

INVENTORS
SHIGEKI KAKIZAWA
TETSUO OTANI
BY

OSTROLENK, FABER, GERBE & SIFFER
ATTORNEYS

FIG. 2a.

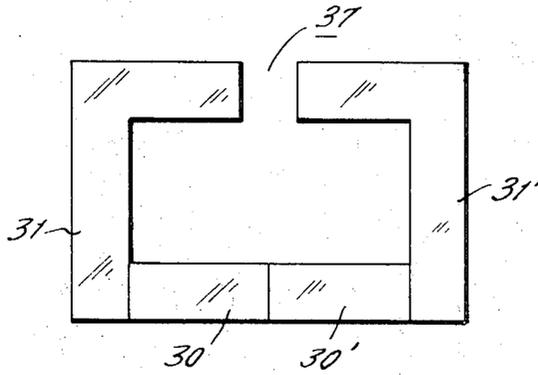


FIG. 2b.

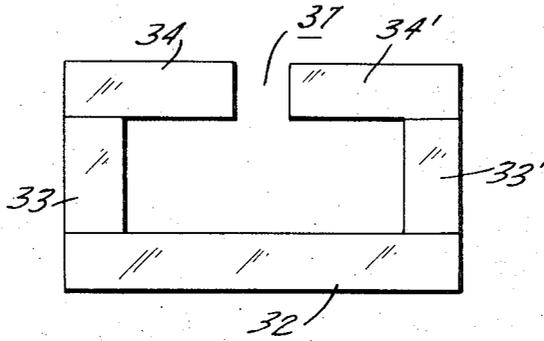


FIG. 2c.

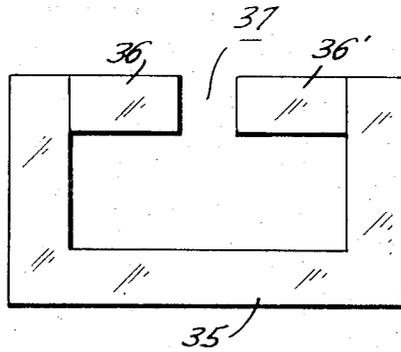


FIG. 4.

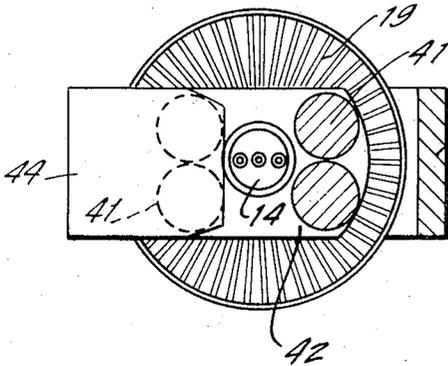
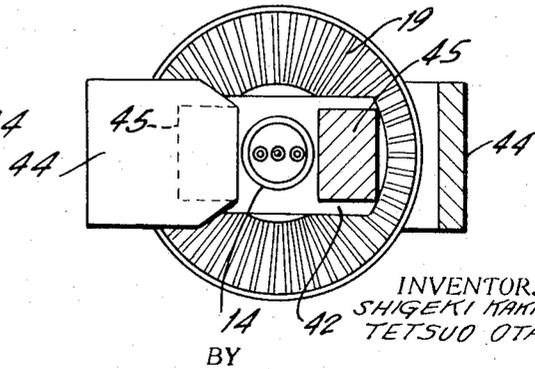


FIG. 5.



INVENTORS
SHIGEKI MATSUDA
TETSUO OTANI

BY

OSTROLENK, FABER, GERB & SOFFEN
ATTORNEYS

**ELECTRON DISCHARGE DEVICE EMPLOYING
INEXPENSIVE PERMANENT MAGNETS OF
SIGNIFICANTLY REDUCED SIZE**

This invention relates to an electron discharge device and, more particularly, to an electron discharge device of magnetron type having a self-contained permanent magnet.

Continuous wave magnetrons have typically been employed for the microwave heating devices, such as an electronic cooking range, which has become popular in recent years. This type of magnetron is provided with an electromagnet for use as a magnetic field generating means to maintain the necessary operating characteristics. On the other hand, a magnetron having a self-contained permanent magnet has been recently employed to make it possible to provide low-cost home electronic ranges which require no electric power source for generating magnetic field. The latter type of magnetron comprises an operative part having a coaxial structure of a cathode, an anode and an output means; two internal magnetic pole pieces located at the both ends (one on the output side and the other on the input bushing side) respectively, of the anode of said operative part; two permanent magnets of circular cylindrical shape disposed at a suitable distance from and in nearly parallel with each other on the both sides respectively, of said operative part; a first external magnetic pole piece plate which is secured to each of the end faces of said two magnets and connected magnetically with the internal magnetic pole piece of the output side; and an external magnetic pole piece cylinder whose one end is magnetically connected to the internal magnetic pole piece of the input bushing side and the other end of which extends outwardly along the center axis of the operative part; and a second external magnetic pole piece plate which is secured to the free end of said external pole piece cylinder and also to each of the other ends of said two magnets.

