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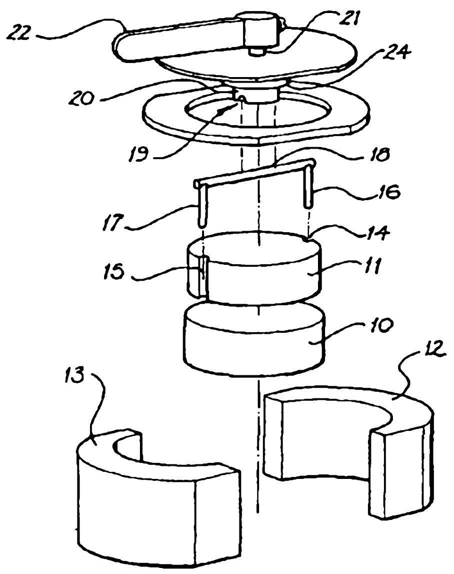
(54) Title: SWITCHABLE PERMANENT MAGNETIC DEVICE



(57) **Abstract:** A switchable magnetic device includes a first magnet (10) and a second magnet (11), both of which are essentially cylindrical. Magnets (10, 11) are housed in a housing made from pole pieces (12,13). Pole pieces (12, 13) are ferromagnetic. Lower magnet (10) is fixedly mounted in the housing whilst upper magnet (11) can rotate within the housing. Upper magnet (11) is formed with notches or grooves (14, 15) along its vertical side walls. These notches or grooves (14, 15) receive downwardly depending arms (16, 17) of bar (18). Bar (18) is received inside a groove (19) formed on boss (20). Boss (20) is connected to a short bar (21) that, in turn, is fixedly connected to a handle or lever (22). By this means, rotation of handle or lever (22) causes rotation of second magnet (11). When the upper magnet (11) is positioned such that its north pole substantially overlies the south pole of lower magnet (10) and the south pole of upper magnet (11) substantially overlies the north pole of lower magnet (10), the first and second magnets act as an internal active magnetic shunt and as a result the external magnetic field strength from the device is quite low. Rotating the upper magnet (11) 180° about its axis of rotation brings the magnets into alignment such that the respective north and south poles of the upper magnet (11) substantially overlie respective north and south poles of lower magnet (10). In this alignment, the external magnet field from the device is quite strong and the device can be affixed to surfaces or objects.

WO 01/43147 A1

Switchable Permanent Magnetic Device

Field of the invention

The present invention relates to a magnetic device. In particular, the present invention relates to a switchable permanent magnet device.

Background of the invention

Permanent magnets consist of a ferromagnetic material that has been suitably magnetized. Permanent magnets provide a magnetic field without requiring an electric current. Permanent magnets are attracted to and can be firmly affixed ferromagnetic materials. However, permanent magnets suffer from the drawback that their energy output is fixed and they cannot be employed if a variation in magnetic field strength is required.

Due to the above-mentioned drawback with permanent magnets, it has been customary to control magnetic fields by using electric currents or electromagnets. The strength and orientation of the magnetic fields of electromagnets can be controlled successfully by controlling the strength and direction of the electric current. However, this introduces the necessity of having to provide a constantly available source of electric current and associated wiring. This can cause complexity and potential hazards.

A number of attempts have also been made to arrange permanent magnets to enable variations to be achieved in magnetic field strength. A number of different approaches have been tried to produce practical solutions. However, these approaches resulted in bulky constructions, complicated constructions, or devices that were expensive to manufacture. The prior art devices also paid little attention to achieving a good holding force between the devices and substrates under conditions where an incomplete external magnetic circuit existed, for example, where there were gaps between the magnet and the keeper, or where the keeper or substrate had a low permeability, such as thin ferrous sheet metal. To achieve good holding forces in the prior art devices, it was necessary that perfect contact between the magnet and the substrate be achieved and that the substrate be of substantial volume to enable a sufficient magnetic flux to be established. This, of course, could be difficult to achieve in practice.

