This patent covers a device which is claimed to have a greater output power than the input power required to run it.

Patent US 6,246,561 12th June 2001 Inventor: Charles J. Flynn

METHODS FOR CONTROLLING THE PATH OF MAGNETIC FLUX FROM A PERMANENT MAGNET AND DEVICES INCORPORATING THE SAME

ABSTRACT

A permanent magnet device includes a permanent magnet having north and south pole faces with a first pole piece positioned adjacent one pole face thereof and a second pole piece positioned adjacent the other pole face thereof so as to create at least two potential magnetic flux paths. A first control coil is positioned along one flux path and a second control coil is positioned along the other flux path, each coil being connected to a control circuit for controlling the energisation thereof. The control coils may be energised in a variety of ways to achieved desirable motive and static devices, including linear reciprocating devices, linear motion devices, rotary motion devices and power conversion.

DESCRIPTION

FIELD OF THE INVENTION

This invention relates generally to permanent magnet devices and more particularly, to a permanent magnet control component in which the flow of flux from a permanent magnet is controlled between two or more flux paths by utilising timed delivery of electrical signals through one or more coils placed along at least one of the flux paths. Such permanent magnet control components may take on a variety of configurations facilitating use of such components in a variety of applications including applications involving the production of reciprocating, linear, and rotary motion and power conversion. Several novel permanent magnet rotary motion devices of motor constructions which operate by controlling the path of magnetic flux from one or more permanent magnets are described, such permanent magnet rotary motor constructions having increased efficiency and more desirable torque characteristics as compared to many currently used motors.

BACKGROUND OF THE INVENTION

Magnetic force of attraction is commonly used in a variety of types of permanent magnet devices including both linear and rotary motors. In the field of such permanent magnet devices there is a continuous pursuit of increased efficiency and reduced complexity.

Accordingly, an object of the present invention is to provide a permanent magnet control component in which the path of a given level of permanent magnet flux can be controlled by a lesser level of electromagnetic flux.

Another object of the present invention is to provide a permanent magnet control component in which substantially all of the flux from a permanent magnet can be switched between at least two different flux paths of the permanent magnet control component so as to enable useful work in the form of linear, reciprocating, and rotary motion.

Still another object of the present invention is to provide permanent magnet control components and motor constructions in which flux path control is provided by energising an electromagnet to oppose the magnetic flux of one or more permanent magnets.

Another object of the present invention is to provide permanent magnet control components and motor constructions in which flux path control is provided by energising an electromagnet to aid the magnetic flux of one or more permanent magnets.

Yet another object of the present invention is to provide permanent magnet motor constructions with improved operating characteristics.

SUMMARY OF THE INVENTION

These and other objects of the invention are attained by an apparatus which, in one aspect, is a permanent magnet device, comprising a permanent magnet having north and south pole faces, a first pole piece, a second pole piece, a first control coil, a second control coil, and circuit means, the first pole piece positioned adjacent the north pole face of the permanent magnet and including a first path portion, a second path portion and a third portion, the first path portion extending beyond a perimeter of the north pole face and the second path portion extending beyond the perimeter of the north pole face to define first and second flux paths for magnetic flux emanating from the north pole face of the permanent magnet, the first path portion of the first pole piece connected to the second path portion of the first pole piece by the third portion which extends across the north pole face of the permanent magnet, the second pole piece positioned adjacent the south pole face and including a first path portion and a second path portion, the first path portion extending beyond a perimeter of the south pole face and substantially aligned with the first path portion of the first pole piece, the second path portion extending beyond the perimeter of the south pole face and substantially aligned with the second path portion of the first pole piece, the first control coil positioned around the first path portion of the first pole piece, the second control coil positioned around the second path portion of the first pole piece, the circuit means connected to each of the first control coil and the second control coil to alternately energise the first coil and the second coil in a timed sequential manner.

Another aspect of the present invention provides a method for controlling the path of magnetic flux from a permanent magnet which involves placing a first pole piece adjacent a first pole face of the permanent magnet so as to have at least first and second path portions extending beyond a perimeter of the first pole face. A second pole piece is placed adjacent a second pole face of the permanent magnet so as to include at least one portion which substantially aligns with the first and second path portions of the first pole piece. A first control coil is placed along and around the first path portion of the first pole piece and a second control coil is placed along and around the second path portion of the first pole piece. The first control coil is repeatedly energised in a permanent magnet magnetic flux opposing manner so as to prevent magnetic flux of the permanent magnet from traversing the first path portion of the first pole piece, and the second control coil is repeatedly energised in a permanent magnet magnetic flux opposing manner so as to prevent magnetic flux of the permanent magnet from traversing the second path portion of the first pole piece.

Yet another aspect of the present invention provides a method for controlling the path of magnetic flux from a permanent magnet by placing a first pole piece adjacent a first pole face of the permanent magnet so as to have at least first and second path portions extending beyond a perimeter of the first pole face. A second pole piece is placed adjacent a second pole face of the permanent magnet so as to include at least one portion which substantially aligns with the first and second path portions of the first pole piece. A first control coil is placed along and around the first path portion of the first pole piece, and a second control coil is placed along and around the second path portion of the first pole piece. The following steps are alternately performed in a repeated manner:

(i) energising the first control coil in a permanent magnet magnetic flux aiding manner so as to couple with substantially all magnetic flux of the permanent magnet such that substantially no magnetic flux of the permanent magnet traverses the second path portion of the first pole piece when the first control coil is so energised; and

(ii) energising the second control coil in a permanent magnet magnetic flux opposing manner so as to couple with substantially all magnetic flux of the permanent magnet such that substantially no magnetic flux of the permanent magnet traverses the first path portion of the first pole piece when the second control coil is so energised.

A further aspect of the present invention provides method for controlling the path of magnetic flux from a permanent magnet by placing a first pole piece adjacent a first pole face of the permanent magnet so as to have at least first and second path portions extending beyond a perimeter of the first pole face, and placing a second pole piece adjacent a second pole face of the permanent magnet so as to include at least one portion which substantially aligns with the first and second path portions of the first pole piece. A first control coil is placed along and around the first path portion of the first pole piece, and a second control coil is placed along and around the second path portion of the first pole piece. The following steps are alternately performed in a repeated manner:

(i) energising the first control coil in a permanent magnet magnetic flux aiding manner so as to couple with substantially all magnetic flux of the permanent magnet such that substantially no magnetic flux of the permanent magnet traverses the second path portion of the first pole piece when the first control coil is so energised; and

(ii) energising the second control coil in a permanent magnet magnetic flux opposing manner so as to couple with substantially all magnetic flux of the permanent magnet such that substantially no magnetic flux of the permanent magnet traverses the first path portion of the first pole piece when the second control coil is so energised.

BRIEF DESCRIPTION OF THE INVENTION

For a better understanding of the present invention reference may be made to the accompanying drawings in which:

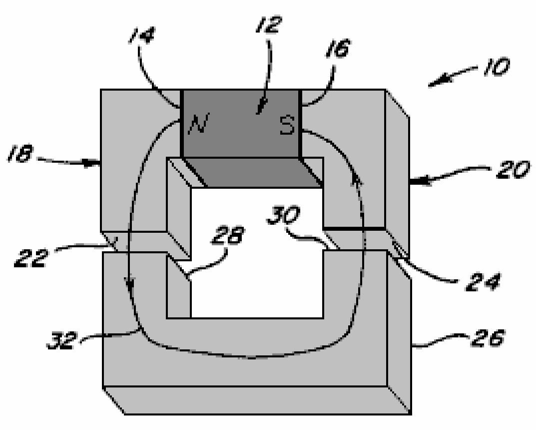


Fig. 1

Fig.1 is a perspective view of a magnetic device in which the magnetic flux from a magnetic member traverse a single path to produce a coupling force;

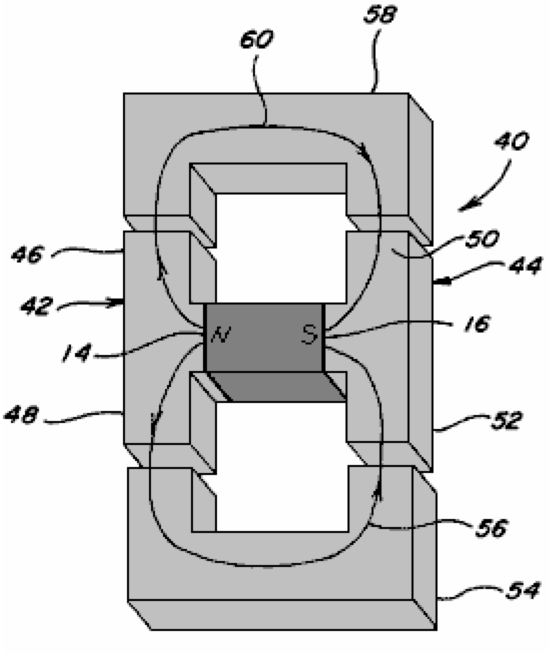


Fig. 2

Fig.2 is a perspective view of a magnetic device in which the magnetic flux from a magnetic member splits between two paths;

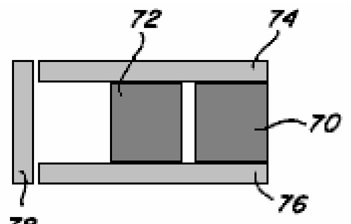


Fig. 3

Fig.3 is a side view of two magnetic members arrange in parallel between pole pieces;

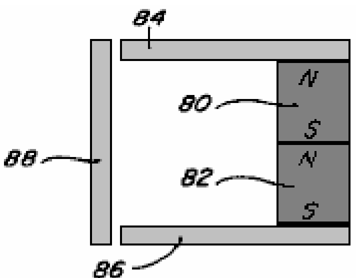


Fig. 4

Fig.4 is a side view of two magnetic members arranged in series between pole pieces;

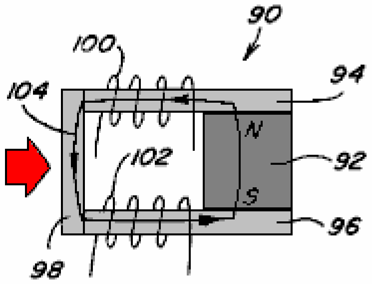


Fig. 5

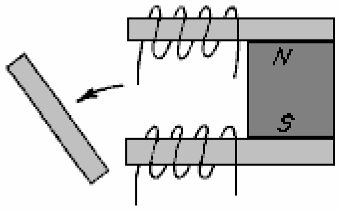


Fig. 6

Fig.5 and **Fig.6** are side views of a permanent magnet device including a permanent magnet having pole pieces positioned against the pole faces thereof and including a movable armature;

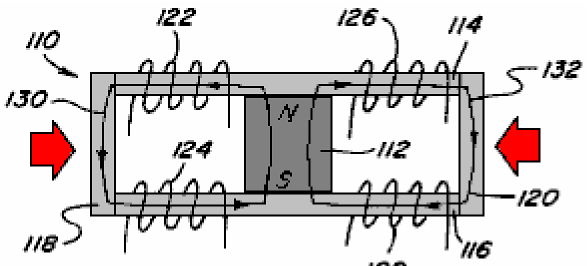


Fig. 7

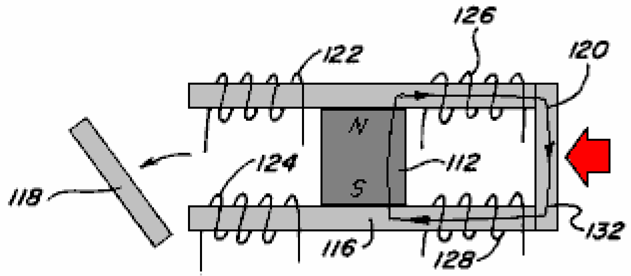


Fig. 8

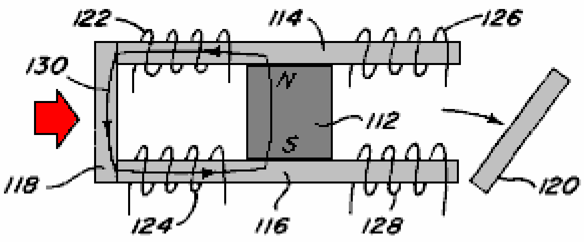


Fig. 9

Fig.7, **Fig.8** and **Fig.9** are side views of a permanent magnet device including a permanent magnet having pole pieces positioned against the pole faces thereof to provide two magnetic flux paths and including a movable armature which can be positioned along each magnetic flux path;

