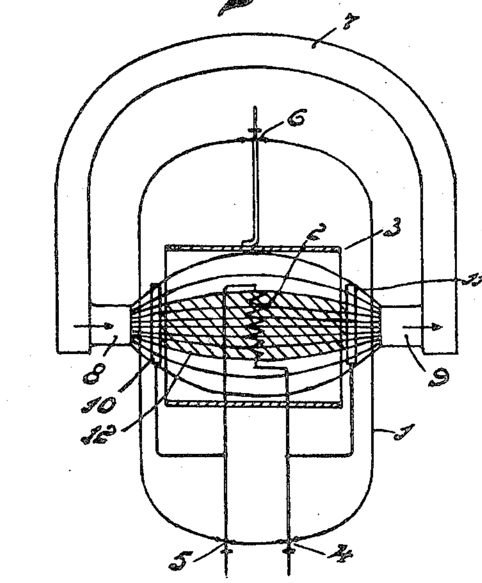
Feb. 27, 1951 J. G. W. MULDER ET AL 2,543,702

MAGNETIC FIELD CONTROLLED GAS FILLED DISCHARGE DEVICE

Filed May 9, 1946

Fig. 1



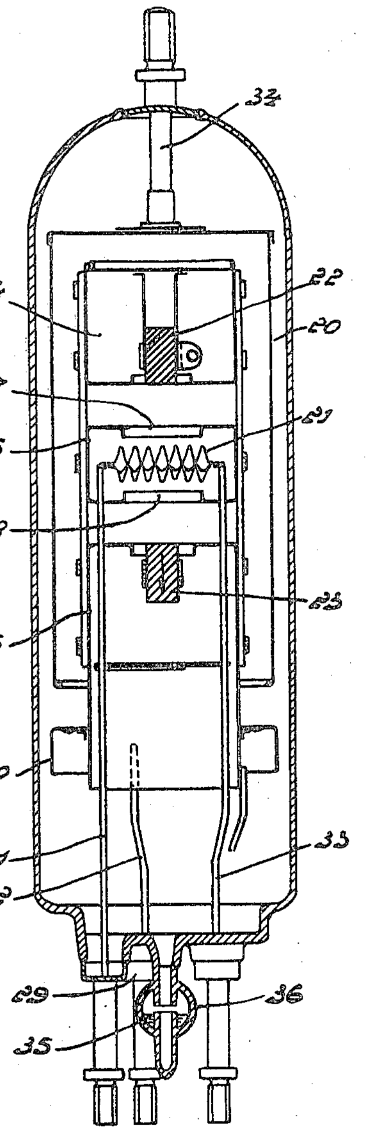


Fig. 2

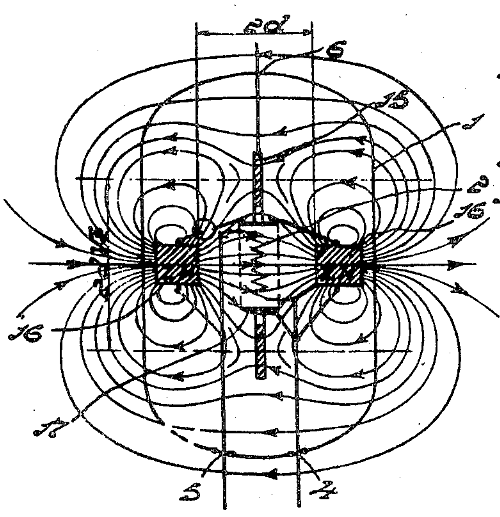


Fig. 3

INVENTORS
JOHANNES G. W. MULDER
TOM JURRIAANSE
FRANS M. PENNING

BY [signature] ATTORNEY.

Patented Feb. 27, 1951

2,543,702

UNITED STATES PATENT OFFICE

2,543,702

MAGNETIC FIELD CONTROLLED GAS FILLED DISCHARGE DEVICE

Johannes Gijsbertus Wilhelm Mulder, Tom Jurriaanse, and Frans Michel Penning, Eindhoven, Netherlands, assignors, by mesne assignments, to Hartford National Bank and Trust Company, Hartford, Conn., as trustee

Application May 9, 1946, Serial No. 668,548
In the Netherlands April 11, 1941

Section 1, Public Law 690, August 8, 1946
Patent expires April 11, 1961

14 Claims. (Cl. 313—161)

1

This invention relates to a device comprising an incandescent-cathode converter tube with gaseous and/or vapour filling whose discharge path between the cathode and the anode is cut by the lines of force of a magnetic field whose field intensity is so chosen as to obtain at least approximately the minimum value of the arc voltage of the tube as a function of this field intensity.