United States patent no 3121193 (Engelstead) describes a permanent magnet-type work holding device especially a chuck that is adapted for use in turning operations. The device of Engelstead consists of arrays of permanent magnets, which magnets are of generally rectangular configuration. In order to adjust the field strength an array of pole pieces was moved away from and out of alignment with another array of pole pieces.

United States patent no 4251791 (Yanagisawa) describes a magnetic base which is switchable between an engaged position and releaseable from a substance by an operation of a single rotating permanent magnet disposed notably in a magnetic circuit block. The rotary magnet in Yanagisawa is rotated by 90° to switch between the exited and the unexcited states. This device relies upon using passive external magnetic members of substantial mass (12 and 14 of Figure 1 of Yanagisawa) having a rotatable magnet (20) positioned therein.

United Kingdom patent application no 2130797 relates to a permanent magnet chuck capable of switching from an excited state to an unexcited state by changing the relative positional relationship between fixed permanent magnets and movable permanent magnets. The movable permanent magnets move laterally with respect to the fixed magnets in order to vary the magnetic filed.

Summary of the invention

It is an object of the present invention to provide a switchable magnetic device having improved properties.

In a first aspect, the present invention provides a switchable magnetic device comprising a housing, a first permanent magnet, a second permanent magnet, said first and second permanent magnets being essentially cylindrically shaped, said first and second permanent magnets being diametrically polarised, said first and second permanent magnets being mounted within the housing such that the first and second permanent magnets are rotatable relative to each other, and actuation means for causing relative rotation of the first and second permanent magnets, wherein said device presents a relatively strong external magnetic field when said first and second permanent magnets are positioned relative to each other such that a north and south poles of the first magnet are in substantial alignment with respective north and south poles of the second magnet, and the device presents a relatively weak external magnetic field when the first and second magnets are positioned relative to each other such that the north pole of the first magnet is in substantial alignment with the south pole of the second magnet and vice versa.

Preferably, the first and second magnets are substantially disc-shaped.

Preferably, the first magnet and the second magnet are mounted in the housing such that a face of the first magnet is opposed to a face of the second magnet. Most preferably, one magnet is mounted above the other magnet.

It is preferred that one magnet is fixedly mounted in the housing and that the other magnet is able to rotate in the housing.

The housing may comprise a pair of passive ferro-magnetic elements which are magnetically separated, for example, by an air gap or by magnetically high reluctance material(s). The housing most suitably defines a chamber in which the first and second magnets are positioned. The chamber may have open ends or, more preferably, is a closed chamber. Chamber closing members are suitably used to close the chamber.

In another embodiment, the housing is made as a unitary construction or from a single piece of material. In this embodiment, it is preferred that there be two portions of the housing having reduced cross sectional area such that the housing acts as two passive poles. Alternatively, portions of the housing may be treated such that the portions become non-magnetic to thereby result in the housing acting as two passive poles.

The housing is preferably made from a material having a low magnetic reluctance. Soft steel, iron or permalloys are examples of suitable materials for the housing.

The housing most preferably comprises a pair of passive poles. The strength of the external magnetic field can be maximised by shaping the pair of passive poles such that they reflect the magnetic field strength around the perimeter of the first and second permanent magnets.

The first and second magnets are preferably substantially disc-shaped. Most preferably, the first and second magnets are essentially cylindrical in shape and the height of the cylinder is less than the diameter of the cylinder. It will be appreciated that the first and second magnets need not be exactly cylindrical and that slight variations from a circular cross-section also fall within the scope of the present invention. The height of the magnets may vary over a wide range, and the ratio of diameter to height may also vary over a wide range.

The first and second magnets are also diametrically magnetised. By that, it is meant that the north pole region is separated by a diameter of the cylindrical surface of the magnet from the south pole region. The north pole region and south pole region both exist on the upper and lower substantially circular faces of the magnet and extend through the length or height of the magnet.