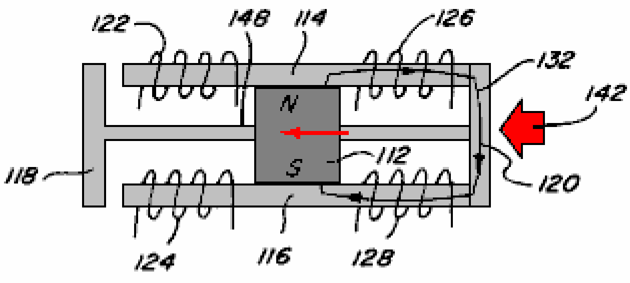


Fig. 10

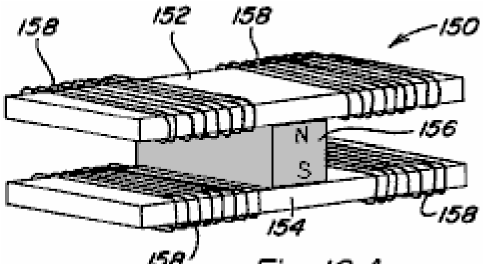


Fig. 10 A

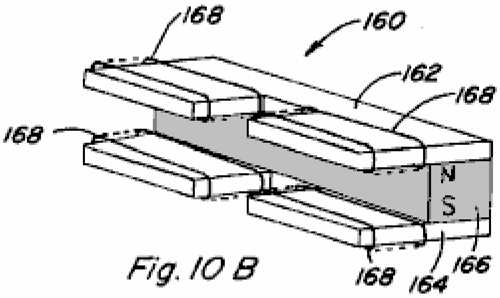


Fig. 10 B

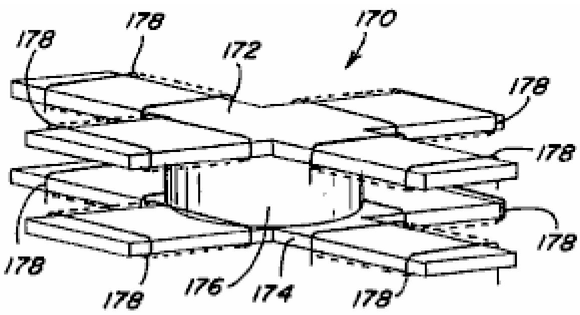


Fig. 10 C

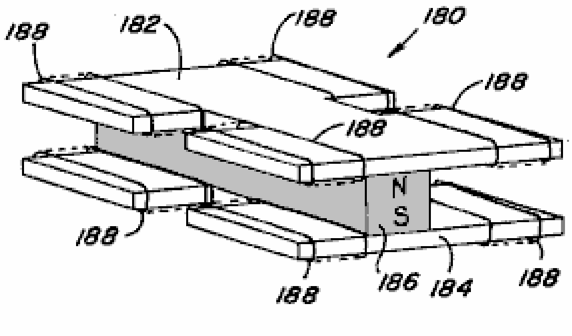


Fig. 10D

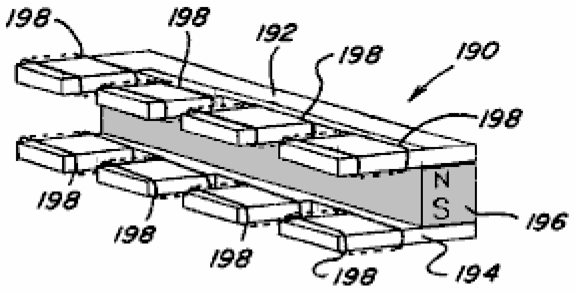


Fig. 10 E

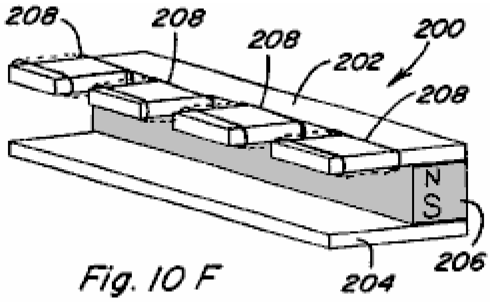


Fig. 10 F

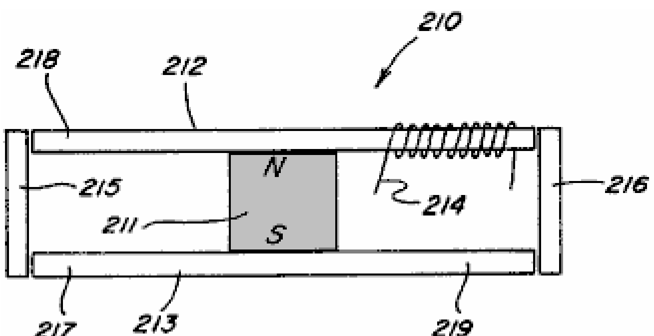


Fig. 10 G

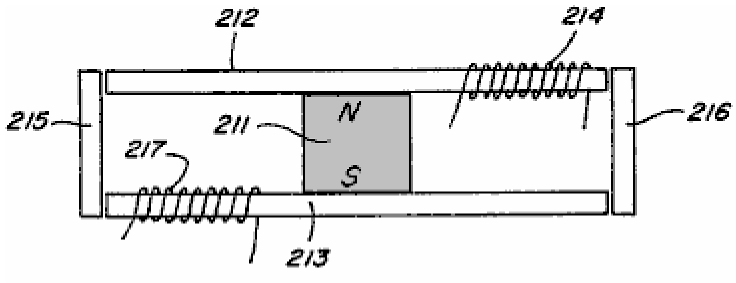


Fig. 10 H

Figs.10, **10A-10H** are perspective views of various embodiments of permanent magnet **5** control components which include two or more magnetic flux paths;

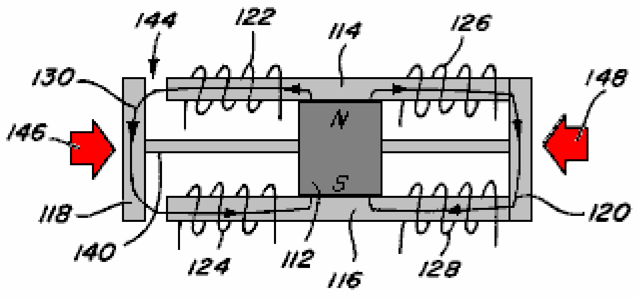


Fig. 11

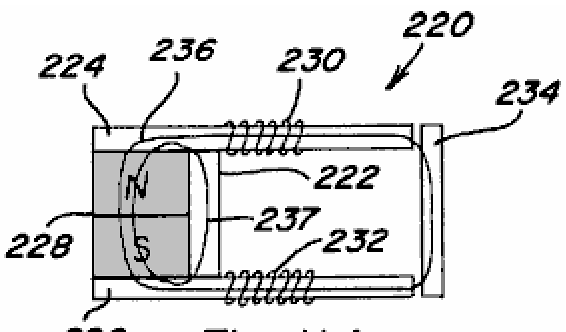


Fig. 11 A

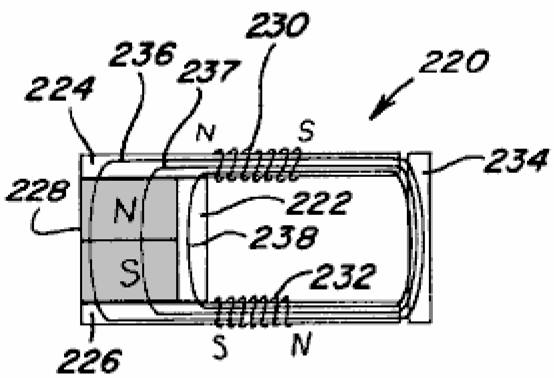


Fig. 11 B

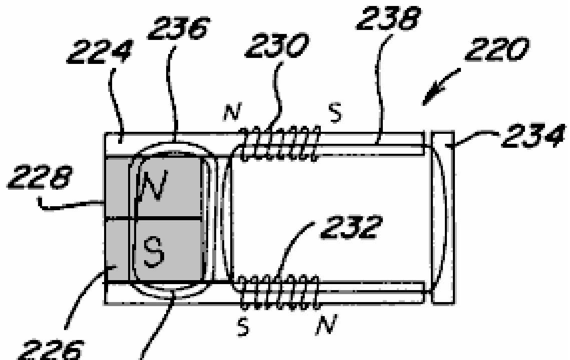


Fig. 11 C

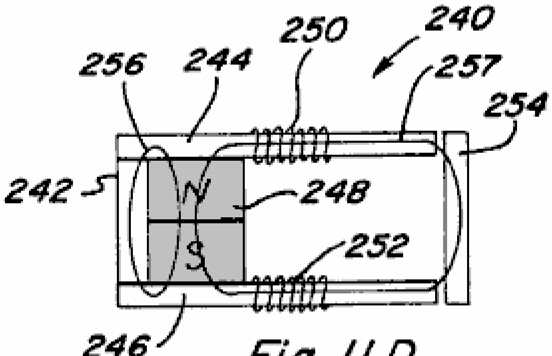


Fig. 11 D

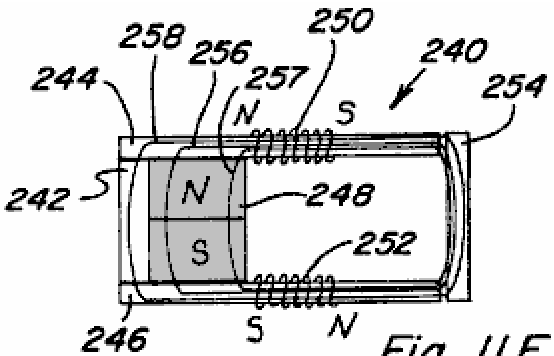


Fig. 11 E

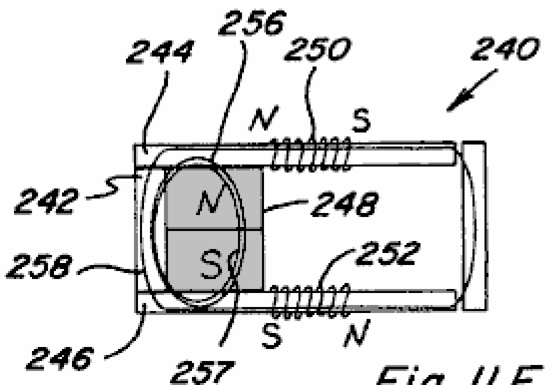


Fig. 11 F

Figs.11, **11A-11F** are side views of a permanent magnet device including a permanent magnet having pole pieces positioned against the pole faces thereof and including a movable armature and a permanent bypass extending between the pole pieces;

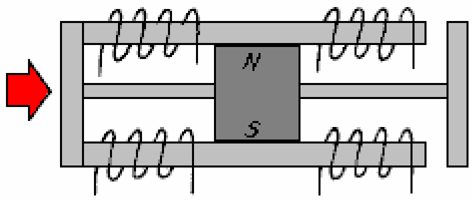


Fig. 12

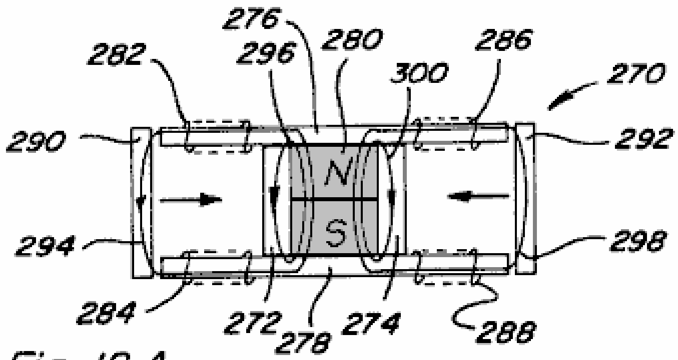


Fig. 12 A

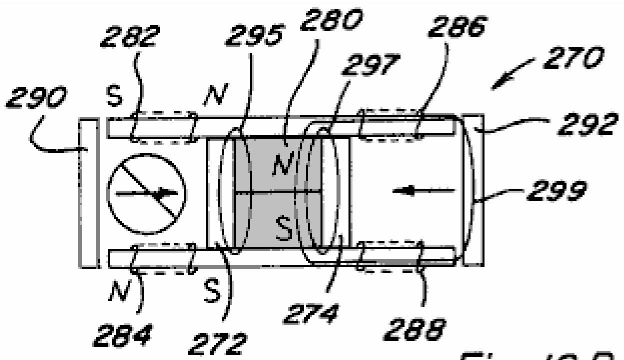


Fig. 12 B

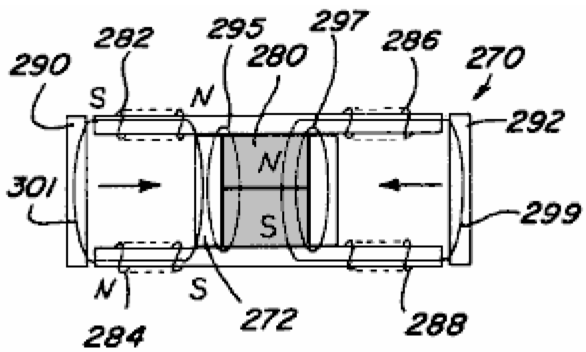


Fig. 12 C

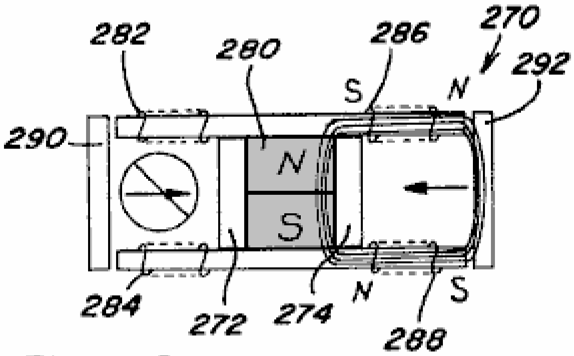


Fig. 12 D

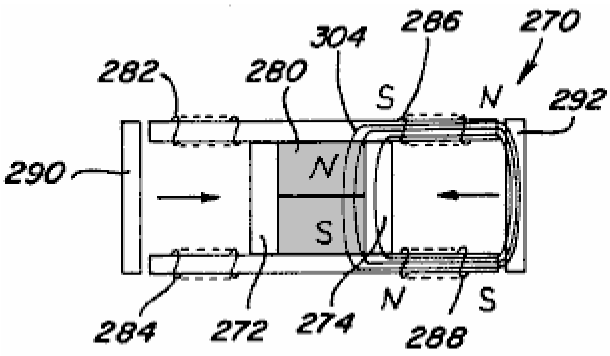


Fig. 12 E

Figs.12, **12A-12E** are side views of a two path permanent magnet device including two bypasses;

