[Second Edition.]

PATENT SPECIFICATION

Application Date : Feb. 25, 1935. *No. 6037/35.* **452,589**

(Patent of Addition to No. 431,327 : dated Oct. 3, 1933.)

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PROVISIONAL SPECIFICATION.

Improvements in Cathode Ray Tubes.

We, FREDERICK HERMES NICOLL, a British Subject, of 17, The Drive, Ickenham, Middlesex, and ELECTRIC AND MUSICAL INDUSTRIES LIMITED, a British Company, of Blyth Road, Hayes, Middlesex, do hereby declare the nature of this invention to be as follows:—

A form of cathode ray tube has been proposed consisting of a highly evacuated envelope in which there is placed an electron emitting cathode behind an apertured diaphragm known as the cathode shield. The electrons from the cathode, after passing through the cathode shield which may be at or near cathode potential, are first accelerated towards an accelerator electrode, then decelerated towards a modulator electrode and again accelerated by a plurality of anodes, usually two in number and referred to as the first and second anodes. The various pairs of adjacent electrodes, at different potentials, in particular the first and second anode serve as electron lenses to focus the beam upon a fluorescent screen. The brightness of the spot formed by the cathode ray upon the screen is varied by applying a varying negative potential to the modulator electrode relatively to the cathode. The electrodes are commonly in the form of metal tubes having apertured diaphragms, and it is usual to make these diaphragms in the form of planar metal discs, provided with circular apertures concentric with the discs.

In an ideal case all the electrons leaving the modulator electrode would reach the fluorescent screen, but in practice this is not the case: it is found that they tend to collect on such electrodes as are above the potential of the cathode, and they are then lost in the form of current in the corresponding electrode circuits. An indication of the efficiency of the tube may be obtained from the ratio of fluorescent screen current to first anode current. This ratio may be increased by lengthening the tubular portion of the modulator electrode, but only at the expense of sharpness of focusing of the beam.

It is an object of the present invention to provide a cathode ray tube of the kind above described in which the efficiency of the tube, measured by the ratio of screen current to anode current, is increased, without resultant decrease in the sharpness of focusing of the beam.

According to the present invention there is provided a cathode ray tube comprising a cathode and a plurality of electrodes for accelerating electrons from said cathode towards and focusing them upon a screen associated with the tube, one or more of said electrodes comprising an apertured diaphragm, the invention being characterised in that the diaphragm is of part spherical or other dished shape. The diaphragm may advantageously be that in the modulator electrode and may be arranged with its concave side facing away from the cathode.

Further according to the present invention, a cathode ray tube having a cathode, a modulating electrode and an electrode system for directing the electrons from the cathode upon a screen associated with the tube is characterised in that the modulator electrode has an apertured diaphragm of dished, frusto-conical or like shape. Preferably the shape of the diaphragm is such that portions thereof around the aperture are substantially normal to the incident ray and portions further from the ray are at progressively decreasing angles to the ray.

In carrying the invention into effect, one may proceed as follows:—

A cathode ray tube is constructed in the manner already described, having the accelerator, modulator and first anode in the form of metal tubes all of the same diameter as the cathode shield. The accelerator tube is short and has an apertured diaphragm in the end remote from the cathode.

The modulator tube is longer than the accelerator and has an apertured diaphragm intermediate between the ends of the tube and on the cathode side of the centre of the tube. The first anode is of much greater length than the modulator, and has an apertured diaphragm in the end nearer the cathode and a second diaphragm with a larger aperture about two-

[*Price* 1/-]

thirds of the way along from this end. The second anode is in the form of a tube of considerably larger diameter, the adjacent edges of the two anodes being located substantially in a plane but slightly overlapping. The second anode may be in the form of a silvering upon the inside of the tube envelope. All the tubes are arranged co-axially. Such a tube gives a well focused beam of electrons on the fluorescent screen in the following way. Electrons are accelerated from the cathode by means of a relatively low positive potential on the accelerator; after passing through the accelerator the electrons are decelerated to the modulating electrode which is at or near zero potential with respect to the cathode screen. The high positive potential of the first anode then accelerates the electrons from the modulator aperture, and they pass through the two apertures in the first anode. The second anode is maintained at a potential higher than the first anode and the field between these two anodes forms an electrostatic lens which focuses the electrons into a fine spot on the screen.

When the diaphragms of the tubes above mentioned are in the form of flat discs with apertures in their centres, it is found that the average ratio of screen current to first anode current is less than unity.

As already stated, it is possible to decrease the first anode current and consequently increase the second anode current or screen current by simply lengthening the modulator tube on the first anode side of the modulator aperture. This is accomplished, however, only at the expense of the focus which becomes very poor.

