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Brown

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[54] **MAGNETIC FIELD GEOMETRY FOR CROSSED-FIELD DEVICES**

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[52] **U.S. Cl.** **315/39.71,** 313/157, 315/39.51, 335/210

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

[58] **Field of Search** 315/39.51, 39.71; 313/157; 335/210

[56] **References Cited**

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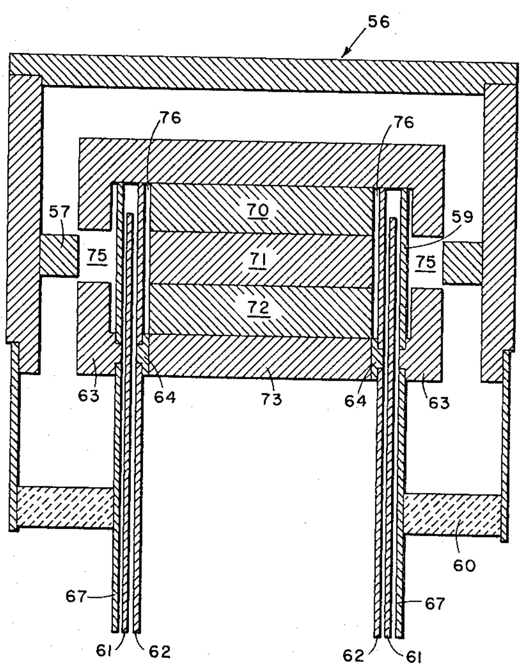
[57] **ABSTRACT**

A method of and means for generating a magnetic field in the interaction area of a cross-field device wherein the permanent magnet is positioned outside of the vacuum of the device is provided. Samarium cobalt magnet material is placed inside the cathode or sole of the device and end caps made from high-permeability material are used for pole pieces. Since the samarium cobalt is at end shield potential, no additional air gap is required.

