

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

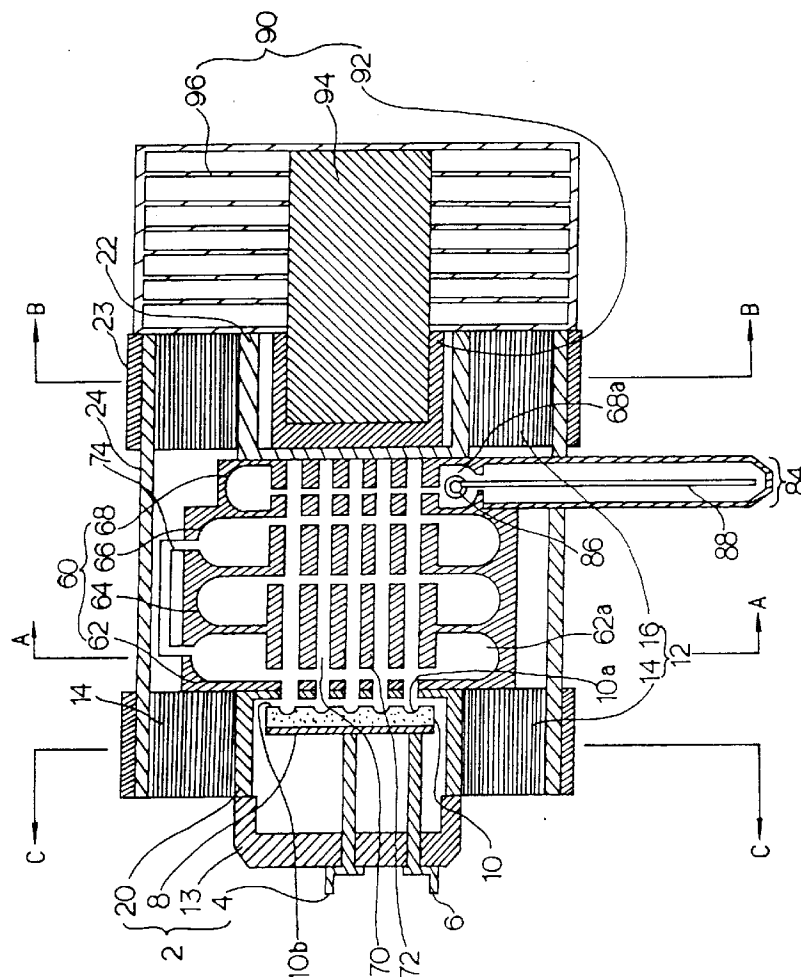
EP 0 724 281 A2

(12)

EUROPEAN PATENT APPLICATION(43) Date of publication:
31.07.1996 Bulletin 1996/31(51) Int Cl.⁶: **H01J 23/087**, H01J 25/10,
H01J 23/20(21) Application number: **96300549.1**(22) Date of filing: **26.01.1996**(84) Designated Contracting States:
DE FR GB(72) Inventor: **Kim, Gweon-Jib**
Paldal-gu, Suwon-City, Kyungki-ko (KR)(30) Priority: **28.01.1995 KR 9501735**(74) Representative: **Read, Matthew Charles et al**
Venner Shipley & Co.
20 Little Britain
London EC1A 7DH (GB)(71) Applicant: **Samsung Electronics Co., Ltd.**
Suwon-City, Kyungki-do 441-742 (KR)(54) **Klystron**

(57) A klystron includes magnets that produce a magnetic field for preventing dispersion of the electron beams (18). The magnets are arranged in two ring-

shaped groups (14,16) on around the cathode structure and the other around the anode structure. The magnets in each group are evenly spaced and have their poles at their radially inwardly and outwardly directed faces.

FIG.2

Description

The present invention relates to a klystron comprising cathode means and anode means for generating an electron beam, and magnetic field generating means arranged to produce a magnetic field so as to prevent dispersion of an electron beam between the cathode and anode means.

An example of a klystron is disclosed in JP-A-02-16533. This klystron is shown in Figure 9 and comprises an electron gun 202 for producing an electron beam, a high frequency circuit unit 204 for density modulating the electron beam and a collector unit 206 providing a target from the electron beam and converting the kinetic energy of the electrons in the beam into heat. The klystron also comprises an input circuit 208, an input magnetic piece 210, ring-shaped permanent magnets 212, a drift channel 216 for the electron beam, an output circuit 218 and an output magnetic piece 220. The output circuit 218 couples high frequency electromagnetic waves out of the klystron for supply to, for example, the cooking chamber of a microwave oven.

The known klystron suffers from the disadvantages that large permanent or electro-magnets are required and it is difficult to maintain a uniform magnetic flux in the drift channel. Furthermore, the efficiency of the device is low.

It is an aim of the present invention to overcome the aforementioned disadvantages of the prior art klystron.

According to the present invention, there is provided a klystron wherein the magnetic field generating means comprises a plurality magnets arranged in a ring.

Preferably, the cathode and anode means are arranged for producing a plurality of electron beams, and the first and second magnetic field generating means are arranged to produce a magnetic field so as to prevent dispersion of each electron beam between the cathode and anode means. More preferably, the magnets are arranged so that their poles are at their radially inner and outer faces.

Separate rings of magnets may be provided about the cathode means and the anode means. Preferably, each magnet of one ring is magnetically coupled to a complementary magnet of the other ring by a respective yoke.

The radially inner ends of each of the magnets of the each ring are preferably magnetically coupled by a pole piece common to the respective ring.