It is already known to choose the intensity of the magnetic field in the above-described manner. Thus, different arrangements of this kind existed already, for example according to British patent specification 396,928 and according to the publication by T. Jurriaanse in "Physica," IV, No. 1, January 1937 pages 23–24. However, in these cases disadvantages were involved such, for example, as a comparatively high arc-voltage as a result of the fact that the arrangement of the magnet poles relatively to the discharge path between the cathode and the anode was not chosen advantageously. This resulted in the life of the tube being injuriously affected due to cathode atomisation.

The purpose of the invention is to increase the life of the tube relatively to the known constructions to a considerable extent whilst retaining a high blocking power, and this more particularly by means of a further decrease of the arc-voltage. In proportioning the electric arrangement, factors were considered which had not been taken into account hitherto.

According to the invention, for this purpose the construction and the arrangement of the tube and of the magnetic field are so chosen that the anode is arranged outside that part of the magnetic field which cuts the emitting surface of the cathode, preferably arranged symmetrically in the axis of the field, and the anode, from the middle of the cathode, can be seen under the largest angle of at least 120°, while the strength of the magnetic field at the active surface of the anode is preferably less than 5 gauss. In such an arrangement the discharge is concentrated to form a beam in the direction of the magnetic field which has approximately the transverse dimensions of the cathode, the light in the remaining part of the discharge vessel being weak. The anode is located outside the highly luminous part of the discharge. This arrangement results in the blocking power of the tube remaining high owing to the arrangement of the anode outside the magnetic field, while a low arc-voltage is obtained as a result of the discharge paths of wide

2

sections and small length which may occur between the anode and the cathode as a result of the arrangement of the former.

The tests on which the invention is based have revealed that the above-mentioned arrangement of the cathode and of the anode permits of obtaining such values for the arc-voltage as corresponds approximately to the ionization voltage of the internal atmosphere of the tube at pressures which, for example for mercury vapour, fall down to the region of 10^{-3} mm. Hg.

In this case in particular, by means of a correct choice of the field strength, of the dimensions of the arrangement and of the place of the emitting surface of the cathode, it is possible to utilize a cathode having about the same size and life as without the use of a magnet field would be possible only at a considerably higher pressure. Use will preferably be made of a large-size cathode whose largest diameter is substantially normal to the lines of force of the magnetic field.

It is known to provide a magnetic field in the longitudinal axis of a cylindrical anode, in which a straightly stretched filiform incandescent cathode is located coaxially. The purpose of this construction is to vary and to reduce to zero the current intensity of the discharge by means of a transverse magnetic field, there being no question of the obtainment of an arc-voltage decrease and still less question of an arc-voltage minimum. The arrangement of the filiform cathode is also less adapted to obtain the effect of the invention.

Using the principle of the invention, it is advisable for the generation of the magnetic field to utilize sharply limited field poles, since in contradistinction to what takes place in the case of generation of the field, for example by means of a solenoid, such field poles offer the possibility inside the discharge vessel to obtain a comparatively sharp boundary of the part of the field with high field strength relatively to the comparatively fieldless parts of the discharge space.

On the one hand it is possible to form the magnetic field about the cathode by blocks of permanent magnet material which are arranged on each side of the cathode, preferably inside the discharge vessel of the tube.

In this case it is possible in a particularly advantageous manner to determine the place where the anode is located in as weak a magnetic field as possible, since when the magnetic lines of force return from the side, remote from the cathode, of one magnet block along the outside to the corresponding side of the other magnet block, the direction of the lines of force is reversed relatively to the axis of the magnetic field. Between these two regions of opposite field directions there is at a given distance from the axis an annular region in which the field strength is nil, whereas it increases outwardly in one direction and inwardly in the other direction, attaining its maximum value in the axis of the magnetic field.

