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H. A. PIDGEON ET AL
ELECTRON DISCHARGE DEVICE

1,923,686

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FIG. 1

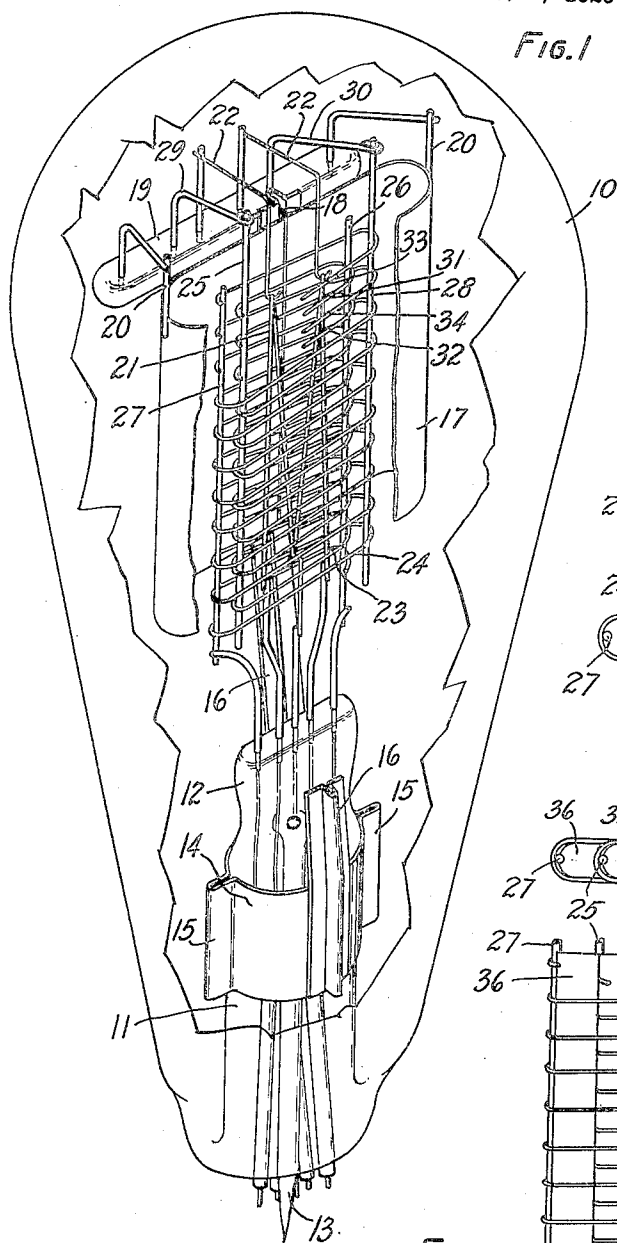


FIG. 2

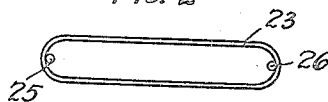


FIG. 2A

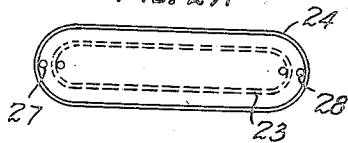


FIG. 3

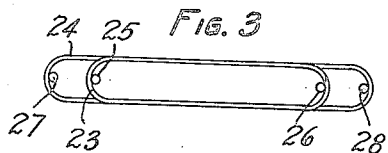


FIG. 5

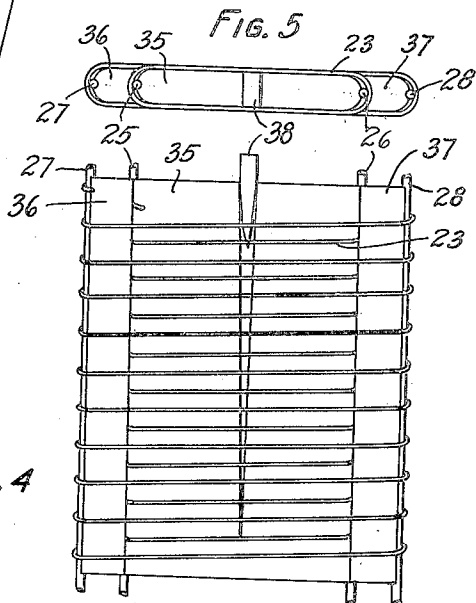


FIG. 4

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ELECTRON DISCHARGE DEVICE

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3 Claims. (Cl. 250—27.5)

This invention relates to electron discharge devices and more particularly to such devices employing four or more electrode elements.

