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H. T. MASER

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ELECTRIC DISCHARGE DEVICE

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Fig. 1.

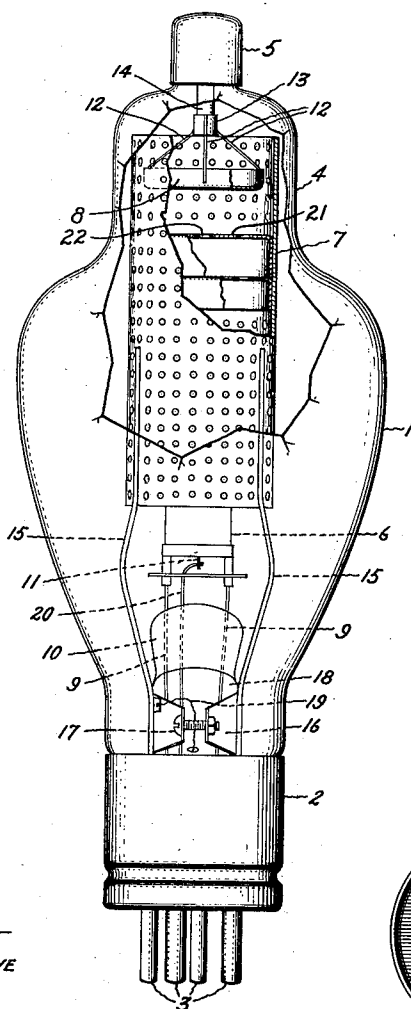


Fig. 4.

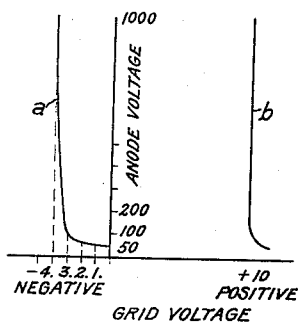


Fig. 3.

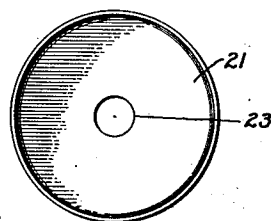
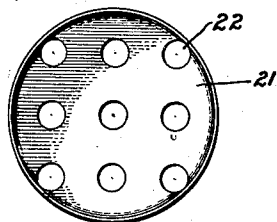


Fig. 2.



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ELECTRIC DISCHARGE DEVICE

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9 Claims. (Cl. 250—27.5)

The present invention relates to electrical discharge apparatus, more particularly to thermionic devices containing an ionizable medium and provided with a source of electrons, a cooperating anode and an electrostatic control member or grid. The invention is directed more particularly to a novel construction and arrangement of the grid electrode for use in this type of apparatus.

10 The invention is principally concerned with devices in which the pressure of the ionizable medium and the impressed voltages are such that a discharge of arc-like character, i. e., having a flat straight line or slightly negative anode voltage-anode current characteristic, is produced between the electrodes, the initiation of the discharge being controlled by the charge on the grid. After the discharge is started, the grid ordinarily loses control unless fairly large and impractical bias voltages are employed but the arc may be conveniently stopped by removing the anode voltage. Upon re-applying this voltage, the grid again determines whether the arc will start and by the continued repetition of this process, the grid can control the average plate current over a period of time. A practical method of obtaining interruption of the anode current or stoppage of the arc discharge is to apply alternating current voltage to the anode, although direct current voltage may also be utilized in case proper circuit interrupting means are available.

When a relatively high voltage is applied to the anode of these devices which operate on the cumulative ionization principle and, particularly, when they employ grids of certain standard designs, it is often necessary to apply a negative charge to the grid to restrain the arc from starting. Tubes of this character are usually designated "negative grid" arc discharge devices or simply "negative tubes". The amount of negative charge necessary to prevent ignition of the tube depends upon the anode voltage except in the case of the improved tubes which constitute the subject of the present invention. Generally speaking, the greater the anode voltage in the prior tubes, the more negative must be the grid voltage with respect to the cathode. In fact, the increase in grid voltage necessary under these conditions is so pronounced in all prior tubes which employ practical electrical dimensions and designs that the starting characteristic of anode voltage versus grid voltage is substantially flat. Such a characteristic obviously is undesirable not only because the grid voltage at the starting of the discharge is variable and depends upon the anode

voltage, but because it reduces the grid control factor of the tube which will be recognized as being synonymous to the well-known amplification factor in pure electron discharge devices.

