United States Patent [19]

MacMaster et al.

[11] **3,855,498**

[45] **Dec. 17, 1974**

[54] **CENTER-POLE MAGNETIC CIRCUIT**

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy**, Washington, D.C.

[22] Filed: **Nov. 1, 1973**

[21] Appl. No.: **411,617**

[52] **U.S. Cl.**..... **315/39.71**, 313/157, 315/39.51, 335/229, 335/302, 335/306

[51] **Int. Cl.**..... **H01j 25/50**

[58] **Field of Search** 315/39.51, 39.71; 313/157; 335/229, 232, 302, 306, 296

[56] **References Cited**

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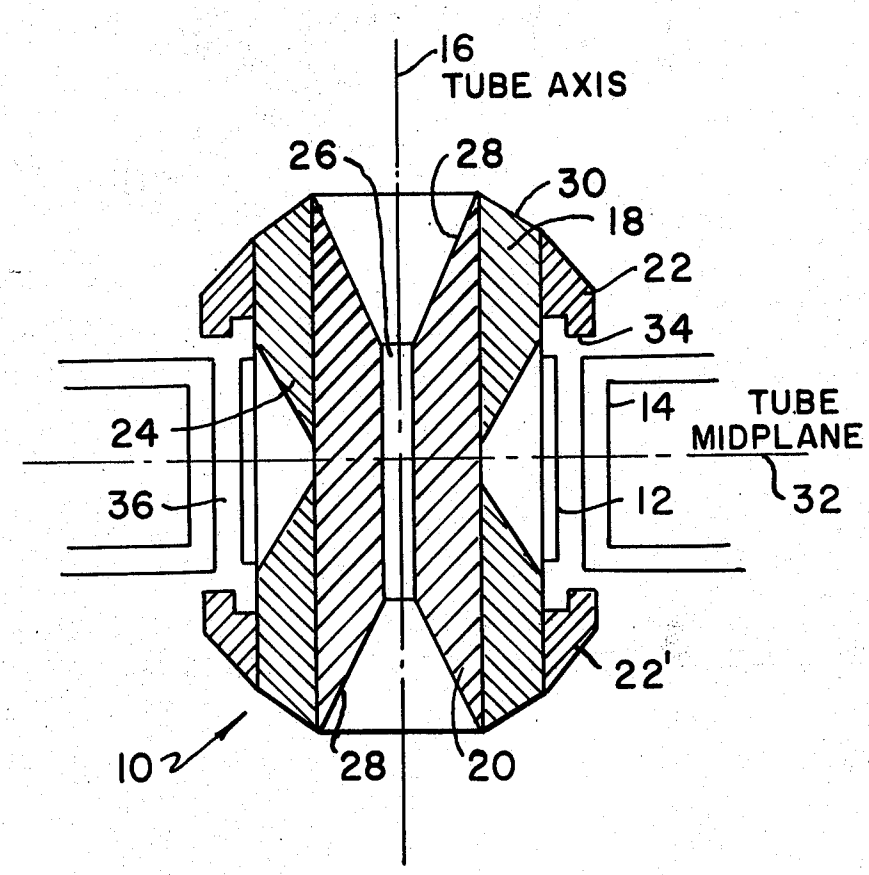
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[57] **ABSTRACT**

A field-producing permanent magnet fitting within the annular cathode of a crossed-field device, such as the magnetron. The magnet is an annular device having an inner cylinder of high-permeability steel forming a flux return path for the middle cylinder which is made of radially gaussed samarium cobalt material, and an outer section comprising two rings of high-permeability steel, one at each end of said middle section, forming pole pieces for the distribution of flux thru the interaction region of said crossed-field device.

10 Claims, 4 Drawing Figures



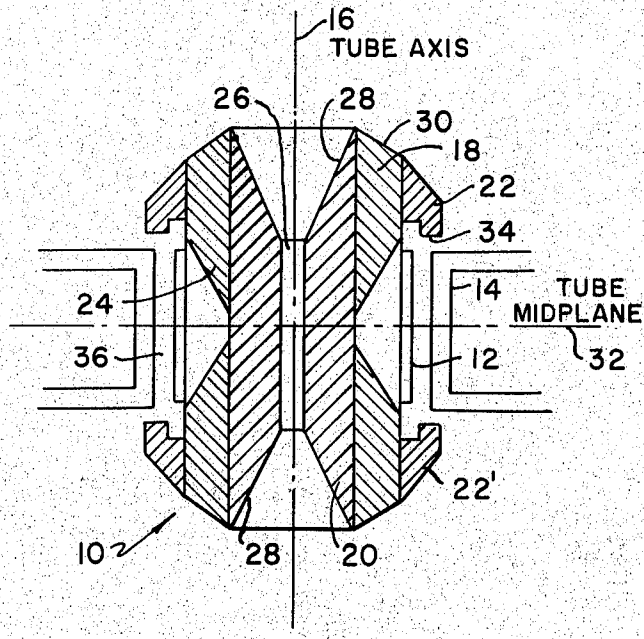


FIG. 1.