In the usual three-element device employing a cathode, grid and anode, the power output is the result of the grid and anode voltages and is confined to close limits by the total space current between the elements. In the usual type of double grid devices another grid has been positioned between the control grid and the cathode of the three-element device and operated as a space charge grid with a positive potential at some value lower than the anode potential. This arrangement has the advantage of increasing the power output over a limited range of operation but this advantage is obtained at the expense of increased space current due to the current to the positive grid being comparable to the plate current. The double grid arrangement also introduces higher internal impedance when operating over a lower range due to the relative spacing between the cathode and anode which constitute the elements between which the electrons must flow.

An object of the invention is to materially increase the power output of electron discharge devices at low operating anode voltages without substantially increasing the space current.

In accordance with this invention considerably more output power of a given quality may be attained when operating with the same plate voltage and plate current as a three element device if two grids are placed in coplanar relation with respect to the filament and plate electrode of the discharge device. For instance, the grids may be formed into flattened cylinders in which the lateral wires of both lie in the same plane on either side of a filament and are surrounded by a plate electrode of flattened cylindrical form. In addition to the high power output at low voltage the coplanar grids reduce secondary emission from the plate to the positive grid and prevent turbulence effects in the discharge path. Due to the location of the grids in the same plane the spacing between the filament and plate may be the same as employed in the three-element device and thereby considerably reduce the internal impedance of the device. Furthermore, the neutralizing action of the two grids on the electron field between the filament and plate accounts in a great measure for the greater power output obtained and this action continues regardless of whether the plate voltage falls below the voltage applied to the positive coplanar grid.

A feature of the invention is the formation of

two grids of flattened cylindrical form so that the lateral wires of the two grids are alternately located or interlaced in the same plane. This is accomplished in accordance with one embodiment of the invention by winding the two grids on separate mandrels of different thicknesses, removing the larger grid, inserting the thinner grid within the other grid, maintaining uniform spacing between the lateral wires of the grids, and finally pressing the lateral wires of the larger grid so that they lie in the same plane as the lateral wires of the thinner grid.

These and other features of the invention are disclosed in the following detailed description and the accompanying drawing in which:

Fig. 1 shows in perspective the complete assembly of a discharge device embodying the coplanar grid arrangement in accordance with this invention;

Figs. 2 and 2—A illustrate the formation of the two grids prior to arranging them in operative relation;

Fig. 3 is a plan view of the two grids combined into a unitary structure with the lateral wires in two parallel planes;

Fig. 4 illustrates a winding form for constructing the two grids as a unit; and

Fig. 5 is an end view of the winding form shown in Fig. 4.

Referring to the drawing, the electron discharge device of this invention comprises a glass enclosing vessel 10 having an inwardly projecting stem 11. The stem is provided with a press portion 12 supporting the sealed leading-in wires and a small diameter tubulation 13 extends from the interior of the stem for evacuating the vessel 10. A metallic collar 14 encircles the stem and is frictionally secured thereto by suitable corrugations 15. A plurality of upright arms 16 of T-shaped cross-section are attached to the collar and support a flattened cylindrical metallic plate electrode or anode 17 formed of two similar portions of U-shaped cross-section, each portion having outwardly bent longitudinal extensions 18. The portions of the plate electrode are joined together at their abutting surfaces by inserting the extensions 18 into the grooved portion of the T-shaped arms 16 and rigidly securing them to the arms by crimping or spot-welding. An elongated glass bead 19 extends along one edge of the plate 17 and is attached thereto by supporting wires 20. A filament or cathode 21 is attached to the respective leading-in wires projecting from the press portion 12 and is resiliently supported in a vertical plane parallel to the plate electrode

surfaces by hooks 22 embedded in the glass bead 19.

Interposed between the cathode and anode and suitably spaced with respect thereto are two coplanar elements or grid electrodes 23 and 24. These electrodes are formed of continuous wire helices of flattened contour to conform to the shape of the plate electrode 17 and are attached to parallel supporting wires 25, 26, 27 and 28 respectively. The smaller grid 23 is supported in operative relation to the cathode, anode and grid 24 by a leading-in wire attached to the supporting wire 26 while the supporting wire 25 loosely extends through the guiding member 29 embedded in the insulating bead 19. The larger grid 24 is supported at one end by the leading-in wire attached to the supporting wire 27, and the guiding member 30 loosely engages the related supporting wire 28. This arrangement efficiently maintains the grids in their correct spaced relation with respect to each other and with respect to the cathode and anode.