7 Claims, 6 Drawing Figures



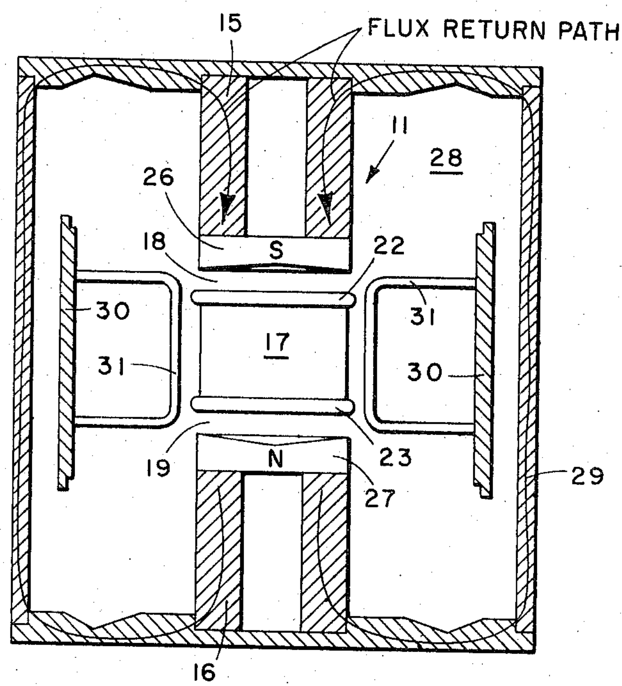

15
FLUX RETURN PATH
11
28
26
S
18
22
30
31
17
31
30
19
N
23
27
29
16

Fig. 1

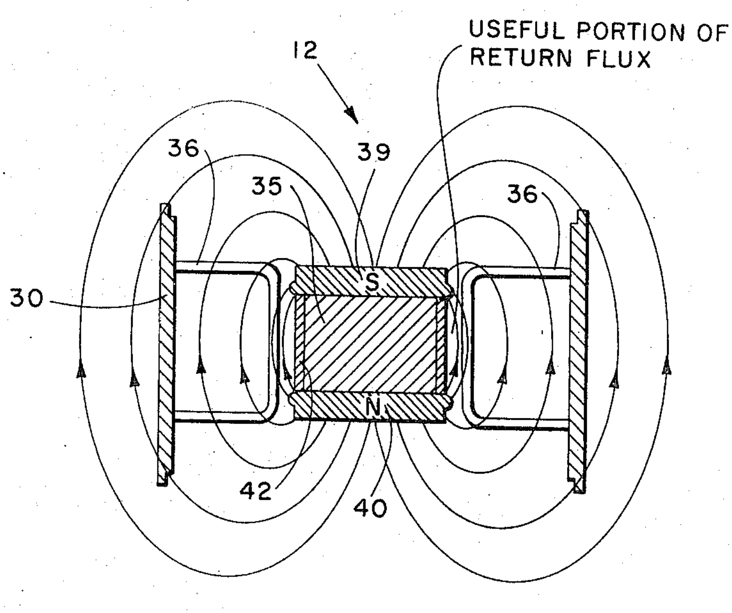

USEFUL PORTION OF
RETURN FLUX
12
36
39
35
36
30
S
N
42
40

Fig. 2

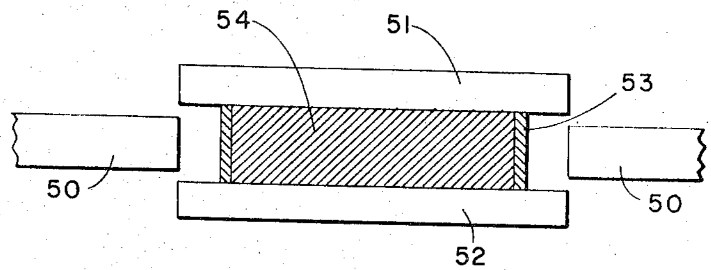


Fig. 3

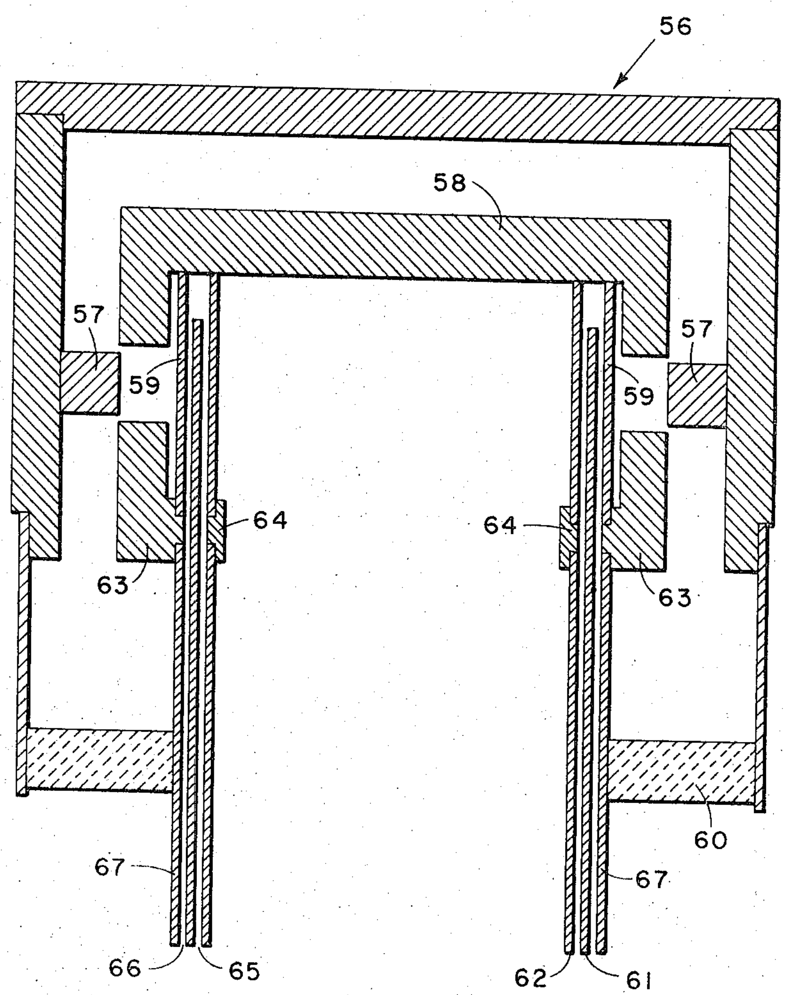


