Dec. 13, 1955 H. RINIA ET AL 2,727,192

MAGNETIC BODY COMPRISING A FERROMAGNETIC PART HAVING A HIGH PERMEABILITY AND A THIN PERMANENT MAGNET

Filed Jan. 4, 1952

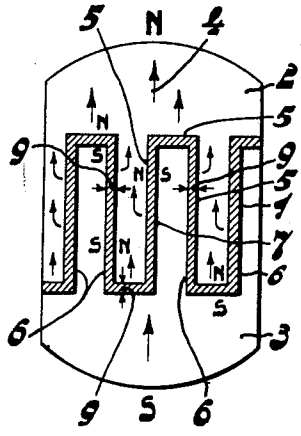


Fig. 1.

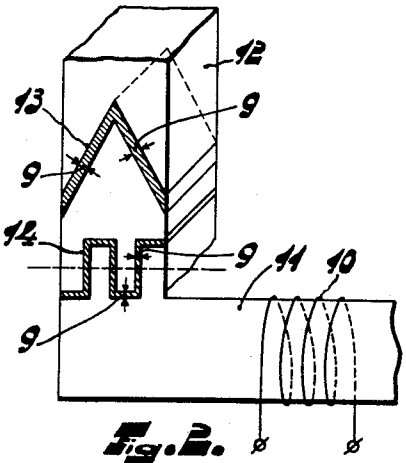


Fig. 2.

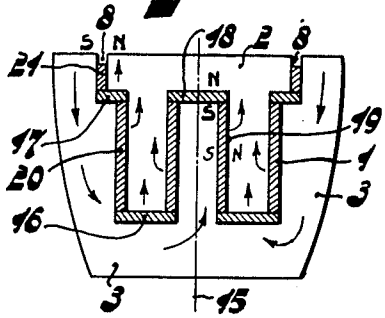


Fig. 3.

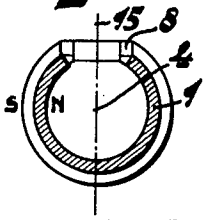


Fig. 4.

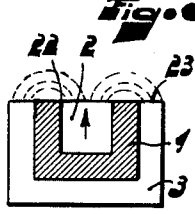


Fig. 6.

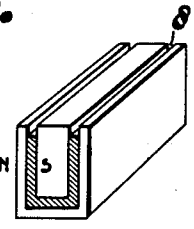


Fig. 7.

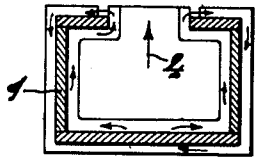


Fig. 5

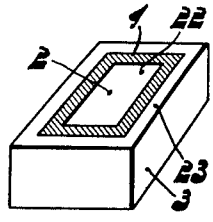


Fig. 8.

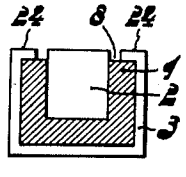


Fig. 9.

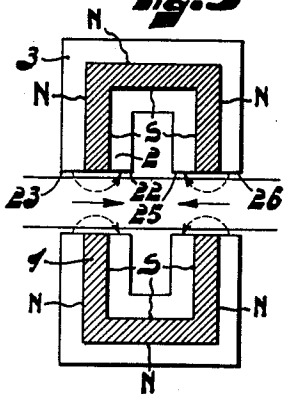


Fig. 10.

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MAGNETIC BODY COMPRISING A FERROMAGNETIC PART HAVING A HIGH PERMEABILITY AND A THIN PERMANENT MAGNET

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Claims priority, application Netherlands April 23, 1951

9 Claims. (Cl. 317—201)

This invention relates to magnetic bodies comprising a ferromagnetic part having a high permeability and a thin permanent magnet magnetised substantially in the direction of its smallest dimension and constituted by material having a high coercive force, at least 750 oersted, and a comparatively low remanence (for example, less than 5,000 gauss), the said smallest dimension being smaller than one quarter of the largest external dimension of one of the pole surfaces. Ferromagnetic materials having a high permeability are to be understood to be materials such as soft iron.