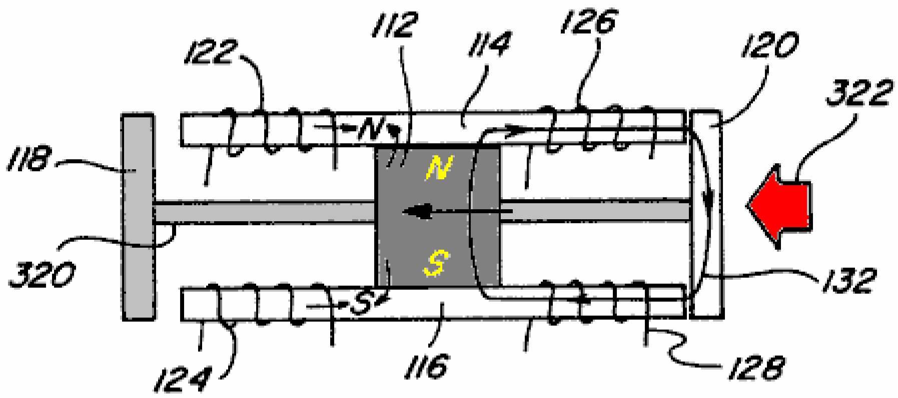


Fig. 13 A

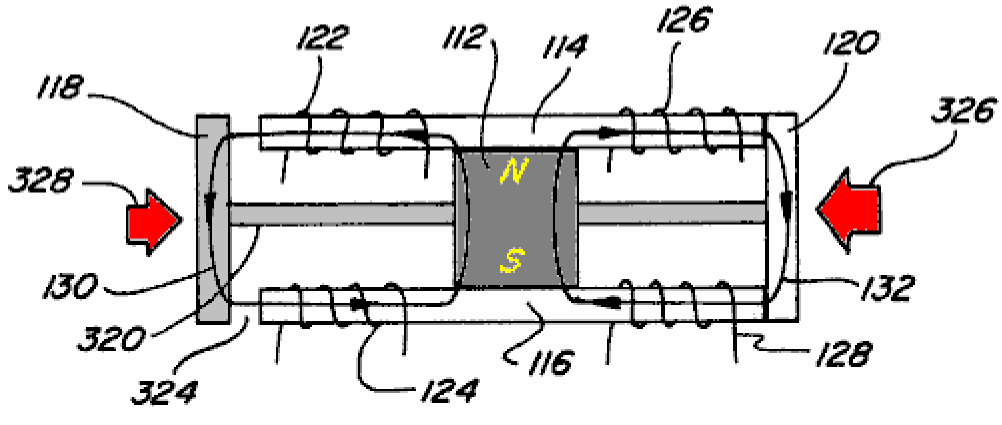


Fig. 13 B

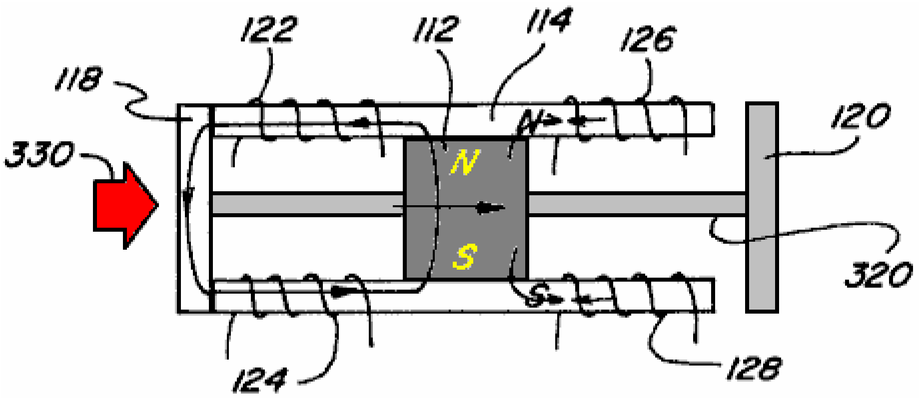


Fig. 13 C

Figs.13A-13C are side views of a permanent magnet linear reciprocating device;

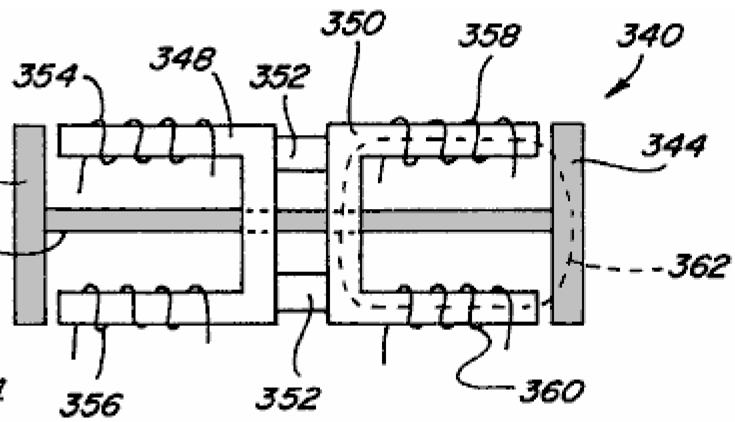


Fig. 14

Fig.14 is a side view of an electromagnetic linear reciprocating device;

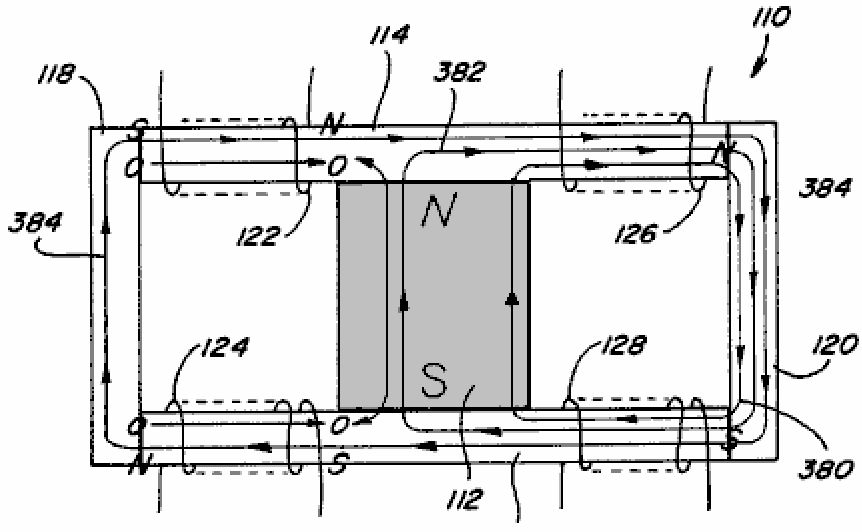


Fig. 15

Fig.15 is a side view of a two path permanent magnet device showing control coils energised in an exceeding manner;

