerals 20, 21, 22 and 23 in that order. In each tube the electrodes are so positioned and dimensioned and the supply voltages are so arranged that the deflecting plates function as control electrodes forming an electron gate which is closed to the electron beam when the deflecting plates are held at or below cathode potential through the resistors 17 and which gate is fully open when both deflecting plates are raised to a given higher potential. When both deflecting plates are at or below cathode potential the gate acts to reflect the electron beam back along its path due to the retarding potential of the deflecting plates. When, however, the deflecting plates are held at different potentials, as by the application of a positive pulse to one but not to the other, the electron beam is deflected to fall on the more positive plate. It should be arranged that when one plate is held at or below cathode potential and the other has applied to it a potential which would be sufficient, if applied to both plates, to fully open the electron gate between them, then substantially all the electron beam current is collected by the more positive plate.

It will be seen that if all the four input terminals are left unenergised, all the electron gates are closed and negligible current will flow through the output load 6. Similarly, if a positive pulse of the said given higher potential is applied to each input terminal all the electron gates are fully opened and maximum current will flow through the output load 6.

Let it be assumed, as indicated in Fig. 1, that like positive pulses are applied to terminals 20, 21 and 22, but no such pulse is applied to terminal 23. In the tube 1 electrode 13 will be raised initially to a potential a little lower than the amplitude of the pulse applied to the terminal 20, the resistors 18 and 17 reducing the amplitude somewhat, while electrode 14 is at cathode potential. In consequence the electron beam in tube 1 will be collected by the electrode 13 as indicated by the dotted line representing the electron beam path. Similarly, in tube 4 the electron beam will be substantially collected by electrode 16. These electron beams constitute low impedance paths across the respective shunt resistors 17 so that the potential of electrodes 13 and 16 fall to a small fraction of the pulse amplitude. Considering, now, tube 2, the potential on electrode 15 is higher than that of electrode 13 whose potential has been reduced as just explained. The electron beam in tube 2 will therefore be deflected towards electrode 15, and dotted lines indicate that it is in part collected by that electrode. A similar result obtains in tube 3 so that, here again, the electron current to electrode 15 shunts the associated resistor 17 and reduces the positive potential on electrode 15. Thus the anode current in tubes 2 and 3 is reduced, not only by the partial collection of the electron beam on the electrodes 15, but also by the reduction of the positive potential of all the control electrodes 13, 15 and 16. Thus the absence of the positive pulse on terminal 23 has not only reduced the output current through the load 6 by closure of the electron gates in the tubes 1 and 4 and the partial collection of the beams in tubes 2 and 3, but has also reduced the amplitude of the positive pulses reaching control electrodes 13, 15 and 16.

It will be seen, in the arrangement of Fig. 1, that even when three out of the four available inputs are energised, the output current is less than one half the maximum current obtained when all inputs are energised. In the same way it will be seen that with two adjacent terminals unenergised the anode current will be less than one quarter of the maximum output, while if two opposite terminals are unenergised the anode current may be substantially cut off. Similarly, if only one terminal is energised negligible output is obtained. It will also be realised that more than four inputs can be catered for by the provision of an appropriate number of additional similar tubes, and thus analogous results will be obtained.

Rather than use separate tubes for each electron beam, we prefer to replace the several tubes of Fig. 1 by a single tube of novel construction which combines in one envelope the basic beam forming elements and control electrodes of the separate tubes 1 to 4. The construction of such a tube is shown somewhat diagrammatically in Figs. 2 and 3. The tube comprises a central cathode 24 surrounded by a squirrel cage formation of accelerating grid wires 25 and a coaxial anode 26. The control electrodes take the form of radial vanes 27 mounted behind the respective grid wires 25. The rear ends of the vanes 27 are provided with flanges 28 projecting at right angles on either side of each vane. These flanges render the electrodes more efficient as electron collectors and assist in controlling the electric field within the electron gates formed between adjacent vanes. In Figs. 2 and 3 we have also indicated a helical screen grid 29 between the ends of the vanes and the anode, which makes the operation of the gates quite independent of the value of the anode potential. The screen grid is normally connected to the cathode. The electrode structure is mounted in conventional manner between mica locating washers 30 and 31. The assembly is mounted within a conventional glass envelope 32 having a glass base 33 through which lead wires 34 are sealed in normal manner. The tube shown in Figs. 2 and 3 has eight control electrodes and eight electron beams. In Fig. 2 some of the control electrodes have been removed in order to show the construction of the remainder of the assembly. It will be seen that the tube provides the essential elements of the several tubes shown in Fig. 1 but, instead of there being pairs of control electrodes connected together as in Fig. 1, each control electrode serves for two adjacent electron beams.