An embodiment of the present invention will now be described, by way of example, with reference to Figures 1 to 8 of the accompanying drawings, in which:

Figure 1 is a front view of a multi-beam klystron according to the present invention;

Figure 2 is a sectional view of the multi-beam klystron of Figure 1;

Figure 3 is an enlarged detail of principal parts in Figure 2;

Figure 4 is a sectional view along the arrow head C-C line in Figure 2;

Figure 5 is a sectional view along the arrow head B-B line in Figure 2;

Figure 6 is a perspective view of a yoke illustrated in Figure 2;

Figure 7 is a sectional view along the arrow head A-A line in Figure 2;

Figure 8 is a distribution graph of density of magnetic flux in the drift channel illustrated in Figure 2; and

Figure 9 is a sectional view of a prior art klystron.

Referring to Figures 1 and 2, a cathode 2 for emitting a plurality of electron beams includes a heater rod 4, an emitter rod 6, a heater 8 coupled to alternating current (120V or 240V) supply through the emitter rod 6, and an emitter 10 which thermionically emits electrons when heated by the heater.

A surface of the emitter 10 is formed with a plurality of emitting units 10a for emitting respective electron beams 18, as illustrated in Figure 3. A thin molybdenum plate 10b is attached to the emitter 10 and is provided with holes which are aligned with the emitting units 10a.

The emitting units 10a are arranged in a plurality of concentric rings (preferably, a total of 25 units in three rings as illustrated in Figure 7). The emitting units 10a are concave, in order to gather together the electrons emitted from the emitting units 10a.

The heater 8 and the emitter 10 are connected in series with each other and with an electric power source (not shown) via the heater rod 4 and the emitter rod 6. The heater rod 4 and the emitter rod 6 are supported by a housing 13.

The magnetic field generating means 12 for generating a magnetic field to prevent dispersion of the electron beams

includes a first group of permanent magnets 14, arranged in a ring around the cathode 2, a second group of permanent magnets 16, arranged in a ring around a collector (described below), first and second pole pieces 20 and 22 for guiding the magnetic flux from the first permanent magnet group 14 to the second permanent magnet group 16 so that the magnetic flux is evenly distributed in the drift channel and yokes 24, 26, 28, 30, 32 and 34 for guiding the magnetic flux from the second permanent magnet group 16 to the first permanent magnet group 14.

The first and second permanent magnet groups 14 and 16 are provided at opposite ends of the drift channel so that the magnetic flux is uniformly applied in the drift channel (described below). Referring to Figure 4, the first permanent group 14 consists of six permanent magnets 36, 38, 40, 42, 44 and 46 arranged in a ring at predetermined intervals. Referring to Figure 5, the second permanent magnet group 16 consists of six permanent magnets 48, 50, 52, 54, 56 and 58 arranged in a ring at predetermined intervals.

The permanent magnets 36, 38, 40, 42, 44 and 46 of the first permanent magnet group 14 have their N-poles directed radially inwardly and their S-poles directed radially outwardly, whereas the permanent magnets 48, 50, 52, 54, 56 and 58 of the second permanent magnet group 16 have their S-poles directed radially inwardly and their N-poles directed radially outwardly.

The internal diameters of the magnet groups 14 and 16 are larger than the diameter of a drift channel (described below) in order that a uniform magnetic flux density exists in the drift channel.

The total mass (M) of the twelve permanent magnets can be determined by the following formulae 1 and 2.

$$B = \left(\frac{1}{2r_b} \frac{PtV}{n} \right)^{\frac{1}{2}} \quad (1)$$

$$M = B^2 L^3 \quad (2)$$

Where " r_b " is the radius of an electron beam, "Pt" is the total permeance of the electron beams 18, "V" is the potential difference between the emitter 10 and the collector (anode) (described below), "B" is the magnetic flux density necessary in the drift channel, and "L" is the separation between the second pole piece 22 and the emitting unit 10a.

The first permanent magnet group 14, the second permanent magnet group 16 and the yokes 24, 26, 28, 30, 32 and 34 are fixed to a holder 23. The second pole piece 22 is connected to a drift tube (described below) so that the electron beams are maintained with a predetermined radius. The yokes 24, 26, 28, 30, 32 and 34 are formed as strips (Figure 6) and are rectangular in cross-section. The yokes 24, 26, 28, 30, 32 and 34 are arranged in a ring so that the magnetic flux follows a complete circuit.

Density modulation means 60 for density modulating the electron beams, emitted from the cathode 2, includes a first cavity 62 for performing a first density-modulation operation on the electron beams 18, a second cavity 64 for performing a second density-modulation operation on the beams 18, a third cavity 66 for performing a third density-modulation operation on the electron beams 18, and a fourth cavity 68 for performing a fourth density-modulation operation on the electron beams 18. The density modulation amplifies the high frequency power of the beams.

The resonant frequencies of the second cavity 64 and the third cavity 66 are a little higher than those of the first cavity 62 and the fourth cavity 68 in order to increase the amplitude of the density modulation of the electron beams 18. The first, second, third and fourth cavities 62, 64, 66 and 68 are formed with a plurality of drift channels 7 for the electron beams 18. The drift channels 70 are formed by rings of parallel copper tubes 72. The drift channels 70 are parallel to the central axes of the first, second, third and fourth cavities 62, 64, 66 and 68. In the illustrated case, twenty-five drift channels 70 are formed in three concentric rings (Figure 7).

A feedback channel 74 is formed between the third cavity 66 and the first cavity 62 so that part of the high frequency power is fed back to the first cavity 62 from the second, third or the fourth cavities 64, 66 and 68.