According to the invention, a magnetic body comprising a ferromagnetic part having a high permeability and a thin permanent magnet magnetised substantially in the direction of its smallest dimension and made of material having a high coercive force, at least 750 oersted, and a comparatively low remanence (for example, less than 5,000 gauss), the said smallest dimension being smaller than one quarter of the largest external dimension of one of the pole surfaces, is characterized in that the magnet is arranged in the ferromagnetic part in a form such that the surface area of the projection of the magnet on to a plane normal to the resultant direction of the lines of force in the ferromagnetic part is at least 1½ times, preferably at least twice as small as one of the pole surfaces of the magnet.

The magnet may thus have a pole surface which is comparatively very large and yet may be readily accommodated in the magnetic body. This is an advantage since the ferromagnetic parts are required to make contact with substantially the entire surface of the pole surfaces so that these parts would otherwise be required to have a very large cross-sectional area. The use of the invention ensures a considerable economy in material and the amount of space occupied thereby. In many cases, it will be preferred first to magnetise the magnet and then to arrange the magnet in the circuit in which it is to be employed. Frequently it will not be found possible to magnetise the magnet when it is arranged in the circuit. However, magnetising outside the circuit is not inconvenient since substantially no de-magnetisation of the material occurs.

Preferably, the smallest dimension of the magnet is less than one quarter of the smallest dimension of one of the pole surfaces.

The magnet may be built up from a number of thin, e. g. annular component members. This permits of providing a simple and economical construction in which magnetisation may and in some cases must be effected outside the circuit.

The magnet may be shaped in the form of a hollow body.

Particular advantages are obtained if the material of the permanent magnet is constituted by a material which is described in British Patent #708,127. Said material may be a ferromagnetic material having as a component essential for the ferromagnetic properties, single crystals

and/or mixed crystals of magnetoplumbite structure of compounds $MO.6Fe_2O_3$ or $MFe_{18}O_{27}$, where M represents one of the metals Pb, Ba or Sr, described in the last mentioned specification, which is characterized by a composition of substantially non-cubic crystals of poly-oxides of iron and at least one of the metals barium, strontium and lead and, if desired, calcium.

Said material may have, for example, a coercive force of 1,400 oersted and a remanence of 2,000 gauss and is favourably differentiated from known materials. A further advantage of said material is that the electrical resistance exceeds 10^5 ohm cm. at frequencies of, say, several mc./s. so that the eddy current losses are very low. Demagnetisation does substantially not occur.

In order that the invention may be more clearly understood and readily carried into effect, it will now be described more fully, by way of example, with reference to the accompanying diagrammatic drawing, given by way of example.

Fig. 1 shows an armature for an electrical machine. A permanent magnet **1** is provided having a castellated form, i. e., a square, toothed form, so that the magnet can be accommodated within the armature. The north and south poles are designed N and S. The resultant direction of the lines of force in soft iron parts **2** and **3** is designated by the arrow **4**. The surface area of the magnet projected onto a plane normal to the arrow **4** is materially less than that of the pole surface **5** or the pole surface **6**. Provision is thus made of an armature having an N-pole at the top of the soft iron part **2** and a S-pole at the bottom of the part **3**. The axis of the armature is designated **7**. The magnet **1** may be built up from flat plates which are first magnetised in the direction of the smallest dimension **9** and then arranged in the armature.

Fig. 2 shows part of the magnetic circuit of a choke (or of a measuring instrument). A coil **10** is arranged to surround a core **11**, a permanent magnet (either **13** or **14**) being included in a limb **12**. As in Fig. 1, the magnet is magnetised in the direction of the smallest dimension **9**. Such a construction may be used, for example, for compensating the direct current magnetisation in the core by a direct current component present in the alternating current which passes through the coil **10** of the choke.