As mentioned earlier, it is preferred that one magnet is fixed in the housing and one magnet can rotate in the housing. It is especially preferred that the rotatable magnet can rotate about the centre point of its essentially circular faces. In this fashion, the requirement for large clearances between the inner walls of the housing and the rotatable magnet are avoided. In this embodiment, the shape of the body of rotation of the rotatable magnet is the same shape as the magnet itself (ie substantially circular in top or plan view) and thus the magnet can rotate and yet retain its positioning relative to the walls of the housing.

The actuation means for causing relative rotation of thc magnets preferably comprises a handle or knob being in connection with one of the magnets. The handle or knob may be connected to the one magnet by one or more intermediate mcmbers.

The handle or knob may be rotated manually, electrically, pneumatically, hydraulically, by the action of expansion of a bimetallic strip, or indeed by any other suitable method

The handle may comprise a torque sensitive lever that does not allow a torque in excess of a predetermined amount to be applied to the one magnet. In this regard, when there is no external load applied to the device, it is difficult to switch device between active and inactive states. Use of a torque sensitive lever as part of the actuation means can result in it being impossible to switch the device between the active and inactive states if no sufficient external magnetic circuit is present.

As mentioned above, the housing preferably includes two passive poles, and it is also preferred that one magnet is fixed in the housing. In this particularly preferred embodiment, the one magnet is fixed in place such that the pole pieces are permanently energised.

The permanent magnets in the present invention may be of any suitable type. The most preferred at present are rare earth magnets because they can have a strong magnetic field. Such magnets also have a high coercivity, which means that they resist becoming demagnetised. It is envisaged that permanent magnet technology will continue to develop and it is likely that more powerful magnets will become available in the future that will be suitable for use in the present invention.

The first and second magnets may be essentially identical to each other. Alternatively, the first and second magnets may have different magnetic properties. The magnets may have the same or different physical dimensions to each other. Varying the magnetic properties or the physical dimensions of the first and second magnets can be used in some embodiments of the invention to vary magnetic switching properties.

The present invention may be used as a switchable magnetic holding device. For example, the device may be used to clasp onto surfaces, especially metal surfaces. In some embodiments, the surface to which the device is affixed is located adjacent or underneath a lower surface of the lower magnet. In other embodiments, the surface to which the device is affixed is located adjacent or beside the side surfaces of the magnets.

Alternatively, the device may be used in applications where mainly use of magnetic field is required or desirable. For example, triggering magnetic sensors, for example, in mines, particle deflection, etc.

Brief description of the drawings

In order to more fully understand the present invention, a preferred embodiment of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of an essentially cylindrically-shaped magnet for use in the present invention;

Figure 2 shows a device in accordance with the present invention apart and in-line for assembly;

Figures 3 and 4 show schematic; cross-sectional side views of the device in accordance with the present invention to demonstrate the principle of the present invention;

Figure 5 shows the relationship between the angle of rotation and the external magnetic field in a device in accordance with the present invention; and

Figure 6 shows an end view of a device in accordance with the present invention, particularly showing one potential suitable shape for the pole pieces.

Detailed description of the embodiments

The magnet 1 as shown in Figure 1 may be described as a cylindrically-shaped magnet. The magnet is diametrically magnetised. By that, is meant that the notional division between the north pole and the south pole of the magnet is achieved by a vertical plane that passes along a diameter 2 of an upper face 3 of the disc magnet 1.

The disc magnet 1 shown in Figure 1 is preferably a rare-earth type magnet, for example, the magnet 1 may be a neodymium-iron-boron magnet. The present invention also contemplates the use of any other permanent magnet material.