Fig. 4

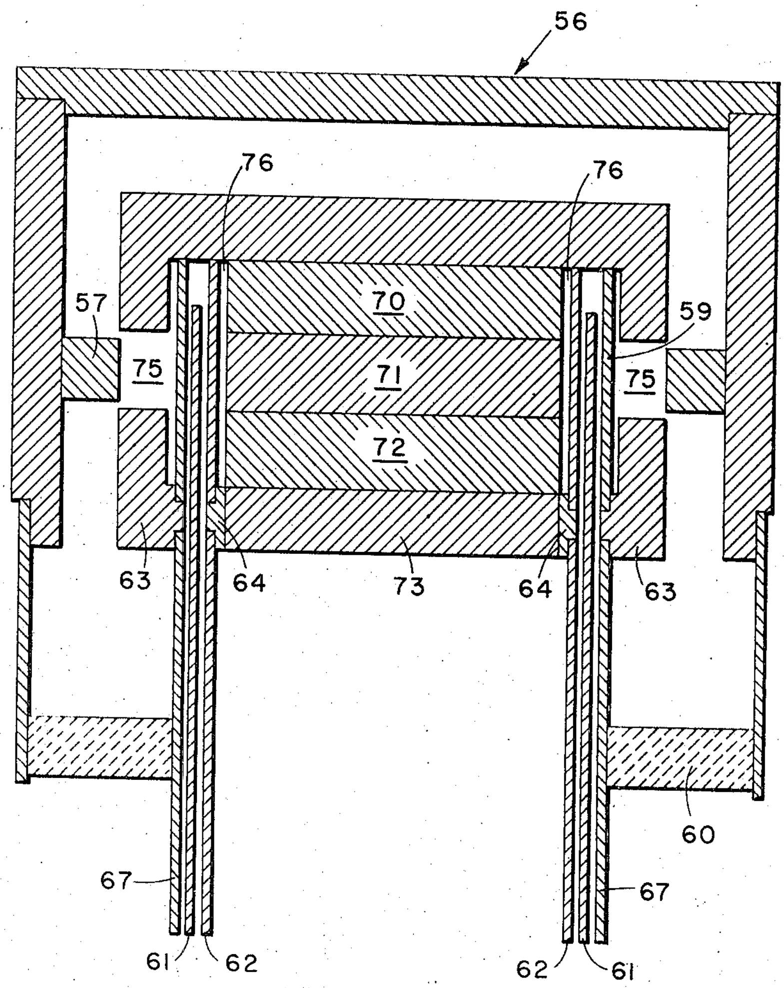


Fig. 5

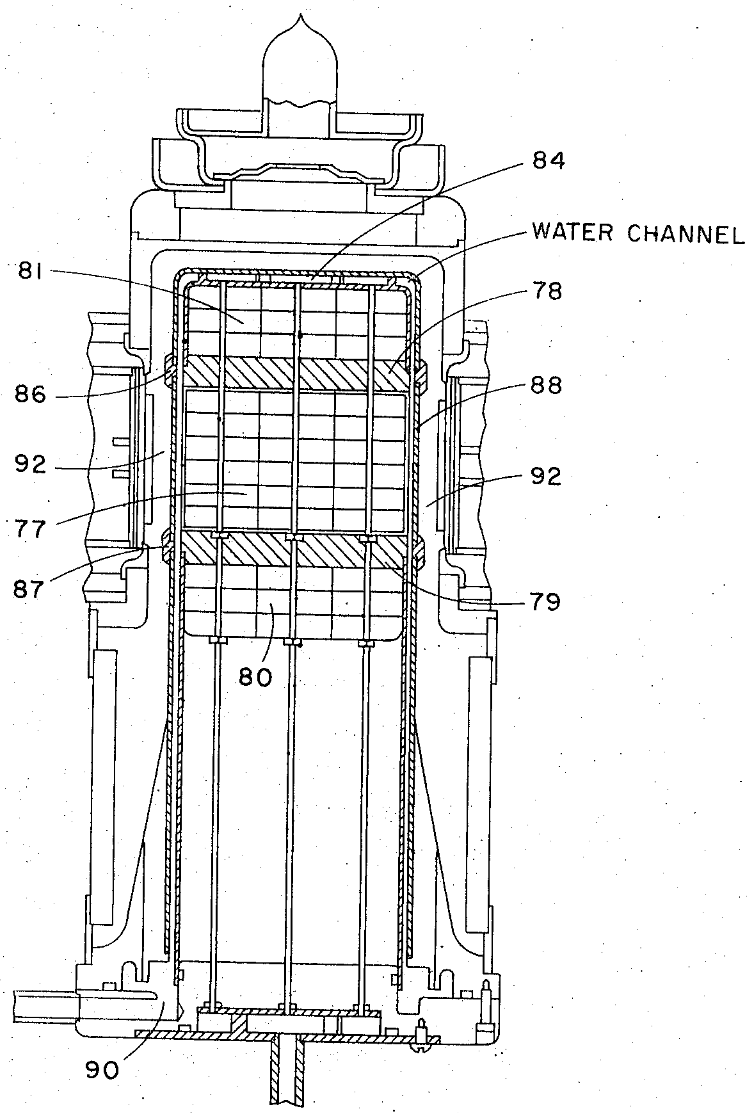


Fig. 6

MAGNETIC FIELD GEOMETRY FOR CROSSED-FIELD DEVICES

This invention concerns crossed-field devices and, more particularly, improvements in establishing a magnetic field in the interaction area of such devices.