According to the invention, it is advisable that this circumstance should be considered with the use of the above-described blocks of permanent magnet material by adapting the pole-strength, the spacing between the blocks and the dimensions of the anode or anodes to each other in such manner that the anode falls within the said substantially fieldless annular region, which exists between the above-mentioned magnetic lines of force of opposite signs.

A highly advantageous embodiment of this idea is obtained if the arrangement is so chosen that a plane anode in the form of a horse-shoe or ring is arranged with its surface normal to the axis of the magnetic field and in the surface of symmetry between the permanent magnet blocks, in which surface the cathode is arranged centrally, while the mean distance between the axis of the field and the various points of the active surface of the anode is the $\sqrt{2}$-fold of half the mutual distance between the permanent magnetic blocks.

Another method of decreasing the intensity of the magnetic field near the anode follows the opposite way by causing the magnetic lines of force to extend through the material of the anode itself, so that the discharge space near the anode is no longer traversed by these lines of force. For this purpose the anode which, if desired, may form the wall of the tube may be utilized as the external magnetic connection of the poles, remote from the cathode, of the blocks of permanent magnet material, preferably in such manner that no appreciable intensity of the magnetic field occurs along the active surface of the anode.

However, it is also possible outside the discharge vessel of the tube to provide a permanent or energized magnet whose pole-shoes are considerably smaller than the diameter of the discharge vessel and placed on each side thereof in line with the cathode.

In all these cases it is advisable for the magnetic bodies or the poles to be made smaller than the largest projection of the cathode in their direction.

It is frequently also possible to maintain the field strength in the proximity of the anode or anodes at a low value by making the latter of a non-magnetic material so as to prevent it from attracting the magnetic lines of force. The same result is obtained when the anode is made of material which is not magnetic at the operating temperature of the tube.

In connection with the load capacity of the tube and the obtainment of a low arc-voltage, it is desirable that the active surface of the anode should not be too small relatively to the transverse dimensions of the magnet field (pole) and of the cathode. A sufficient surface of the anode is considered to be present if the width of the active surface of the anode is larger than the smallest dimension of the transverse section of the magnet pole.

It is desirable that on each side of the cathode conductive bodies, for example plates, should be provided transversely to the magnetic lines of force and the anode or anodes should be placed in a circular and symmetrical manner relatively to this axis about the cathode, these limiting bodies covering at least the projection of the cathode in the direction of the lines of force and being preferably arranged at such a mutual distance that approximately the minimum value of the arc-voltage as a function of this distance is obtained. In fact, the experiments on which the present invention is based have revealed that this function exhibits a minimum. Under otherwise unvaried conditions the arc-voltage increases with the distance between the pole-bodies of the magnetic field, as it then occurs that the limiting bodies are too far remote from each other. Also with too small a dimension of the discharge space in the direction of the magnetic field, it then occurs that there is too small a spacing between the limiting bodies.

The foregoing may be taken into account in a highly advantageous manner by utilizing the pole-bodies or pole-shoes in the tube, which are arranged on each side of the cathode, as limiting bodies, it being advisable to give the latter cathode potential, or a potential which is at most a few tens of volts negative or a few volts positive relatively to the cathode. The latter offers in some cases the advantage that the arc-voltage in the direction of passage is still further decreased.

It is advisable for the anode or the anodes and the cathode to be separated by a screen arranged within the anode or anodes, preferably in such manner that all straight lines which may be drawn between arbitrary points of the active surface of the cathode on the one hand and points of the surface of the anode on the other hand cut the screen. It is thus possible for the blocking power of the tube to be increased to a considerable extent, since the particles originating from the cathode are prevented from reaching the anodes along a straight-line path.

This screening bush between the anode and the cathode must be made of non-magnetic material, or at least of a magnetic material which at the operating temperature attains a temperature above the Curie-point as a result of the heat production of the cathode.

A highly advantageous construction of the device according to the invention is obtained if the internal members of the tube between which a high potential difference, for example the blocking voltage of the tube, may occur, are so arranged that the length of the free electrostatic paths of the lines of force between the said members is not more than about the average free length of the electron path at the operating pressure of the tube. It is thus always ensured that the pd-value for the discharge path between the anode and the cathode is equal to a point of the break-down potential curve of Paschen which is located on the left of the minimum. As is well-known, in this case a higher blocking voltage is obtained according as the electrode spacing is smaller so that the compactness of the construction is promoted.