Turning to Figure 2, the device includes a first magnet 10 and a second magnet 11. Both magnets 10, 11 are essentially disc shaped magnets and are similar to magnet 1 as shown in Figure 1. Magnets 10, 11 are housed in a housing that is made from pole pieces 12, 13. Pole pieces 12, 13 are preferably made from a material that is ferromagnetic with low magnetic reluctance. The pole pieces 12, 13 are arranged such that they fixedly hold lower magnets 10 in a fixed position. Upper magnet 11, however, is able to be rotated within the housing formed by pole pieces 12, 13.

In order to facilitate rotation of upper magnet 11, the magnet 11 is formed with notches or grooves 14, 15 along its vertical side walls. These notches or grooves 14, 15 receive the downwardly depending arms 16, 17 of bar 18. Bar 18 is received inside a groove 19 formed on boss 20. Boss 20 is connected to a short bar 21 that, in turn, is fixedly connected to a handle or lever 22. By this means, rotation of handle or lever 22 causes rotation of second magnet 11. It will be appreciated that second magnet 11 rotates essentially about its centre point.

The device further includes a top cover 23 that is fixedly secured to the housing formed by pole pieces 12 and 13. Cover 23 seals the top of the housing formed by pole pieces 12, 13. It will be noted that boss 20 extends through an opening in top cover 23 and that sealing member 24 assists in forming a water tight and dust proof seal around that opening.

In one embodiment of the device shown in Figure 2, the lower surface of lower magnet 10 formed part of the lower surface of the device. In this embodiment, the lowest surface of the lower magnet 10 is positioned such that it lies essentially adjacent to the lower surfaces of respective pole pieces 12, 13.

In another embodiment, the lower surface of the device is provided by a lower cover (not shown).

In either embodiment, it is preferred that the device is essentially sealed, such that it is substantially waterproof and dustproof. This enables the device to be used in harsh environments, such as dusty environments, wet environments, or even fully submerged.

The principle of operation of the device in accordance with the present invention is shown in Figures 3 and 4. In Figures 3 and 4, first magnet 10 and second magnet 11 are mounted such that first magnet 10 is below second magnet 11. The first and second magnets 10, 11 are mounted such that they are in face to face juxtaposition. First magnet 10 is fixedly mounted, whilst second magnet 11 is mounted for rotation about axis of rotation 24.

In Figure 3, the second magnet 11 has been positioned such that its north pole substantially overlies the south pole of first magnet 10. Similarly, it follows that the south pole of second magnet 11 substantially overlies the north pole of first magnet 10. In this arrangement, the first and second magnets act as an internal active magnetic shunt and as a result the external magnetic field strength from the device is quite low.

Rotating the upper magnet 11 180° about its axis of rotation brings the magnets into the alignment as shown in Figure 4. In this alignment, the respective north and south poles of the upper magnet 11 substantially overlie respective north and south poles of lower magnet 10. In this alignment, the external magnet field from the device is quite strong and the device can be firmly attached to ferromagnetic surfaces. The passive poles are important in assisting the magnetic functionality shown in Figures 3 and 4.

Figure 5 shows the analogue relationship between the angle of rotation and the variation of the external magnetic field. The exact characteristics of the curve depend on the way the disc magnets are magnctised in their physical shape as well as the shape of the poles (12, 13). Variation of the ratio of the magnetic energy products of the magnetic discs 10, 11 can achieve further modification of the curve in figure 5 to suit particular applications.

Further increases in external magnetic field strengths can be accomplished by shaping the wall thickness of the pole pieces 12, 13 in such a way that they reflect the variation of the magnetic field strength around the perimeter of the permanently magnetised discs 10, 11.

Figure 6 indicates the design of the pole pieces 12, 13 shaped in accordance with the variation of the field strength H around the perimeter of the magnetic discs 10, 11. The application of the inverse square law of magnetic fields achieves good results but specific materials and applications they influence the optimal shape. In particular, the wall thickness of the poles may be varied as follows:

(a) oval poles, where the wall thickness is a mathematical function of the field strength of the perimeter of the magnets;

(b) oval poles, where the wall thickness is a mathematical function of the distribution of the magnetic mass of magnets 10 and 11;

(c) round pole pieces, where the wall thickness is constant and the magnetic field strength is lower but uniform around the perimeter.