The two grids are formed so that the lateral wires are equally spaced from the cathode and anode, i. e., the lateral wires of one grid lie in the same plane as those of the other grid. The coplanar relation of the two grids is conveniently accomplished by alternating the respective turns of the grids so that the adjacent lateral wires in the same plane comprise interlaced wires of the two grids. This arrangement of the two grids accomplishes a number of desirable electrical results in the operation of electron discharge devices, such as increased power output, reduction of secondary emission from the plate electrode, lower inter-electrode impedance, increased transmission gain without sacrifice of quality, reduction of turbulence effects in the space discharge, increased stability for variations in input impedance over the operating grid cycle, distortionless signals even when the plate potential falls below the potential applied to the positive grid element, lower mutual conductance, dual control of the space discharge, mutual shielding of each grid by the other, and suppression of harmonics to a low level so that the fundamental frequency is relatively undistorted.

It is well known that the ordinary three-electrode device may be operated to obtain increased power output by applying a high negative potential to the grid although quality is materially impaired as the negative grid potential is increased. Similarly, this result may be obtained by operating the grid at a positive potential but under this condition the grid collects electrons from the filament electrode, the input impedance is relatively low and the amplification factor is decreased. Furthermore, the percentage of harmonics is so high that for most applications the device is inefficient unless some means is provided for suppressing the harmonics. It is also known that by introducing another grid between the control grid and the plate electrode and maintaining this grid at a positive potential of a value lower than the plate potential certain advantages result. In particular the amplification is high, the interelectrode capacity is low. This change, however, due to the additional grid, causes various irregularities which limit the range of operation of the device. The current-voltage characteristic is greatly distorted by secondary electrons liberated by the plate electrode and collected by the positive grid. In the event that the plate potential decreases to a value equal to or less than the potential of the positive grid, turbulence ef-

fects occur in the space discharge. Finally the introduction of the additional grid causes the internal impedance to be increased due to the greater distance between the filament and plate electrode and also due to the high amplification factor. The elimination of secondary emission from the plate electrode may be accomplished by the addition of another grid between the positive grid and plate electrode and maintained at a potential lower than that ever reached by the plate but this introduces further spacing of the filament and plate and increases the internal resistance of the device and, therefore, is impractical from an operating standpoint.

The principal reason for the limitation of power output from double grid structures with the inner grid positive may be found in their fundamental characteristics. They are essentially low voltage, high space current devices and are capable of giving a fair gain over a limited range of operation. When operated over a wider range as they must be for larger output power, the positive grid is of little service and may even render the tube less effective than a well designed three-electrode device.

The arrangement of the two grids in coplanar relation has been found to be particularly effective in reducing space discharge effects by neutralization. The principal reason for the large power output from a discharge device having the two grids interlaced or meshed so that the lateral wires of each are alternately arranged in the same plane is that the fixed component of positive grid potential contributes the greater portion of the potential across the device necessary to draw the required current at the instant when the control grid potential is zero. Consequently, a larger proportion of plate voltage is available as useful voltage drop across the external load resistance. This, of course, means increased power. The positive grid intermeshed with the control grid greatly reduces the phenomenon of secondary emission due to the shielding effect on the positive grid by the field of the negative control grid. In effect the strong oppositely directed field formed by the large difference of potential between the control grid and the plate prevents the electrons emitted by the plate from being collected by the positive grid. Due to the spacing of the two grids with respect to the filament and plate electrode which is comparable to the spacing of the electrodes in a three-element device, the plate impedance is considerably reduced in comparison to the impedance of other double grid devices. At the same time this arrangement eliminates a region between the two grids affected by space charge or excessive turbulence in the flow of electrons. Another application of the coplanar grids is the dual control of the output current by the separate controlling action of the two grids. This double control may be utilized even when one of the grids is positively charged. In this case the amplification constant of the two grids can be made approximately equal which is impractical with other double grid devices.

In electron discharge devices where power output is the primary consideration, it is necessary to form the electrodes so that the maximum result may be obtained in an efficient manner and the electrodes should be designed so that commercial fabrication may be attained at low cost. This has been found to be accomplished by forming the elements of discharge devices other than the filament into flattened cylindrical form

to present larger surfaces to the flow of electrons and in which the inter-electrode spacing may be maintained relatively small. In order to introduce a double grid structure in the space between the cathode and anode, it is desirable to arrange the grids so that the adjacent wires of each are alternately positioned in the same plane opposite the surfaces of the cathode and plate.