Fig. 3 shows a permanent magnet system for a loudspeaker, the magnet **1** constituting, in this case, a solid of rotation, the axis of rotation being designated **15**. In this embodiment, an active airgap **8** is formed between the soft iron parts **2** and **3** to accommodate an annular coil secured to a diaphragm. The magnet **1** may be built up from flat rings **16** and **17**, a flat disc **18** and cylinders **19**, **20** and **21**. Fig. 4 shows a modification in which the magnet **1** is constituted by a bowl-shaped hollow solid of revolution and Fig. 5 shows a further modification in which the magnet **1** is shaped in the form of a cylinder closed at one end and partially closed at the other.

In all these embodiments it is preferable to build the magnet up from components which are first magnetised and then assembled and arranged in the circuit. Thus, the cylinders **19** and **20** of Fig. 3 may with advantage, be built up from a number of rings since such rings may be magnetised in the manner desired more readily than long cylinders.

The embodiments shown in Figs. 3 and 4 and 5 have the advantage that substantially the total flux is concentrated in the active airgap **8** so that the construction is highly economical.

In Fig. 6, the airgap is formed between the concentric pole surfaces **22** and **23** of the soft iron parts **2** and **3**. This construction is particularly suited for use as sticking magnet, in which a body, for example, an incandescent

lamp, which is secured to the magnetic circuit can be stuck to a ferromagnetic body, for example to the coachwork of a motor-car.

The advantage of the use of the permanent magnetic material for such purposes is that the adhesive force substantially does not decrease in the course of time in spite of the opening and short circuiting of the circuit.

The magnetic circuits shown in Figs. 3 to 6 may as an alternative to being shaped in the form of a solid rotation, be constructed to provide straight airgaps in the manner shown in Fig. 7. The magnetic circuits shown in Figs. 3 to 6 and 7 may be used in measuring instruments.

Fig. 8 shows a construction having an airgap of rectangular form, the basic form being essentially similar to that of Fig. 6. Magnetic bodies otherwise similar to those shown in Figs. 3 to 5 may be constructed in other shapes, for example, square in section.

There is no objection to providing parts of the ferromagnetic components (separated by an airgap) in the direction of the lines of force of the magnet and so as to make contact with the magnet since magnetic short-circuiting does not result therefrom. Such a construction is shown in Fig. 9 in which provision is made of the parts 24.

Fig. 10 shows a modification of the device shown in Fig. 6 which is particularly suitable for use in an electron discharge tube, the magnet being used for electron-optical purposes and being shaped in the form of a rotation-symmetrical body within and/or without which are arranged the soft iron parts 2 or 3 respectively which are also rotation-symmetrical. The soft iron part 2 may be formed as a solid disc, a magnetic field being thus developed between the poles 22, 23, and 25, 26 respectively, said magnetic field exercising a focussing effect on an electron beam passing axially through the lens. A property of this construction is that whilst at the one hand the strength of such a lens, which is proportional to the square of the field strength at the axis, is increased by the combined action of the field between the poles 22, 23 and 25, 26, rotation of the image projected by the electron beam, which is proportional to the first power of the field strength at the axis, substantially does not occur, because the fields between the poles 22, 23 and 25, 26 respectively are substantially equal and opposite in direction.

What we claim is:

1. A magnetic body comprising a ferromagnetic part having a high permeability and a thin bent permanent magnet disposed within and abutting said ferromagnetic part and having a smaller linear dimension in a given direction than dimensions at right angles thereto, said magnet being magnetized along an axis parallel to said given direction and having poles on its end surfaces which are perpendicular to said smaller dimension, said magnet consisting essentially of non-cubic crystals of a material selected from the group consisting of $MO \cdot 6Fe_2O_3$ and $MFe_{18}O_{27}$, M being at least one of the metals selected from the group consisting of barium, strontium and lead, said material having a coercivity of at least 750 oersted and a low remanence, said smaller dimension being smaller than one-quarter of the largest dimension of either of said end surfaces, each of said end surfaces having a total area which is at least one and one-half times greater than the projected surface area of the magnet on a plane in the ferromagnetic part normal to the resultant lines of force in said part.