The mode of operation of a tube such as is shown in Figs. 2 and 3 is entirely similar to that explained in connection with the arrangement of Fig. 1, the analogous circuit being shown in Fig. 4 where an eight beam tube is represented having opposite control electrodes connected together to form an arrangement with four input terminals as in the arrangement of Fig. 1.

In Fig. 4 electrodes are identified by the same reference numerals as in Figs. 2 and 3 but an additional squirrel cage set of grid wires 35 is shown between the cathode 24 and grid 25. The grid wires 35 are positioned in line with the accelerating grid wires 25 and are connected together to form a control grid whose use assists in beam focussing and reduces current to the vanes 27 and to the grid wires 25 when the electron gates are fully open.

The circuit components connected to the control electrodes 27 in Fig. 4 which are the same as in Fig. 1 are identified by the same reference numerals. The anode 26 is connected as in Fig. 1 to the output terminal 7 and load resistor 6. For the battery 12 of Fig. 1 a battery 36 has been substituted in Fig. 4, the accelerating grid wires 25 being fed from a tapping point on this battery. The grid wires 35 are shown biassed negative with respect to ground by means of the battery 37. To avoid confusing the diagram, arrows *a*, *b*, *c* and *d* are indicated to denote connections from the respective control electrodes to correspondingly lettered points in the networks connected to the respective terminals 20—23.

As in Fig. 1, it is assumed that like positive pulses are applied to terminals 20, 21 and 22 but that terminal 23 is left unenergised. Electron beams are each indicated by a pair of dotted lines. The control electrodes connected to terminals 20 and 22 are represented as receiving and collecting the whole of the electron current to one side of them, while the control electrodes associated with terminal 21 are indicated as receiving part of the respective beams to either side of them, the remainder of these beams being collected by the anode 26. The electron gates to either side of the control electrodes connected to terminal 23 are indicated as being fully closed.

For purposes of illustration we quote below electrode dimensions of tubes such as indicated in Figs. 2 and 3 together with the details of operation in a circuit similar to Fig. 4. The tube for which results are given includes a screen grid 29, but no control grid wires 35.

The cathode 24 is indirectly heated and has a sleeve 2.5. mm. dia. and length 2.4. cm. with a central length of 12 mm. coated with electron emissive material. The accelerating grid wires 25 are each of 0.51 mm. diameter and are equally spaced about the cathode on a pitch circle of approximately 4 mm. diameter, eight such wires being welded at one end to a circlip not shown on the drawings.

The control electrodes are constructed by folding 0.127 mm. thick nickel strips to the required form, so that the flange portions 28 project 0.27 mm. from the centre of the vane portion 27. A control electrode is placed behind each accelerating grid wire 25 so that its ends lie on pitch circles of respective diameters 5.3 and 10.9 mm. approximately. The screen grid 29 is formed of .013 mm. diameter wire, formed into a helix of approximately 6.3 turns per cm. and of mean diameter of the order of 15 mm. The surrounding anode is formed of sheet metal approximately 19 mm. in diameter.

The following values of circuit components and operating voltages were used with an experimental tube dimensioned as above:

Load resistor 6	39,000ω.
Series resistors 18	150,000ω.
Accelerating grid potential	+1.5 volts.
Anode potential (zero anode current)	+300 volts.

Screen grid 29 connected to cathode and ground.

The following results were obtained when 1 μsec. input pulses of approximately square waveform of 35 volts amplitude were applied to various input terminals:

Number of terminals energised	Output voltage at terminal 7
8	266
7	89
6	34

With two or more terminals unenergised the output pulse amplitude depended upon the relative positions of the idle inputs, being least when, as far as possible, the idle terminals were equally spaced around the tube. If it is desired to utilise an eight input electrode valve to indicate a number of coincidences smaller than eight, the idle terminals are connected to a D. C. source of the same positive potential as the pulses which occur on the active terminals. The tube may thus be used for indicating e. g. five coincidences by taking three terminals through the associated resistance networks to a point held at 35V positive to cathode.

When, as in Fig. 4, only four inputs are required, the discrimination obtained is greatest when opposite control electrodes are connected in parallel. Clearly for only two inputs the alternate electrodes can be strapped together.

The minimum pulse width thus can usefully be used and the maximum repetition frequency at which the tube will operate consistently depends upon the interelectrode and circuit capacities and electron transit times involved. In the tube whose dimensions are given above the relevant average interelectrode capacities are:

	pF
Input capacity per electrode	3.5
Output capacity in valve socket	6.0

Ratios of output voltages not differing appreciably from the results quoted above have been obtained with pulse repetition frequencies of 200 kc./s., using 1 μsec. pulses. The maximum frequency is limited by the anode-ground capacitance and anode load resistor in the ordinary way. If operation at high frequencies is desired the load resistance is reduced and the current increased by increasing the accelerating grid potential to compensate for the reduced voltage across load resistor 6. For the values given 1 μsec. is about the minimum permissible pulse duration. The maximum repetition frequency with this tube has not yet been determined, but is considerably higher than 200 kc./s.