In elaborating the foregoing it is advisable for one or more anodes to be placed in a hollow-cylindrical manner about the cathode and coaxially of the magnetic field and to cause them, jointly with the limiting bodies in which blocks of magnetic material are inserted on each side of the cathode, to constitute a box-shaped screening which contains, symmetrically relatively to the discharge space, the cathode screened radially relatively to the anode or anodes, this space being bounded on each side in the field direction by flat planes, of which the front sides of the magnet blocks form part. This construction offers the advantage that a highly compact discharge space is obtained which may be circumscribed on all sides by smooth surfaces, while the formation of free electrostatic paths of lines of force of excessive length is preliminarily avoided by the box-shaped character of the whole of screens and anode or anodes.

If in one of the above-described manners the cathode is separated from the anode by a screen, it is advantageous to construct this screen, preferably jointly with the limiting bodies, as a control member for the passage of the discharge.

In order that the invention may be more clearly understood and readily carried into effect, it will be explained more fully with reference to the accompanying drawing showing, by way of example, a few embodiments thereof.

Figs. 1, 2 and 3 show constructions of tubes to be used in devices according to the invention.

Fig. 1 shows schematically a converter tube comprising a discharge vessel 1, an incandescent cathode 2 and an anode 3 which are led to the exterior in a vacuum-tight manner in 4, 5 and 6 respectively. Outside the tube is a permanent magnet 7 with pole-pieces 8 and 9, arranged on each side of the discharge vessel 1. In addition, two limiting bodies 10 and 11 are located at the height of these pole-pieces and traverse to the axis of the cylindrical anode 3, said limiting members being connected electrically and mechanically to the cathode. Due to the action of the magnetic field, the discharge is concentrated in the cross-hatched region 12 which is constituted by projection of the cathode in the direction of the lines of force and bounded on each side by the bodies 10 and 11. The anode 3 is located very advantageously outside this concentrated part of the discharge with the result that low arc-voltages are obtained, while also the intensity of the magnetic field of the anode has still a but low value and the blocking power of the tube is not appreciably decreased.

Fig. 2 shows a construction in which the anode is also arranged cylindrically about the cathode but is located in a magnetic field generated by blocks 22 and 23 of magnetic material with poles of the same sign, which are mounted symmetrically above and below the cathode in cylindrical box-shaped limiting members 24 and 25 which are co-axially arranged in the tube. The cathode 21, too, is surrounded by a box-shaped screen 26 having axial apertures 27 and 28 whose section is so chosen that a sufficient electrostatic screening of the cathode is obtained without involving an undesirable increase of the arc-voltage in the direction of passage. The bodies 24, 25 and 26 are constructionally joined to each other and led to the exterior in 29, so that it is possible to use the whole as a control member for the tube. Besides, the lower part of the body 25 is provided with an annular screen 30 which constitutes an obturation relatively to the glass wall which adjoins the anode cylinder 20 closed on top, the arrangement being such that electrostatic paths of lines of force of undesired length cannot extend freely between the terminal wires 31, 32 and 33 on the one hand and the terminal wire 34 of the anode on the other hand. This construction permits of obtaining a tube having an extremely high blocking power which, in spite of the required low pressure of the gaseous or vapour atmosphere during operation, exhibits an excellent life of the cathode, since the arc-voltage in the direction of passage is very low in spite of the low pressure.

Fig. 3 shows schematically a tube of which like parts are provided with the reference numerals as in Fig. 1. The discharge vessel 1 contains an incandescent cathode 2 whose supply wires are led to the exterior in 4 and 5, whereas the flat annular anode 15 is led to the exterior in 6 at the opposite end of the discharge vessel. In contradistinction to the case shown in Fig. 1, the magnets 16 are here located inside the discharge vessel 1, coaxial and on each side symmetrical of the anode 15. The direction of the magnetic lines of force is shown schematically, whereas the region having a field strength equal to naught is indicated by a dot-and-dash line. The construction is so proportioned and arranged that the anode lies in a region where the field strength is practically nil. In this connection it may be mentioned that with a distance $2d$ of the blocks the diameter of the equator plane in which the field strength is nil has about the size of $2d\sqrt{2}$. A cylindrical screen 17 is arranged coaxially inside the anode 15, said screen separating the cathode in the radial direction from the anode and being placed at cathode potential. Due to this screen, the cathode "cannot see" the anode so that the latter is screened in straight line from particles, for example of activating material, originating from the cathode.

