Dec. 14, 1937. A. G. THOMAS 2,102,045

ELECTRON DISCHARGE TUBE

Filed May 13, 1936 3 Sheets-Sheet 1

Fig. 1

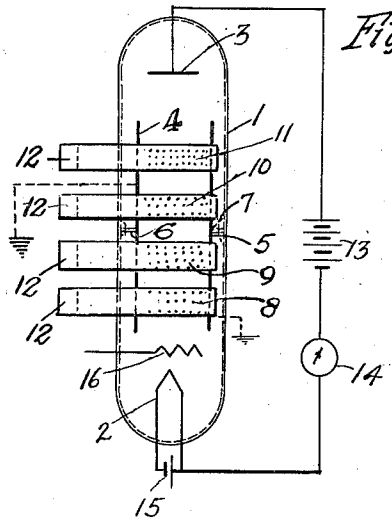


Fig. 2

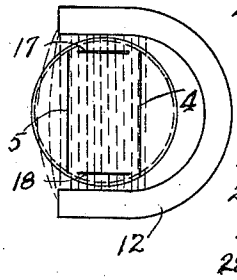


Fig. 3

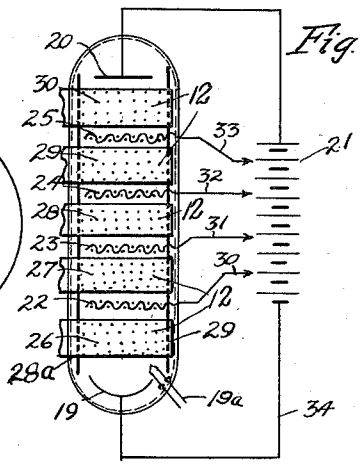


Fig. 4

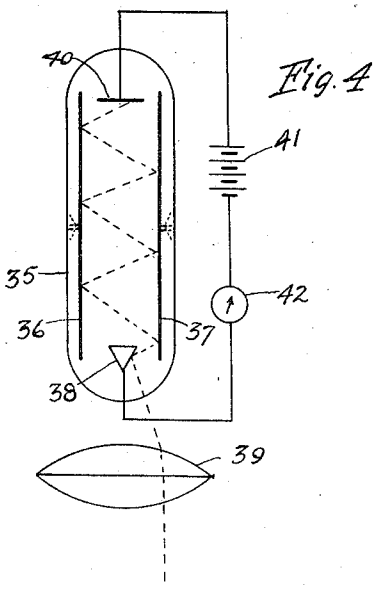


Fig. 5

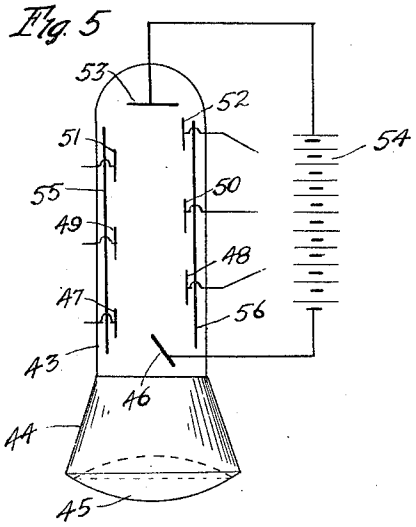
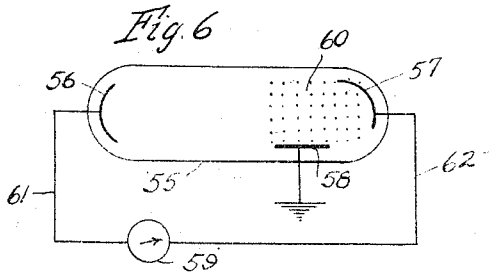