The fourth cavity 68 is formed a little smaller than the first, second and the third cavities 62, 64 and 66 in order to increase output efficiency.

Referring to Figure 3, intervals D1, D2 and D3 at gaps 76, 78, 80 and 82 between the first cavity 62, the second cavity 64, the third cavity 66 and the fourth cavity 68 gradually decrease in order to increase the degree of mutual reaction between the first, second, third and fourth cavities 62, 64, 66 and 68.

In the illustrated case the intervals D1, D2 and D3 gradually decrease as shown in the following formulae (3), (4) and (5).

$$D1 = \lambda p/4 \quad (3)$$

$$D2 = \lambda p/6 \sim 8 \quad (4)$$

$$D3 = \lambda p / 12 \quad (5)$$

Where " ω_p " represents the plasma frequency within the electron beams 18 determined from theory.

The interval D3 between the gaps 80 and 82 is smaller than the intervals D1 and D2. Furthermore, the gap 82 at the fourth cavity 68 is smaller than the other gaps 76, 78 and 80 in order to improve the characteristics of the density modulation means 60.

Output probe 84 includes a coupling ring 86 for extracting high frequency energy from the fourth cavity 68 and an antenna 88 for radiating, as high frequency electromagnetic waves, the energy absorbed by the coupling ring 86.

A collector 90 includes a collector plate 92 for collecting electrons from the second pole piece, a heat conductor 94 for removing heat generated by electrons hitting the pole piece 22. The collector plate 92 is connected to the second pole piece 22 in order to easily remove the heat generated therein.

The heat sink 96 is attached to the heat conductor 94, which is brazed to the collector plate 92.

The collector plate 92 is connected to an output terminal of a 600V dc electric power source, so that an electric potential difference is established for accelerating the electron beams 18 between the emitter 10 and the collector plate 92.

If the electric potential difference between the emitter 10 and the collector plate 92 is "V", the permeance of individual electron beams 18 is "Pe", the total permeance of the electron beams 18 is "Pt", the total beam current is "I", and the output is "P", and if the number of the electron beams is "n", following formulae (6), (7), (8), (9), (10), (11) and (12) it can be established, according to the I-V characteristics of thermionic diodes that:

$$Pt = nPe [1/(\Omega V^{1/2})] \quad (6)$$

$$I = Pt V^{3/2} [A] \quad (7)$$

$$I = nPe V^{3/2} [A] \quad (8)$$

$$P = I V [W] \quad (9)$$

$$= V nPe V^{3/2} \quad (10)$$

$$= nPe V^{5/2} \quad (11)$$

The electric potential difference "V" can be derived from the above formula (9) as:

$$V = \{P/(nPe)\}^{2/5} [V] \quad (12)$$

If the number n of the electron beams 18 is increased in the above formula (12), the electric potential difference V can be lowered, and if the number n of the electron beams 18 is increased in the above formula (11), the output P is increased.

The operation of the klystron of Figure 1 will now be described.

First, an alternating current AC electric voltage of 220V is applied between the heater rod 4 and the emitter rod 6 and a DC voltage of 600V is applied to the collector plate 92. Then, THE AC voltage of 220V is applied between the heater 8 and the emitter 10 to cause the heater 8 to generate heat. When the heater 9 generates heat, the emitter 10 is heated to temperature above 1000°C, so that electrons are emitted from the emitting unit 10a to form the electron beams 18. The electron beams 18, emitted from the emitting unit 10a of the emitter 10 toward the collector plate 92, are accelerated toward the collector plate 92 due to the electric potential difference of 600V between the emitter 10 and the collector plate 92.

The electron beams 18 reach the gap 76 of the first cavity 62, where an electric field is formed by a small high frequency signal introduced into space 62a at the first cavity 62 from an external signal source (not shown). The electrons in the beams 18 are velocity modulated by the electric field caused by the small high frequency signal. When the electrons in the electron beams 18 are velocity modulated, the density of the electron beams 18 is modulated.

When the electron beams 18 reach the gap 78 at the second cavity 64, the velocity modulation of the electrons is re-generated by interaction between the second cavity 64 and the electron beams 18, by which, electron density at a

portion where the density in the electron beams 18 is high is further increased. Similarly, when the electron beams 18 reach the gap 80 at the third cavity 66, the portion where the electron density was high is once again further increased i density.

Accordingly, electron beams having regions of high density are formed, enabling the generation of a high power microwave signal.

When the electron beams 18 having sufficient electron density, reach the gap 82 at the fourth cavity 68, current is induced into the fourth cavity 68, by which electric and magnetic fields are created in the fourth cavity 68. At this point, the electric field mainly exists in the gap 82 of the fourth cavity 68 whilst the magnetic field is present in the space 68a of the fourth cavity 68.

As can be seen from the foregoing, the electron beams 18 pass by the gap 82 of the fourth cavity 68 and introduce an electromagnetic field in the space 68a of the fourth cavity 68.

The electrons absorbed by the second pole 22 flow to the collector plate 92 and into an electric source wire (not shown) connected to the collector plate 92.

In this case, the residual kinetic energy, possessed by the electrons absorbed by the second pole piece 22, generates heat in the second pole piece 22, and the heat generated in the second pole piece 22 is conducted to the heat conductor 94 and the heat sink 96 through the collector plate 92.

The coupling ring 86 couples to the magnetic field energy within the space 68a and extracts high frequency energy. The high frequency energy is radiated into a space, for instance the cavity of a microwave oven, by the antenna 88 as microwaves.

