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MAGNETIC CIRCUIT

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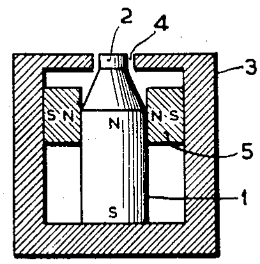

FIG.1

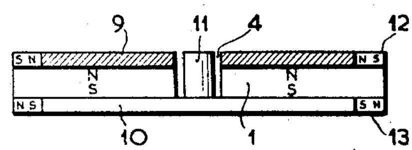

FIG.3

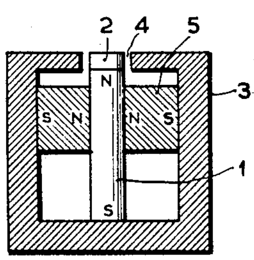

FIG.2

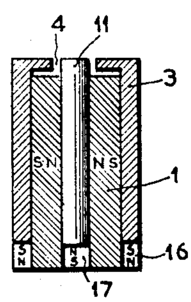

FIG.4

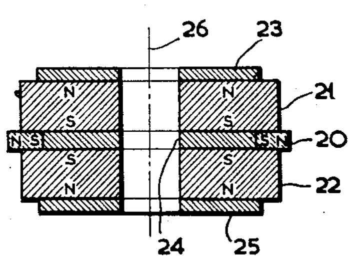

FIG.5

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MAGNETIC CIRCUIT

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8 Claims. (Cl. 317—201)

This invention relates to magnetic circuits comprising a permanent main magnet, one or more permanent auxiliary magnets made from different material, and a soft-magnetic part for the transmission of the magnetic flux produced by the permanent magnets to an operating or active point. Such circuits are used, for example, in loudspeakers and in magnetic electron lenses respectively, the field set up at the operating point acting upon a loudspeaker moving coil and an electron beam to be focussed, respectively. However, the invention can generally also be used in bias magnetisation arrangements.

In such magnetic circuits, use is generally made of permanent magnets having a high magnetic output, which are included in the circuit so that they are operated at their maximum BH-product or peak energy product (where B is the magnetic induction and H is the magnetic fieldstrength within the magnet). Thus, the magnet produces a magnetic potential and a magnetic flux which is transmitted by the soft magnetic part to the operating point. The magnetic potential drop along the soft magnetic part gives rise to stray or leakage fluxes between various points of this part, so that only a materially smaller flux arrives at the operating point.

It is an object of the invention to increase the effective flux and/or to reduce the stray flux. To this end, it can be ensured by a suitable design of the magnetic circuit that about one-half of the flux produced by the permanent main magnet arrives at the operating or active point.

It is also an object of the invention to increase further the magnetic flux produced at the operating point and/or to reduce further the stray flux produced outside the operating area. This object can be realized by compensating this stray field by a field of the same strength originating from at least one auxiliary magnet made from a different permanent magnet material, having a different operative fieldstrength and being arranged at at least one point at which a comparatively strong stray flux is produced.

A magnetic circuit in accordance with the invention is characterized in that the main magnet and the auxiliary magnets are magnetized perpendicularly to each other, and in that the materials from which the magnets are made are different, in the sense that the fieldstrength of the main magnet and the auxiliary magnet respectively at that point of the BH-curve or magnetization characteristic where the product of the induction B and the fieldstrength H becomes maximum-$(BH)_{max}$ is essentially different, and that the fieldstrength of the auxiliary magnet corresponding with its $(BH)_{max}$-product is substantially the same as the stray fieldstrength produced by the main magnet at the place of the auxiliary magnet, increased, as the case may be, by its own demagnetization fieldstrength.

The invention is based on the recognition of the fact that, due to the addition of an auxiliary magnet, the fluxes which are produced in the soft magnetic part by the main magnet and the auxiliary magnet are added substantially linearly, and a suitable choice of the permanent magnet material enables the auxiliary magnet to be operated so that it provides its maximum magnetic output. (Generally, in carrying out this step the length of the magnet measured in the direction of magnetization must be made slightly greater in order to adjust the magnetic circuit so that its BH-product is a maximum.) Preferably the auxiliary magnet is arranged so that the stray flux produced by the main magnet is also reduced. However, this compensation, which can only be partial, does not provide any further increase of the effective flux.