2. A magnetic body comprising a ferromagnetic part having a high permeability and a thin bent permanent magnet disposed within and abutting said ferromagnetic part and comprising a plurality of stacked, thin annular members, said magnet having a smaller linear dimension in a given direction than dimensions at right angles thereto, said magnet being magnetized along an axis parallel to said given direction and having poles on its end surfaces which are perpendicular to said smaller dimension, said magnet consisting essentially of non-cubic crystals of a material selected from the group consisting of

$$MO \cdot 6Fe_2O_3$$

and $MFe_{18}O_{27}$, M being at least one of the metals selected from the group consisting of barium, strontium and lead, said material having a coercivity of at least 750 oersted and a low remanence, said smaller dimension being smaller than one-quarter of the largest dimension of either of said end surfaces, each of said end surfaces having a total area which is at least one and one-half times greater than the projected surface area of the magnet on a plane in the ferromagnetic part normal to the resultant lines of force in said part.

3. A magnetic body comprising a ferromagnetic part having a high permeability and a thin permanent magnet defining a hollow body and disposed within and abutting said ferromagnetic part and having a smaller linear dimension in a given direction than dimensions at right angles thereto, said magnet being magnetized along an axis parallel to said given direction and having poles on its end surfaces which are perpendicular to said smaller dimension, said magnet consisting essentially of non-cubic crystals of a material selected from the group consisting of $MO \cdot 6Fe_2O_3$ and $MFe_{18}O_{27}$, M being at least one of the metals selected from the group consisting of barium, strontium and lead, said material having a coercivity of at least 750 oersted and a low remanence, said smaller dimension being smaller than one-quarter of the largest dimension of either of said end surfaces, each of said end surfaces having a total area which is at least one and one-half times greater than the projected surface area of the magnet on a plane in the ferromagnetic part normal to the resultant lines of force in said part.

4. A magnetic body comprising a ferromagnetic part having a high permeability and a thin castellated permanent magnet interposed between two adjoining portions of said ferromagnetic part and having a smaller linear dimension in a given direction than dimensions at right angles thereto, said magnet being magnetized along an axis parallel to said given direction and having poles on its end surfaces which are perpendicular to said smaller dimension, said magnet consisting essentially of non-cubic crystals of a material selected from the group consisting of $MO.6Fe_2O_3$ and $MFe_{18}O_{27}$, M being at least one of the metals selected from the group consisting of barium, strontium and lead, said material having a coercivity of at least 750 oersted and a low remanence, said smaller dimension being smaller than one-quarter of the largest dimension of either of said end surfaces, each of said end surfaces having a total area which is at least one and one-half times greater than the projected surface area of the magnet on a plane in the ferromagnetic part normal to the resultant lines of force in said part.

5. A magnetic body comprising a ferromagnetic part having a high permeability and a thin V-shaped permanent magnet interposed between two adjoining portions of said ferromagnetic part and having a smaller linear dimension in a given direction than dimensions at right angles thereto, said magnet being magnetized along an axis parallel to said given direction and having poles on its end surfaces which are perpendicular to said smaller dimension, said magnet consisting essentially of non-cubic crystals of a material selected from the group consisting of $MO.6Fe_2O_3$ and $MFe_{18}O_{27}$, M being at least one of the metals selected from the group consisting of barium, strontium and lead, said material having a coercivity of at least 750 oersted and a low remanence, said smaller dimension being smaller than one-quarter of the largest dimension of either of said end surfaces, each of said end surfaces having a total area which is at least one and one-half times greater than the projected surface area of the magnet on a plane in the ferromagnetic part normal to the resultant lines of force in said part.

