Sept. 20, 1955

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2,718,606

COMBINATION ELECTROMAGNET-PERMANENT MAGNET FOCUSING DEVICES

Filed Aug. 2, 1952

Fig. 1.

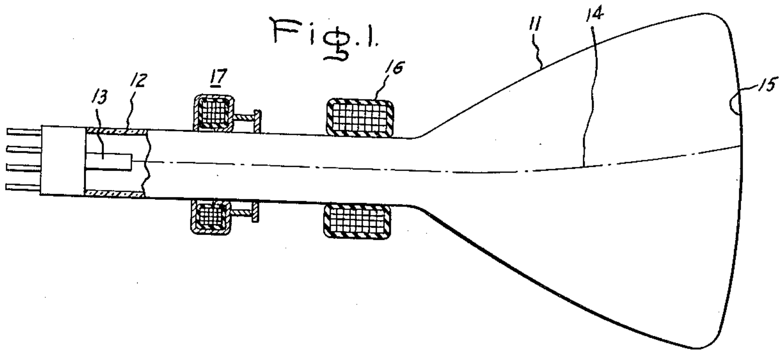


Fig. 3.

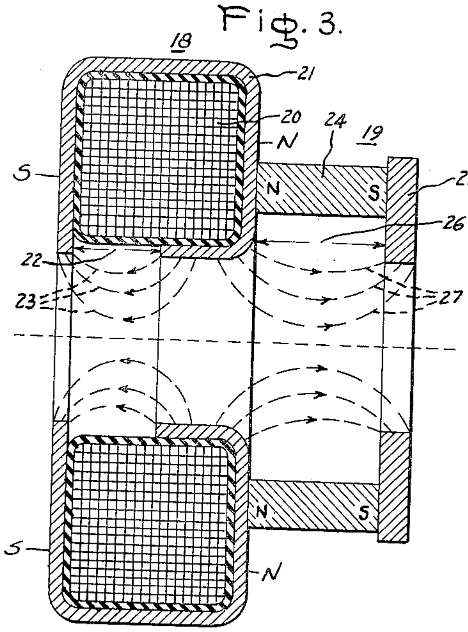


Fig. 2.

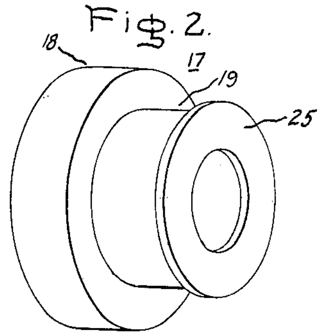
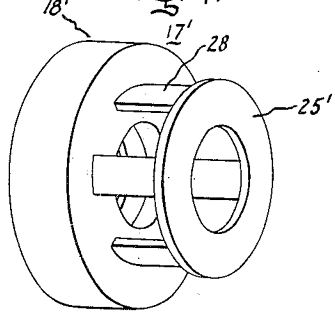


Fig. 4.



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United States Patent Office 2,718,606
Patented Sept. 20, 1955

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COMBINATION ELECTROMAGNET-PERMANENT MAGNET FOCUSING DEVICES

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Application August 2, 1952, Serial No. 302,313
10 Claims. (Cl. 313—76)

My invention relates to structures for focusing electron beams in electron discharge devices of the cathode-ray type, and more particularly to focusing structures employing both permanent magnets and electromagnets as sources of magnetomotive force.

In cathode-ray tubes, such as are employed in television receivers, oscilloscopes, and the like, it is generally necessary to provide means for centering and adjusting the electron beam in order to orient properly the image traced by the electron beam on the picture screen. It is common practice to accomplish this function by means of a magnetic focusing device. This may be of the electromagnetic type, employing a solenoid coil positioned externally around the neck of the cathode-ray tube, or of the permanent magnet type, having a toroidal structure arranged to produce a generally cylindrical magnetic field along the beam axis.

One problem encountered in the electromagnetic type of focusing device is that of "drift," a gradual defocusing due to fluctuations in coil current caused by resistance variations as a result of heat generated therein. These fluctuations have been reduced by providing, in addition to the electromagnetic coil, a permanent magnet in cooperation therewith, thereby reducing the flux demand on the electromagnet, and resulting in lower current requirements for the electromagnet. Such combination focusing devices further tend to stabilize the focus by compensating for line voltage variations.