An object of the present invention, therefore, is to provide a tube of the arc-like or glow discharge type which has a starting characteristic in which the negative grid voltage is substantially independent of anode voltage, at least much more independent than any prior tubes of this character. In other words, the object is to provide a tube in which the starting negative grid voltage versus anode voltage characteristic is steep.

In certain forms of circuits such as special types of inverters, i. e., systems for changing direct into alternating current or for changing current of one frequency into current of a different frequency, it is highly desirable to prevent the arc from starting when the grid is no more negative than the cathode and even when a positive charge is applied to the grid. Tubes of this character are usually designated "positive grid" arc discharge devices, or simply "positive tubes", meaning that it takes a charge on the grid which is positive with respect to the cathode to initiate a discharge, and any charges less positive, i. e., more negative than the predetermined charge will not ignite the tube.

Accordingly, another object of the invention is to provide a tube in which the electrode structure will not only provide the improved negative characteristic, as stated hereinbefore, but by a suitable and simple change in the structure, will also provide a positive characteristic of improved character. The positive grid voltage-anode voltage characteristic obtained by the structure as thus modified and described hereinafter, is so steep that it closely approaches a vertical straight line, indicating that the positive grid voltage necessary to cause the arc to start is entirely independent of the anode voltage.

A more specific object is to provide an improved grid or control member which will give the improved negative and positive characteristics referred to above in tubes of the character described.

While I am aware that certain grid structures are known to the art in which negative and positive characteristics have been obtained, in no case to my knowledge, has the electrode structure been such as to provide a steepness of grid voltage-anode voltage characteristic, under either negative or positive grid starting conditions, comparable to the structure which forms the subject of the present invention. In general, the prior tubes of this character have employed cylindrical

control members, either entirely open, i. e., without a baffle, or provided with a single perforated cross-piece or baffle. However, in accordance with my invention, a double cross-piece or baffle is advantageously employed. By a proper determination of the distance between baffles, size and number of the openings therein and thickness of baffle, the tube may be given either a negative or positive characteristic of the most desirable character.

Other objects and features will be apparent as the following specification is perused. As examples of additional features, it has been found that in the improved tube of the positive type, if the grid were accidentally disconnected from its energizing circuit, so that it assumes a floating potential, nearly that of the cathode, no discharge will be initiated; this advantage is directly attributable to the independency of the grid starting voltage with respect to the anode voltage. Moreover, in case a slow leak should develop in the envelope of the improved tube so that the internal pressure is increased, the tube will not accidentally continue to fire or ignite. The invention will be better understood when reference is made to the accompanying drawing in which Fig. 1 represents an elevational view, partly broken away and in cross section, of a tube improved in accordance with the present invention; Fig. 2 is a plan view of one of the baffle members employed in the grid construction; Fig. 3 is a plan view of the modified transverse section, while Fig. 4 is a graph depicting the negative and positive starting characteristics of the improved tube.

Referring more especially to Fig. 1, numeral 1 designates a glass envelope having a bulbous form and which terminates at the lower end in a metal socket member 2, carrying several contact pins 3. The envelope at the top is drawn down to a portion 4 of reduced size which supports a relatively large metal thimble 5 secured thereto in any suitable and well-known manner. The envelope contains a plurality of cooperating electrodes including the cathode 6, an electrostatic control member 7 and an anode 8.

There is inert gas such as argon, neon, etc. in the envelope at a pressure sufficient to support an arc-like discharge at the impressed voltages or if desired, the envelope may contain a globule of mercury which produces vapor at the operating temperature sufficient to carry the desired current.