The magnetic flux from the N-pole of the permanent magnets 36, 38, 40, 42, 44 and 46 is guided to the drift channel 70 and to the left side of a tube 72 through the first pole piece 20 where the magnetic flux is directed toward the tube 72 and the drift channel 70. The magnetic flux radiated from the first pole piece 20 extends parallel to electron beams 18 and enters the second pole piece 22 through the drift channel 70 and the tube 72. Then, the magnetic flux is incident on the S pole of the permanent magnets 48, 50, 52, 54, 56 and 58 of the second permanent magnet group 16.

As can be seen from the foregoing, the magnetic flux flows via a complete closed circuit which is formed by the permanent magnets 36, 38, 40, 42, 44 and 46 of the first permanent magnet group 14 - first pole piece 20 - drift channel 70 - feedback channel 74 - second pole piece 22 - permanent magnets 48, 50, 52, 54, 56 and 58 of the second permanent magnet group 16 - yokes 26, 28, 30, 32 and 34, so that the magnetic flux necessary for the drift channel 70 where the electron beams 18 is present.

In this case, as illustrated in Figure 7, it should be noted that an improvement has been made in the uniformity of the magnetic flux density distribution (S) when a plurality of permanent magnets are disposed in a ring at predetermined intervals, when compared with the magnetic flux density distribution (T) when a ring-shaped permanent magnet is used.

Referring to Figure 7, the X axis represents the position where the electron beams 18 proceed from the left to the right side in the drift channel 70 of the multi-beam klystron illustrated in Figure 2, and the Y axis represents the magnetic field density generated by the electron beams 18 of the multi-beam klystron. The magnetic flux is uniformly distributed in the drift channel 70, so that dispersion of the electron beams 18 is inhibited, and, at the same time, the electron beams are maintained with a predetermined radius from the emitting unit 10a to the second pole piece 22.

As is apparent from the above description, there is an advantage in a klystron according to the present invention in that a first permanent magnet group and a second permanent magnet group are arranged around a cathode and a collector, to thereby enable the density of the magnetic flux of the electron beams to be uniform across the drift channel, so that output of the device is stable and increased. There is another advantage in that the efficiency is improved.

There is still another advantage in that the increased output of the device reduces the device's weight and volume, so that, in place of additional parts for obtaining higher output, the device can be manufactured more cheaply.

Claims

1. A klystron comprising cathode means (10) and anode means (90) for generating an electron beam, and magnetic field generating means (14,16) arranged to produce a magnetic field so as to prevent dispersion of an electron beam between the cathode and anode means, **characterized in that** the magnetic field generating means comprises a plurality magnets (36,38, 40,42,44,46,48,50,52,54,56,58) arranged in a ring.
2. A klystron according to claim 1, wherein the cathode and anode means are arranged for producing a plurality of electron beams, and the magnetic field generating means (14,16) is arranged to produce a magnetic field so as to prevent dispersion of each electron beam between the cathode and anode means.
3. A klystron according to claim 1 or 2, wherein the magnetic field generating means comprises a first ring of magnets

(14) arranged about the cathode means and a second ring of magnets (16) arranged about the anode means.

4. A klystron according to claim 2, wherein each magnet of the first ring is magnetically coupled to a complementary magnet of the second ring by a respective yoke (24,26,28,30,32,34).

5. A klystron according to claim 3 or 4, wherein the radially inner ends of each of the magnets of the first ring are magnetically coupled by a pole piece (20).

6. A klystron according to claim 3, 4 or 5, wherein the radially inner ends of each of the magnets of the second ring are magnetically coupled by a pole piece (22).

7. A multi-beam klystron comprising:

a cathode for emitting a plurality of electron beams;
density modulation means for modulating density of the electron beams emitted from the cathode;
magnetic force generating means for generating magnetic force to prevent diffusion of the plurality of electron beams emitted from the cathode;
high frequency generating means for coupling energy of the electron beams density-modulated by the density modulation means to thereby generate high frequencies; and
a collector for collecting the electron beams which have passed the density modulation means to thereby output high frequencies.

8. A klystron according to claim 7, wherein the density modulation means comprises:

a first cavity for density modulating in the first time the electron beam emitted from the cathode to thereby amplify the high frequency power;
a second cavity for density modulating in the second time the electron beams emitted from the cathode to thereby amplify the high frequency power;
a third cavity for density modulating in the third time the electron beams emitted from the cathode to thereby amplify the high frequency power; and
a fourth cavity for density modulating in the fourth time the electron beams emitted from the cathode to thereby amplify the high frequency power.

9. A klystron according to claim 7 or 8, wherein the magnetic force generating means comprises:

a first permanent magnet group arranged in a ring shape around the cathode;
a second permanent magnet group arranged in a ring about the collector;
first and second pole pieces for guiding the magnetic flux from the first permanent magnet group to the second permanent magnet group so that the magnetic flux can be evenly distributed in density thereof in the drift channel where the electron beam moves; and
yokes for guiding the magnetic flux from the second permanent magnet group to the first permanent magnet group.