However, such an integral permanent-magnet-type magnetron has, as will be described later, a large leakage of flux in its magnetic circuit which is composed of each magnet, the first external magnetic pole piece plate, the internal magnetic pole piece of the output side, interaction space, the internal magnetic pole piece of the input bushing side, the external magnetic pole piece cylinder, and a second external magnetic pole piece plate. This is the reason why it has been necessary to use a permanent magnet of large size so as to obtain a necessary magnetic flux density in the interaction space between the internal magnetic pole pieces. This magnet is far more expensive per weight or volume than the other ferromagnetic materials which constitute the magnetic circuit. Accordingly, a magnetron using such large permanent magnet is very expensive.

An object of this invention is to provide an inexpensive magnetron in which the foregoing disadvantages are eliminated, the leakage flux is reduced and the size of the permanent magnet is a significantly reduced.

According to this invention, there is provided an electron discharge device which comprises an operative part and two internal magnetic pole pieces similar to those of the prior art; one or more rod-type permanent magnets of which one end is substantially connected to the internal magnetic pole piece of the input bushing side and whose other end extends outwardly along the center axis of the interaction space; a first external magnetic pole piece whose center part is connected magnetically to the internal magnetic pole piece of the output side and whose balance are extended perpendicularly to the center axis of the interaction space, and; a second external magnetic pole piece disposed between the free end of said first external magnetic pole piece and the free end of said rod magnet.

The electron discharge device according to this invention causes little leakage flux, as will be described later, in its magnetic circuit which is composed of each magnet, the second external magnetic pole piece, first external magnetic pole piece, internal magnetic pole piece of the output side, interaction space, and internal magnetic pole piece of the input bushing side. As a consequence, a permanent magnet of small size

has been found to be sufficient to produce the necessary flux density. In addition, it is possible to utilize a stack of popularly available rod magnets, such as those placed on the market as magnets for loud speaker use. In this way, a highly efficient magnetic circuit can be formed with relatively inexpensive rod magnets enabling the overall cost of the electron discharge device to be reduced.

A primary object of the present invention is to provide a novel electron discharge device having an improved magnetic circuit.

Another object of the invention is to provide a novel magnetic circuit for electron discharge devices wherein the permanent magnet members are uniquely positioned to obtain maximum flux density in the magnetic circuit and reduced size of the magnetic members.

These as well as other objects of the invention will be explained more specifically by referring to the appended drawings in which:

FIG. 1 is an axial sectional view showing a conventional electron discharge device,

FIGS. 2a, 2b and 2c are three different magnetic circuit diagrams, respectively, illustrating the principle of this invention,

FIG. 3 is an axial sectional view showing an electron discharge device according to this invention,

FIG. 4 is a sectional view along the X-X line of FIG. 3, and
FIG. 5 is a sectional view showing another embodiment of this invention corresponding to the embodiment as in FIG. 4.

Referring to FIG. 1, a conventional magnetron 10 of the integral permanent-magnet-type comprises an operative part which is composed of a cylindrical anode 11, a plurality of substantially radially aligned anode vanes 12 extending toward the center axis from the inner wall of anode 11 to define each resonant cavity, a cathode 13 disposed along the central axis, an input bushing 14 containing the lead wires from said electrodes, and an output part 15 from which power output is derived. An internal magnetic pole piece 17 is located adjacent the bottom of the output part and an internal magnetic pole piece 17' is located adjacent the top of the input bushing, both of which pole pieces are made of a low magnetic reluctance material such as pure iron, low carbon steel or the like. The pole pieces 17 and 17' to opposite ends of the anode 11 and extend toward an interaction space 16 between the anode vanes 12 and the cathode 13. The interaction space and the magnetic pole pieces are mounted within the vacuum chamber whose envelope is sealed together in a vacuum-type fashion by the use of sealing parts 18 and 18' which are preferably formed of an alloy of iron, nickel and cobalt. The sealing parts 18 and 18' serve as part of the enclosure and also as the flux path of low magnetic reluctance. A multivaned radiator 19 is mounted to the outer periphery of the anode 11.