The cathode 6 is preferably of the well known indirectly heated type, although it will be understood that if desired, a directly heated filamentary cathode may be employed, depending upon the type of tube, anode voltage, current requirements, etc. The cathode is constituted of a metal casing (not shown) which contains a longitudinal helix (not shown) serving as a heater. About the casing, there are secured, as by welding, a number of equidistantly spaced longitudinal vanes which are secured at their radial extremity to a metal cylinder which serves to prevent radiation of heat. The recesses between the vanes are open at the end nearer the anode and are preferably coated on the interior with electronically active material, such as barium oxide. Several other heat shields spaced apart in any suitable manner may surround the cylinder referred to above, to further reduce heat radiation. The outermost of these heat shields is illustrated in the drawing and is designated by the reference character 6.

A pair of load current conductors 9, connected in parallel, may be taken from the cathode structure through the press 10 of the envelope to the exterior and connected to one of the contact pins 3. One end of the filamentary spiral is connected within the interior of the casing to the cathode, and the other end is brought out by a lead 11 to a conductor 20 which also passes through the press and is connected to one of the contact pins 3. A cathode of this general type, including the vanes and heat shields, is disclosed and claimed in the Hull and Ruggles Patent No. 1,924,318, August 29, 1933, assigned to the same assignee as the present application.

The anode 8 may be fabricated of carbonized nickel or graphite and is mounted in place by means of a plurality of support wires 12 which terminate in a metal sleeve 13 secured to a glass pant leg 14. A leading-in conductor for the anode is taken through the pant leg and makes connection with the external contact member 5.

The control member or grid which constitutes the subject of the present invention is preferably made in the form of a long metal cylinder which may or may not be perforated. The cylinder is spaced away from the envelope and extends at one end, well beyond the anode 8 and at the other end, well beyond the inner edge or the electron-emitting mouth of the cathode. As shown, the anode is completely surrounded by the grid cylinder, while the cathode has only a small portion of its lower surface projecting therefrom and that portion does not emit electrons. As stated hereinbefore, the function of the control member or grid is to control the starting of the arc or glow during the recurring positive half-cycles of the alternating voltage on the anode, thereby determining the average current flowing through the tube over a period of time.

Intermediate the ends of the metal cylinder, there are two metal cross-pieces, baffles, or layers 21 which have circular openings 22 therein in register with one another as shown more clearly in Fig. 2, the peripheral edges of these metal layers being secured to the interior surface of the cylinder in any suitable and well known manner. The baffles may be spun to shape with a downwardly extending flange which fits snugly within the grid cylinder and is secured thereto. Each baffle may have a large number of relatively small openings as illustrated in Figs. 1 and 2, or one circular central opening 23, as shown in Fig. 3 which is preferably of larger size than the openings provided in the multi-opening baffle. While in the drawing, I have indicated that the transverse members within the grid cylinder 7 are made of metal, it is understood that, if desired, these members, also the cylindrical portion of the grid, may be fabricated of semi-conducting material such as graphite.

The control member as a whole, is supported in position by several equidistantly spaced rod uprights 15, which are secured at one end to the outer surface of the grid, and at the other end, terminate in a metal collar 16 which may be clamped tightly by means of screws 17 to the stem 18 of the envelope. A leading-in conductor 19 may be taken from a convenient part of the collar 16 and passed through the envelope to make contact with one of the terminal pins 3.

A tube of the type described in which a grid is employed having two perforated cross-pieces or baffle members offers many advantages over tubes which are provided with other types of control members, including variously shaped

grids and those in which only one baffle is employed. In the first place, the long cylindrical member 7 which extends well beyond the active surfaces of both the cathode and anode shields the current path between the electrodes from the electric charges which inevitably collect on the interior surface of the envelope. Moreover, the provision of the two cross-piece or baffle members offers the distinct advantage over the open cylindrical grid, i. e., one without a baffle, that in the case of proper electrode design, including the distance between baffles and size of openings therein, a "positive grid characteristic" of the most desirable sort may be imparted to the device, by which is meant that the discharge will be restrained so long as the grid is not positive or, at least, is no more negative than the cathode. As stated hereinbefore, such a characteristic is highly desirable in certain forms of translating circuits. An open cylindrical grid type of tube, i. e., one not provided with baffles, offers only a negative characteristic within practical operating anode voltage ranges, which obviously restricts the use of such a tube.