According to the present invention, however, the efficiency can be increased by providing a modulator diaphragm of a dish-shaped or frusto-conical form, positioned in such a way that the aperture in it is nearer to the cathode than the rim where it joins the modulator tube. The effect of such a tube is to so shape the equipotential lines of force that they tend to converge the electrons into a beam which passes through the apertures of the first anode, so that only a very small fraction of the beam is collected by the first anode.

The preferred shape for the aforementioned dish-shaped diaphragm is hemispherical and it may be placed with its concave side facing away from the cathode end of the tube, but the invention is not restricted to this shape. The diaphragm may for example be parabolic.

The invention is of course not restricted in its application to the particular form of cathode ray tube described above, which is by way of example.

The diaphragm of the present invention may be of thick material or may be arranged with a second apertured diaphragm close to it to form a double apertured modulator as described in co-pending Application No. 33294/34 (Serial No. 447,493).

Dated this 25th day of February, 1935.

REDDIE & GROSE,
Agents for the Applicant,
6, Bream's Buildings, London, E.C.4.

COMPLETE SPECIFICATION.

Improvements in Cathode Ray Tubes.

We, FREDERICK HERMES NICOLL, a British Subject, of 17, The Drive, Ickenham, Middlesex, and ELECTRIC AND MUSICAL INDUSTRIES LIMITED, a British Company, of Blyth Road, Hayes, Middlesex, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The present invention is an improvement in or modification of the invention forming the subject of Patent No. 431,327.

In the specification of that Patent there is described and claimed an electric circuit comprising a cathode ray tube of the hard type having arranged within its envelope, in the order mentioned, a cathode, a first accelerator, a decelerator having an apertured diaphragm, and a second accelerator, the accelerators and decelerator being so disposed that the ray can pass through them to a screen associated with the tube, and the tube having means whereby the ray can be deflected over the screen, and electrostatic or electromagnetic means for focussing the ray in a small spot upon the screen, characterised by means for applying to the accelerators potentials positive with respect to the cathode potential and to the decelerator a potential equal, or nearly equal to the cathode potential, the shape and disposition of the electrodes and the potentials applied thereto being such that, in operation, increases of potential of the decelerator, in the negative sense with respect to the cathode potential, produce increases of current flowing to the

first accelerator.

The said electric circuit as described and claimed in the parent Patent may comprise a cathode ray tube having arranged within its envelope, between said second accelerator and said screen, a second decelerator adjacent said second accelerator, and a third accelerator, characterised by means for applying to the accelerators potentials positive with respect to the cathode potential and to the decelerators potentials equal, or nearly equal, to the cathode potential.

In the parent Patent there is also described and claimed a cathode ray tube of the hard type having an indirectly heated cathode and an anode, and having, between the cathode and anode, at least four auxiliary electrodes including two accelerators and a decelerator, one of said accelerators being arranged upon either side of said accelerator, the arrangement being such that when the accelerators are maintained at suitable positive potentials, relative to the cathode and when the decelerator is at a potential in the neighbourhood of cathode potential, increases of potential of the decelerator in a negative sense with respect to the cathode potential produce increases in current flowing to the accelerator located upon the cathode side of the decelerator.

With cathode ray tubes of the kind to which the parent specification relates, it is usual to vary the brightness of the spot, formed by the cathode ray upon the screen, by applying to the decelerator electrode between the first and second accelerator electrodes a varying potential which is negative with respect to the cathode. The decelerator may therefore be regarded as the modulator. The electrodes are commonly in the form of metal tubes having apertured diaphragms, and it is usual to make these diaphragms in the form of planar metal discs, provided with circular apertures concentric with the discs.

In an ideal case all the electrons leaving the modulator electrode would reach the fluorescent screen, but in practice this is not the case; it is found that they tend to collect on such electrodes as are above the potential of the cathode, and they are then lost in the form of current in the corresponding electrode circuits. An indication of the efficiency of the tube may be obtained from the ratio of fluorescent screen current to first anode current. This ratio may be increased by lengthening the tubular portion of the modulator electrode, but only at the expense of sharpness of focusing of the beam.

Objects of the present invention are to provide an electric circuit of the kind hereinbefore set forth, and a cathode ray tube adapted for use in such a circuit, in which the efficiency of the tube, measured by the ratio of screen current to anode current, is increased without resultant decrease in the sharpness of focusing of the beam.

According to the present invention in an electric circuit of the kind hereinbefore specified, at least one of the said decelerators, and/or a cathode shield electrode if provided, comprises an apertured diaphragm the surface of which facing the screen is of dished or frusto-conical shape and has its concave side turned towards said screen.

According to the present invention in a further aspect, in a cathode ray tube of the kind hereinbefore specified said decelerator, and/or a cathode shield if provided comprises an apertured diaphragm the surface of which facing the anode is of dished or frusto-conical shape and has its concave side turned towards said anode.

Preferably the shape of the diaphragm is such that portions thereof around the aperture are substantially normal to the incident ray and portions farther from the ray are at progressively decreasing angles to the ray.