Fig. 6



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Fig 7

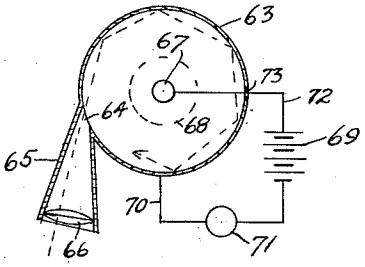
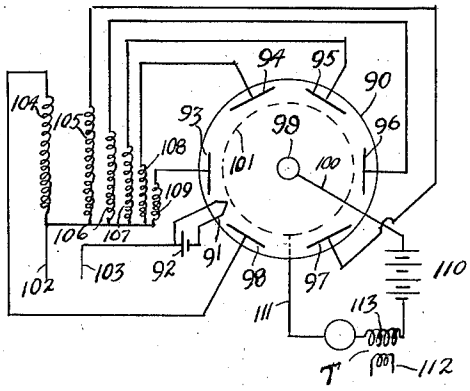


Fig. 10



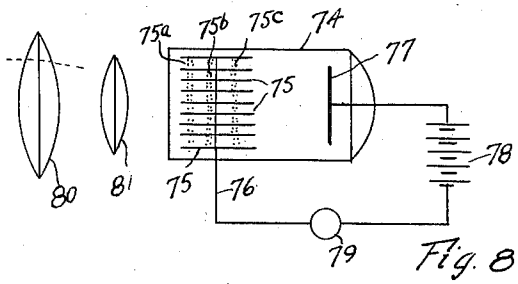


Fig. 8

Fig. 9

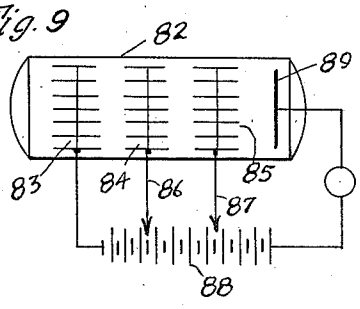


Fig. 11

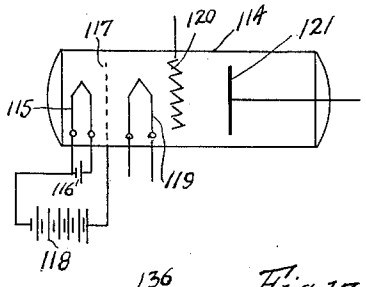


Fig. 12

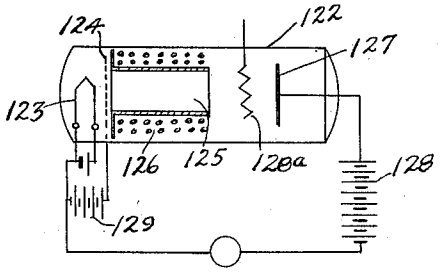
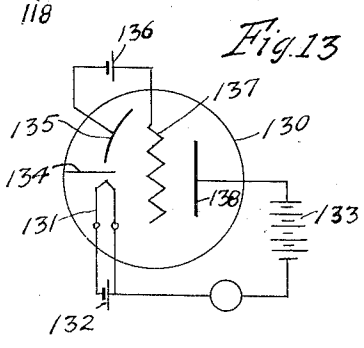