The shape of the outer casing of the housing shown in figure 6, being an oval-shape, maximises the external field strength and assists in holding the device in place in incomplete magnetic circuits. Incomplete magnetic circuits are met in practice when there is an air gap between the bottom of the device and the surface to which it is to be attached, or were there is a non-magnetic material interposed between the surface to which the device is designed to be attached and the bottom of the device.

It is another feature of preferred embodiments of the present invention that the poles are of the shortest possible length. The poles form part of the magnetic circuit (along with the magnets). The poles have an inherent magnetic resistance ("reluctance") which results in loss of magnetic energy. Thus, the present invention, in minimising the length of the poles, minimises loss of magnetic energy and hence maximises the external field strength.

It has also been found that the required torque to shift the upper magnet 11 to the "on" position decreases markedly with the increase of magnetic flux through the external circuit. An added feature is therefore a torque sensitive lever which will only allow the device to be switched to the "on" position if an appropriate external magnetic circuit is present.

The present invention utilises an "active" shunting technique wherein the magnetic circuit is switched from a strong external field to a weak external field by performing a magnetic short circuit using the magnets themselves. The passive poles can be reduced to a minimum of mass which, in turn, is a prerequisite for retaining the highest possible magnetic force. This should be contrasted with "passive" shunting, as disclosed in the Yanagisawa reference cited earlier, in which passive ferromagnetic external poles establish a magnetic short circuit between the poles of the permanent magnet. A strong permanent magnet requires relatively large amounts of passive material to perform this shunting.

The present invention, in its preferred embodiments, also has the advantage of having very low friction between the magnets and around the magnets and between the magnets and the poles. This is a result of the symmetrical pull between the cylindrical magnets and the poles and the walls of the housing, resulting in a zero net attraction.

The preferred embodiments of the present invention also make greater use of the area under the B-H curve. The use of shorter pole lengths also reduces the reluctance of the poles, thereby minimising magnetic losses through the poles.

It is a further advantage of preferred embodiments of the present invention that the bulk of the field lines are directed through the pole pieces to the workpiece or surface.

The switchable magnetic device of the present invention provides a compact and rugged device capable of many uses. The use of diametrically polarised, essentially cylindrically shaped magnets allows the device to be compact and it also enables the magnets to be rotated relative to each other without the necessity of having larger void spaces within the internal chamber for the magnets to be moved into. The shape of the external pole pieces enables the external magnetic fields to be maximised. The device is simple to use and can provide a strong holding force to hold objects firmly in place.

Those skilled in the art will appreciate that the present invention may be susceptible to variations and to modifications other than those specifically described. It is to be understood that the present invention encompasses all such variations and modifications that fall within its spirit and scope.

Claims

1. A switchable magnetic device comprising a housing, a first permanent magnet, a second permanent magnet, said first and second permanent magnets being essentially cylindrically shaped, said first and second permanent magnets being diametrically polarised, said first and second permanent magnets being mounted within the housing such that the first and second permanent magnets are rotatable relative to each other, and actuation means for causing relative rotation of the first and second permanent magnets, wherein said device presents a relatively strong external magnetic field when said first and second permanent magnets are positioned relative to each other such that a north and south poles of the first magnet are in substantial alignment with respective north and south poles of the second magnet, and the device presents a relatively weak external magnetic field when the first and second magnets are positioned relative to each other such that the north pole of the first magnet is in substantial alignment with the south pole of the second magnet and vice versa.

2. A device as claimed in claim 1 wherein the first and second magnets are substantially disc-shaped.

3. A device as claimed in claim 1 or claim 2 wherein the first and second magnets are mounted in the housing such that a face of the first magnet is opposed to the face of the second magnet.