Crossed-field devices as presently constructed require a permanent magnet which is installed within the evacuated volume of the device. In such a position, these magnets cannot be removed for inspection or replacement without both exposing the evacuated volume and substantially taking apart the device. In conventional circuits the permanent magnets are at ground potential but the cathode and shields are at cathode potential, necessitating an appreciable air gap to eliminate arcing between the cathode pole piece and the external magnet. The permanent magnets are also unnecessarily bulky, heavy and costly. The present invention provides for generating the magnetic field of a crossed-field device by samarium cobalt permanent magnets which are removably inserted in the cathode structure of the device. These permanent magnets permit a substantial reduction in the weight and size of the device. They also reduce the total air gap required.

According to the invention, the magnetic field in the interaction area of the crossed-field microwave generator or other crossed-field device is generated by samarium cobalt magnet material which is placed inside the cathode or sole of the device. End caps made from high-permeability material are used for pole pieces, permitting a suitable magnetic field intensity to be formed within the interaction area for a variety of crossed-field devices. The samarium cobalt magnet material is at end shield potential so that an additional air gap is not required.

Accordingly, it is an object of the present invention to provide a method of and means for generating a magnetic field in the interaction area of a crossed-field device wherein the permanent magnet is positioned outside of the vacuum of the device.

It is another object of this invention to provide a method of and means for generating a magnetic field in the interaction area of a crossed-field device wherein the permanent magnets are at end shield potential so that an additional air gap is not required.

A further object of this invention is to provide a method of and means for generating a magnetic field in the interaction area of a crossed-field device wherein the size, weight, and potentially the cost of the magnet are greatly reduced as is the total air gap required in the magnetic field circuit.

A further object is to eliminate the need for a highly permeable material for a flux return path.

Other objects, advantages, and novel features of the invention will become apparent from the following detailed description thereof when considered in conjunction with the accompanying drawings in which like numerals represent like parts throughout and wherein:

FIG. **1** is a schematic drawing of the magnetic circuit of a conventional crossed-field device;

FIG. **2** is a schematic drawing of the magnetic circuit in a crossed-field device made according to the present invention;

FIG. **3** is a schematic drawing of one embodiment of the invention showing a magnetic field source configuration for a crossed-field device;

FIG. **4** is a schematic drawing of a crossed-field tube made according to the present invention with the magnetic material of the lower pole removed;

FIG. **5** is a schematic drawing of a crossed-field tube made according to the present invention showing the magnetic field source configuration of FIG. **3** inserted in the tube embodiment of FIG. **4**; and

FIG. **6** is a front elevation, partly in section, of a working embodiment of an internal magnetic circuit for a crossed-field device incorporating the present invention.

Referring to FIGS. **1** and **2**, a magnetic circuit **11** made according to conventional design is shown opposite a magnetic circuit **12** made according to the teachings of the present invention. In circuit **11**, a pair of Alnico magnets **15** and **16** are shown positioned in opposed relation to a cathode **17** and spaced therefrom to form air gaps as indicated at **18** and **19**. A pair of end shields **22** and **23** are attached to cathode **17** and a pair of pole pieces **26** and **27** are attached to magnets **15** and **16**, respectively, all of these components being deployed in an evacuated volume as indicated at **28**. A magnetic return path for the flux from the Alnico magnets is indicated by **29**. The return path is usually made from iron or steel. An anode wall **30** and a vane **31** complete the basic components of the conventional configuration.

The magnetic circuit of the present invention as shown in FIG. **2** includes a samarium cobalt magnet **35** which is positioned within the periphery of a vane **36**, the permanent magnet having pole pieces **39** and **40** contiguously positioned on opposite ends and a cathode **42** which surrounds and is in contiguous contact with the periphery of magnet **35**. As will be described infra, magnet **35** may be separated from pole pieces **39** and **40** and a magnetic circuit formed with magnet **35** and lower pole piece **40** separated from cathode **42** and upper pole piece **39**. The return path for the flux is through the surrounding vacuum and air space. Part of the return flux provides the useful flux in the gap between the cathode and anode of the tube. In such an arrangement, the cathode, upper pole piece **39**, anode **30** and vane **36** would be disposed in the vacuum while magnet **35** and lower pole piece **40** are deployed outside the vacuum. FIG. **3** illustrates schematically how this separation is accomplished to form a magnetic circuit.