In combination electromagnet-permanent magnet focusing devices previously known, the arrangement of the magnets around the neck of the tube has generally been such, e. g. concentric, that the fluxes of both magnets pass through the permanent magnet structure. In such case, when the coil is energized, the flux which it produces through the permanent magnet, causes the latter to change its operating point on the de-magnetization curve along a minor hysteresis loop. Since the magnetic material in the permanent magnet is usually of high reluctance, the electromagnet is therefore required to supply an appreciable amount of magnetomotive force to increase the flux through the permanent magnet and, in addition, to supply the increased power needed to produce the flux in the air gap. It becomes impractical, therefore, to allow the electromagnetic component of the focusing field to exceed approximately ten percent of the total required flux. This in turn results in a decrease of efficiency which ordinarily necessitates increasing the cross-section of the permanent magnet over that which is otherwise required to provide the necessary field. This correction results in a permanent magnet that is heavier and bulkier and that requires more magnetic material than would otherwise be necessary.

In accordance with one aspect of my invention, an electron-beam focusing apparatus is provided which combines the electromagnetic type of focusing means and the permanent magnet type of focusing means in polar opposed relation. More specifically, it comprises an electron-beam focusing lens including electromagnetic focusing means and permanent magnet focusing means axially aligned with one another in successive relation. These means are arranged so that magnetic poles of like polarity face one another and so that each of said magnet means maintains a flux pattern across a separate and distinct gap, thus excluding said permanent magnet means from the flux path of said electromagnetic means.

Thus, it is a main object of my invention to provide an improved electron-beam focusing apparatus having both permanent magnet and electromagnet focusing means wherein the efficiency of the electromagnet is not affected by the permanent magnet.

Another object of my invention is to provide a more efficient electron-beam focusing apparatus of the combination electromagnet-permanent magnet type than has heretofore been achieved, wherein a reduced quantity of magnetic material is required, thereby effecting a saving of size, weight and cost of the apparatus.

For additional objects and advantages, and for a better understanding of the invention, attention is now directed to the following description and accompanying drawings. The features of the invention which are believed to be novel are particularly pointed out in the appended claims.

Referring to the drawings, Fig. 1 shows a cross-sectional view of a cathode-ray tube incorporating a magnetic focusing structure embodying the invention; Fig. 2 is a perspective view of a magnetic focusing structure embodying the invention; Fig. 3 is an enlarged view of a longitudinal cross section through the magnetic focusing structure of Fig. 2; and Fig. 4 is a perspective view of a modified magnetic focusing structure embodying the invention.

Referring now to Fig. 1, there is shown a conventional cathode-ray tube assembly including an electron-beam focusing lens embodying one form of the invention. The cathode-ray tube is provided with a glass envelope comprising a bowl portion **11** and an elongated cylindrical neck **12**. Within the neck **12** near the end farthest from the bowl **11** there is provided an electron gun **13**, the construction and operation of which are well known in the art. The gun **13** projects a beam of electrons **14** along the axis of the neck **12** and against the fluorescent screen **15**, causing it to emit light in a well known manner.

A conventional deflecting coil assembly **16** is mounted on the neck **12** adjacent the bowl **11** to provide vertical and horizontal beam deflection in order to provide means for scanning the screen **15** to produce an image, in a manner well understood in the art. Although magnetic deflecting coils have been shown, it is apparent to those skilled in the art that electrostatic deflecting means or combination electrostatic-magnetic deflecting means may be employed instead.

In accordance with the invention, an electron beam focusing lens **17** is also mounted on the neck **12** at a position between the gun **13** and the deflecting coils **16**. Its function is to produce an axial magnetic field of proper intensity to cause the beam of electrons **14** to come to a sharp focus in the form of a spot on the screen **15** and to center the spot thus formed.

As shown in Fig. 2, focusing lens **17** comprises an electromagnet component shown generally at **18** and a permanent magnet component shown generally at **19**. As is illustrated more clearly in the cross-sectional view of Fig. 3, the lens is provided with a generally toroidal coil **20** which is supplied with electric energy by connecting it to some convenient direct current source (not shown) in order to develop an electromagnetic field along its axis in a conventional manner. Coil **20** is provided with a generally toroidal housing **21** completely surrounding it except for axially-extending annular gap **22** concentric with the coil **20**. Housing **21** is made of low reluctance material, such as soft iron, which provides a low-resistance path for the electromagnetic flux sustained by the coil **20** and concentrates the entire electromagnetic flux across the gap **22** in well known manner, as represented by the dashed flux lines **23** in Fig. 3.