FIG.1

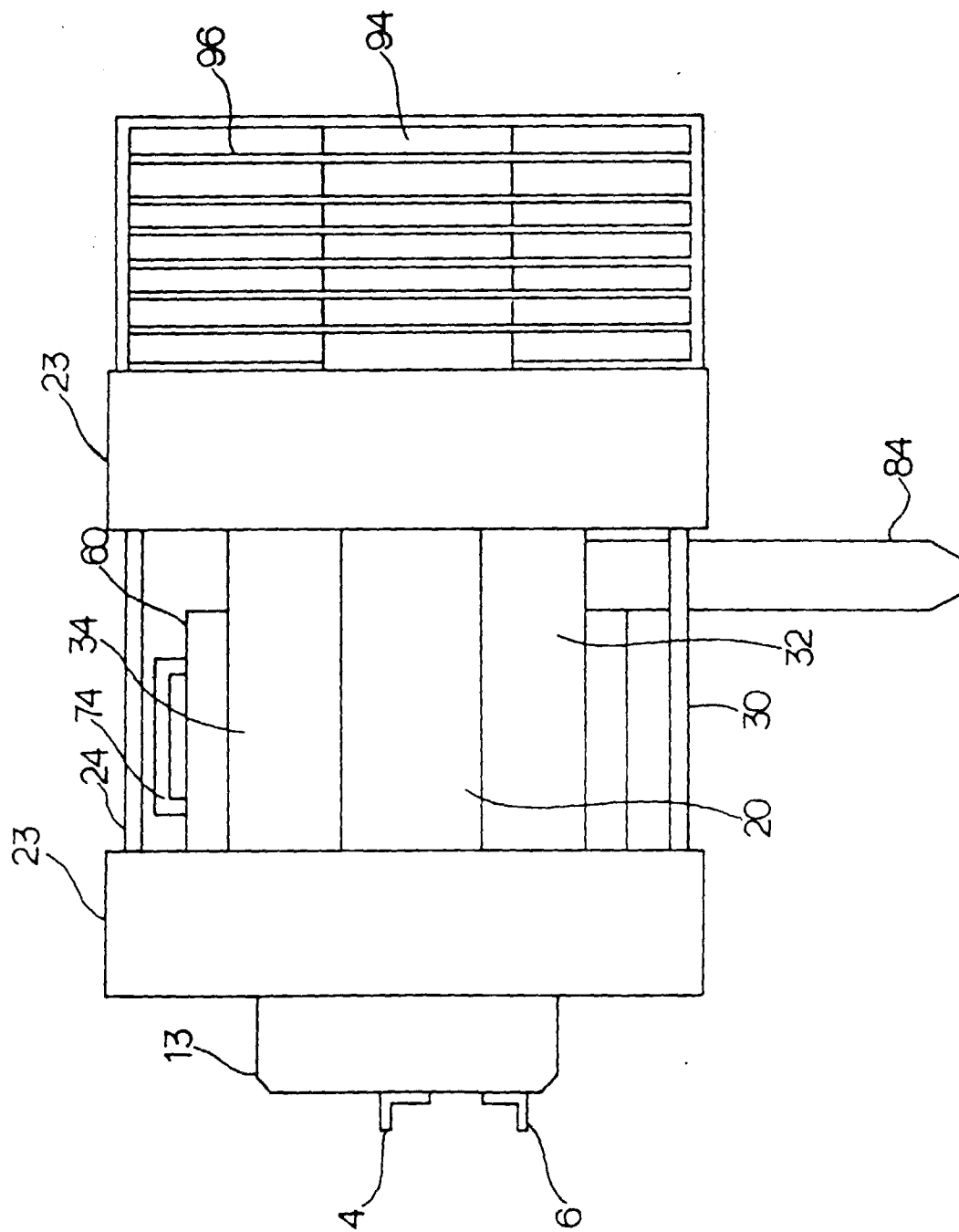


FIG.2

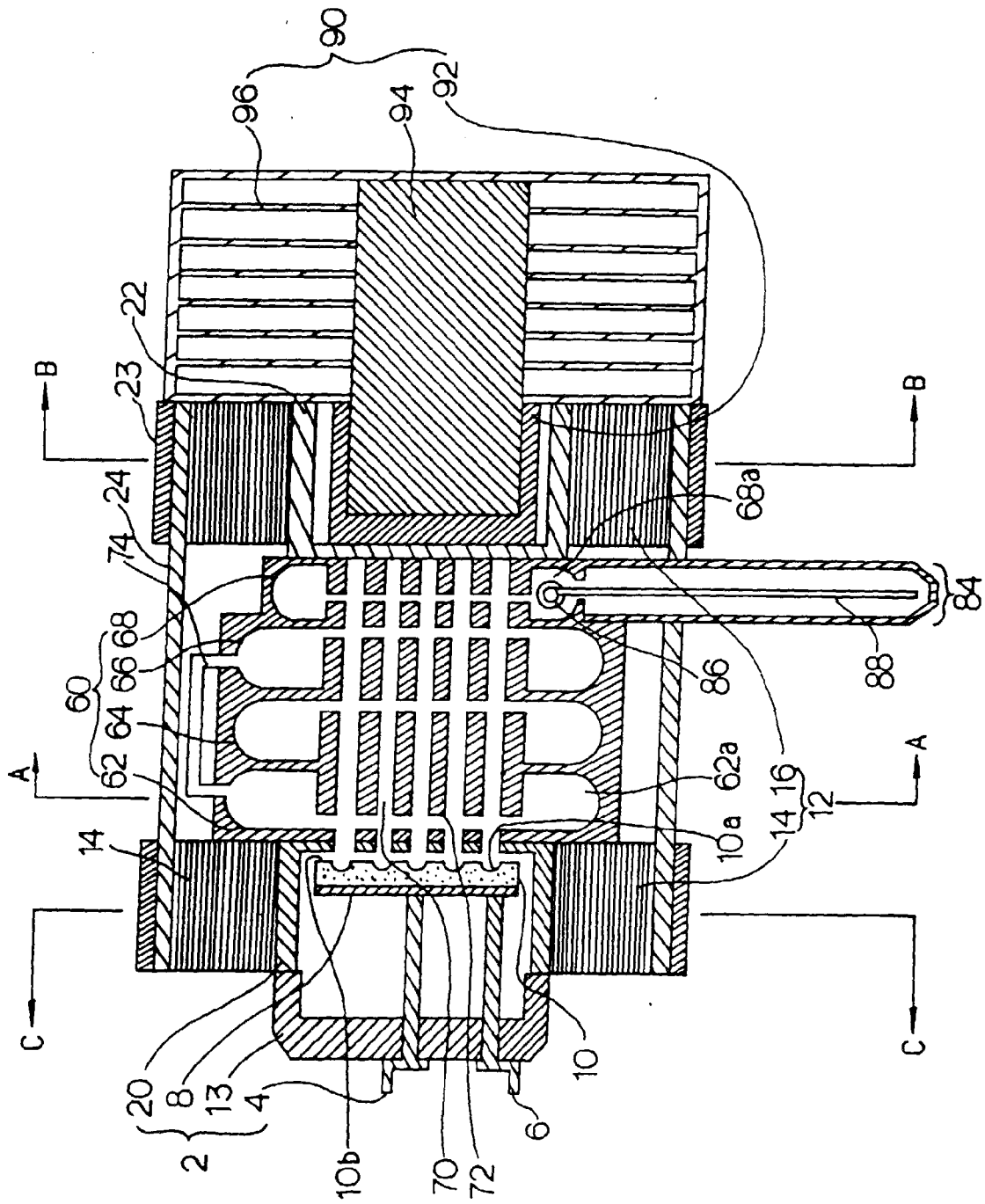


FIG.3