In FIG. **3**, the compact form of a magnetic field source made according to the invention is illustrated schematically. The elements of the source include an anode **50**, north and south pole pieces **51** and **52**, respectively, a cathode **53** and a permanent magnet of samarium cobalt **54** or other suitable magnet material. FIG. **4** illustrates the general structural arrangement of recent crossed-field devices which employ a large-diameter, platinum cathode. The structure includes an outer vacuum-forming envelope **56** within which is positioned an anode **57**, an upper pole piece **58**, a cathode **59**, a ceramic shield **60** and liners **61** and **62** for forming passages for the flow of coolant through the device. Segment **63** and end cap **64** of the lower pole piece are components associated with the present invention and are also preassembled as shown. Cathode **59**, ceramic shield **60**, envelope **56** and pole piece **58** form an evacuated enclosure which is unaffected by the insertion or removal of the elements required to complete the magnetic circuit of the device. An interior passage **65** between liners **61** and **62** is preferably used as the inlet passage for the coolant while a passage **66** between liner **61** and an extension **67** of cathode **59** form an outlet for the coolant. The lower pole piece of the magnetic field-forming couple is omitted in this figure.

Referring to FIG. **5**, the crossed-field device of FIG. **4** is duplicated and a plurality of samarium cobalt magnets **70, 71** and **72** and a lower pole piece **73** are shown inserted within lining **62** with pole piece **73** in register with end cap **64** thereof. The samarium cobalt magnets and lower pole piece **73** complete the material required to be inserted in the device to form a complete magnetic field for interaction with the anode-cathode electrical field in the area indicated at **75.** Segment **63** adjoins cathode **59** and is at its potential. End cap **64** is positioned sufficiently close to segment **63** to allow the desired magnetic lines of force to span the gap between these elements of the lower pole piece. The thickness of end cap **64** may be adjusted to form an air space **76** of selected width as desired.

In FIG. **6,** a practical embodiment of the invention is presented which includes a plurality of samarium cobalt magnets in layer form as indicated at **77,** an upper pole **78,** a lower pole **79,** and a pair of bucking magnets **80** and **81** which also are formed of layers of samarium cobalt. The liners of the device form a water channel **84** for the flow of water for other coolant. A pair of pole pieces and end shields **86** and **87** complete the components necessary for an understanding of the embodiment. The magnetic field required in the electron beam region of the crossed-field amplifier is produced by permanent magnets **77** in association with the high permeability pole pieces **86** and **87** and, where required, high permeability return circuits. In this embodiment as in the embodiment of FIG. **5,** the samarium cobalt permanent magnets are removably placed inside the cathode structure of the device and are held in position within a cathode **88** by conventional means such as a cathode bushing **90.** The high coercive force of the samarium cobalt magnets enable bucking magnets **80 – 81** to be used in the novel magnetic circuits to increase the magnetic field in the electron beam region. The bucking magnets may be positioned either inside the cathode structure as shown or externally around the anode of the crossed-field amplifier, in either event being placed outside of the vacuum envelope so that they may be replaced, serviced, etc., without interfering with the vacuum.

These magnetic circuits of samarium cobalt permanent magnets operate at their maximum energy production and require a minimum loss of flux leakage paths outside of the electron beam region. The permanent magnets are positioned within the cathode structure but outside of the vacuum so that they can be inserted or removed through the large cathode bushing **90.** End shields **86** and **87** are also made of high permeable material for magnetic field shaping. Bucking magnets **80 – 81** are positioned on poles **78 – 79** to direct the magnetic field into the interaction space which is indicated at **92.** The height of the magnet is substantially 1.4 inches between the pole pieces and the diameter of the magnet is substantially 2.5 inches. The pole pieces are 3 inches in diameter and 0.350 inches thick to produce the desired field uniformity. Bucking magnets **80** and **81,** which increase the flux density in the interaction space, are 0.7 inches thick and have a diameter of 2.5 inches. The total weight of this magnetic circuit is 6 pounds and it obtains a magnetic field intensity of 2,400 gauss in the interaction space.