The permanent magnet field of lens **17** is provided by a permanent magnet **24** in the form of a cylinder that is axially aligned with coil **20** and housing **21** and magnetized to produce an axial magnetic field of opposite polarity, as indicated by dashed flux lines **27**. In the form of the invention shown in Fig. 3, the north pole of electromagnetic coil **20** faces the north pole of permanent magnet **24** and the north end of magnet **24** abuts against housing **21**. However, in some cases it may be desirable to place the south poles of the respective magnets in opposition, rather than the north poles as illustrated. It may, likewise, be desirable in some cases not to have the opposing members in abutting relationship, providing that a portion of the flux from each flows through a common pole piece. As shown, annular pole piece **25**, formed of low reluctance material, such as soft iron, is axially aligned with permanent magnet **24** and abuts against the end thereof remote from housing **21**. It is apparent to those skilled in the art that a path of low resistance to magnetic flux is thus provided for the flux of permanent magnet **24** through pole piece **25** and a portion of housing **21** within the circumference of permanent magnet **24**. The last-mentioned portion of housing **21** therefore forms a common pole piece for both electromagnet **20** and permanent magnet **24** and, together with pole piece **25**, tends to concentrate the entire flux of permanent magnet **24** across the gap **26** as represented by the flux lines **27**.

It is seen from the above that although a part of housing **21** is common to the flux circuits of both the electromagnet **20** and the permanent magnet **24**, the flux of the electromagnetic circuit does not pass through the permanent magnet **24** and, hence, it is unnecessary to consider the reluctance of the cylindrical permanent magnet **24** in determining its size relative to that of the electromagnet **20**.

Referring again to Fig. 1, when an electron beam **14** is projected through lens **17**, it comes under the influence of the two magnetic fields in succession. First, it is subjected to the focusing action of the field developed by electromagnet **20** and then it is subjected to the focusing action of the field developed by permanent magnet **24**. As indicated by the directions of the arrow-heads on flux lines **23** and **27** in Fig. 3, the fields associated with the respective magnets **20** and **24** are aligned in opposite directions. This will have little or no effect on the focusing of the two fields, however. The axial component of the magnetic fields will exert a small or negligible influence on the velocity of the electrons, especially since the fields are short, and any effect due to one magnetic field will tend to be canceled by the other acting in the opposite direction. The combination radial and tangential components are essentially the forces responsible for focusing. Thus, axial electrons will pass straight through the magnetic center of lens **17**, subject only to the minimal effect of the axial components of the two fields. Paraxial electrons will be subject to the effect of the axial component to a like extent and will also be affected by the radial and tangential components in the usual manner, causing them to be focused according to well known principles of electron optics. It is noted, however, that the usual rotation to which paraxial electrons are subjected in passing through a magnetic focusing lens will be somewhat reduced since the rotations imparted by the separate magnetic fields associated with magnets **20** and **24** will be in opposite directions, according to the familiar right-hand rule.

In Fig. 4, there is shown a modified form of the invention in which the magnetic cylinder (**24** of Figs. 2 and 3) has been replaced by a plurality of magnetized bars or slugs **28** having their poles aligned in conformity and disposed at equi-spaced positions about the axis of the lens.

The portions of Fig. 4 bearing the numerals designated prime correspond to the portions of Fig. 2 having similar numerals. In cooperation with the associated pole pieces, the bars or slugs **28** are essentially as effective as the magnetized cylinder **24** of Fig. 3. This construction is also less difficult to manufacture and represents a cost reduction over the cylindrical form.

It is seen from the foregoing description that I have provided an improved combination electromagnet-permanent magnet electron-beam focusing lens of increased efficiency having a permanent magnet portion of reduced size and weight, thus representing a saving in the quantity of magnet material used.

While specific embodiments have been shown and described, it will, of course, be understood that various modifications may be made without departing from the principles of the invention. The appended claims are therefore intended to cover any such modifications within the true spirit and scope of the invention.