In accordance with this invention the two grids, as shown in Figs. 2 and 2-A are wound on separate mandrels, the grid 23 being wound on a thin mandrel and the grid 24 on a thicker mandrel. The grid 24 is then removed from the mandrel and the contour of this grid is shown in Fig. 2-A. The next step of fabricating the two grids is the insertion of grid 23, which is still maintained on the winding mandrel, into the larger grid 24 which has been removed from the mandrel. This relation is shown in Fig. 2-A in which the smaller grid 23 is shown in dotted outline within the larger helix of the grid 24. After the grids have been coaxially positioned with their lateral wires in parallel relation the grid 24 is pressed between plates so that the wires of the grid 24 in the flat planes are brought into alignment with the wires in the flat planes of the grid 23. The form of the grids after the pressing operation is shown in Fig. 3. It will be seen from Fig. 1 that the adjacent lateral turns 31 and 32 of grid 23 alternate with the adjacent lateral turns 33 and 34 of grid 24 and are equally spaced from each other and lie in two parallel planes with the adjacent wires of the two grids on one side being in coplanar relation.

Fig. 5 shows another method of fabricating the two grids by winding the grid 23 on a contracting mandrel 35 and after the grid has been welded to the supporting wires 25 and 26, enlarging members 36 and 37 are applied to the curved edges of the mandrel 35 and the wound grid 23 and carry the supporting wires 27 and 28. The grid 24 is then wound over the enlarged mandrel and welded to the supporting wires 27 and 28. The mandrel is then removed from the composite structure by removing the wedge 38 from the mandrel 35 and the grids 23 and 24 may be slipped off the forms.

Negative biasing potential E_c can be supplied to the control grid in any suitable manner, as for example by a battery or other source of direct potential connected in circuit between the filament and the control grid as usual in vacuum tube circuits. Potential E_s can be supplied to the other grid for example by a battery or other source of direct potential having its negative pole connected to the filament and its positive pole connected to that grid. Plate potential E_b can be supplied to the plate in any suitable manner, as for example by a plate voltage supply battery or generator connected in circuit between the filament and plate as usual in vacuum tube circuits.

An indication of the comparative performances for a co-planar grid tube of the type described above and the 101-D and 104-D Western Elec-

tric Co. (three electrode) vacuum tubes, is given by the following observed values, 2F and 3F being the second and third harmonics expressed in db. (decibels) below the level of the fundamental wave:

Type of tube	Volts			$I_b + I_a$ space current (milliamperes)	Gain (db.)	Output (milliwatts)	2F	3F
	E_b	E_s	E_c					
101-D-----	130	-----	-9	8	29.5	60	26.3	48
101-D-----	130	-----	-13	4.5	28	85	20	40
104-D-----	130	-----	-20	23	26.8	160	25	50-55
104-D-----	130	-----	-32	12	24.8	260	20	40-50
Co-planar grid tube.	130	80	-64.5	23	25.3	1,170	22	21
Co-planar grid tube.	130	60	-49	23	27.1	1,050	21	27.5
Co-planar grid tube.	130	40	-34.5	23	28.8	740	22	36
Co-planar grid tube.	130	40	-35	23	28.9	400	25	42
Co-planar grid tube.	250	93	-90	55	27.7	3,950	26.5	29
Co-planar grid tube.	180	76	-70	33.3	26.4	1,800	32	26

The term "decibel" is a unit for expressing telephone transmission efficiencies and levels.

While the invention has been disclosed in a particular embodiment designed to disclose the features of this invention, it is, of course, understood that various modifications may be made in the complete assembly without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. A discharge device comprising an enclosing vessel having a stem, leading-in wires sealed in said stem, an anode supported by said stem, an insulating member carried by said anode, a cathode within said anode and supported by said leading-in wires and said insulating member, and intermeshed double grids between said cathode and anode, said double grids having upright supporting wires, the alternate ends of said wires adjacent said stem and said insulating member being respectively connected to said stem and said insulating member.

2. The method of forming two interlaced electrodes for discharge devices, which comprises winding separate helices of flattened cylindrical form having boundaries of different width, positioning one within the other, and pressing the outer helix into the boundary occupied by the inner helix.

3. An electron discharge device comprising an enclosing vessel having a stem, a flattened cylindrical anode supported from said stem, an insulator supported by said anode, a plurality of spaced supports extending from said insulator, a filament within said anode and attached to said stem and centrally adjacent supports in said insulator, a plurality of rigid rods on each side and in the same plane of said filament, and coplanar grids wound on said rods, alternate rods of said grids being insulatingly supported by said stem and insulator respectively.

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