The magnetron 10 further comprises two cylindrical permanent magnets 20 and 20' disposed in substantially spaced parallel fashion with both sides of the operative part; and a first rectangular-shaped external magnetic pole piece plate 21 made of low carbon steel. The ends of plate 21 are secured to the top ends of the magnets 20 and 20' respectively. Plate 21 is magnetically connected to the internal magnetic pole piece 17 of the output side of the center portion of the plate where an aperture is provided. An external magnetic pole piece cylinder 22 made of low carbon steel extends upwardly along the center axis from the internal magnetic pole piece 17' of the input bushing side. A second rectangular-shaped external magnetic pole piece plate 23 made of low carbon steel has its ends secured to the bottom ends of magnets 20 and 20' and is secured to the cylinder 22 at the center portion of the plate where an aperture is provided.

As will be explained later, referring to FIGS. 2a — 2c this magnetron 10 causes a large leakage flux in its magnetic circuit which is composed of the magnet 20 (20') — plate 21 — sealing part 18 — magnetic pole piece 17 — interaction space 16 — magnetic pole piece 17' — sealing part 18' — cylinder 22 — plate 23 — magnet 20 (20'). To produce the necessary flux density in the interaction space 16, the size of the magnets 20 and 20' must be quite large.

According to a practical example of a magnetron suited for use in electronic ranges in which the anode voltage is 4 kv., anode current 300 ma., and power output 800 (where kv. =kilovolts; ma. =milliamps, and w. =watts), the magnets 20 and 20' which are of the standard casting type of magnet of cylindrical shape, each have a diameter of 35 mm. and a length of 75 mm. and weigh about 500 g. (where mm. =millimeters and g. =grams).

FIGS. 2a—2c show different magnetic circuits having magnets and magnetic pole pieces in combination; FIG. 2a is a first circuit in which magnetic pole pieces 31 and 31' are disposed at both ends of permanent magnets 30 and 30' respectively; FIG. 2b is a second circuit in which magnetic pole pieces 34 and 34' are disposed at both ends of a pole piece 32 by way of permanent magnets 33 and 30'; and FIG. 2c is a third circuit in which permanent magnets 36 and 36' are disposed at both ends of a magnetic pole piece 35. As described in detail on pp. 153—154 of "Permanent Magnets and Their Application" jointly written by R.J. Parker and R. J. Studders, published by John Wiley and Sons, Inc. in 1962, the leakage flux is remarkably decreased as the positions of the magnets 30, 30', 33, 33', 36, 36' with respect to the gap 37 are changed from said first circuit FIG. 2a in which the magnet is farthest from the gap 37 to the third FIG. 2c in which the magnet is closest to the gap 37, by way of the second circuit FIG. 2b under the condition that the gap 37 and magnets 30, 30', 33, 33', 36, 36' are kept identical. For example, the ratio of the flux at the gap 37 to the total flux produced from the permanent magnet increases from 1/14.1 to 1/9.5 to 1/4.78 in the first, second and third circuits respectively; and the flux density is accordingly increased to 908, 1,300, and 1,975 gauss, respectively.

In the magnetic circuit of the conventional magnetron 10 as shown in FIG. 1, the magnetic pole piece sets 21—18—17 and 23—22—18'—17' are disposed at both ends of magnets 20 and 20'. This arrangement comes under the first circuit as in FIG. 2a. Therefore, the flux leakage in this circuit must be great.

The magnetic circuit of the electron discharge device according to this invention causes little leakage of flux and makes it possible to significantly reduce the size of the permanent magnet.

FIG. 3 shows a magnetron 40 of this invention, which has an operative part and two internal magnetic pole pieces similar to those shown in FIG. 1. Also, this magnetron has a magnetic means 41 which is substantially connected to the internal magnetic pole piece 17' of the input bushing side. The magnetic means 41 is composed of four sets of rod magnets, each set comprising stacked two permanent magnets 22 mm. in diameter and 30 mm. in length of standard casting magnet, said four sets being disposed in parallel to each other around the input bushing 14 as shown in FIG. 4. For connection between the magnetic means 41 and the internal magnetic pole piece 17', it is desirable to use a connecting plate 42 of the low carbon steel of plate-tray shape, of which one surface is in close contact with the sealing portion 18' which is secured to the internal magnetic pole piece 17' and the other surface is in close contact with the end face of the magnetic means 41.