Fig. 13



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Fig. 14

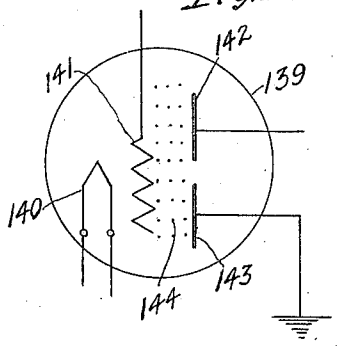


Fig. 15

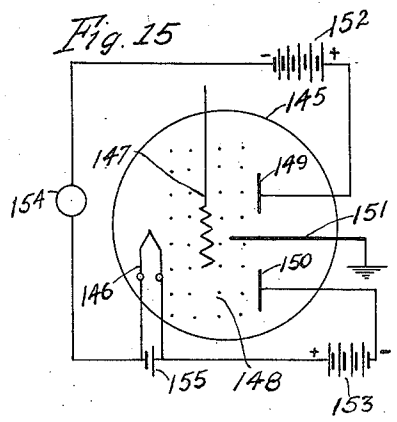


Fig. 16

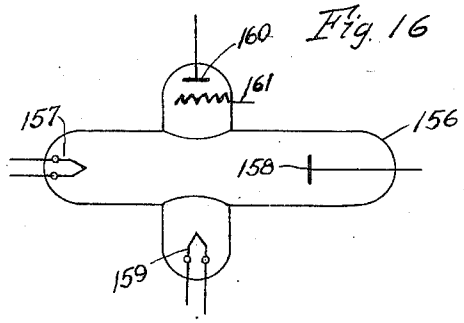


Fig. 18

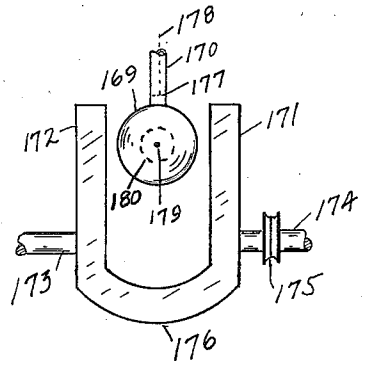
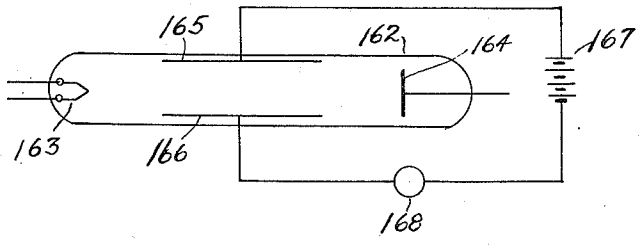


Fig. 17



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Patented Dec. 14, 1937

2,102,045

UNITED STATES PATENT OFFICE

2,102,045

ELECTRON DISCHARGE TUBE

Albert G. Thomas, Lynchburg, Va.

Application May 13, 1936, Serial No. 79,420

3 Claims. (Cl. 250—27.5)

This invention relates to vacuum tubes such as electron discharge tubes and phototubes which are used in radio, television, and for many other purposes.

An object is to provide a vacuum tube in which the advantages of secondary emission are easily utilized.

Another object is to provide a phototube in which successive reflections from photo-emissive surfaces are employed to increase the electron output.

A further object is to design a phototube combined with light gathering means, to increase the sensitivity of the tube.

An additional object is to design a phototube of many photo-emissive surfaces to increase the output of the tube.

Another object is to provide a self generating phototube, requiring little or no outside source of potential.

A still further object is to provide a combined phototube and filament tube designed so that the photo-emitted electrons will control the filament emitted electrons.

An additional object is to provide a tube in which gaseous ionization can be utilized efficiently.

Other objects will appear in the following description.

In the drawings:

Figure 1 is an elevation of a filament type vacuum tube with magnetic fields and secondary electron emitting plates.

Figure 2 is an end view of electron-emitting plates similar to those of Figure 1, and showing the position of one of the permanent magnets used with the tube of Figure 1 to produce the magnetic fields shown in that figure.

Figure 3 is an elevation of a phototube using secondary electron-emitting plates, magnetic fields to deflect the electrons, and charged screens to move the electrons toward the anode plate.

Figure 4 is an elevation of a phototube employing light reflections between photo-emissive surfaces, to increase the electron output.

Figure 5 shows an elevation of a phototube combined with a lens for gathering light.

Figure 6 shows an elevation of a vacuum tube with a photo-emissive cathode, a photo-emissive anode, and a deflecting magnetic field to assist in building up a potential difference between the cathode and anode.

Figure 7 is a part sectional view of a closed phototube with inner surface coated with photo-emissive material. A light gathering lens and an opening for admitting light are shown.

Figure 8 is an elevation of a phototube with a cathode composed of a plurality of plates.

Figure 9 is an elevation of a phototube with a series of cathodes composed of a plurality of plates.

Figure 10 is a plan view of a filament cathode tube employing phase charging of plates to rotate electrons and so to produce secondary electrons.

Figure 11 is an elevation of a vacuum tube employing bombardment of a gas by electrons from an auxiliary filament.

Figure 12 is a part-sectional elevation of a vacuum tube with an auxiliary tubular cathode to produce secondary electrons under electronic bombardment.

Figure 13 is an elevation of a combined filament cathode and photo-emissive cathode tube.

Figure 14 is an elevation of a vacuum tube employing a deflecting magnetic field and two plates, one of them being grounded.