The invention will now be described with reference to the accompanying diagrammatic drawings in which Figs. 1 and 2 illustrate the electrode system of two forms of cathode ray tube according to the parent Patent modified according to the present invention, and Fig. 3 shows an alternative form of electrode in the tube shown in Fig. 1.

Referring to Fig. 1, there is illustrated a cathode ray tube constructed in the manner already described, and having the accelerator 1, modulator 2 and first anode 3 in the form of metal tubes all of the same diameter as the cathode shield 4. The latter is arranged next to the cathode 5, the other electrodes being arranged in the order mentioned proceeding from the cathode shield 4. The accelerator tube 1 is short and has an apertured diaphragm 6 in the end remote from the cathode 5. The modulator tube 2 is longer than the accelerator and has an apertured diaphragm 7 intermediate between the ends of the tube and on the cathode side of the centre of the tube. The first anode 3 is of much greater length than the modulator, and has an apertured diaphragm 9 in the end nearer the cathode and a second diaphragm 10 with a larger aperture about two-thirds of the way along from this end. The second anode 8 is in the form of a tube of considerably larger diameter, the adjacent edges of

the two anodes 3 and 8 being located substantially in a plane but slightly overlapping. The second anode 8 may be in the form of a silvering upon the inside of the tube envelope. All the tubes are arranged co-axially. Such a tube gives a well focused beam of electrons on the fluorescent screen which is not shown, but which is disposed on the side of the second anode 8 remote from the cathode in the following way. Electrons are accelerated from the cathode 5 by means of a relatively low positive potential on the accelerator 1; after passing through the accelerator 1 the electrons are decelerated to the modulating electrode 2 which is at or near zero potential with respect to the cathode screen 5. The high positive potential of the first anode 3 then accelerates the electrons from the modulator aperture, and they pass through the two apertures in the first anode 3. The second anode 8 is maintained at a potential higher than the first anode 3, and the field between these two anodes forms an electrostatic lens which focuses the electrons into a fine spot on the screen.

When the diaphragms of the tubes above mentioned are in the form of flat discs with apertures in their centres, it is found that the average ratio of screen current to first anode current is less than unity.

As already stated, it is possible to decrease the first anode current and consequently increase the second anode current or screen current by simply lengthening the modulator tube on the first anode side of the modulator aperture. This is accomplished, however, only at the expense of the focus which becomes very poor.

According to the present invention, however, the efficiency can be increased by providing a modulator diaphragm the surface of which has a dished or frusto-conical shape, positioned in such a way that the aperture in it is nearer to the cathode than the rim where it joins the modulator tube. The effect of such a tube is to so shape the equipotential lines of force that they tend to converge the electrons into a beam which passes through the apertures of the first anode, so that only a very small fraction of the beam is collected by the first anode.

The preferred shape for the aforementioned dish-shaped diaphragm is hemispherical with its concave side turned towards the screen end of the tube, but the invention is not restricted to this shape. The diaphragm may for example be parabolic. In Fig. 1 the modulator diaphragm 7 is shown as having a surface 11 of hemispherical shape, and having its concave side turned towards the screen.

In Fig. 2 there is shown a cathode ray tube having a cathode 5, a cathode shield 4, a first accelerator 12, a decelerator and modulator 13, a second accelerator 14, a second decelerator 15 and first and second anodes 3 and 8. All the electrodes are in the form of co-axial metal tubes of equal diameters with the exception of the second anode 8 which has the form already described with reference to Fig. 1.

In this tube, according to the present invention there is provided a dish-shaped surface 11 on the diaphragm 7 of the second decelerator 15, shown in this case as hemispherical, and with its concave side turned towards the fluorescent screen.

In operation of the tube means are provided for maintaining the electrodes of the tube at various voltages of which the following is an example. The potentials are given relative to the potential of the cathode 5. The cathode shield 4, −0 volts; first and second accelerators 12 and 14, +250 volts; second decelerator 15, +5 volts; first anode, +800 volts; second anode +4000 volts. The intensity of the beam is modulated by varying the potential of the modulator 13 from zero to about −30 volts.

If desired, the first decelerator may be provided with a dished diaphragm having its concave side turned towards the fluorescent screen. A cathode ray tube according to the present invention, of the kind shown in Fig. 2, may have either or both decelerators provided with such diaphragms.

An advantageous focusing effect is also obtained if the cathode shield 4 of either of the tubes shown in the drawings has a diaphragm of dished form with its concave side turned towards the screen. Such a diaphragm serves to concentrate more electrons through the aperture in the first accelerator (1, in Fig. 1 or 12, in Fig. 2).