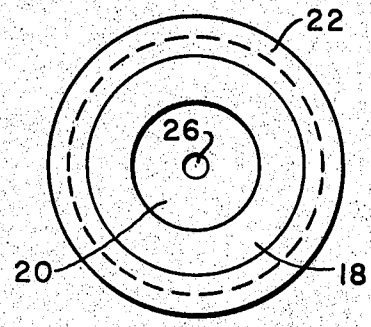


FIG. 2.

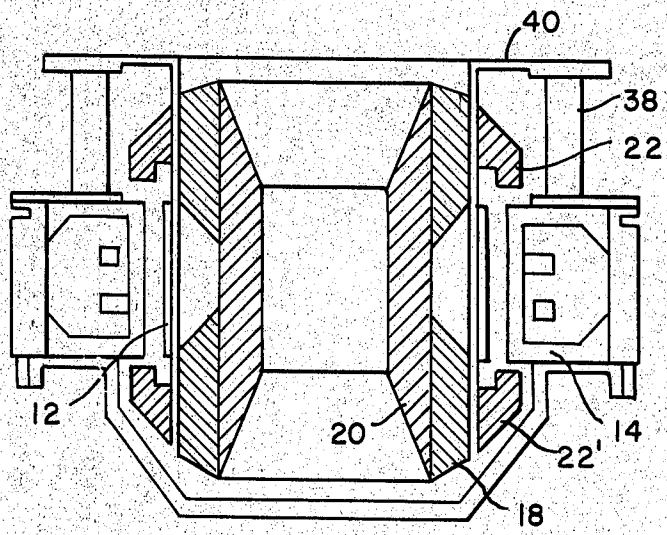


FIG. 4.