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

1. An electron beam focusing lens for cathode-ray tubes and the like comprising, in combination, first, second and third generally annular pole pieces axially aligned in that order in spaced relation with one another to provide axial gaps therebetween, electromagnetic means for developing a first axial field across the gap between said first and said second pole pieces, and permanent magnet means for developing a second axial field in polar opposed relation to said first field across the gap between said second and third pole pieces.

2. An electron beam focusing lens for cathode-ray tubes and the like comprising, in combination, electromagnetic focusing means including a generally toroidal coil, and north and south pole pieces, permanent magnet focusing means also including north and south pole pieces, and means for axially aligning said first and second focusing means in polar opposed relation, one of said pole pieces being common to both said focusing means.

3. An electron beam focusing lens for cathode-ray tubes and the like comprising, in combination, electromagnetic focusing means including a generally toroidal coil and a housing of low reluctance material enclosing said coil except for a generally annular gap therein, and permanent magnet focusing means including a pair of spaced pole pieces bridged by permanently magnetized material, one of said pole pieces including a generally annular ring of low reluctance material and the other including a portion of said housing, said electromagnetic focusing means and said permanent magnet focusing means being arranged in polar opposed relation to one another.

4. An electron beam focusing lens for cathode-ray tubes and the like comprising, in combination, a first pair of spaced generally annular pole pieces defining a first axial gap therebetween, a second pair of spaced generally annular pole pieces including one of said first pair of pole pieces and defining a second axial gap therebetween, electromagnetic means including a generally toroidal coil and a housing for said coil for developing an axial magnetic field across said first gap, and permanent magnet means for developing an axial magnetic field across said second gap in polar opposed relation to the field across said first gap.

5. An electron beam focusing lens for cathode-ray tubes and the like comprising, in combination, electromagnetic focusing means including a generally toroidal coil, means for supplying an operating potential to said coil, and a pair of pole pieces defining a first cylindrical gap, permanent magnet focusing means including a generally annular permanent magnet assembly having a pair of pole pieces defining a second cylindrical gap, and means for axially aligning said electromagnetic focusing means and said permanent magnet focusing means in polar opposed relation, said means including a pole piece common to both focusing means.

6. An electron beam focusing lens for cathode-ray tubes and the like comprising, in combination, electromagnetic focusing means including a generally toroidal coil and a low reluctance housing enclosing said coil except for an annular gap therein, and permanent magnet focusing means axially aligned in polar-opposed relation to said electromagnetic means, said permanent magnet means including a pair of spaced pole pieces bridged by a generally cylindrical permanent magnet, one of said pole pieces including a generally annular ring of magnetic material and the other including a portion of said housing.

7. An electron beam focusing lens for cathode-ray tubes and the like comprising, in combination, a generally toroidal coil, means for energizing said coil to develop a magnetic field, a low reluctance housing enclosing said coil except for an annular gap therein concentric with said coil, a generally cylindrical permanent magnet axially aligned with said coil in polar opposed relation to the field developed in said coil and abutting against said housing, and a generally annular pole piece axially aligned with said permanent magnet and abutting against the end of said permanent magnet remote from said housing.

8. An electron beam focusing lens for cathode-ray tubes and the like comprising, in combination, a generally toroidal coil, means for energizing said coil to develop a magnetic field, a low reluctance housing enclosing said coil except for an annular gap therein concentric with said coil, a plurality of permanent magnet slugs in parallel relation radially displaced about an axis aligned with the axis of said coil, in polar opposed relation to the field developed in said coil and abutting against said housing, a generally annular pole piece axially aligned with said permanent magnets and abutting against the ends of said permanent magnets remote from said housing.

9. In combination with a cathode-ray tube, three axially aligned and axially spaced generally annular pole pieces, electromagnetic means for developing a first axial field across a gap between the center pole piece and a first end pole piece, and permanent magnet means for developing a second axial field in polar opposed relation to said first field across a gap between said outer pole piece and said other end pole piece.

10. In combination with a cathode-ray tube, a first pair of spaced annular pole pieces defining a first axial gap therebetween, a second pair of spaced annular pole pieces including one of said first pair of pole pieces and defining a second axial gap therebetween, electromagnetic means for developing a magnetic field across said first gap, and permanent magnet means for developing a magnetic field across said second gap in polar opposed relation to the field across said first gap.

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