6. A magnetic body comprising a ferromagnetic part

having a high permeability and a thin U-shaped permanent magnet interposed between two adjoining portions of said ferromagnetic part and having a smaller linear dimension in a given direction than dimensions at right angles thereto, said magnet being magnetized along an axis parallel to said given direction and having poles on its end surfaces which are perpendicular to said smaller dimension, said magnet consisting essentially of non-cubic crystals of a material selected from the group consisting of $MO.6Fe_2O_3$ and $MFe_{18}O_{27}$, M being at least one of the metals selected from the group consisting of barium, strontium and lead, said material having a coercivity of at least 750 oersted and a low remanence, said smaller dimension being smaller than one-quarter of the largest dimension of either of said end surfaces, each of said end surfaces having a total area which is at least one and one-half times greater than the projected surface area of the magnet on a plane in the ferromagnetic part normal to the resultant lines of force in said part.

7. A magnetic circuit comprising a ferromagnetic part having a high permeability and a thin hollow rectangular permanent magnet interposed between two adjoining portions of said ferromagnetic part and having a smaller linear dimension in a given direction than dimensions at right angles thereto, said magnet being magnetized along an axis parallel to said given direction and having poles on its end surfaces which are perpendicular to said smaller dimension, said magnet consisting essentially of non-cubic crystals of a material selected from the group consisting of $MO.6Fe_2O_3$ and $MFe_{18}O_{27}$, M being at least one of the metals selected from the group consisting of barium, strontium and lead, said material having a coercivity of at least 750 oersted and a low remanence, said smaller dimension being smaller than one-quarter of the largest dimension of either of said end surfaces, each of said end surfaces having a total area which is at least one and one-half times greater than the projected surface area of the magnet on a plane in the ferromagnetic part normal to the resultant lines of force in said part.

8. A magnetic body comprising a ferromagnetic part having a high permeability and a thin permanent magnet disposed within said ferromagnetic part and having a smaller linear dimension in a given direction than dimensions at right angles thereto, said magnet being magnetized along an axis parallel to said given direction and having poles on its end surfaces which are perpendicular to said smaller dimension, said magnet being a solid of revolution with a U-shaped cross-section, the open end of the U facing towards the axis of revolution and defining a channel, portions of said ferromagnetic part extending along the opposing surfaces of said magnet and beyond the ends of said magnet to thereby define two coaxial air-gaps in which lines of force are in opposite directions, said magnet consisting essentially of non-cubic crystals of a material selected from the group consisting of $MO.6Fe_2O_3$ and $MFe_{18}O_{27}$, M being at least one of the metals selected from the group consisting of barium, strontium and lead, said material having a coercivity of at least 750 oersted and a low remanence, said smaller dimension being smaller than one-quarter of the largest dimension of either of said end surfaces, each of said end surfaces having a total area which is at least one and one-half times greater than the projected surface area of the magnet on a plane in the ferromagnetic part normal to the resultant lines of force in said part.

9. A magnetic body comprising a ferromagnetic part having a high permeability and a thin permanent magnet defining a hollow body disposed within said ferromagnetic part and having a smaller linear dimension in a given direction than dimensions at right angles thereto, said magnet being magnetized along an axis parallel to said given direction and having poles on its end surfaces which are perpendicular to said smaller dimension, portions of said ferromagnetic part extending along opposite sides of said magnet and beyond the ends thereof to define a plurality of air-gaps, said magnet consisting essentially of non-cubic crystals of a material selected from the group consisting of $MO.6Fe_2O_3$ and $MFe_{18}O_{27}$, M being at least one of the metals selected from the group consisting of barium, strontium and lead, said material having a coercivity of at least 750 oersted and a low remanence, said smaller dimension being smaller than one-quarter of the largest dimension of either of said end surfaces, each of said end surfaces having a total area which is at least one and one-half times greater than the projected surface area of the magnet on a plane in the ferromagnetic part normal to the resultant lines of force in said part.

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