In addition to providing a positive characteristic, the double-baffle grid structure, improved in accordance with the present invention, upon proper change in the spacing between baffles, thickness of baffle and size of opening therein may impart a negative characteristic to the tube, also of the most desirable sort. In general, in changing from a positive to a negative tube, the baffles are made thinner and the distance between baffles decreased. The openings in the baffles are also made larger. The cross-pieces exert a stronger control effect, i. e., greater restraining effect on the discharge, than the cylindrical portion. The chief function of the cylinder, apart from the cross-pieces, is to protect the discharge path from migratory charges on the envelope, i. e., to provide simply a shielding or screening effect.

The effect of modifying the cross-piece structure to obtain different characteristics is clearly shown in Fig. 4 wherein curves "a" and "b" depict the "negative" and "positive" characteristics respectively, obtainable in a typical tube improved in accordance with the present invention. The curves are plotted against anode voltage as ordinate, and grid voltage at the time of starting as abscissa. These curves demonstrate that in the improved tube, the grid voltage on the negative side of the ordinate is almost independent of the anode voltage while on the positive side, it is absolutely independent thereof, since the curve "b" is exactly vertical over practically its entire length. In both cases, the curves are extremely steep, indicating a most desirable relation between the grid voltage necessary to restrain the arc from starting and the anode voltage. Tubes having characteristic curves of this order or steepness obviously have a relatively high grid control or amplification factor.

The double cross-piece type of grid not only offers many advantages over the open cylinder type of grid, as stated hereinbefore, but also advantages over a grid which is provided with only a single cross-piece or baffle. As indicating a few of the more important advantages in this respect, it is pointed out that when a single cross-piece or baffle is used and a more positive characteristic is desired, the method commonly employed is to make the hole or holes in the cross-piece smaller. However, in case there is only one hole in the cross-piece and the size of this

hole is made smaller, the arc stream becomes more concentrated, and gives rise to electrical transients due to partial stoppage of the current if the hole is extremely small. In any case, there is considerable grid emission from the edges of the restricted hole or holes which obviously, are heated by the arc stream. On the other hand, in the case of the two-baffle form of grid, it is not necessary to make the holes so small, as the more positive characteristic is obtained by the use of two baffles instead of one and consequently, the disadvantages accompanying a restricted opening or openings are eliminated.

As stated hereinbefore, when a two-baffle grid of proper design is employed in a negative tube, the starting grid voltage is substantially independent of the anode voltage over a large portion of the operating range while in the case of a positive tube, the grid voltage is entirely independent of the anode voltage. However, in the case of a single-baffle grid tube, the grid starting voltage versus anode voltage characteristic, both on the negative and positive side of the ordinate are more or less flat, or at least much more curved than those of the double-baffle grid tube, so that the grid voltage is not independent of the anode voltage.

In the case of the double-baffle tube, the features of changing the thickness of the baffle in order to obtain a more positive characteristic has a much more decided effect than in a tube in which only one baffle is employed. A positive tube with a double layer grid will also operate at a much lower condensed mercury temperature than a single tube and such a tube is not subject to variation in characteristic from tube to tube as is the case of a tube provided with a single layer grid. Finally, there is less probability of sputtered material from the cathode such as the thermionically active coating, being able to get through the grid, and being deposited on the surface of the anode, and cause back emission.

In view of the fact that the improved tube provided with a double cross-piece form of grid may be designed to give a definite positive characteristic, obviously, if the grid were accidentally disconnected from its energizing circuit, so that it assumes a floating potential, nearly that of the cathode, the arc will be extinguished at the end of the positive alternating voltage cycle of the anode. This consideration is of extreme importance when employing tubes of this character as signal relays. Since the improved tube will fail to ignite on the succeeding positive half-cycle of the anode voltage when the grid becomes disconnected, a false signal is precluded from being given by the relay.

Moreover, it has been found that in the event a slow or rapid air leak should develop in the envelope at the time the grid was accidentally disconnected from its energizing circuit so that the internal gas pressure is increased, the improved tube will be definitely and permanently prevented from igniting, and in the case of signaling, could not give a false signal. Many other desirable advantages of the highly positive grid tube which constitutes the subject of the present invention will occur to those skilled in the art.