Figure 15 is an elevation of a vacuum tube with a grounded shield between two plates, one of which is positively charged and the other negatively charged with respect to the cathode.

Figure 16 is an elevation of a vacuum tube employing a cross stream of electrons to control the main electronic stream.

Figure 17 is an elevation of a filament-cathode tube employing ionized gaseous conduction between charged plates.

Figure 18 is an end view of a tube with an associated rotatable magnet for deflecting air ions out of the tube.

The various tubes shown are represented diagrammatically and therefore well known details of construction such as press seals, element supports, and other conventional details will not be described for the most part.

In Figure 1 tube 1 has filament cathode 2 and plate anode 3. Parallel plates 4 and 5 are supported by rods 6 and 7 pressed into the cylindrical wall of tube 1. The inner surfaces of plates 4 and 5 are coated with some suitable substance such as barium oxide or the like so that several secondary electrons will be emitted from these plates when they are struck by an electron. Magnetic fields 8, 9, 10 and 11, seen endwise and extending across the cross-sectional area between plates 4 and 5 as shown, are provided by a series of permanent magnets 12, preferably, placed at different positions along the length of plates 4 and 5 and positioned as

shown in Figure 2. Each succeeding magnetic field is reversed in direction to the field preceding it so that electrons given off by filament 2 and attracted by plate 3, made positive with respect to filament 2 by battery 13, will be alternately deflected against plate 4 and plate 5 so that the electrons will strike these plates a number of times before reaching plate 3. In addition the secondary electrons produced will also be deflected back and forth between plates 4 and 5 so that the effect will be cumulative, with the result that a large current will pass through the output element 14, which may be a transformer or any other suitable device. Battery 15 supplies current for filament 2 and grid 16 may be provided to control the filament produced electrons. Plates 4 and 5 may be grounded to prevent the building up of positive charges on them, if desired.

Filament 2 may be replaced by a photo-emissive cathode instead. Plates 17 and 18, similar to plates 4 and 5, may be provided to catch any stray electrons ejected in an upward or downward direction. Iron plates may be placed between the magnets to act as shields to separate the fields, if desired.

In Figure 3 a similar principle is employed except that electrons are pulled from photo-emissive cathode 19 by screens 22, 23, 24 and 25 placed across the cross-sectional area between plates 28*a* and 29 as shown but insulated from these plates. The negative terminal of battery 21 is connected to cathode 19 and the positive terminal to anode plate 20 and screens 22, 23, 24 and 25 are connected to battery 21 by wires 30, 31, 32, and 33 respectively, to charge the aforesaid screens at successively higher potentials with respect to cathode 19 so that electrons given off from cathode 19 under influence of light or otherwise, will be attracted by the screens through magnetic fields 26, 27, 28, 29 and 30, produced by magnets 12*a*, alternately of opposite polarity so that the cathode-emitted electrons as well as secondary electrons will be deflected back and forth from plate 28*a* to plate 29 and vice versa until all the electrons are finally attracted to plate 20 of highest potential.

Therefore, light falling upon photo-emissive cathode 19 will produce large currents in circuit 34 which may be connected in well known manner to any suitable device. The plates 28*a* and 29 are coated with a suitable substance for producing secondary electrons under bombardment of primary electrons. Such substances as barium oxide, strontium oxide, etc., are well known for this purpose. Cathode 19 may be coated with a cesiated layer or other well known substance which will eject electrons under influence of light. Filament 19*a* may also be employed as an additional source of electrons.

It is obvious that either one of the plates 4 or 5 in Figure 1 or either one of the plates 28*a* or 29 in Figure 3 may be eliminated since the alternate magnetic fields will cause the electrons to be repeatedly curved against one surface even though the opposing surface is absent. The two surfaces are preferable however since they will produce more secondary electrons than the one surface.

In Figure 4 tube 35 has parallel plates 36 and 37 supported similarly to plates 4 and 5 of Figure 1. Wedge-shaped cathode 38 is suitably supported in tube 35 and is coated with potassium hydride or a caesium compound or with any suitable substance that emits electrons under influence of light. The inner surfaces of plates 36 and 37 are similarly coated. Anode plate 40 is connected to the positive terminal of battery 41, the negative terminal being connected to cathode 38. Element 42 may be included in the output circuit for any desired purpose. Lens 39 is placed so that it will gather a large amount of light and concentrate it on the inclined faces of cathode 38 so that a large number of electrons will be liberated from this cathode, since the number of electrons emitted is substantially proportional to the intensity of the light striking the cathode.