4. A device as claimed in claim 3 wherein one magnet is positioned above the other magnet.

5. A device as claimed in any one of claims 1 to 4 wherein one magnet is fixedly mounted in the housing and the other magnet is able to rotate within the housing.

6. A device as claimed in claim 5 wherein the other magnet is rotated through 180° to vary the device from a state having a relatively strong external magnetic field to a state having a relatively weak external magnetic field.

7. A device as claimed in any one of the preceding claims wherein the housing comprises two pole pieces.

8. A device as claimed in any one of claims 1 to 6 wherein the housing is made as a unitary construction or from a single piece of material.

9. A device as claimed in claim 8 wherein two portions of the housing have reduced cross sectional area such that the housing acts as two passive poles.

10. A device as claimed in claim 8 wherein portions of the housing are treated such that the portions become non-magnetic to thereby result in the housing acting as two passive poles.

11. A device as claimed in any one of the preceding claims wherein the housing defines a chamber in which the first and second magnets are mounted.

12. A device as claimed in claim 11 wherein the chamber has open ends.

13. A device as claimed in claim 12 wherein one or more chambers closing means close one or more open ends of the chamber.

14. A device as defined in claim 12 or claim 13 wherein a lowermost of the magnet and the second magnet closes a lower end of the chamber.

15. A device as claimed in claim 11 wherein the chamber has closed ends.

16. A device as claimed in any one of the preceding claims wherein the housing is made from a material having a low magnetic reluctance.

17. A device as claimed in claim 16 wherein the housing is made from soft steel, iron or a permalloy.

18. A device as claimed in any one of claims 7-17 wherein the pole pieces are shaped to maximise the external magnetic field.

19. A device as claimed in claim 17-18 wherein the poles are of minimum length.

20. A device as claimed in any one of the preceding claims wherein the actuation means comprises a handle or knob connected to one of the magnets.

21. A device as claimed in claim 20 wherein the handle or knob is connected to one of the magnets via one or more intermediate members.

22. A device as claimed in claim 20 or claim 21 wherein the handle comprises a torque in excess of a predetermined amount to be applied to the one magnet.

23. A device as claimed in any one of claims 20 to 22 in which the handle or knob is actuated manually, electrically, pneumatically, hydraulically or by the action of expansion of a bimetallic strip.

24. A device as claimed in any one of the preceding claims wherein the first and second magnets comprise rare earth type magnets.