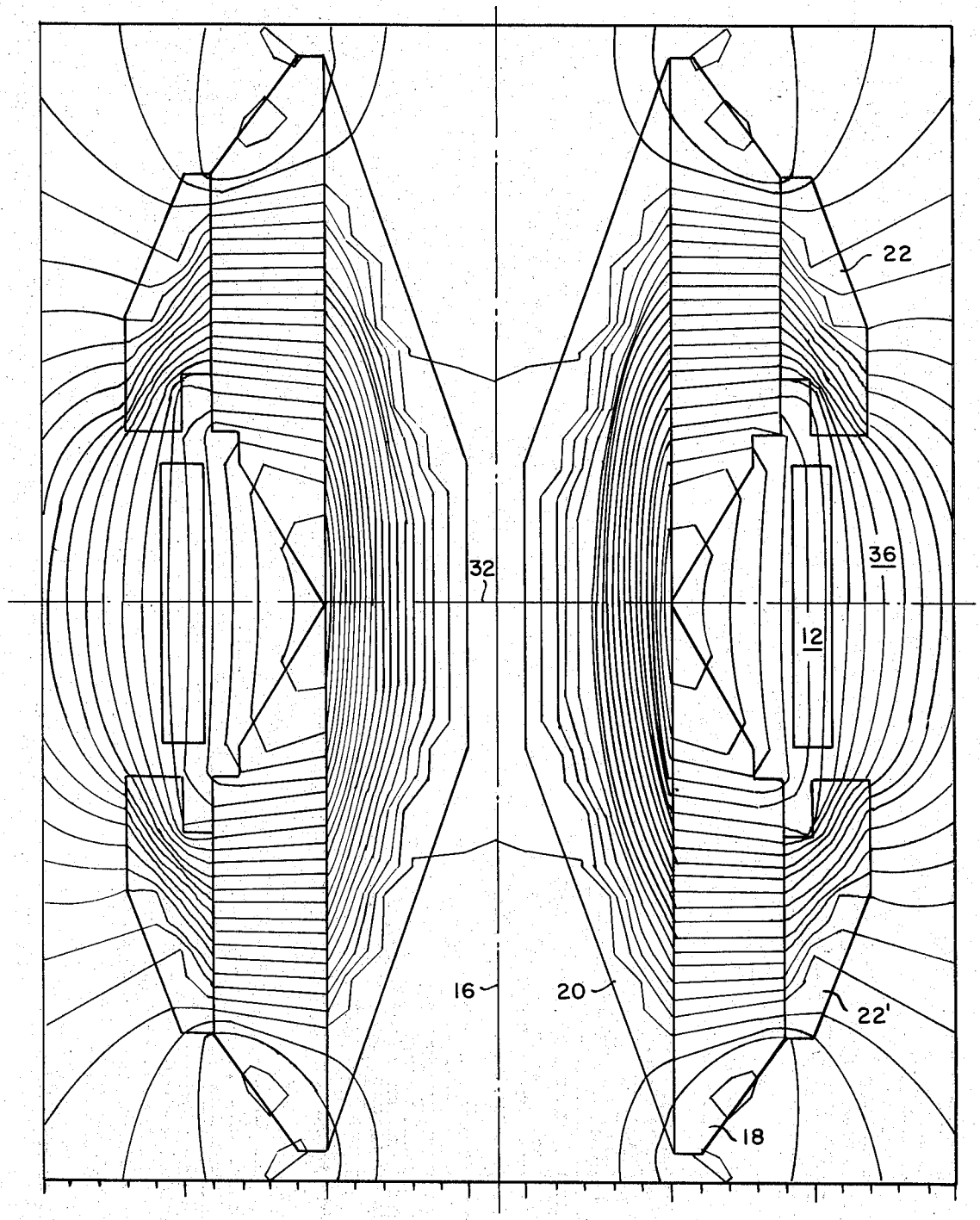


FIG. 3.

CENTER-POLE MAGNETIC CIRCUIT

BACKGROUND OF THE INVENTION

This invention relates to crossed-field devices (CFD) and especially to a center-pole magnet for establishing the magnetic field in a CFD.

Certain types of electronic tubes use a magnetic field transverse to the electron discharge path between the cathode and the anode. These tubes may be termed crossed-field devices, and the magnetron is an example of this type of electron tube.

In a CFD it is desired that the magnetic field in the interaction space (between the cathode and the anode) be as uniform and as nearly parallel to the cathode surface as possible. Most CFD's utilize large, heavy Alnico magnets outside the tube vacuum envelope to provide the magnetic field and the weight and size of the magnets make the tubes very cumbersome.

SUMMARY OF THE INVENTION

The present invention comprises a magnet with an annular inner pole section encircled by an annular permanent magnet. These sections are roughly cylindrical in shape and fit inside an annular cathode in a CFD. An annular pole piece is set on each end of the permanent magnet to overhang and direct flux through the interaction space between the cathode and anode of the CFD.

An object of the invention is to reduce the size of the magnet or magnets used with current crossed-field devices.

Another object is to provide an magnet for a CFD small enough to be located inside the cathode structure.

A further object is to increase the Gauss-carrying capacity of an internal magnet in a CFD by providing a high-permeability center pole for the magnet.

Yet another object is to provide a new magnetic circuit for a CFD which can produce a high-density, annular field with very little magnetic material.

Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an elevational cross-sectional view of a magnet according to this invention and its physical location with respect to the cathode and anode of a CFD;

FIG. 2 is a top view of the magnet showing its annular structure;

FIG. 3 is a plot showing the magnetic field of a center-pole magnet; and

FIG. 4 is an elevational cross-section of another magnet with a thinner center pole.

DETAILED DESCRIPTION

FIG. 1 shows a magnet in accordance with the invention in a CFD tube only the cathode and anode of which are shown. The magnet, shown generally by numeral **10**, fits inside a cylindrical cathode **12**. Spaced at a short distance away is an annular anode **14**. The axis **16** of the tube is a vertical line which passes through the middle of the magnet **10**; the axis of the magnet is identical with the tube axis.

The magnet **10** itself is formed in three sections. The middle section **18** is a cylindrically shaped, radially gaussed, permanent magnet made of samarium cobalt. ("Radially gaussed" is intended to mean "magnetized so that the lines of force extend in the radial direction.") Samarium cobalt magnets have a very high coercive force or resistance to demagnetization and have energy products as high as 20×10^{16} gauss-oersteds. In a microwave tube, samarium cobalt can replace several times its weight in Alnico. The central portion of the middle section **18** is tapered **24** to balance out leakage flux. When the leakage is exactly balanced out, an axial field with excellent uniformity can be obtained. By varying the tapered section, the field shape can be made straight, barreling or antibarreling. The middle section (permanent magnet section) is tapered **30** at its ends to lengthen the leakage path without using much magnetic material.