Cathode 38 is also smoothly coated so that it will readily reflect light so that the light rays will be reflected from the inclined faces of wedge-shaped cathode 38 and thence back and forth from plate 36 to 37 and vice versa, each reflection producing additional electrons so that a large number of electrons will finally reach positively charged plate 40. Plates 36 and 37 may be grounded if desired and charged screens similar to those of Figure 3 may be employed. These screens themselves may be coated with substances suitable for emitting secondary electrons by electronic bombardment or by the action of light.

A series of alternately oppositely disposed magnetic fields may be used with tube 35 so that the electrons will be deflected back and forth between plates 36 and 37 as well as light, with the result that secondary electrons will be produced by electronic bombardment also. The added effects of the reflected and re-reflected light and the electronic bombardment of plates 36 and 37 will cause a very high output current through element 42. Plates 36 and 37 may be grounded to prevent the accumulation of positive charges on them or they may be connected to cathode 38 through a high resistance. Mirrors may be used to collect light instead of lens 39. Cathode 38 may be a cone, and plates 36 and 37 may be replaced by a cylinder with coated inner surface.

In Figure 5 tube 43 has flared end 44 with which lens 45 is made integral. Light reflecting and photo-emissive cathode 46 is placed so that the light concentrated by lens 45 will strike cathode 46 and from there will be reflected successively to electron-emissive and light reflecting plates 47, 48, 49, 50, 51, and 52. Liberated electrons will finally reach anode 53 which is charged positively with respect to cathode 46 by battery 54. Plates 55 and 56 are coated and are provided so that any light or electrons missing any of the plates 47, 48, 49, 50, 51, and 52 will strike one of the plates 55 or 56 and will produce secondary electrons. These two plates are insulated from the other plates which are suitably connected to a source to be charged by phases so that each in turn will be successively higher in potential than cathode 46. Such a system of phase charging is described in connection with Figure 10.

In Figure 6 phototube 55 has photo-emissive cathode 56 and photo-emissive "anode" 57. Metal plate 58 is placed in tube 55 near "anode" 57 and is grounded as shown. Magnetic field 60, shown endwise, is provided so that any electrons ejected from "anode" 57 will be bent downward to strike grounded plate 58 and electrons ejected from cathode 56, travelling in opposite direction, will be bent upward to strike "anode" 57. The curvature of cathode 56 may also be arranged so that the electrons which are emitted normally to the surface, will strike anode 57 and this anode

may be similarly curved so that electrons ejected from it will strike plate 58. In either case the electrons from anode 57 will strike grounded plate 58 and will be neutralized or removed from tube 55 so that anode 57 will be left positively charged so that electrons from cathode 56 will be attracted to anode 57 with the result that a current will be indicated by instrument 59 connected to wires 61 and 62 leading to cathode 56 and anode 57 respectively.

Anode 57 may also be illuminated more strongly than cathode 56 to enhance further its positive potential with respect to cathode 56. It will be seen then that electrons leaving cathode 56 will strike anode 57 but electrons leaving anode 57 will not strike cathode 56. The result will be that a current will flow in the outside circuit 62, 59, 61, without an anode battery.

In Figure 7 spherical photo-emissive cathode 63 is coated on its inner surface with a cesiated substance or other substance which emits electrons under influence of light. Opening 64 in cathode shell 63 is provided and it is covered by funnel 65 attached to shell 63. Mounted in funnel 65 is lens 66 so that a relatively large amount of light will be collected by this lens and will be directed through opening 64 to strike the inner surface of cathode 63. The light will then be reflected and re-reflected many times so that a large number of electrons will be released from the inner reflecting and electron-emitting surface of cathode 63.