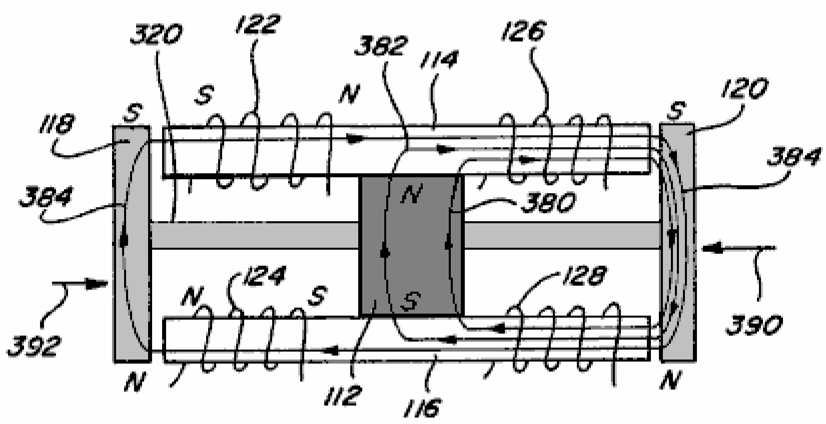


Fig. 16 A

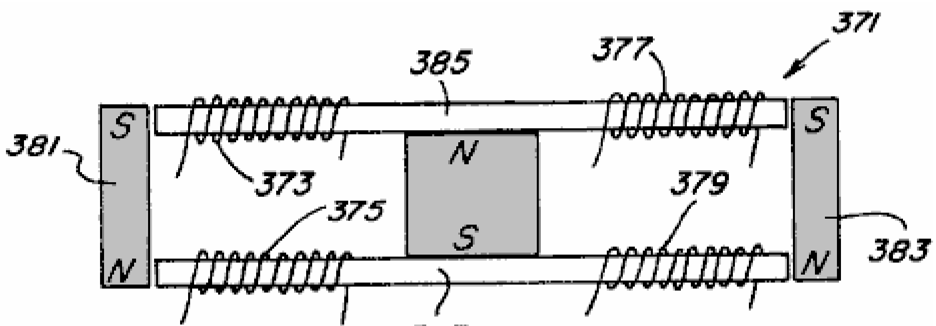


Fig. 16 B

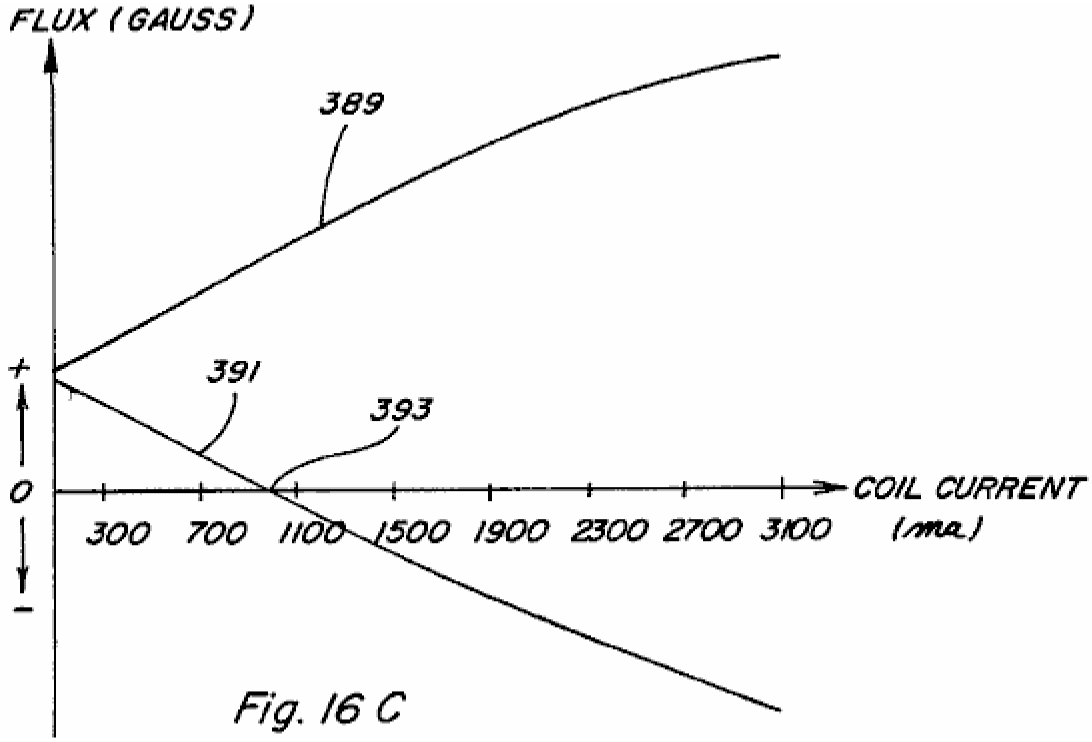


Fig. 16 C

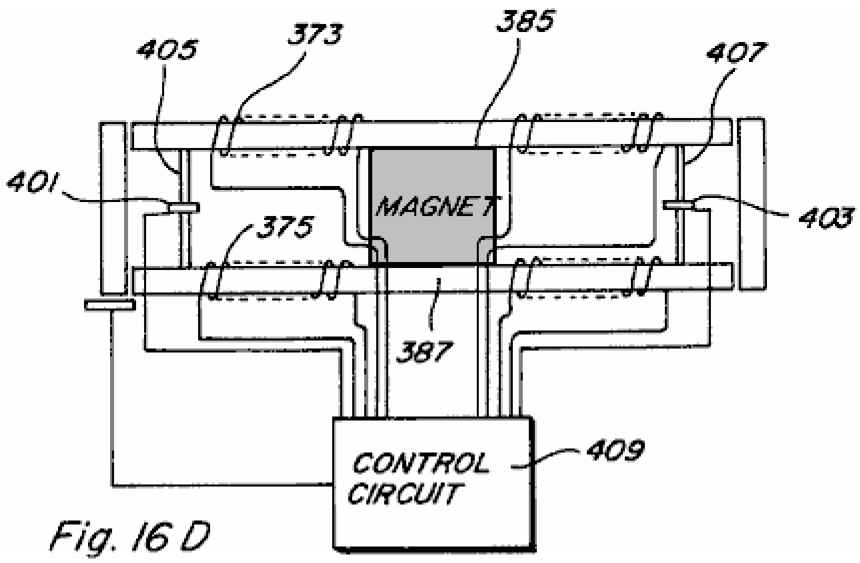


Fig. 16 D

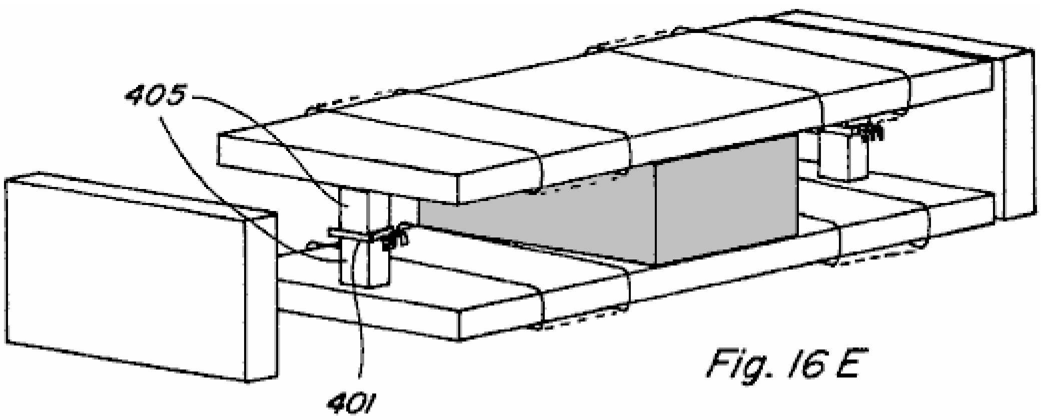


Fig. 16 E

Figs.16A-E are a side view of a linear reciprocating device with control coils energised in an exceeding manner;

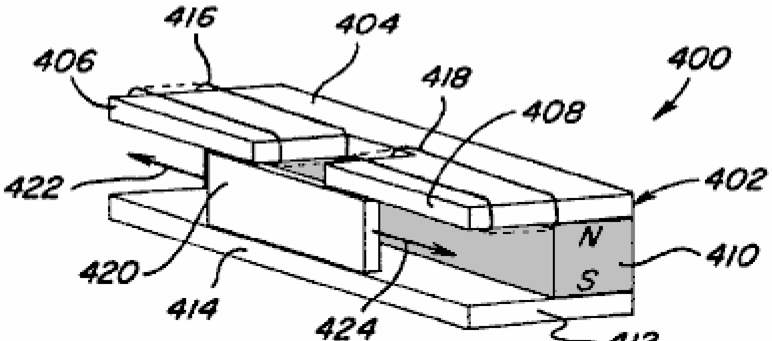


Fig. 17A

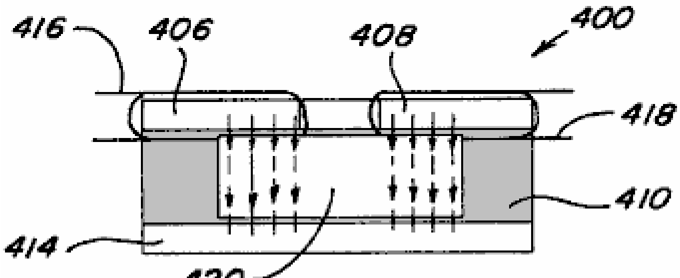


Fig. 17B

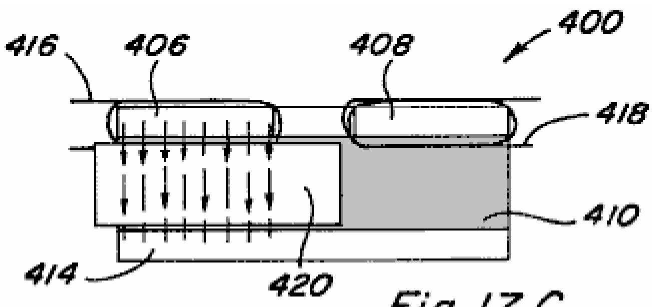


Fig. 17 C

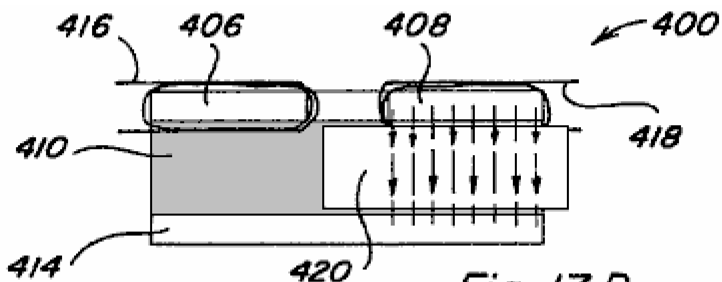


Fig. 17 D

Figs.17A-17D depict another embodiment of a linear reciprocating device;

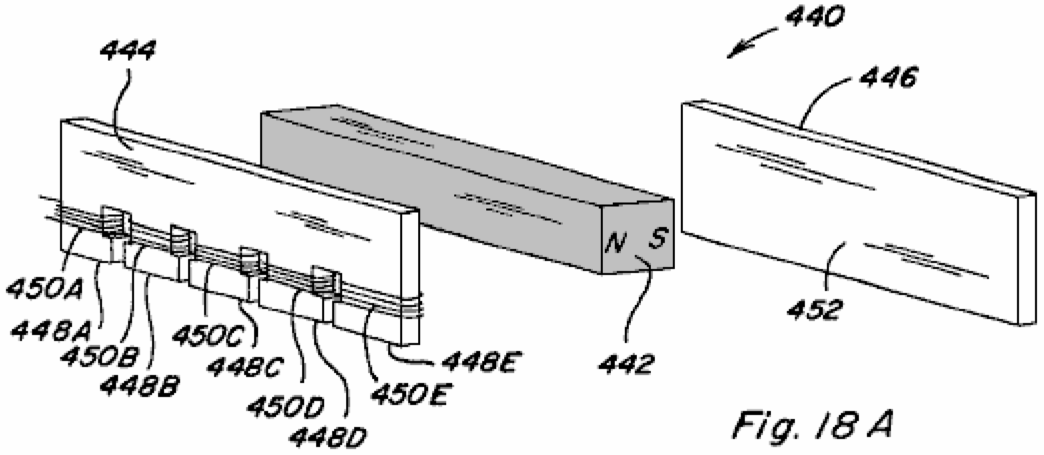


Fig. 18 A

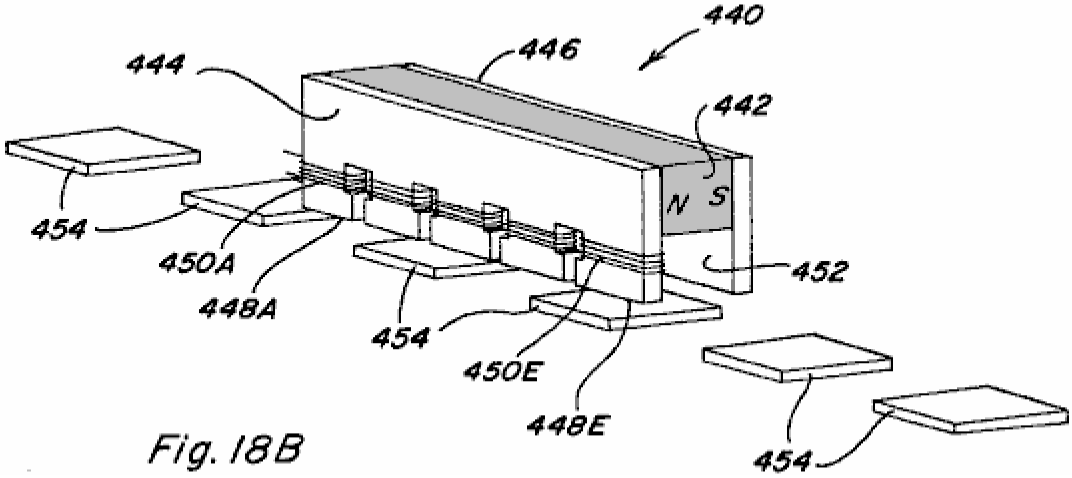


Fig. 18B

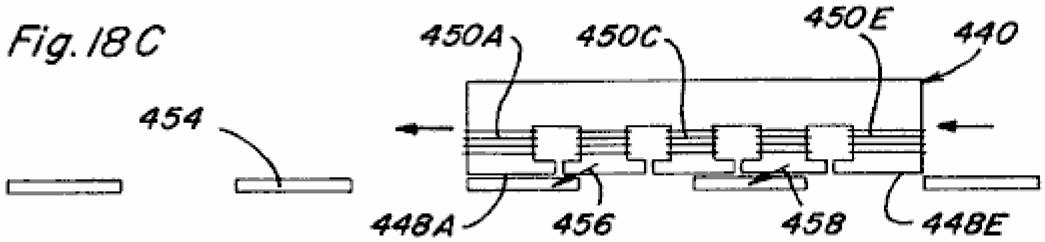
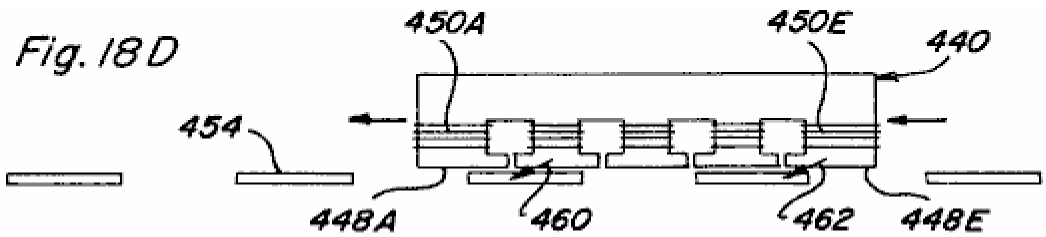
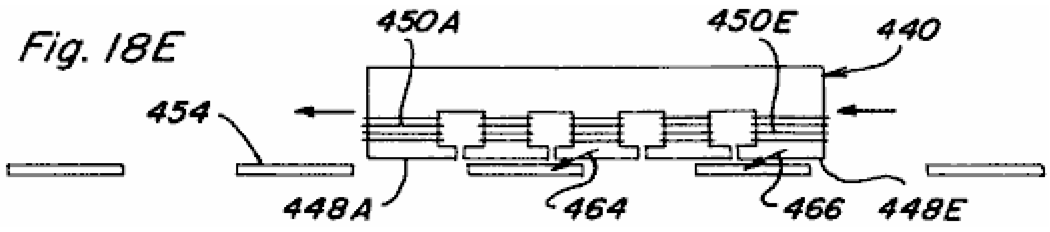
Fig. 18C