Though hemispherical diaphragms have been shown in the Figures, other dished shape or the like diaphragms may be used. For example, the surface 11 may be frusto-conical, or parabolic. It is preferred to use surfaces such that portions thereof around the aperture are substantially normal to the ray, and portions farther from the ray are at progressively decreasing angles to the ray. The surface has, in other words, preferably the form of the surface of revolution of a curve.

It is not essential for the dished or frusto-conical diaphragm according to the present invention to present a continuous surface. The diaphragm may thus comprise a plurality of flat plates spaced at short intervals apart and having co-axial

apertures of progressively varying diameters. Thus the modulator 2 of Fig. 1 may be replaced by the electrode shown in Fig. 3 where the dished diaphragm is composed of the four flat apertured plates 7, 11*a*, 11*b* and 11*c*.

The aperture in the diaphragm of the modulator electrode may be lengthened in any of the ways, and for the purposes, described in Patent Application No. 33294/34 (Serial No. 447,493).

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. An electric circuit constituting an improvement in or modification of the invention forming the subject of Patent No. 431,327 wherein at least one of the decelerators of the cathode ray tube, and/or a cathode shield electrode if provided comprises an apertured diaphragm the surface of which facing the screen is of dished or frusto-conical shape and has its concave side turned towards said screen.

2. An electric circuit as claimed in claim 1, wherein said surface is of such shape that portions thereof around the aperture are substantially normal to the ray and portions farther from the ray are at progressively decreasing angles to the ray.

3. An electric circuit as claimed in claim 2 wherein said surface is of part-spherical shape.

4. An electric circuit as claimed in claim 3 wherein said surface is hemispherical.

5. An electric circuit as claimed in any of the preceding claims wherein a decelerator having said dished or frusto-conical diaphragm surface also serves as a modulator electrode.

6. A cathode ray tube constituting an improvement in or modification of the invention forming the subject of Patent No. 431,327 wherein said decelerator and/or a cathode shield electrode if provided comprises an apertured diaphragm the surface of which facing the anode is of dished, or frusto-conical shape and has its concave side turned towards said anode.

7. A cathode ray tube, as claimed in claim 6 wherein said surface is of such shape that portions thereof around the aperture are substantially normal to the ray and portions farther from the ray are at progressively decreasing angles to the ray.

8. A cathode ray tube as claimed in claim 7, wherein said surface is of part-spherical shape.

9. A cathode ray tube as claimed in claim 8, wherein said surface is hemispherical.

10. Electric circuits substantially as described herein.

11. Cathode ray tubes substantially as described herein, with reference to the accompanying drawings.

Dated this 6th day of February, 1936.

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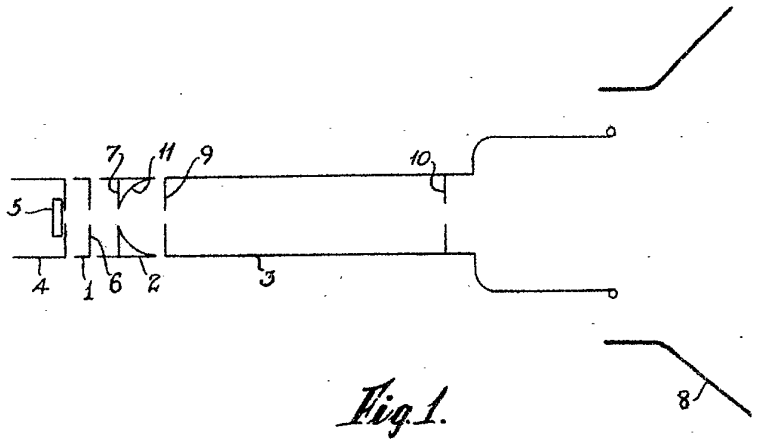

Fig. 1.

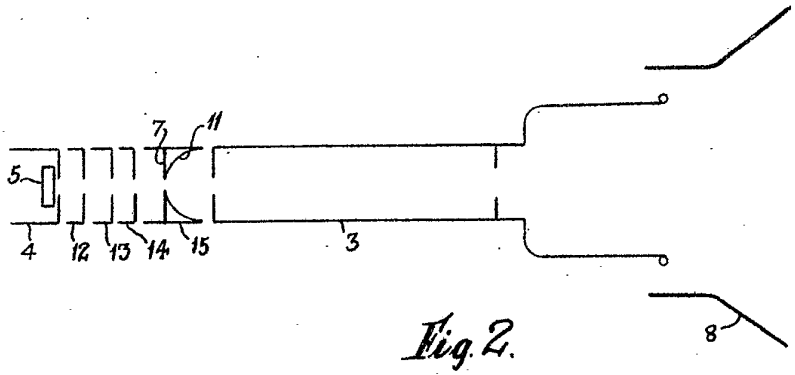

Fig. 2.

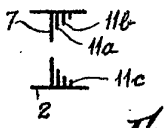

Fig. 3.

Malby & Sons, Photo-Litho.