Anode 67 is preferably in the form of a sphere and is supported by wire 72 which passes through insulating plug 73 fixed in shell 63. The positive terminal of battery 69 is connected to spherical anode 67 and the negative terminal to cathode 63, output element 71 being included in the circuit. This phototube will, therefore, concentrate a large amount of light in a closed space so that many photo electrons will be liberated to be attracted to anode 67. A large output current will then be realized. Spherical grid 68 may be provided.

The cathode 63 is shown as a sphere but it can be of any suitable shape such as a closed cylinder or a cylinder with open ends. In case a cylinder is used, opening 64 should preferably be a rectangular slot parallel to the axis and anode 67 should be an axially placed wire.

In Figure 8 phototube 74 has a photo-emissive cathode consisting of a plurality of parallel plates 75 coated on both faces with a suitable electron-emitting substance, the plates being supported and connected together electrically by wire 76 sealed into tube 74. The usual anode 77, battery 78, and output element 79 are provided.

Lenses 80 and 81 may be independently supported or may be combined with tube 74 so that light will be directed towards the edges of plates 75 at slight angle to cause reflections back and forth from plate to plate. The light may also be directed through plates 75 parallel to the planes of the plates. This multi-surface cathode makes possible a high output of tube 74 with adequate illumination of the cathode.

Cross magnetic fields 75a, 75b, and 75c may be provided to cause the liberated electrons to oscillate between the plates also, thus liberating additional electrons. The cathode 75 may consist of a spiral strip or of a series of concentric circles or surfaces arranged in any convenient way to increase the area.

In Figure 9 phototube 82 has multi-plate cathode 83 similar to cathode 75 of Figure 8 and similar cathodes 84 and 85 are connected to wires 86 and 87 respectively. These wires are connected at different points to battery 88, the negative pole of which is connected to cathode 83 and the positive pole of which is connected to anode plate 89. With the connections shown cathode 84 will be at a positive potential with respect to cathode 83 and cathode 85 will be at a positive potential with respect to cathode 84, and plate anode 89 will be at still higher positive potential. Therefore, light passed through the plates of cathodes 83, 84 and 85 will liberate electrons, and electrons attracted from cathode to cathode will liberate secondary electrons to increase the number of electrons finally reaching anode 89.

In Figure 10 vacuum tube 90 has filament cathode 91 fed by battery 92 and a series of plates 93, 94, 95, 96, 97, and 98 are equally spaced and are supported by tube 90 as shown. Wire 103 is connected to a lead from filament 91 and wire 102 is connected to plates 93, 94, 95, 96, 97, and 98 through progressively larger inductances 109, 108, 107, 106, 105, and 104 respectively. Therefore, if an alternating potential difference be applied between wires 102 and 103 the plates 93, 94, etc., will be charged to maximum potential, respective to filament 91, in consecutive order so that in effect there will be a rotating field of electrical potential to pull electrons emitted from filament 91 first to plate 93, then to plate 94, and so on to plate 98 and then to plate 93 again so that a large number of secondary electrons will be released.

Plates 93, 94, etc., are coated with barium oxide, strontium oxide, or with any suitable substance for liberating secondary electrons under electronic bombardment and the inner surface of tube 90 may likewise be coated. It is assumed of course that the plates are insulated from tube 90 if that is conducting. Anode 99 of any suitable shape is provided and screen 101, surrounding anode 99, is connected to the negative terminal of battery 110, the anode 99 being connected to the positive terminal. The wire 111 could be connected to filament 91 and screen 101 could be eliminated.

If an alternating potential is placed across the primary 112 of transformer T and if the secondary is connected in series with battery 110, and if the phase of the extra potential difference across transformer secondary 113 is adjusted so the total potential difference between anode 99 and screen 101 is at a maximum when the potential between filament 91 and any plate 93, etc., is at a minimum, then the cloud of electrons liberated will be periodically drawn to anode 99 with the result that a current will be set up between collector screen 101 and anode 99. The screen 101 may be placed back of plates 93, 94, etc., instead of in front as shown or the screen may be eliminated entirely and wire 111 could then be connected to the inner conducting surface of tube 90. Plates 93, 94, etc., would of course be insulated from tube 90.