While the double cross-piece grid having either a plurality of openings as shown in Fig. 2 or a single central opening of somewhat larger dimension as shown in Fig. 2, is considered to come within the purview of my invention, the single opening form of baffle offers certain advantages

over the multi-opening baffle in that in the design of a negative grid tube, the point where the starting characteristic curve of grid voltage versus anode voltage crosses the axis of zero grid voltage of a tube employing a single opening is much lower than when a large number of holes are used. This means that with zero voltage on the grid, only a small anode voltage is required to start discharge and such a characteristic is sometimes desirable.

From the foregoing, it is evident that I have disclosed an improved grid structure for tubes of the arc or glow discharge type in which a steep "negative" or a steep "positive" starting characteristic may be obtained without introducing the limiting factors in operation which usually accompany tubes of this character.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. An electron discharge device including an envelope containing a thermionic cathode, an anode, and an electrostatic control element, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge at the impressed voltages, said control element comprising a hollow member surrounding the discharge path between the cathode and anode and provided with only two perforated sheets positioned in the discharge path, the perforations in said sheets being of circular configuration and in effective alignment.

2. An electron discharge device including an envelope containing a thermionic cathode, an anode, and an electrostatic control element, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge at the impressed voltages, said control element comprising a hollow member surrounding the discharge path between the cathode and anode, and provided with only two sheets having circular openings in register with one another and mounted transversely across the interior of said element.

3. An electron discharge device including an envelope containing a thermionic cathode, an anode, and an electrostatic control element, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge at the impressed voltages, said control element comprising a cylindrical member spaced away from the envelope and provided with only two perforated sheets extending across the interior of said member, the perforations in said sheets being of circular configuration and in effective alignment.

4. An electron discharge device including an envelope containing a thermionic cathode, an anode, and an electrostatic control element, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge at the impressed voltages, said control element comprising a cylindrical member spaced away from the envelope and extending substantially to the rear surface of the cathode and anode, said member provided with only two perforated sheets extending transversely across the interior thereof, the perfora-

tions in said sheets being of circular configuration and in effective alignment.

5. An electron discharge device including an envelope containing a thermionic cathode, an anode, and an electrostatic control element, an ionizable medium in said envelope at a pressure under operating conditions sufficient to support an arc-like discharge at the impressed voltages, said control element comprising a cylindrical member spaced away from the envelope and surrounding the cathode and anode, said member being provided with only two perforated sheets extending transversely across the interior thereof, each of said sheets being provided with a peripheral flange which fits snugly within the cylindrical member and is secured thereto, the perforations in said sheets being of circular configuration and in effective alignment.

6. An electron discharge device including an envelope enclosing a thermionic cathode and an anode, and containing an ionizable medium for supporting a self-sustaining discharge between said cathode and said anode, and a control electrode comprising a pair of parallel metal sheets, each having a plurality of circular perforations of uniform diameter and mounted with the perforations in effective alignment, said sheets being spaced apart a distance at least as great as the diameter of the perforations in said sheets.

7. An electron discharge device including an envelope enclosing a thermionic cathode and an anode, and containing an ionizable medium for supporting a self-sustaining discharge between said cathode and anode, and a control electrode including a tubular member having a pair of perforated discs mounted in said member perpendicular to its longitudinal axis, said perforations being in alignment and spaced apart a distance at least equal to the average diameter of the perforations in said discs.

8. An electron discharge device including an envelope enclosing a thermionic cathode and an anode and containing an ionizable medium for supporting a self-sustaining discharge between said cathode and said anode and a control electrode between the anode and the thermionic cathode and comprising a tubular member provided with a pair of metal members having parallel surfaces, each of said members having a plurality of perforations of uniform size and mounted with the perforations in effective alignment, said members being spaced apart a distance at least equal to the average diameter of the perforations in said members.

9. A discharge device including an envelope enclosing a thermionic cathode and an anode and containing an ionizable medium for facilitating the maintenance of a low voltage discharge between said cathode and anode, and a control electrode comprising a pair of parallel metal sheets, each having a plurality of generally similar perforations of substantially the same area and mounted with the perforations in effective alignment, said sheets being spaced apart a distance at least as great as the average diameter of the perforations in said sheets.

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