In order that the invention may readily be carried out, some embodiments thereof will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

Fig. 1 shows a magnetic circuit for use in a loudspeaker,

Fig. 2 is a modification of the circuit shown in Fig. 1,

Fig. 3 shows a magnetic circuit for a loudspeaker of different design,

Fig. 4 shows a third embodiment of such a magnetic circuit and

Fig. 5 shows a magnetic circuit for an electron lens.

The loudspeaker magnetic circuit shown in Fig. 1 comprises a cylindrical axially magnetised permanent main magnet **1** made of a material having a high magnetic output but a comparatively low operative fieldstrength. Use may, for example, be made of the material known under the trade name "Ticonal" which has an operative fieldstrength H of 500 oersted and an operative induction B of 10,000 gauss. The magnet **1** is provided with a soft magnetic pole hood **2** and a cylindrical soft magnetic shell **3** between which an airgap **4** is produced in which a loudspeaker moving coil can be arranged.

Between the magnet **1** and the shell **3** a comparatively strong stray field is produced, which, particularly in the proximity of the airgap **4**, may materially exceed the operative field strength produced within the magnet **1**. Owing to the high value of the stray fieldstrength, with respect to the fieldstrength within the main magnet, the provision of an auxiliary permanent magnet made of a similar material would give little advantage, since the operating point of this auxiliary permanent magnet would be highly unfavourable, for, as is well-known, a permanent magnet has its greatest effect when it is operated at that point of the BH-curve where its energy product is at its peak. In order to reduce this stray field and to increase the effective field produced in the airgap **4**, provision is made of an annular radially magnetized auxiliary magnet **5** made of a magnetically stronger material, for example, Ferroxdure, having a fieldstrength of about 1250 oersted and an induction of about 1700 gauss at the operating point where the product BH of the induction and the fieldstrength becomes a maximum. According to the invention the auxiliary magnet **5** is operated at substantially its maximum magnetic output, that is to say at its peak energy product, in a manner such that the fieldstrength of the auxiliary magnet **5** corresponding with its $(BH)_{max}$-product is substantially the same as the stray fieldstrength produced by the main magnet **1** at the place of the auxiliary magnet **5**. The field of this auxiliary magnet **5** is added to the field of the main magnet **1** and provides a real increase of, say, from 20% to 30% of the effective field in the airgap **4**, and hence of the effective flux. The gain in flux may be eliminated while maintaining the same magnetic potential by an increase in the magnetic reluctance of the main magnet **1**. The main magnet **1** is accordingly prolonged and can be made substantially more slender as is shown in Fig. 2. Consequently, a larger space becomes available for the auxiliary magnet **5** in Fig. 2 so that it may be made from Ferroxdure having a field strength of 1000 oersted and an induction of 2200 gauss at its operating point and hence provides an even greater contribution to the effective flux.

Since the stray fieldstrength decreases in the direction towards the end remote from the airgap 4, the magnet 5 may, if required, be tapered and the shell 3 may be conical (not shown).

Fig. 3 shows a loudspeaker magnetic circuit comprising a disc-shaped axially magnetised Ferroxdure main magnet 1 and a soft magnetic part constituted by discs 9 and 10 and by a central cylindrical core 11 which together with the disc 9 bounds the airgap 4. Between the outer circumferences of the discs 9 and 10 a considerable stray flux is produced, however, its fieldstrength is less than the operative fieldstrength of the main magnet 1.

By the provision of two annular radially magnetised auxiliary magnets 12 and 13, made for example from "Ticonal," the effective field produced in the air-gap 4 is increased. At the same time the circumferential stray field of the main magnet 1 is partially compensated for by the magnets 12 and 13, so that there is less interference in electronic apparatus arranged in the proximity of the circuit. Since the auxiliary magnets 12 and 13 lie in an open magnetic circuit, use must be made of a permanent magnet material having an operative fieldstrength which is substantially equal to the total sum of the stray fieldstrength and the natural demagnetisation fieldstrength produced by the cylindrical circumferences. If required, this latter step can be dispersed with or can be assisted by the provision of an annular auxiliary magnet encircling the main magnet 1 and being magnetized in the same direction but having a lower operative field strength.