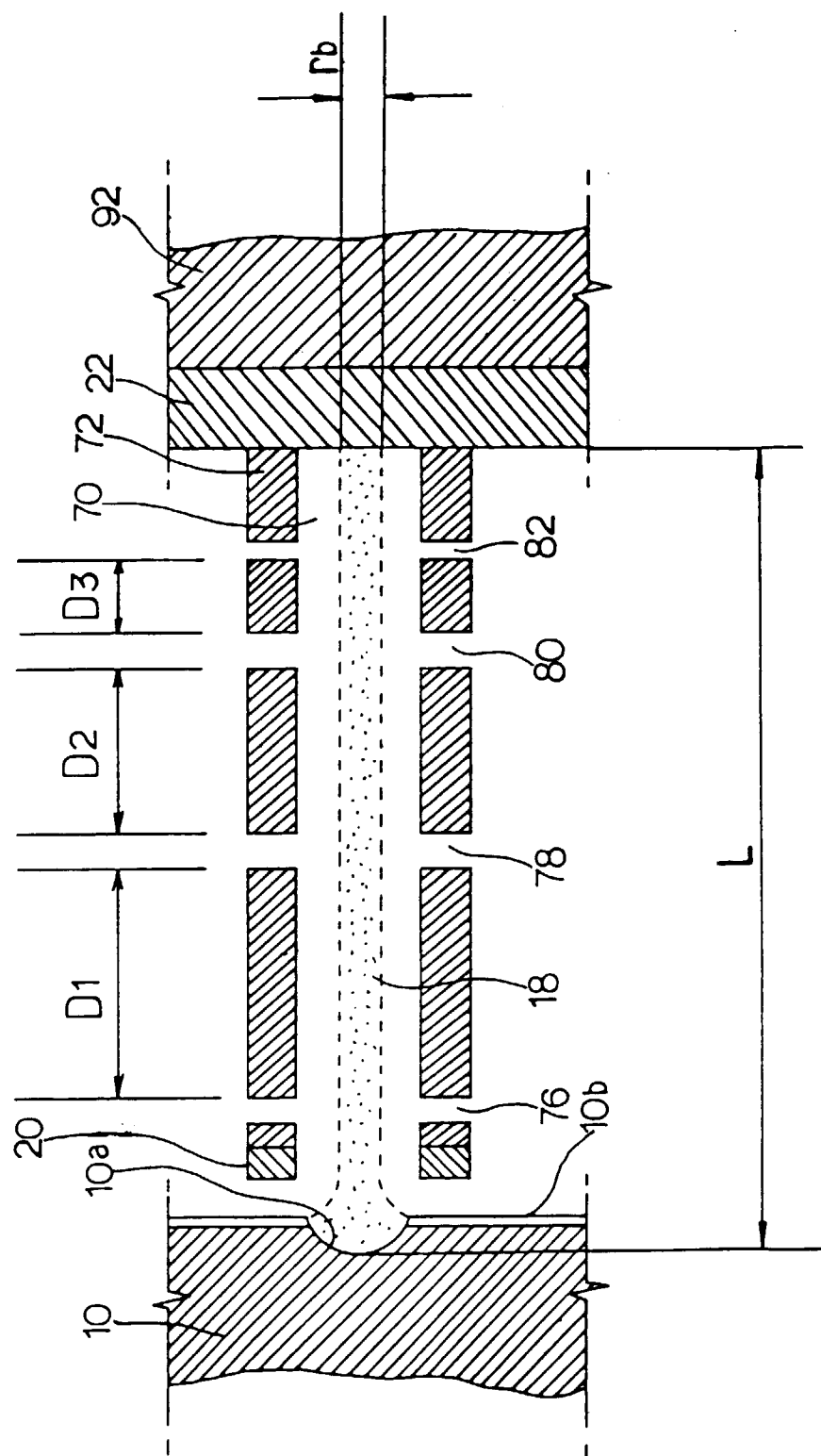


FIG.4

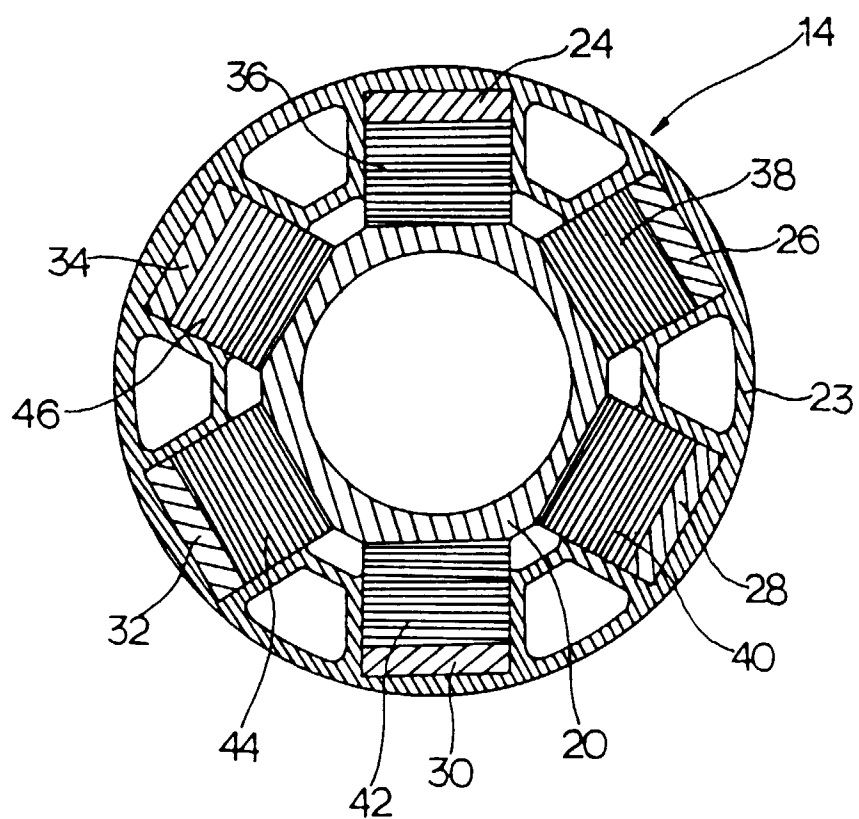


FIG.5