Fig. 18D




Figs.18A-18E show a linear motion device;

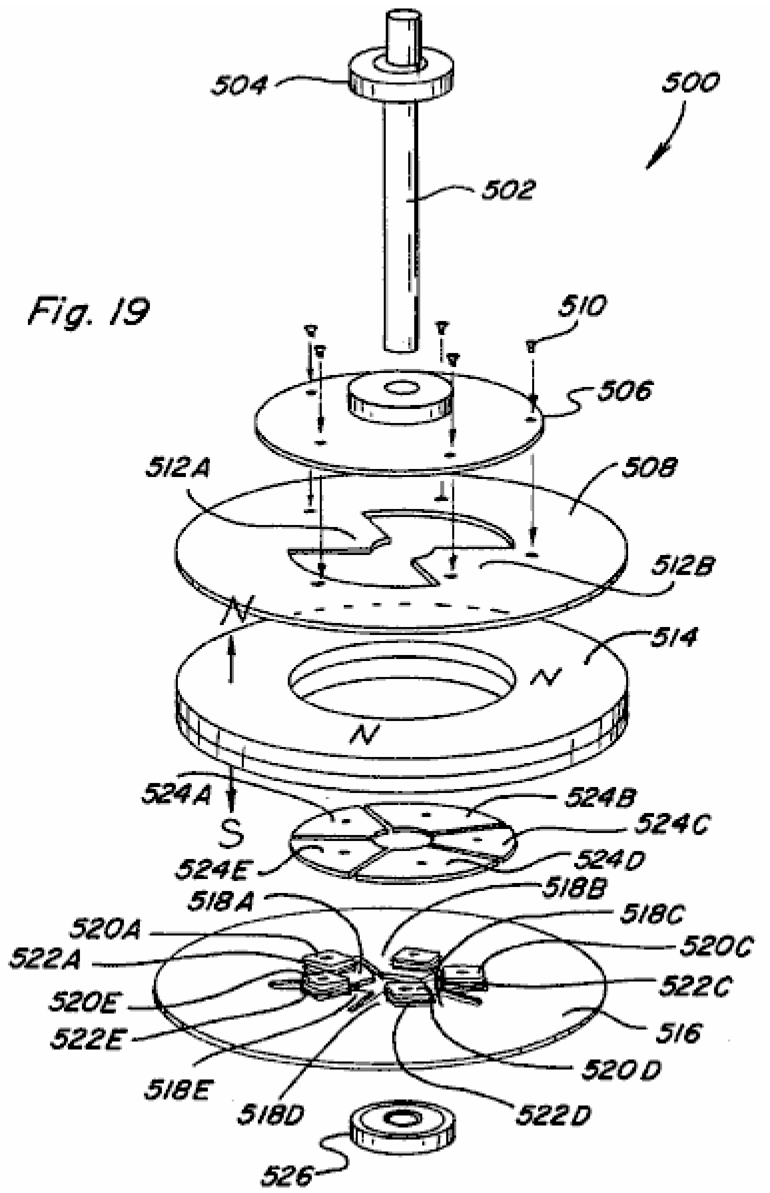


Fig.19 is an exploded perspective view of a rotary motion device;

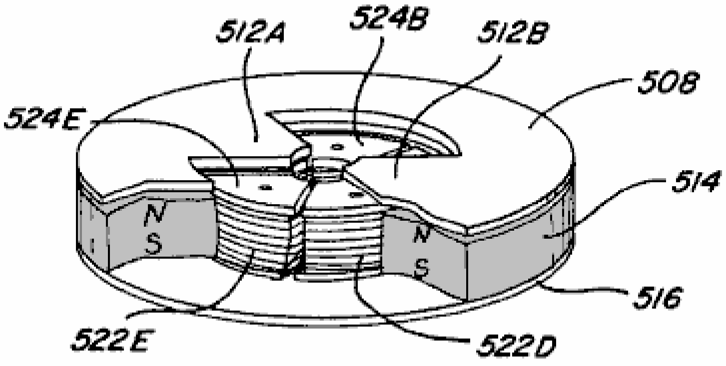


Fig. 20

Fig.20 is a partial assembled and cut away view of the rotary motion device of Fig.19;

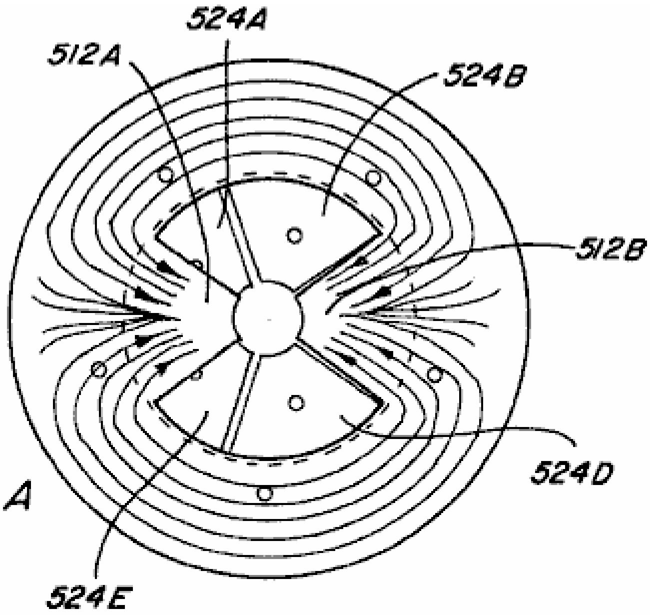


Fig. 21A

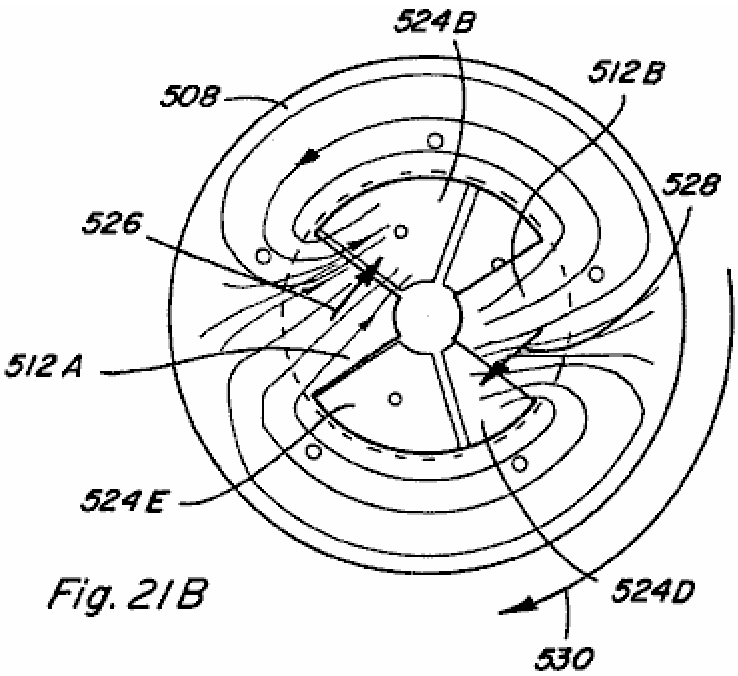


Fig. 21B

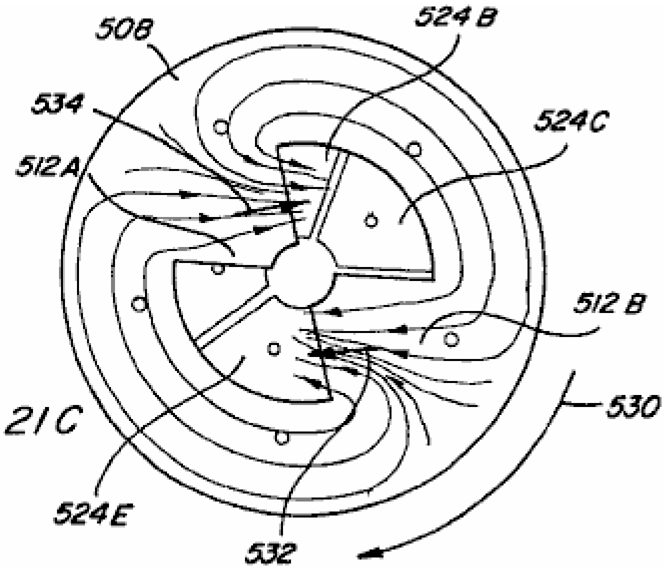


Fig. 21C

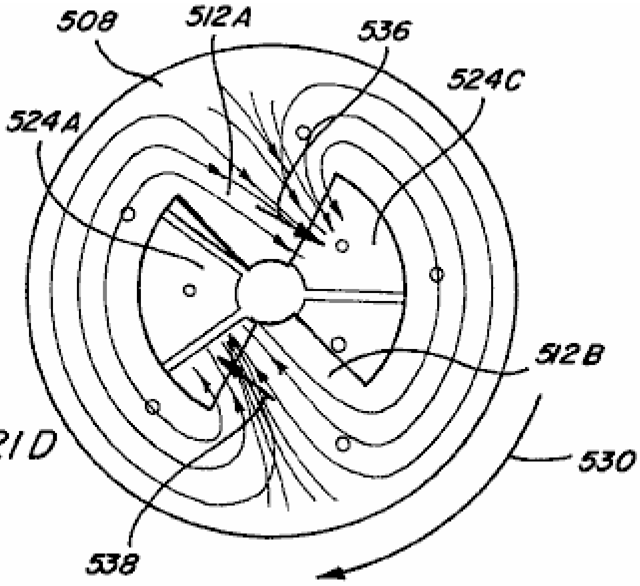


Fig. 21D

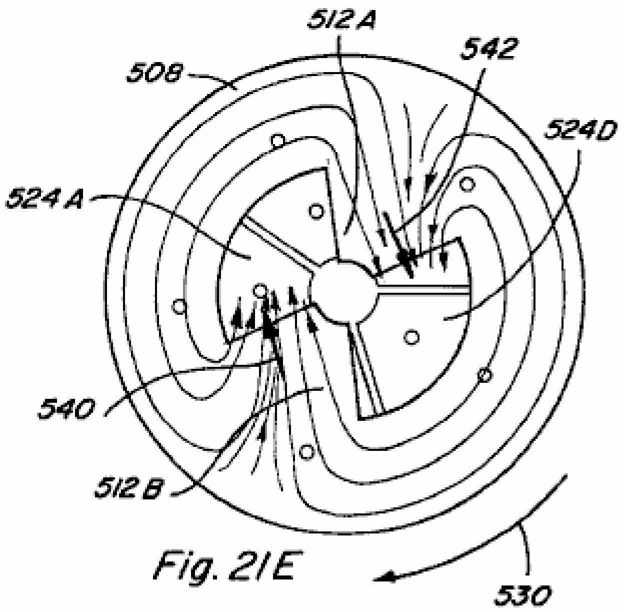


Fig. 21E

Figs.21A-21E are top views of the partial assembly of Fig.20, which views depict rotational motion thereof,

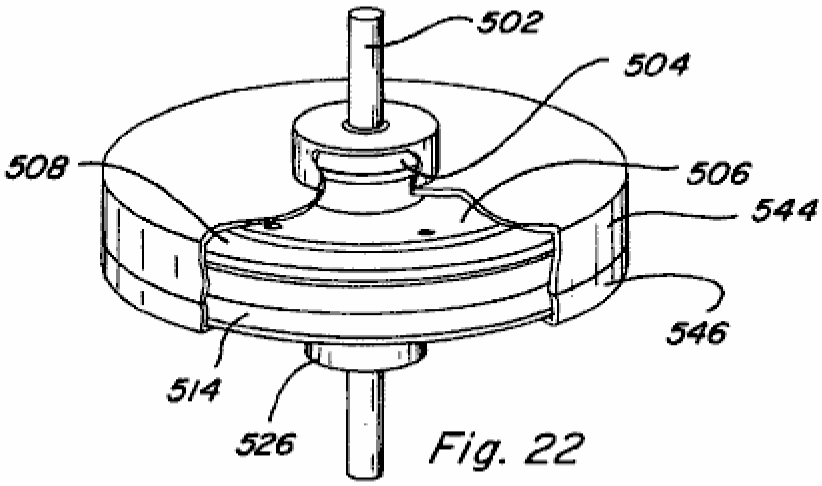


Fig. 22

Fig.22 is an assembled, cut-away view of the rotary motion device of Fig.19 including a housing;