The magnetron 40 of this invention further comprises a first external magnetic pole piece 43, made of a rectangular shape low carbon steel plate having an aperture in its center portion for connecting magnetically to the internal magnetic pole piece 17 of the output side, of which the balance portion is extended perpendicular to the center axis of the operative part; and a second external magnetic pole piece 44, made of iron, is disposed between the free end of said magnetic pole piece 43 and the free end of said magnetic means 41. In order to reduce the flux leakage, it is desirable to use a rectangular plate as the second external magnetic pole piece 44 and to bend the plate so that it makes a large radius at the bend portion. Also, it is desirable that the width (i.e., thickness) of the first external magnetic pole piece 43 is made equal to that of the second external magnetic pole piece 44, and that the connecting plate 42 for the magnetic means 41 is preferably formed into a frustum of substantially rectangular pyramidal shape, in which the distance between a pair of opposed parallel vertical side

surfaces is substantially equal to the width of the magnetic pole piece 44.

In the magnetron 40 according to this invention as explained, the permanent magnet 41 is disposed in closer proximity to the interaction space 16 than in the case of the conventional magnetron 10 shown in FIG. 1. Further, in the magnetron 40, the magnets are disposed in the direction along the axis of the gap, that is, interaction space 16. Therefore, as is evident from the description of FIG. 2, the leakage flux is reduced and the flux density is increased. As a matter of fact, according to the experiment conducted by the inventors of this invention, the conventional structure as shown in FIG. 1 required two cylindrical permanent magnets of 35 mm. in diameter and 75 mm. in length, in order to obtain a certain flux density; whereas the embodiment of this invention shown in FIG. 3 required eight cylindrical permanent magnets of 22 mm. in diameter and 30 mm. in length, to obtain the same flux density. This shows that the total weight of the permanent magnets of the magnetron of this invention is only about 60 percent of that of the conventional magnetron.

According to the prior art as shown in FIG. 1, the permanent magnets 20 and 20' are exposed to the outer atmosphere and, as the result, these magnets tend to attract tools on handling the magnetron 10, thereby demagnetizing said magnets 20 and 20'. In the present invention, the permanent magnet 41 is covered and nearly concealed by the external magnetic pole piece 44 and is therefore hardly demagnetized. This structure therefore needs no cover to prevent demagnetizing.

Furthermore, the magnetron cooling air directed toward the anode 11 from the input bushing 14 as indicated by the arrows A is interrupted by the magnetic pole piece cylinder 22 in the conventional structure shown in FIG. 1. In the present invention as illustrated in FIG. 3, the cooling air passes through the gaps of the magnets 41 to significantly improve cooling efficiency.

FIG. 5 shows another embodiment of this invention, in which two permanent magnets 45 of rectangular shape are employed in place of the magnetic means 41 as in FIG. 3 comprising a plurality of popularly available cylindrical magnets. The effect of this embodiment is the same as that of the embodiment as in FIG. 3.

While the invention has been explained in detail concerning the specific embodiments, it is understood that the invention is not limited thereto or thereby.

We claim:

1. An electron discharge device having a cathode electrode disposed along the longitudinal axis of the device, an anode electrode disposed therein in coaxial relationship with said cathode, a magnetic circuit for providing a magnetic field along said axis and in the space between said two electrodes characterized in that said magnetic circuit comprises a first magnetic pole piece disposed at one axial end of said anode, a permanent magnet which is substantially connected to and forms a flux path with said first pole piece and extends in said axial direction, and a second magnetic pole piece for magnetically connecting the free end of said permanent magnet and the other axial end of said anode;

said second magnetic pole piece having a first face engaging said other axial end of said anode and a second face engaging said permanent magnet; the surface area of said second face being greater than the surface area of said first face; the width of said second pole piece being substantially equal to the width of said first pole piece.

2. An electron discharge device having: a cathode electrode disposed along the longitudinal axis of said device; a hollow metallic anode surrounding and substantially concentric with said cathode; means cooperative with said anode for hermetically sealing the interior region of said anode; a pair of substantially C-shaped pole pieces each being positioned on opposite sides of said anode;

5

each of said C-shaped pole pieces having a first end of said C-shaped pole pieces positioned on opposite sides of and adjacent a first end of said anode;
 a pair of permanent magnet members being disposed substantially parallel to said longitudinal axis and extending between the second ends of said anode and the second ends of said C-shaped pole pieces;
 the first ends of said members positioned on opposite sides of and adjacent the second end of said anode; and
 the second ends of said members respectively engaging and substantially covered by the second ends of an associated C-shaped pole piece, said permanent magnet members

6

and said C-shaped pole pieces all being on the exterior sides of said hermetically sealed region.

3. The device of claim 2 wherein the second end portions of each of said pole pieces is tapered to form an end surface narrower than the first ends thereof.

4. The device of claim 2 wherein each of said permanent magnets is in turn comprised of a pair of magnets spaced apart from one another on their respective sides of said anode each forming a passageway for air entering the open space to cool said anode.

15

20

25

30

35

40

45

50

55

60

65

70

75