The inner section **20**, or center pole, is substantially a cylindrically shaped section with a hollow center **26** thru which the magnet and tube axes pass. The cylinder is tapered **28** at both ends to make it lighter. The center pole **20** is made of a high-permeability material, such as steel. This flux return path down the center of the magnet **10** results in reduced leakage, less iron in the magnet, and a shorter return path, thus requiring much less samarium cobalt to obtain the required field strength.

The outer section **22** is actually formed in two portions, an upper ring and a lower ring, with an outer flange **34** facing downwards on the upper ring and upwards on the lower ring. These rings **22** and **22'** constitute field-forming poles, or field-forming pole end shields. The flanges direct the magnetic field into the interaction region **36** between the cathode **12** and the anode **14** in a direction substantially parallel to the surface of the cathode.

The tube midplane **32** passes through the centers of the anode, the cathode and the magnet **10** and will be called the transverse axis of the magnet.

FIG. **3** shows a plot of the magnetic field flux lines **21** through the magnet **10.** Note the substantially uniform field in the interaction region **36** and the concentration of flux lines in the center pole **20.**

FIG. **2** shows a top view of the magnet **10,** indicating the annular shapes of its component parts.

FIG. **4** shows another magnet with a thinner center pole **20** to reduce the weight of the magnet. The tube structure is shown in a little more detail. The magnet, cathode and anode are shown held together by a frame **40,** a high-voltage spacer **38** being placed between the frame which is at cathode potential and the anode.

In a magnetron, this magnetic circuit design can supply greater than 2,000 gauss in a 0.5 inch gap at 1.0 inch diameter with less than 5 percent variation. The samarium cobalt magnet weighs less than 3 ounces and the whole magnetic circuit less than 6 ounces. A conventional Alnico magnetic circuit to supply this amount of field with this uniformity would weigh several pounds. If the latter weight were 3 pounds, this would amount to a reduction in weight of approximately 90 percent.

The new center-pole magnetic circuit produces the desired field and field geometry with very little samarium cobalt magnetic material. This design is less restrictive of cathode size, produces a more uniform field

geometry and a stronger field than previous CFD magnetic circuits.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A magnet comprising:

a middle section formed in a cylindrical shape with an inwardly tapered central portion, said middle section being formed from a material which is permanently magnetized and is radially gaussed;

an inner section formed in a cylindrical shape and placed radially inward of and abutting said middle section, said inner section being fabricated from a high-magnetic-permeability material and forming a flux return path; and

an outer section comprising two rings fabricated from a high-magnetic-permeability material, each ring comprising a pole piece, said rings being placed abutting the outer surface of said middle section, one ring near the top thereof and one near the bottom, so that said pole pieces face each other and a substantially uniform magnetic field extends therebetween.

2. A magnet as in claim **1,** wherein each said ring is formed with a peripheral flange extending axially downward therefrom, and forming said pole piece, said rings being disposed so that said flanges face each other.

3. A magnet as in claim **1,** wherein said middle section is formed from samarium cobalt.

4. A magnet as in claim **1,** wherein said inner section is tapered inwardly at both ends.

5. A magnet as in claim **1,** wherein said inner and outer sections are fabricated from steel.

6. In a crossed field device having an annular cathode and an annular anode structure spaced radially outward therefrom, a magnet comprising:

a middle section formed in a cylindrical shape with an inwardly tapered central portion, said middle section being formed from a material which is permanently magnetized and is radially gaussed;

an inner section formed in a cylindrical shape and placed radially inward of and abutting said middle section, said inner section being fabricated from a high-magnetic-permeability circuit material and forming a flux return path; and

an outer section comprising two rings fabricated from a high-magnetic-permeability material, each ring comprising a pole piece, said rings being placed abutting the outer surface of said middle section, one ring near the top thereof and one near the bottom, so that said pole pieces face each other and a substantially uniform magnetic field extends therebetween.

7. A magnet as in claim **6,** wherein each said ring is formed with a peripheral flange extending axially downward therefrom and forming said pole piece, said rings being disposed so that said flanges face each other.

8. A magnet as in claim **6,** wherein said middle section is formed from samarium cobalt.

9. A magnet as in claim **6,** wherein said inner section is tapered inwardly at both ends.

10. A magnet as in claim **6,** wherein said inner and outer sections are fabricated from steel.

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