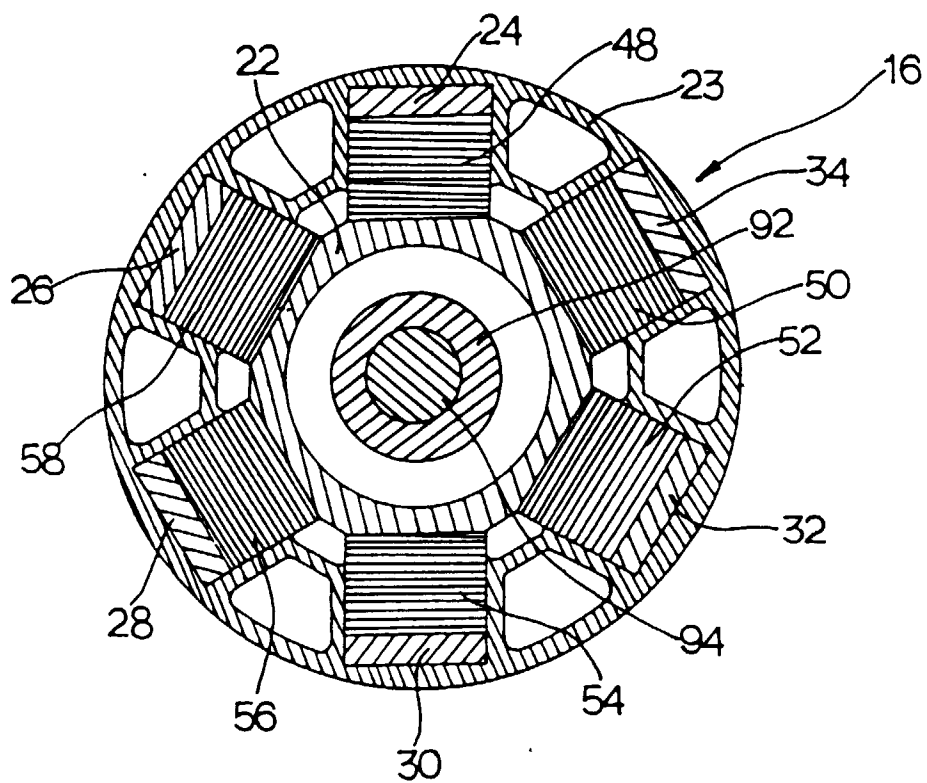


FIG.6

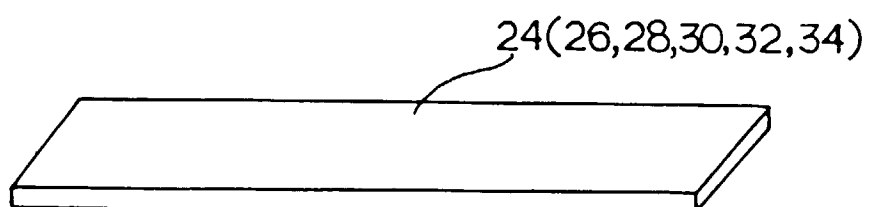


FIG.7