Battery 110 may be eliminated so that the potential difference across transformer secondary 113 alone could be utilized but the use of battery 110 will assist in adjusting the potential. Deflecting magnetic fields may be used with this tube too and these fields may be periodically energized to bend the liberated electrons toward anode 99. This tube in effect therefore creates a number of rotating primary and secondary electrons which rapidly produce a cloud of elec-

trons which are periodically drawn to the anode. A suitable control grid may be provided.

In Figure 11 tube 114 has filament 115 fed by cell 116, and screen 117 is placed at high positive potential relative to filament 115, by battery 118. Filament 119, grid 120, and plate anode 121 are provided as in the usual three element tube. A certain quantity of gas such as argon or hydrogen is sealed in tube 114 and therefore this gas can be ionized to any degree desired by regulating the current passing through filament 115 and by adjusting the potential difference between filament 115 and screen 117, since many of the electrons attracted toward screen 117 will pass through this screen and will strike the gas molecules. The various elements may be connected in any way desired to insure that the electrons from filament 115 will travel the full distance to plate 121 to ionize the whole path of gas. In this way the gas may be ionized to optimum degree so that the output of the tube will be increased. The screen 117 and filament 115 may be replaced by an ultra violet or an X-ray tube.

In Figure 12 tube 122 has filament 123 and screen 124 is positively charged by battery 129 to throw electrons into hollow cylindrical cathode 125 which is coated to produce secondary electrons. Wire coil 126 is wound around cylinder 126 to produce an axial magnetic field so that electrons will be whirled around in cylinder 125 to produce secondary electrons. Plate 127 is made positive with respect to filament 123 by battery 128 so that the primary and secondary electrons will finally reach plate 127. Grid 128a may be provided.

In Figure 13 tube 130 has filament cathode 131, grid 137, and plate anode 138. Photo-emissive cathode 135 is also provided and it is made negative with respect to grid 137 by cell 136 although this cell is not essential since cathode 135 may be so curved and so placed that it will eject electrons upon grid 137 when the cathode 135 is struck by light. Now filament 131 fed by cell 132; grid 137; plate 138; and plate battery 133; connected as shown constitute a usual three electrode tube but the addition of photo-emissive cathode 135 makes it possible to control the filament-plate current by means of light. Shield 134 may be employed to prevent light from filament 131 from acting upon cathode 135 and it may also serve to separate the electrical fields. This shield may be grounded if desired.

Since grid 137 is slightly positive with respect to cathode 135 it will be seen that the grid will accumulate electrons in proportion to the degree of illumination of the cathode 135 and grid 137 will in turn control the tube current from filament 131 to plate 138. Battery cell 136 may be eliminated and also a suitable grid leak may be employed to prevent too great an accumulation of negative charge on grid 137. The upper part of grid 137 may be a solid plate to receive more electrons from cathode 135.

In Figure 14 tube 139 has filament 140, grid 141, plate 142, and auxiliary plate 143 placed as shown and grounded. Magnetic field 144, seen endwise, is provided so that negative electrons liberated from filament 140 or from gas in tube 139 will be deflected upward to plate 142 but positive gas ions will be deflected downward to strike against grounded plate 143 and so will become neutralized. Grid 141 controls the current as usual. A series of grounded plates 143 placed at strategic points may be used.

This tube then will make possible the use of high gaseous ionization produced from electronic bombardment or otherwise with resulting increased currents since the erratic gaseous ions are deflected from the main current stream. A suitable gas would be hydrogen, which produces positively charged ions.

In Figure 15 a similar principle to that employed in the tube illustrated in Figure 14 is used. Tube 145 has filament 146 fed by battery 155. The negative terminal of plate battery 152 is connected to filament 146 through output element 154 and the positive terminal is connected to plate 149. The negative terminal of battery 153 is connected to plate 150 and the positive terminal to filament 146. Placed between plates 149 and 150 may be grounded shield 151 to separate the oppositely disposed fields. Control grid 147 is placed in magnetic field 148 which serves to deflect negatively charged electrons to plate 149 and positively charged gas ions to plate 150. It will be noted also that plate 150 is negatively charged by battery 153, with respect to filament 146, so that the positive ions will be electrostatically attracted to plate 150 and so will be removed from the main current stream. Shield 151 may be eliminated if desired. Cathode grid 147 may be so placed that most of the positive ions produced by electronic bombardment will be deflected from grid 147 and so will not strike it.