It will therefore be appreciated that the present invention greatly decreases the weight of the permanent magnet required in crossed-field devices as well as the cost of the magnet over a period of time because of the reduced weight and the reasonable cost of samarium cobalt. The invention also decreases the tube size of the device and provides for a better shaped magnetic field in specific applications. The total air gap required in the magnetic field circuit is greatly reduced over that required in conventional devices. In the conventional circuit, the magnets are at ground potential but the end shields are at cathode potential thereby necessitating an appreciable air gap to eliminate arcing between the pole pieces and the end shields. In the present invention, the magnets are at end shield potential so that an additional air gap is not required. Higher magnetic fields may be obtained where the length of the samarium cobalt magneto motive source is considerably greater than that of the air gap.

What is claimed is:

1. In a crossed-field device having a generally cylindrical cathode and an anode circumferentially disposed thereabout defining an electronic interaction area therebetween, the improvements comprising:

means for generating the magnetomotive force necessary to provide the magnetic field of said device;

means associated with said generating means for forming a partial magnetic circuit disposed exterior of and adjacent to one end of said cathode;

means forming an evacuable envelope enclosing said interaction area and

means completing said partial magnetic circuit disposed adjacent to the other end of said cathode in the region of said interaction area,

said generating means comprising a main magnet encompassed by the cathode of said device and disposed outside the vacuum envelope thereof,

whereby a compact crossed-field device is provided in which the magnetomotive force is at the potential of the cathode and is removable without affecting the vacuum envelope thereof.

2. The device as defined in claim **1** wherein said enveloe forming means defines a central opening of regular cross-section without said envelope and said magnet is a permanent magnet disposed in said central opening.

3. The device as defined in claim **2** and further including means forming passages for coolant flow adjacent the interior surface of said cathode,

said permanent magnet and said means completing said partial magnetic circuit disposed interior of said means forming passages for coolant flow.

4. The device as defined in claim **3** wherein said permanent magnet is made of samarium cobalt so that a compact crossed-field device is formed whose permanent magnet may be removed and replaced without affecting the evacuated volume of the device.

5. In a crossed-field device having a generally cylindrical cathode and an anode circumferentially disposed thereabout defining an electronic interaction area therebetween, the improvements comprising:

means for generating the magnetomotive force necessary to provide the magnetic field for said device;

means associated with said generating means for forming a partial magnetic circuit disposed exterior of and adjacent to one end of said cathode;

said magnetic circuit formed of upper and lower pole pieces,

said means associated with said generating means forming passages for coolant flow so that a compact crossed-field device is formed whose permanent magnet may be removed and replaced without affecting the evacuated volume of the device,

said upper pole piece unitary and disposed entirely within the evacuable envelope,

said lower pole piece fragmented and including a circumferential segment one end of which forms said interaction area with a corresponding end of said upper pole piece and the other end of which terminates within said cathode, a circumferential end cap spaced from and in register with said other end of said segment, and a transverse segment adjacent to and substantially contacting said end cap,

means forming an evacuable envelope enclosing said partial magnetic circuit;

said envelope forming means defining a central opening of regular cross-section within said envelope;

means completing said partial magnetic circuit disposed adjacent to the other end of said cathode in the region of said interaction area,

said generating means including a main samarium cobalt permanent magnet encompassed by the cathode of said device and disposed in said central opening so that the magnetomotive force is at the potential of the cathode;

said permanent magnet and said means completing said partial magnetic circuit disposed interior of said circumferential segment disposed in said evacuable envelope,

said circumferential end cap disposed in said passage forming means,

said transverse segment removably received in said central opening,

whereby a compact crossed-field device is provided which has a removable permanent magnet disposed outside the evacuated envelope and in which the magnetomotive force is at the potential of the cathode.

6. A method of forming the magnetic field of a crossed-field microwave generator device having a cylindrical cathode to permit removal of the magnetic field forming material from the device without affecting the evacuated chamber thereof comprising:

forming one wall of the evacuated chamber of the device with the exterior surface of the cathode thereof;

removably positioning magnetic field forming material opposite the interior surface of the cathode and outside the evacuated chamber; and

completing a major internal portion of a flux path about the cathode by pole pieces disposed within the evacuated chamber and completing a minor external portion of the flux path by pole pieces disposed outside of the evacuated chamber so that the magnetic field forming material and the external portion of the flux path may be readily removed from the device.

7. The method of claim 6 and further including defining the area through which the magnetic field forming material and the external portion of the flux path are inserted by nonmagnetizable material; and

forming liquid coolant passages between the interior surface of the cathode and the area defining material.

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