When in this description and in the claims reference is made to "the anode," this has to be understood to mean also a plurality of anodes.

What we claim is:

1. An electron discharge device comprising a converter tube with a gaseous filling, an incandescent cathode in said tube and having a major axis, an electron emitting surface along said major axis of said cathode to emit electrons substantially perpendicularly to said emitting surface, means to establish a magnetic field transversely to said major axis of said cathode and having a part of said field passing through the said emitting surface in the direction of said electron emission, and an anode in said tube encircling said cathode and substantially symmetrically positioned with respect thereto and coaxially disposed about and outside of that part of the magnetic field which passes through the emitting surface of said cathode, said magnetic field having a strength such that approximately the minimum value of the arc voltage of the tube as a function of the field strength is obtained and the intensity of the field at the anode is within 5 gauss.

2. A device as claimed in claim 1, in which the magnetic field is constituted by blocks of permanent magnet material which are arranged coaxially one on each side of the cathode and within the discharge vessel of the tube.

3. A device as claimed in claim 2, in which the anode is in the form of a ring, and is arranged with its surface normal to the axis of the magnetic field and in the surface of symmetry between the permanent magnetic blocks, in which surface the cathode is placed centrally, while the average distance between the axis of the field and the various points of the active surface of the anode is the $\sqrt{2}$-fold of half the distance between the permanent magnetic blocks.

4. A device as claimed in claim 1 in which a magnet is disposed outside the discharge vessel of

the tube the magnet having pole-shoes that are considerably smaller than the diameter of the discharge path and that are placed on each side thereof in line with the cathode.

5. A device as claimed in claim 2 in which the magnetic poles are smaller than the largest projection of the cathode in their direction.

6. A device as claimed in claim 2 in which the anode is made of material which is not magnetic at the operating temperature of the tube.

7. A device as claimed in claim 2 in which the width of the active surface of the anode is larger than the smallest dimension of the transverse section of the magnet pole.

8. A device as claimed in claim 2 comprising conductive plates arranged on each side of the cathode transversely to the magnetic lines of force and the anode is placed in a circular manner and symmetrically relatively to this axis about the cathode, the conductive plates having a dimension transverse to the axis that is sufficient to cover the projection of the cathode in the direction of the axis the lines of force and said plates being arranged at such a mutual distance that approximately the minimum value of the arc-voltage as a function of this distance is obtained.

9. A device as claimed in claim 8, in which the plates provided on each side of the cathode are constituted by pole-shoes present in the tube.

10. A device as claimed in claim 9, in which the plates are placed at cathode potential.

11. A device as claimed in claim 10, in which the anode and the cathode are separated by a screen arranged within the anode in such manner that all straight lines which may be drawn between points of the active surface of the cathode and of the surface of the anode cut the screen.

12. A device as claimed in claim 11, in which the screening bush between the cathode and the anode is non-magnetic at the operating temperature that the tube attains as a result of the heat production of the cathode.

13. A device as claimed in claim 11, in which the internal members of the tube between which a high potential difference, for example the blocking voltage of the tube, may occur, are so arranged that the length of the free electrostatic paths of the lines of force between these members is not more than about the average free length of the electron path at the operating pressure of the tube.

14. A device as claimed in claim 11, in which the screen about the cathode, and the plates are adapted for use as control members for the control of the passage of the discharge through the tube.

JOHANNES GIJSBERTUS WILHELM MULDER.
TOM JURRIAANSE.
FRANS MICHEL PENNING.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,558,120	Simpson	Oct. 20, 1925
1,666,858	Jahn	Apr. 17, 1928
1,791,973	Perryman	Feb. 10, 1931
1,807,098	Bodde	May 26, 1931
2,116,393	Griffith	May 3, 1938
2,135,006	Jurriaanse	Nov. 1, 1938

FOREIGN PATENTS

Number	Country	Date
147,856	Great Britain	Jan. 9, 1922
660,398	Germany	May 21, 1938