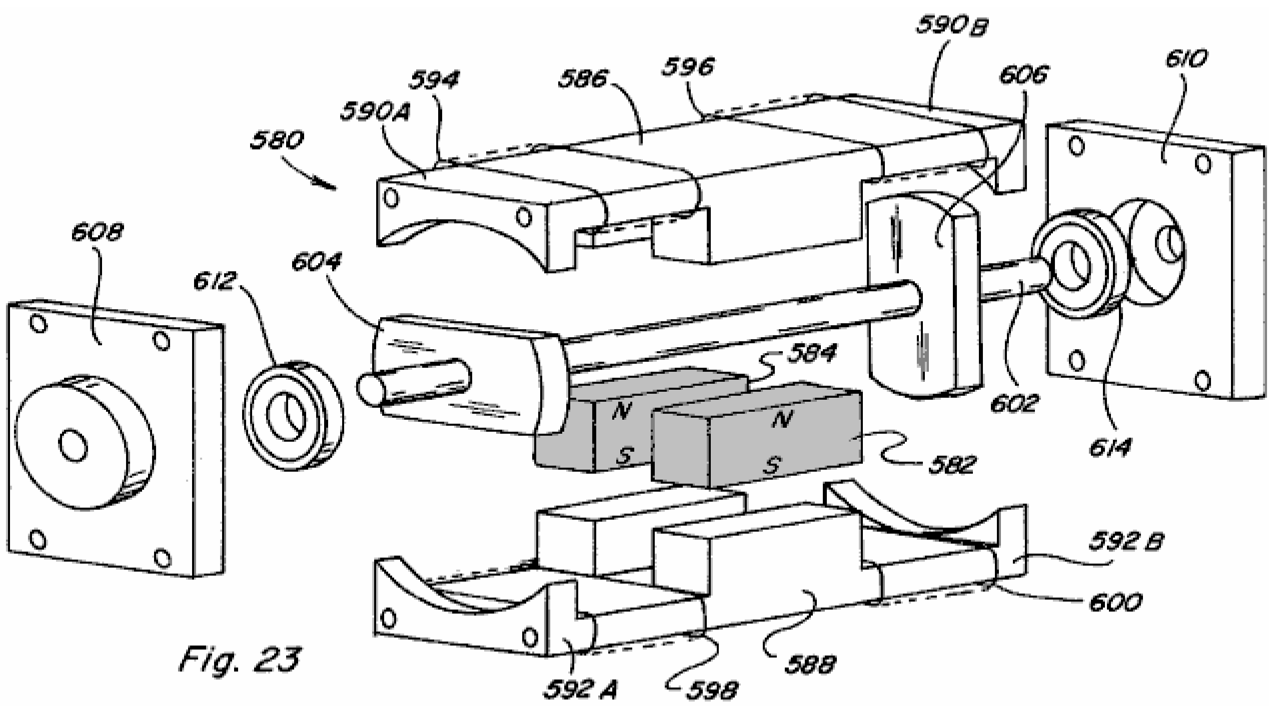


Fig. 23

Fig.23 is an exploded perspective view of another embodiment of a rotary motion device;

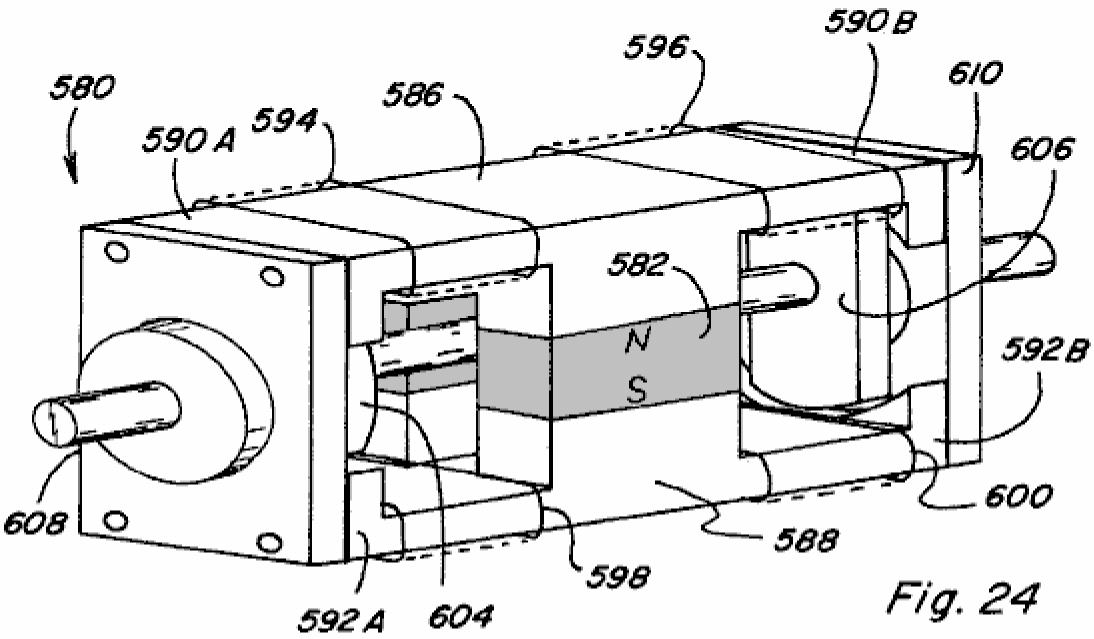
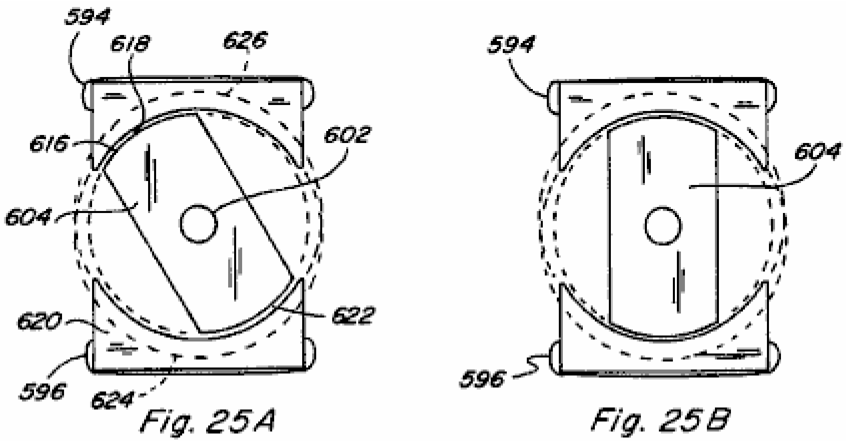
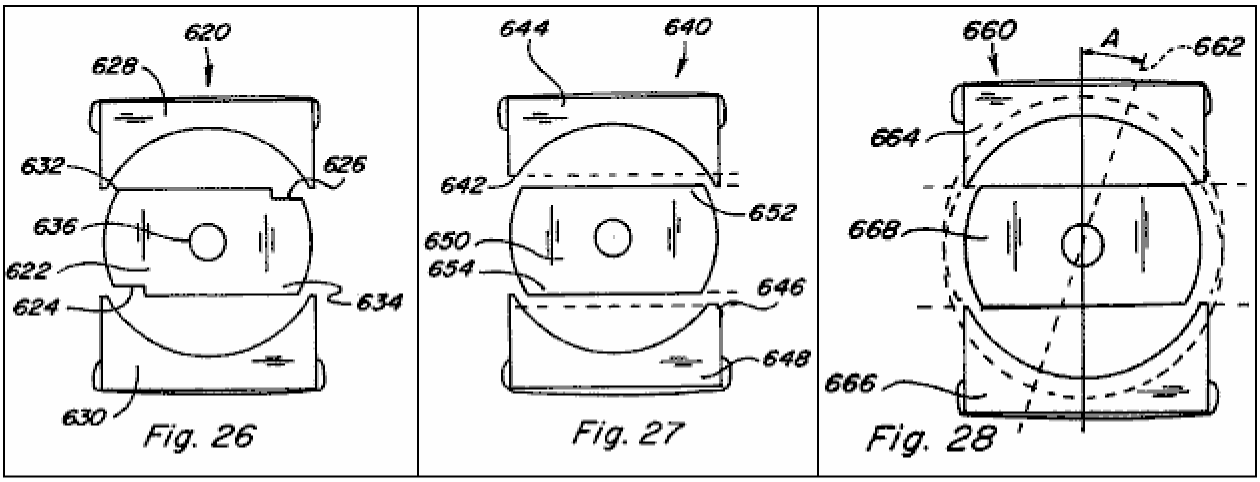


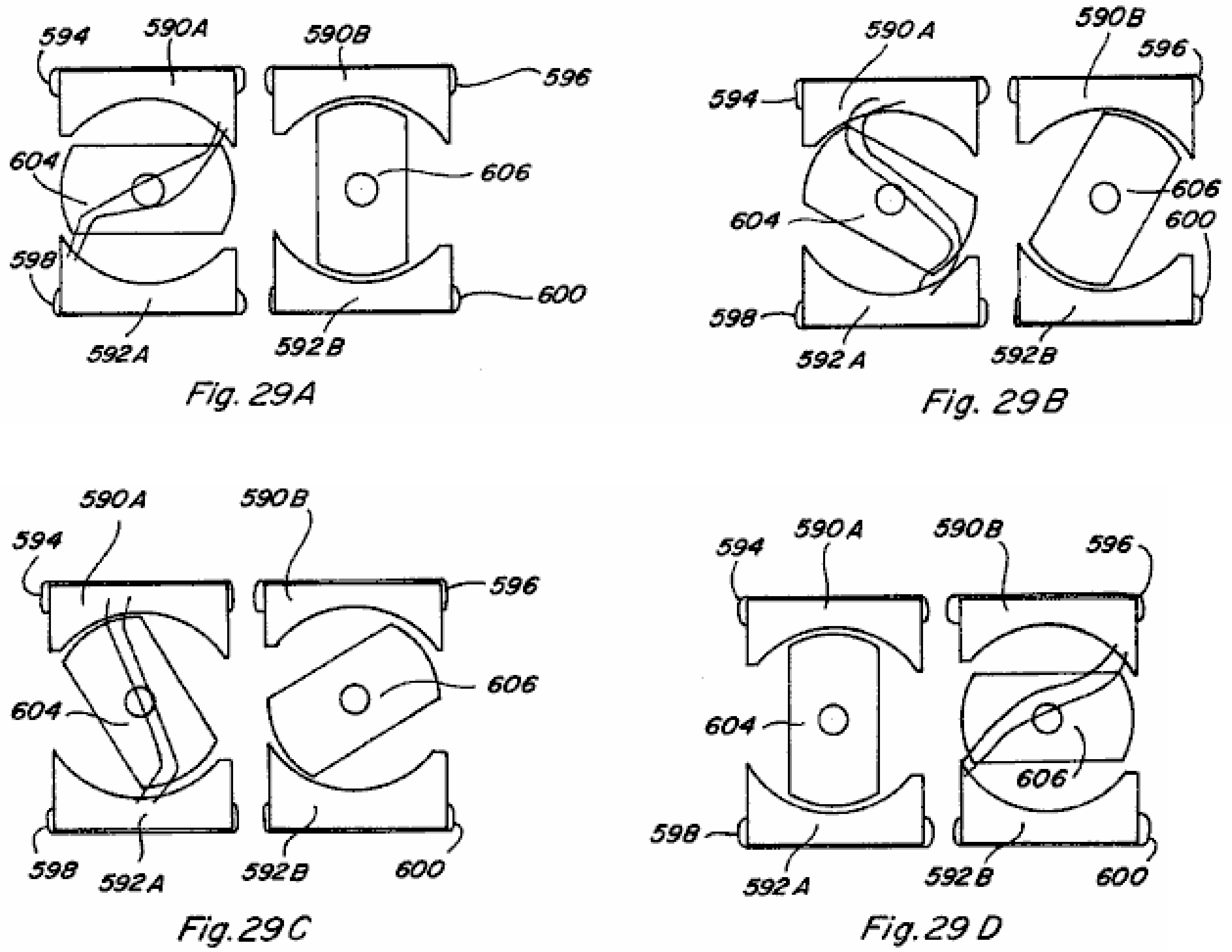
Fig.24 is a perspective view of the rotary motion device of Fig.23 as assembled;



Figs.25A-25B are end views of the rotary motion device of Fig.24 with the end cap removed to expose the rotor member;



Figs.26-28 show end views of various configurations for skewing the direction of rotation in the rotary motion device of Fig.24;



Figs.29A-29D are end views of the rotary motion device of Fig.24 illustrating a sequence of its rotational movements;