25. A switchable magnetic device substantially as hereinbefore described with reference to the accompanying drawings.

Dated this 19th day of June 2002

The Aussie Kids Toy Company Pty Ltd

by their attorneys

Freehills Carter Smith Beadle

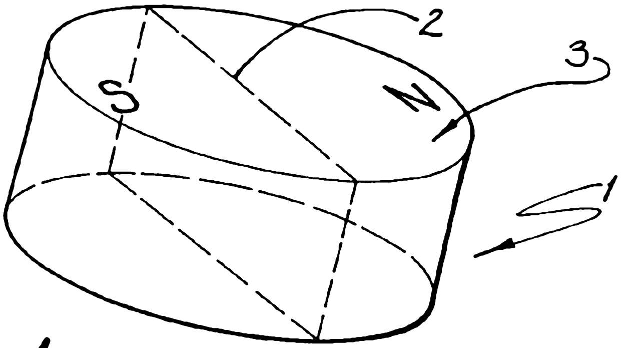


FIG. 1

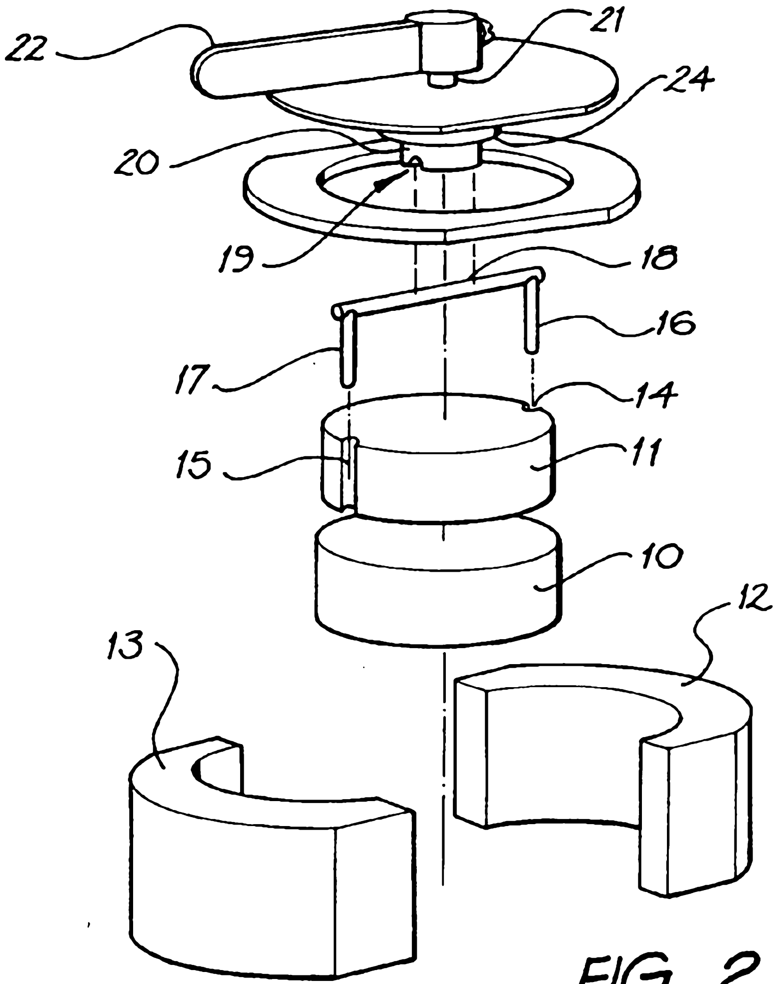


FIG. 2

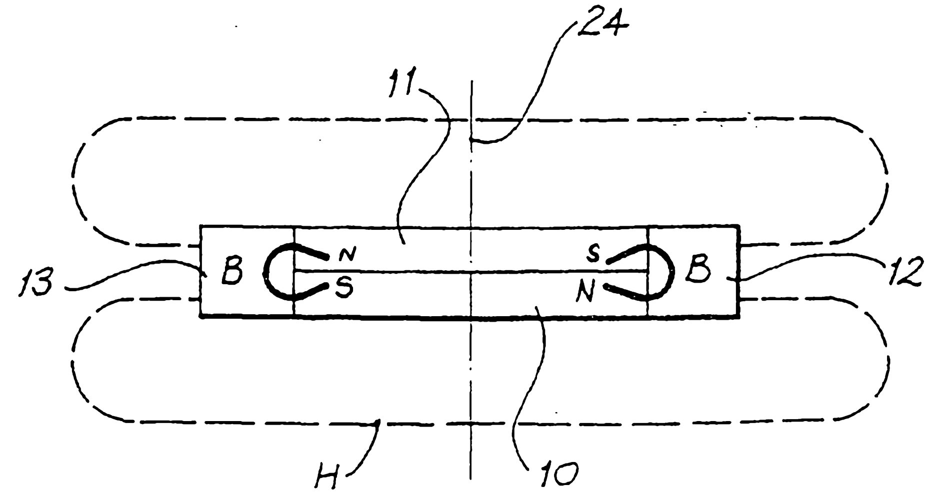


FIG. 3

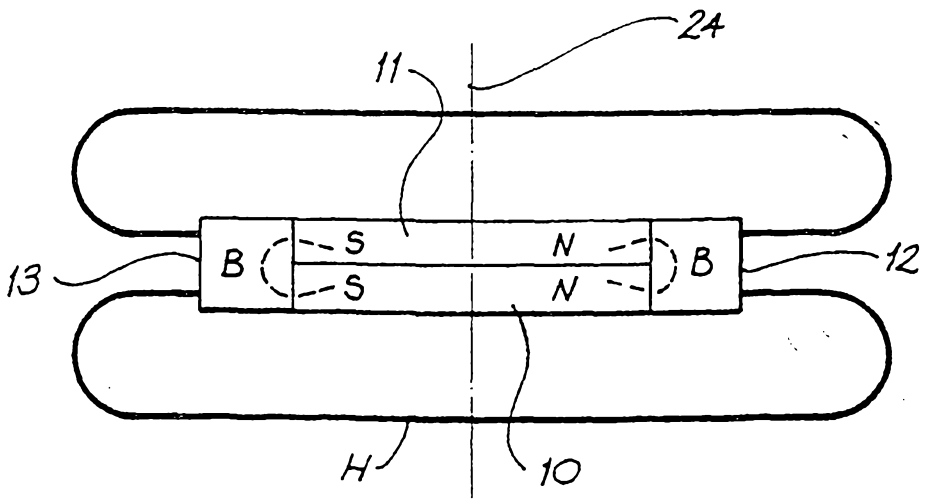


FIG. 4

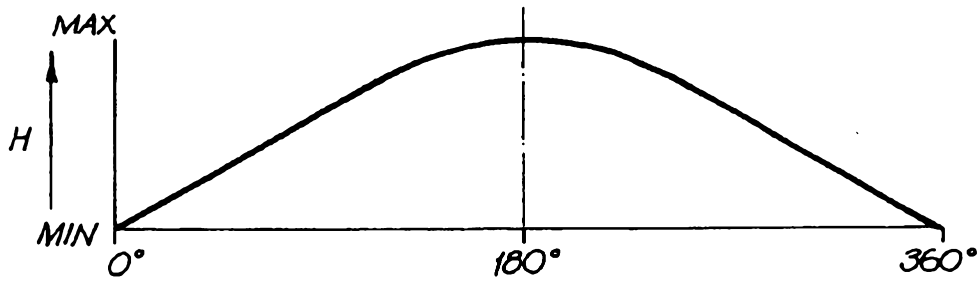


FIG. 5

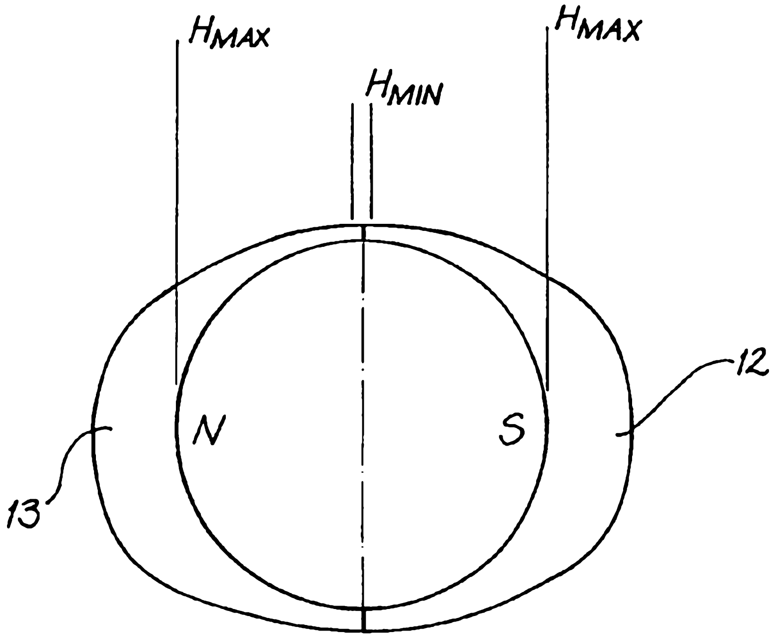


FIG. 6