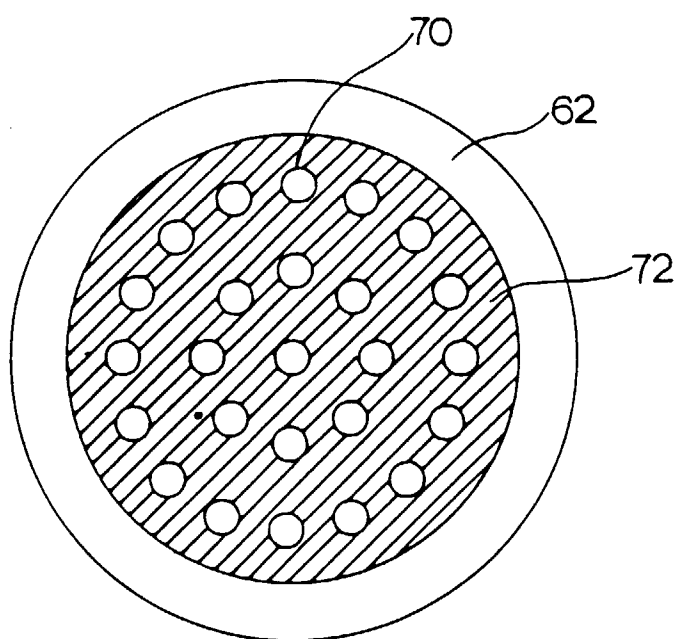


FIG.8

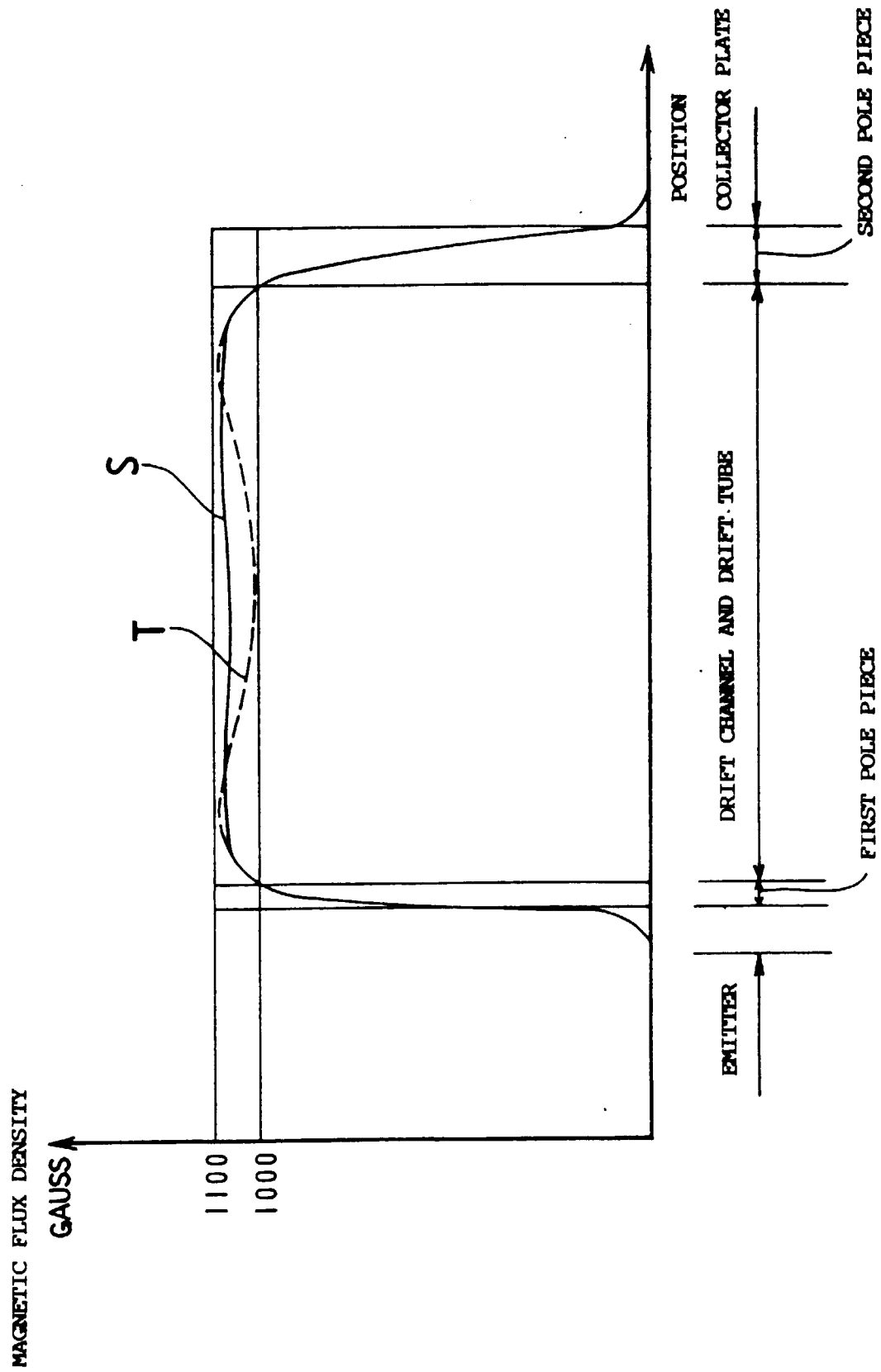


FIG. 9
(PRIOR ART)