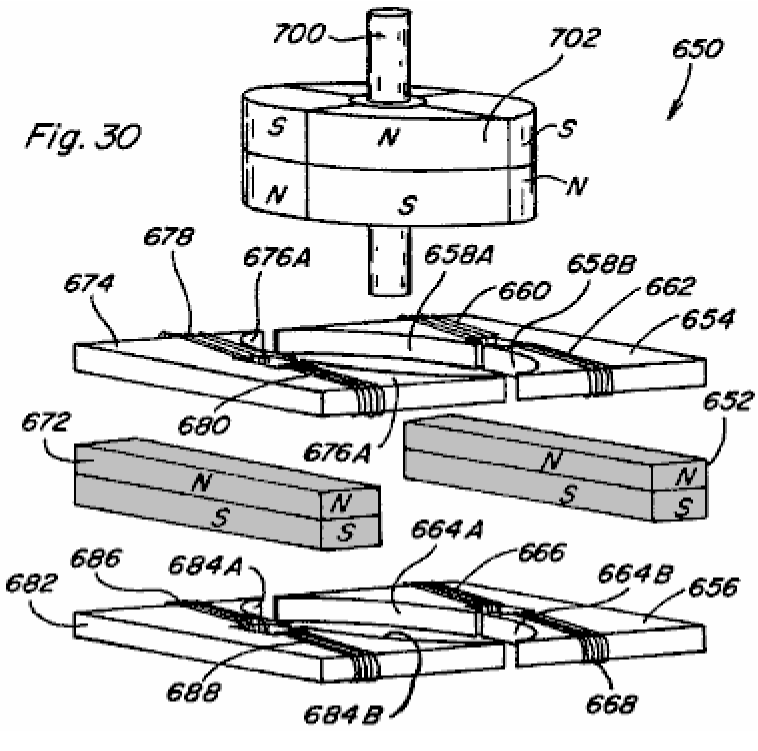


Fig.30 is an exploded partial perspective view of another embodiment of a rotary motion device;

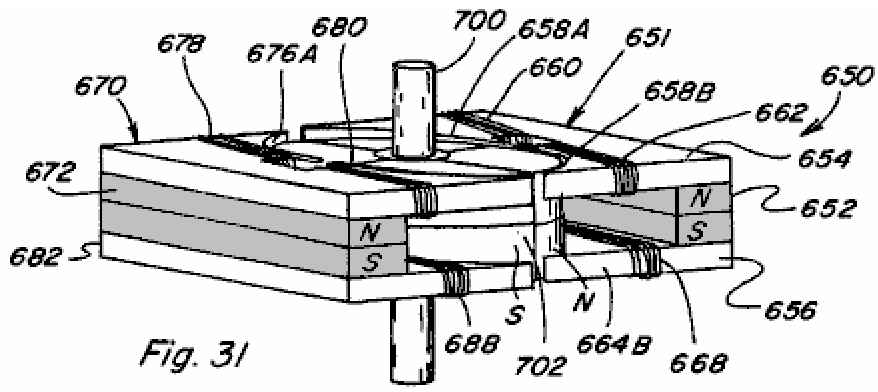


Fig. 31

Fig.31 is a perspective view of the rotary motion device of Fig.30 as assembled

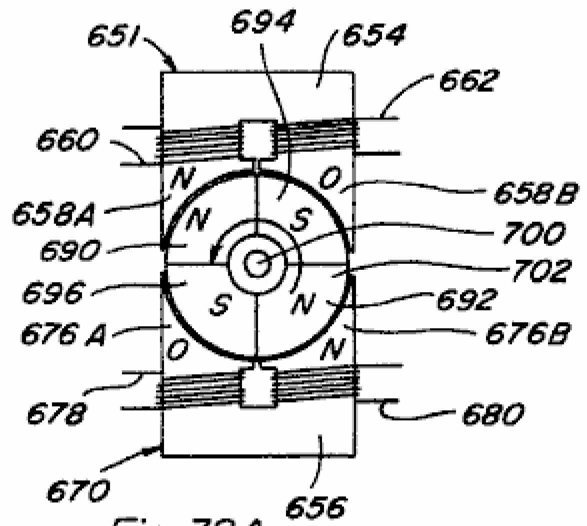


Fig. 32A

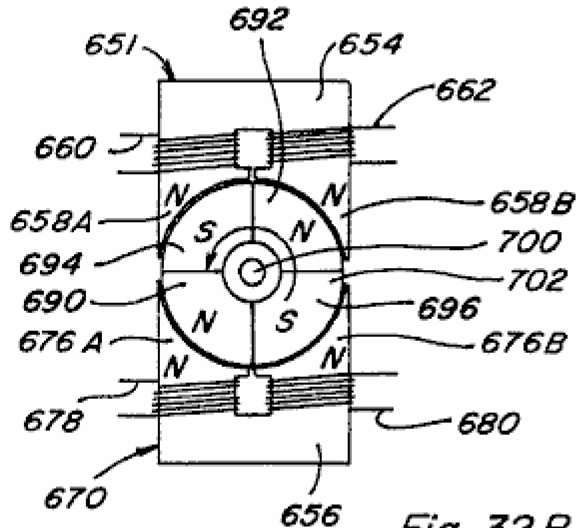


Fig. 32 B

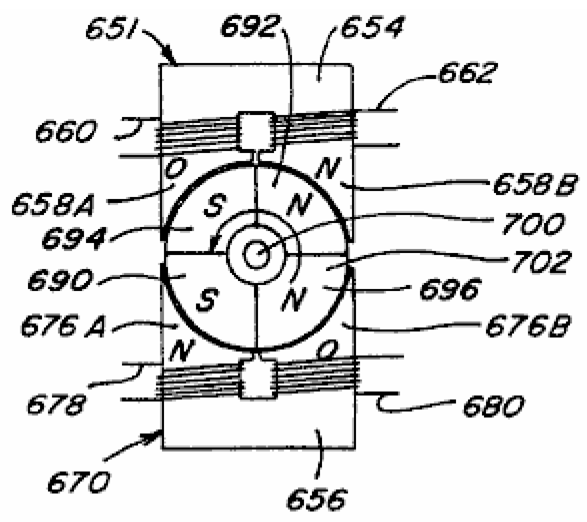


Fig. 32 C

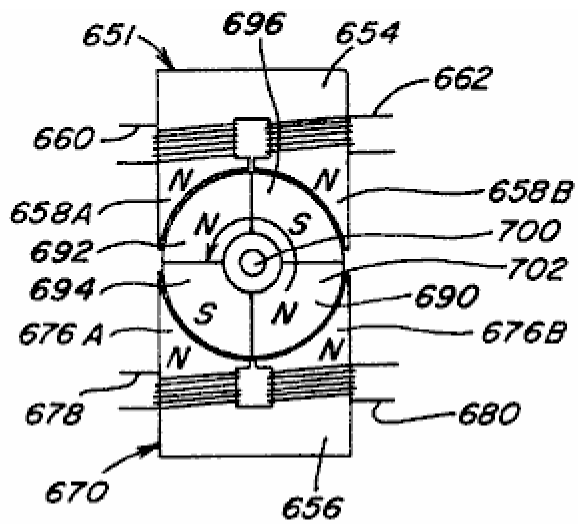


Fig. 32 D

Figs.32A-32D are top views of the rotary motion device of Fig.31 illustrating it's rotational movement;

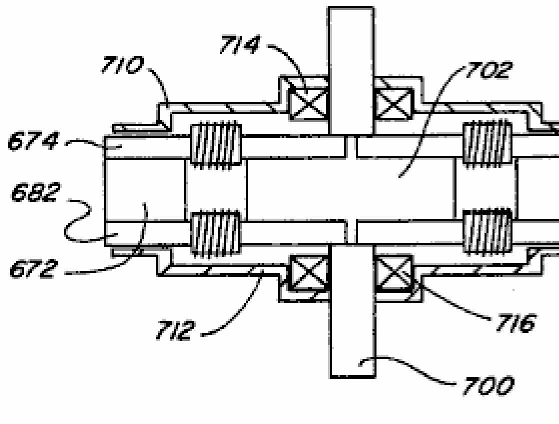


Fig. 33

Fig.33 is a side view of the rotary motion device of Fig.31 as assembled and including a housing;

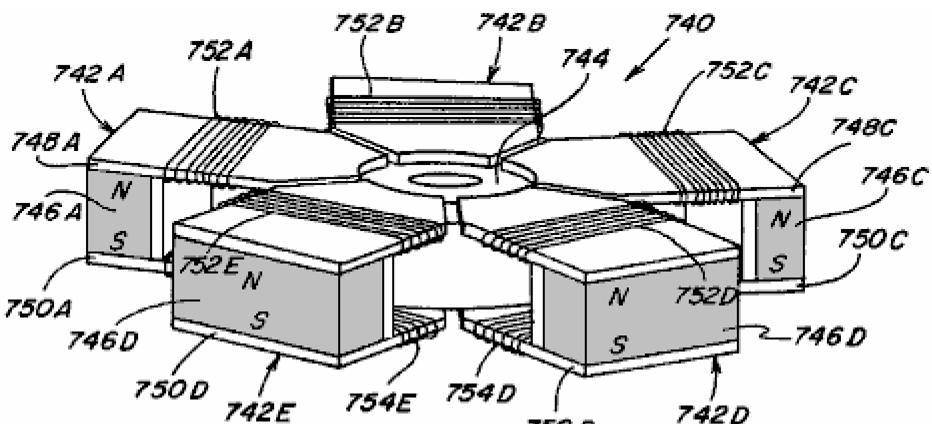


Fig. 34

Fig.34 is a perspective view of another embodiment of a rotary motion device;

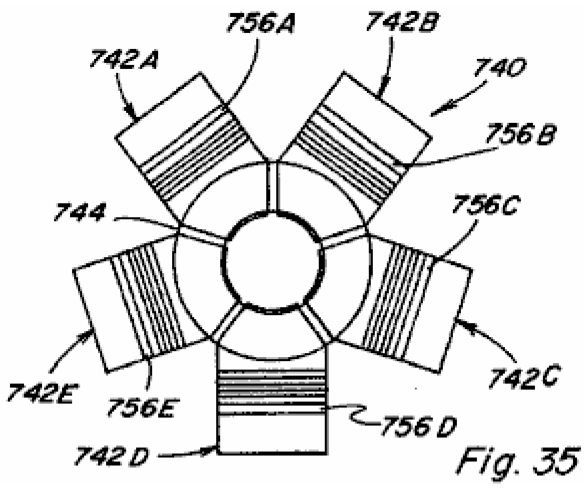


Fig. 35

Fig.35 is a top view of the rotary motion device of Fig.34;

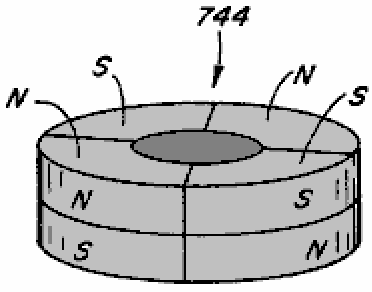


Fig. 36

Fig.36 is a perspective view of the permanent magnet rotor member of the rotary motion device of Fig.34;

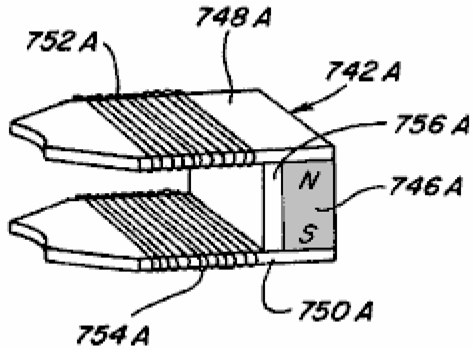


Fig. 37

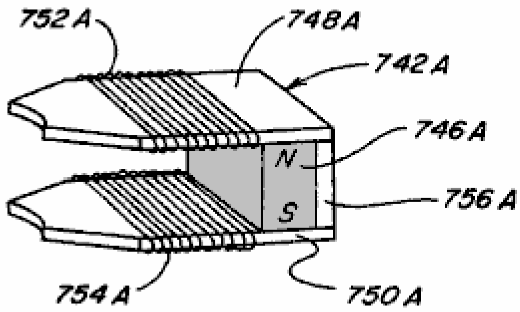


Fig. 38

Fig.37 and **Fig.38** show alternative configurations for the control component incorporated into the rotary motion device of Fig.34;