In the embodiment shown in Fig. 4, the main magnet 1 of higher operative fieldstrength, which may be made from Ferroxdure, is tubular and magnetized radially. The soft-magnetic parts comprise a rod-shaped core 11 and a cylindrical shell 3 the upper ends of which are spaced apart to form an air-gap 4. The stray flux at their lower ends can be materially reduced by the provision of an annular and/or a rod-shaped axially magnetised magnet 16 and/or 17 respectively of lower operative fieldstrength. (Owing to the lesser concentration of lines of magnetic force, the magnet 16 can usually be dispensed with.)

A similar effect is achieved by the auxiliary magnet 20 of the magnetic electron lens shown in Fig. 5. This lens comprises two disc-shaped main magnets 21 and 22 axially magnetised in opposite directions and soft-magnetic disc-shaped parts 23, 24 and 25, between which an electron-focussing field is set up along the optical axis 26. The discs 23 and 25 have equal magnetic potentials and consequently do not give rise to a mutual stray flux. At the circumference of the discs only, a considerable stray flux is produced from the discs 23 and 25 to the disc 24, however, this stray flux is at least partially compensated for at the point of highest concentration of the lines of magnetic force by means of the auxiliary magnet 20 having a lower operative fieldstrength.

The material "Ticonal" as mentioned herebefore, is described in U.S. Patent No. 2,295,082.

Ferroxdure materials are oxidic permanent magnetic materials, the constituents essential to the permanent magnetic properties of which are compounds having a hexagonal crystal structure and a chemical formula $M_2Ca_{(1-x)}O{\cdot}6Fe_2O_3$, in which $0.6 \leqslant x \leqslant 1$ and in which M stands for one or more of the metals Ba (barium), Sr (strontium) and Pb (lead), these materials being more amply described in U.S. Patent No. 2,762,777.

What is claimed is:

1. A magnetic circuit comprising main and auxiliary permanent magnets arranged so that their magnetization directions are substantially at right angles to one another and a soft magnetic member for carrying the flux of the magnets to an active point, said main and auxiliary magnets being composed of materials having magnetization characteristics such that their field strengths at which their energy products are a maximum are different, said auxiliary magnet being located at a position in the circuit where the sum of its own demagnetizing field strength and the stray field strength produced at that position by the main magnet substantially matches the field strength of the auxiliary magnet at which its energy product is a maximum.

2. A circuit as set forth in claim 1 wherein one of the magnets has a high field strength and low induction at its peak energy product, and the other magnet has a low field strength and a high induction at its peak energy product.

3. A magnetic circuit comprising main and auxiliary permanent magnets arranged so that their magnetization directions are substantially at right angles to one another and a soft magnetic member for carrying the flux of the magnets to an active point, said main and auxiliary magnets being composed of materials having magnetization characteristics such that their field strengths at which their energy products are a maximum are different, said auxiliary magnet being located at a position in the circuit where the sum of its own demagnetizing field strength and the stray field strength produced at that position by the main magnet substantially matches the field strength of the auxiliary magnet at which its energy product is a maximum, said auxiliary magnet having a higher field strength at its operating point than that of the main magnet.

4. A circuit as set forth in claim 3 wherein the main magnet is rod-shaped and is magnetized axially, and the auxiliary magnet is annular and surrounds the main magnet and is magnetized radially.

5. A magnetic circuit comprising main and auxiliary permanent magnets arranged so that their magnetization directions are substantially at right angles to one another and a soft magnetic member for carrying the flux of the magnets to an active point, said main and auxiliary magnets being composed of materials having magnetization characteristics such that their field strengths at which their energy products are a maximum are different, said auxiliary magnet being located at a position in the circuit where the sum of its own demagnetizing field strength and the stray field strength produced at that position by the main magnet substantially matches the field strength of the auxiliary magnet at which its energy product is a maximum, said auxiliary magnet having a lower field strength at its operating point than that of the main magnet.

6. A circuit as set forth in claim 5 wherein the main magnet is disc-shaped and is magnetized axially, and the auxiliary magnet is annular and magnetized radially.

7. A circuit as set forth in claim 6 wherein soft iron discs are provided on opposite sides of the main magnet, and the auxiliary magnet surrounds one of these soft iron discs.

8. A circuit as set forth in claim 5, wherein the main magnet is tubular and magnetized radially, and the auxiliary magnet is rod-shaped and magnetized axially.

References Cited in the file of this patent

UNITED STATES PATENTS

2,398,653 Linlor ---------------- Apr. 16, 1946