This tube then will carry large currents with more stability than the usual form of tube containing an ionizable gas. A gas such as hydrogen may be introduced in proper amount into tube 145.

In Figure 16 tube 156 is in the shape of a cross as shown and contains filament cathode 157 and anode 158. An additional filament 159 and plate anode 160 are placed perpendicularly as shown so that the electronic stream passing from cathode 159 to anode 160 will create a negatively charged electron cloud to control the stream of electrons passing from filament 157 to anode 158, suitable charging batteries being provided. Grid 161 may be employed to control the electron stream from cathode 159 to anode 160. Likewise cathode 159 may be a photo-emissive plate so that the current between cathode 157 and anode 158 may be controlled by light. In this way the main current stream is unobstructed by solid objects such as grids.

In Figure 17 tube 162 has filament cathode 163 and anode 164 is positively charged with respect to cathode 163 as usual. Metal plate electrodes 165 and 166 are connected to battery 167 with output device 168 in series. A certain amount of gas is introduced into tube 162 so that it will become ionized by the electrons passing from cathode 163 to anode 164 so that the path between electrodes 165 and 166 will become more conducting. This tube will then make an effective relay. A grid may also be used in front of filament 163 and this element may be a photo-emissive cathode instead of a filament.

In Figure 18 a method of evacuating tubes is illustrated. Air is pumped from tube 169 through small connecting tube 170 which may be sealed off when the proper degree of vacuum is reached. In order to assist in removing the air, horseshoe magnet 176 is provided. This magnet has fastened to it shafts 173 and 174 which may be rotated at high speed in suitable bearings. Pulley 175, fastened to shaft 174, serves to rotate

the shafts and magnet 176 so that the magnetic field between poles 171 and 172 will be swept across tube 169 periodically at high speed to deflect any charged air ions out through tube 170. These ions may be produced by electronic bombardment within the tube 169, or by ultraviolet or X-ray radiation. Since there will usually be both positive and negative ions magnet 176 should be rotated for a while in one direction and then for a period in the reverse direction so that practically all gaseous ions will be deflected through tube 170 to which an evacuating pump will be connected as usual. Electrode 177 of wire screening or otherwise may be connected to wire 178 charged positively for a period and then negatively, with respect to the elements in tube 169 so that the air ions will also be removed electrostatically. The sign of the charge on screen 177 should be such that it will assist the magnetic deflecting action.

If the tube 169 has a metal shell a high potential difference may be maintained between filament 179 and shell 169 or between filament 179 and grid 180 or between any two so that the remaining air molecules will become ionized by electronic bombardment, or as stated, X-rays can be directed through the air in the tube to cause the ionization.

A series of magnets similar to magnet 176 may be rotated or a rotating magnetic field produced by suitably placed coils with currents out of phase may be employed to deflect the gaseous ions out of the tube.

This method furnishes a very effective means for producing very high vacua in tubes.

Many possible combinations of the various elements shown are possible without departing from the spirit of my invention.

What I claim is:

1. A vacuum tube comprising a cathode, an anode, a pair of opposed surfaces on either side of the normal electron path from said cathode to said anode for producing secondary electrons and means for producing a plurality of magnetic fields of alternately opposite polarity spaced between said surfaces at intervals for deflecting electrons emitted by said cathode from surface to surface along with secondary electrons to produce a relatively large number of electrons finally reaching said anode.

2. A vacuum tube comprising, a cathode, an anode, a pair of opposed surfaces on either side of the normal electron path from said cathode to said anode for producing secondary electrons, a plurality of electrically conducting members positioned between said surfaces at intervals, and means for producing a plurality of magnetic fields of alternately opposite polarity between said surfaces to deflect electrons from surface to surface to liberate secondary electrons from said surfaces.

3. An electron discharge tube comprising: an anode, a cathode, a surface intermediate said anode and cathode for producing secondary electrons, and means for producing a plurality of magnetic fields of alternate opposite polarity disposed across said surface so that primary and secondary electrons directed toward said anode will be repeatedly directed against said surface to liberate additional electrons.

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