While the principles of the invention have been described above in connection with specific embodiments, and particular modifications thereof, it is to be clearly understood that this description is made by way of example and not as a limitation on the scope of the invention.

What we claim is:

1. An electric circuit arrangement comprising means including a cathode for projecting a plurality of electron beams each along a given separate path, anode means positioned at the end of each path, said anode means having a single output, a plurality of means each controlling one of said beams and including a pair of control electrodes mounted adjacent each path on opposite sides thereof between said beam projecting means and its associated anode means and responsive to equal voltages below a given value on each of the electrodes of its said pair for cutting off the beam and responsive to equal voltages above a given value on each of the electrodes for projecting the beams onto said anode means, each of said control means being responsive to unequal voltages on the electrodes of its pair to deflect the beam to impinge on one of its electrodes, conductors connecting each electrode of each pair to one and only one separate electrode of a separate pair and impedance means connected between each of said conductors and said cathode whereby the impingement of its beam on an electrode of said beam controlling means reduces the voltage of the control electrode to which it is connected, if said voltage is above said given value, and a separate input connection to each of said conductors.

2. An electric circuit arrangement comprising means including a cathode for projecting a plurality of electron beams each towards anode means connected to a single output and means providing an electron gate in the path of each said beam, said gate means including control electrodes positioned on opposite sides of said beams, impedance means interconnecting said cathode and said control electrode for normally maintaining said control electrodes at a common potential whereby said gates are in a predetermined condition, means for applying control potentials differing from said common potential independently to said control electrodes tending to change the condition of said gates, whereby a difference in potential exists between adjacent control electrodes except when no control potential is applied and when the same control potential is applied to all said control electrodes and whereby said beams are deflected toward the positive electrode of said adjacent electrodes for at least partial

interception when a difference in potential exists between said adjacent control electrodes.

3. An electron discharge tube comprising electrode means for projecting a plurality of electron beams along respective paths, a common anode positioned in the respective paths of said beams and a single control electrode between each pair of beams and intermediate said projecting electrode means and said anode, whereby each beam passes between control electrodes, means for applying a given low potential to all said control electrodes whereby all said beams are substantially reflected back toward said projecting means, and means for selectively applying to said control electrodes a given higher potential than said low potential whereby in response to all said control electrodes being at said higher potential all said beams flow to said anode without substantial interception by any control electrode, while in response to any adjacent two of said control electrodes being at appreciably different potentials within the range of said given potentials the electron beam whose path lies between said two electrodes is deflected, at least in part, onto the control electrode of higher potential so that said electrode of the higher potential collects substantially all of the deflected beam when the said different potentials are substantially at the limit of their range and impedance means interconnecting each said control electrode and said low potential applying means effectively to lower the potential of said control electrode collecting said beam.

4. An electric circuit arrangement comprising beam forming means for projecting a plurality of radial electron beams from a central cathode toward a surrounding anode, a plurality of control electrodes equally spaced about said cathode on opposite sides of said beam intermediate said cathode and said anode, said successive control electrodes forming a corresponding plurality of electron gates, a corresponding shunt impedance connected between each said control electrode and said cathode and a series impedance connected to each said control electrode and to separate sources of positive potential pulses, the potential being of value that in the absence of any of said pulses on said control electrodes the said electron beams are all reflected back toward said cathode by said electron gates, said shunt impedances serving in response to a positive pulse applied to some but less than all said control electrodes respective electron beams to deflect said beams toward the control electrodes positively biased by said pulses, to reduce the effective amplitude of said pulses and to restrict the flow of electron current to said anode while in response to said positive pulses being applied to each control electrode the electron beams pass between the control electrodes forming the electron gate to said anode without any substantial interception by said control electrodes.

5. A discharge tube according to claim 3, wherein said electron beam source comprises a central cathode and accelerating grid wires parallel to and spaced coaxially about said cathode in a squirrel cage formation, and said control electrodes comprise a plurality of vanes aligned radially with said accelerating grid wires, and further comprising a helical screen grid surrounding said vanes, said anode coaxially surrounding the aforementioned electrodes.

6. A discharge tube according to claim 5 in which said vanes are each provided at their radial ends remote from the cathode with flanges projecting to either side of the radius of the vanes.

7. A discharge tube according to claim 5 further comprising a squirrel cage formation and control grid wires adjacent said cathode and aligned with said vanes.

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