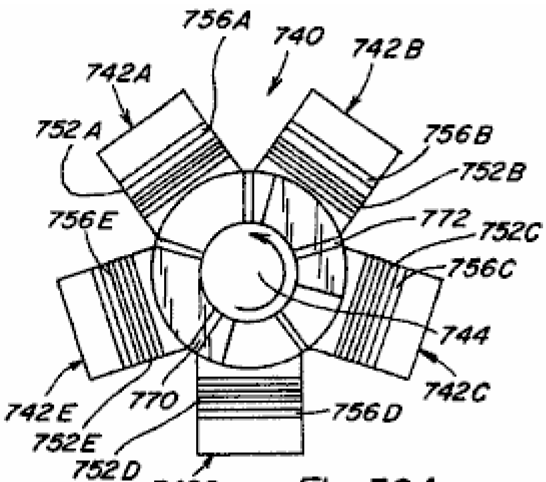


Fig. 39A

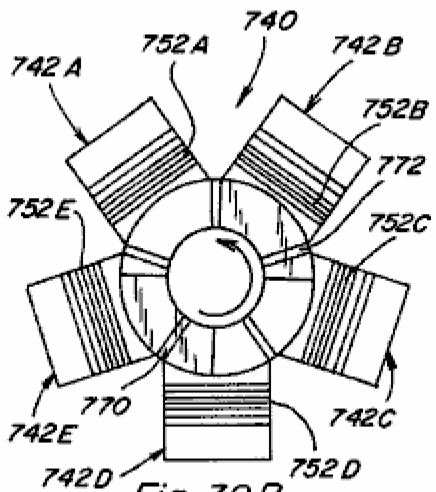


Fig. 39 B

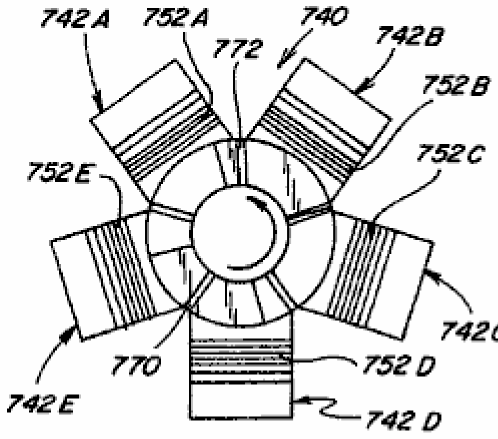


Fig. 39 C

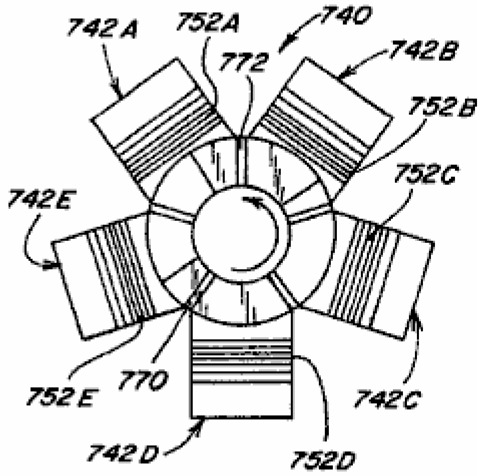


Fig. 39 D

Figs.39A-39D are top views of the rotary motion device of Fig.34 and depict its rotational movement;

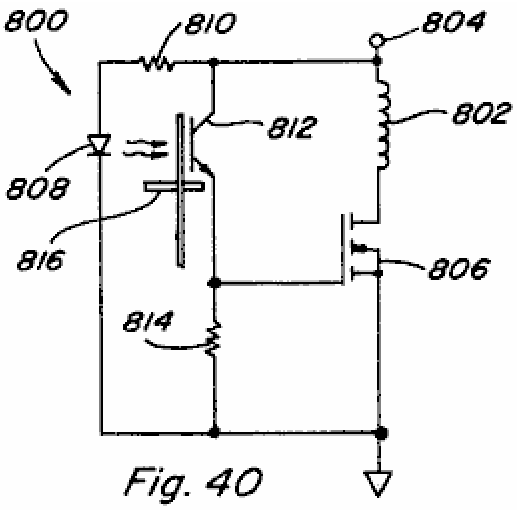


Fig. 40

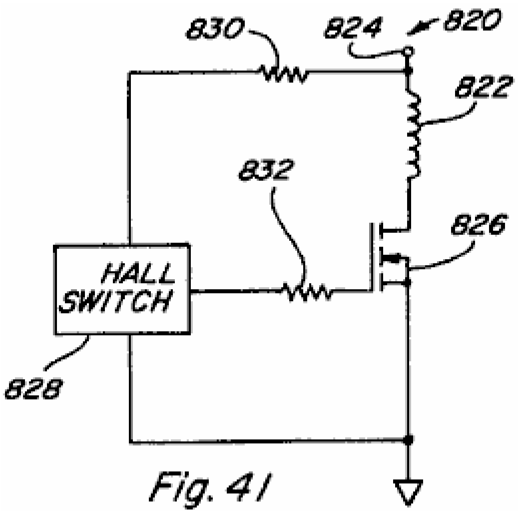


Fig. 41

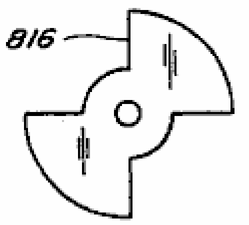


Fig. 42

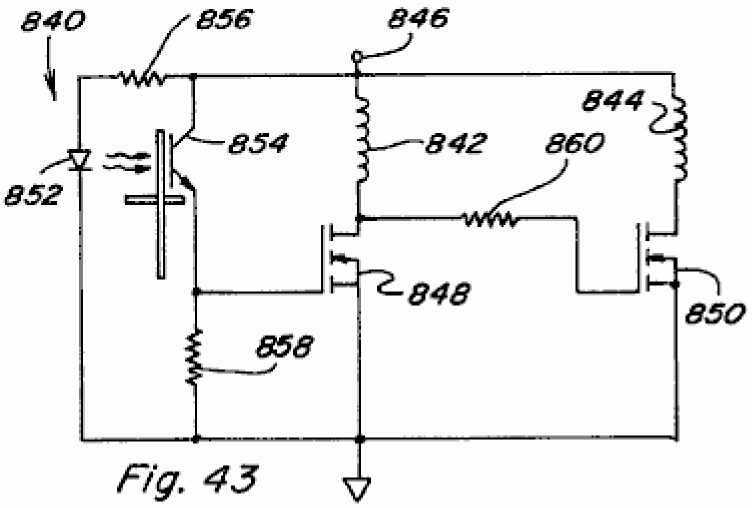


Fig. 43

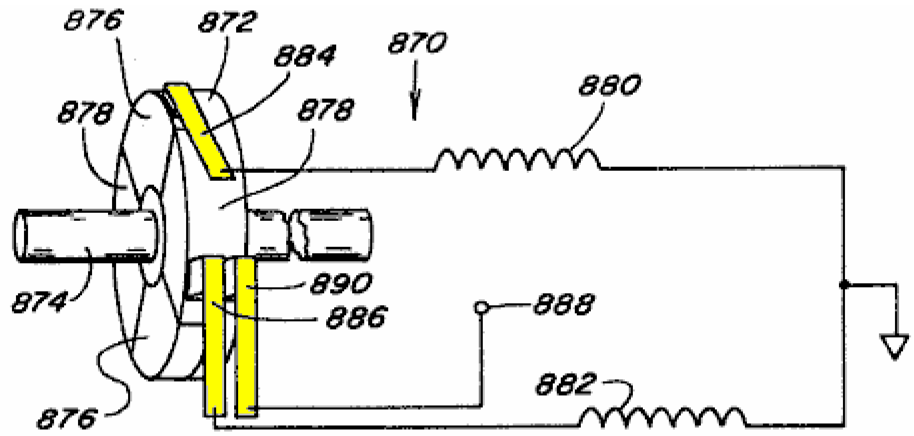


Fig. 44

Figs.40-44 are alternative variations of the circuit for controlling the timed energisation of control coils in the various devices of the present invention;

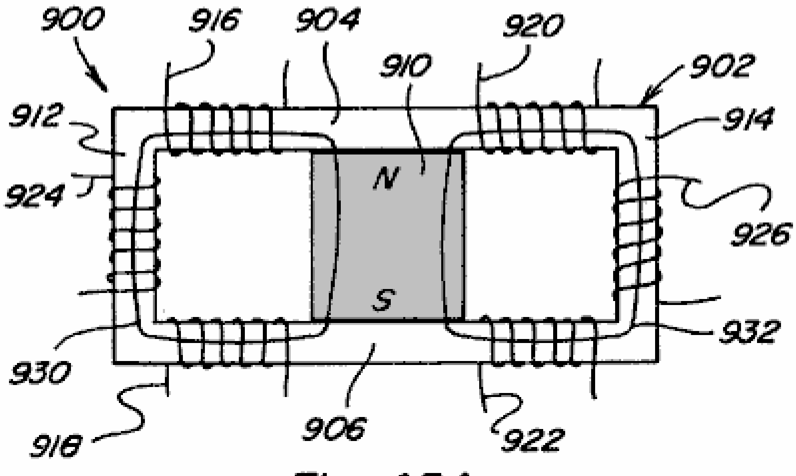


Fig. 45A

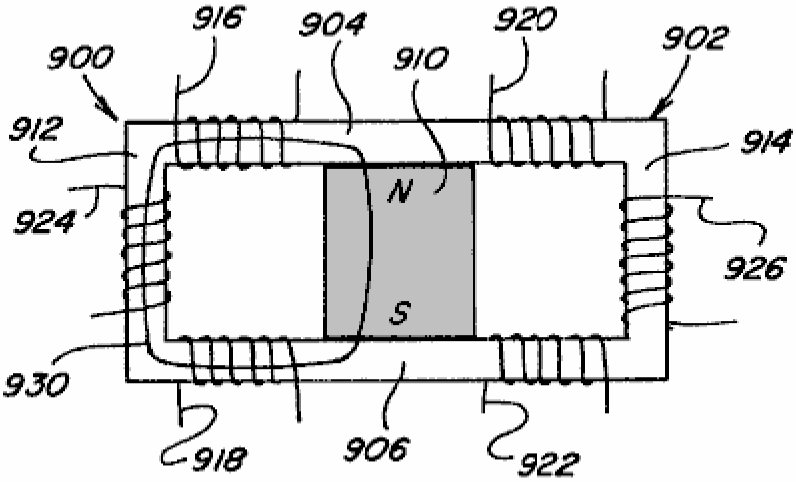


Fig. 45B

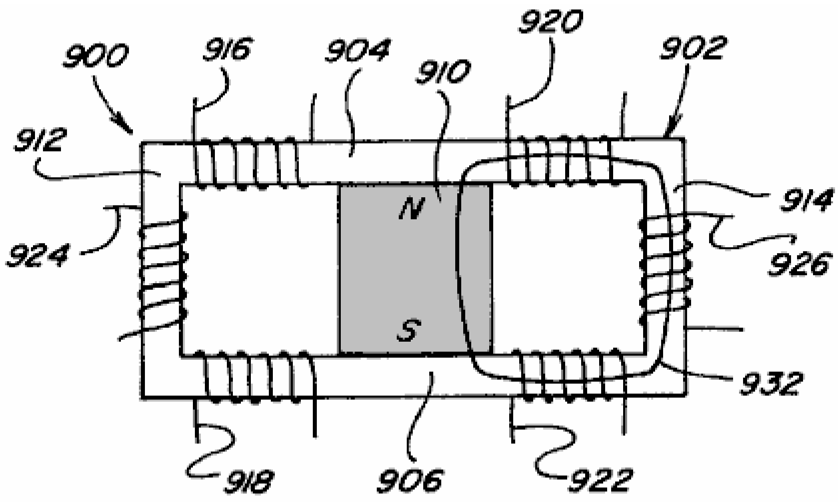


Fig. 45C

Figs.45A-45C and **Figs.45X-45Z** are side views of two path power conversion devices;

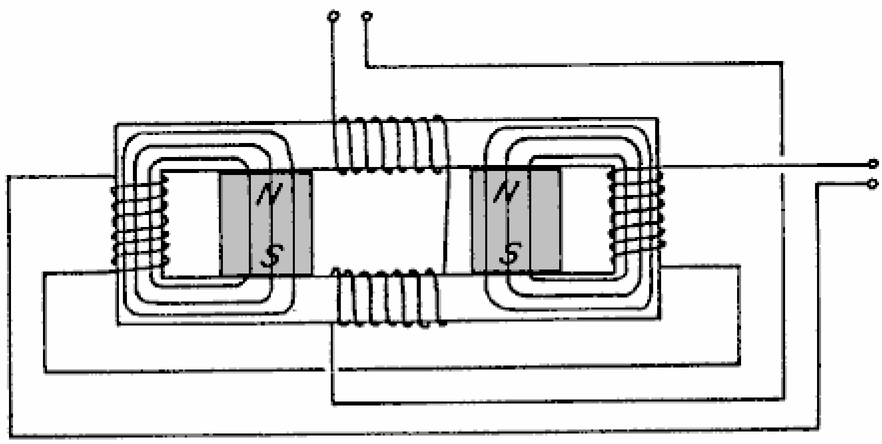


Fig. 45 X

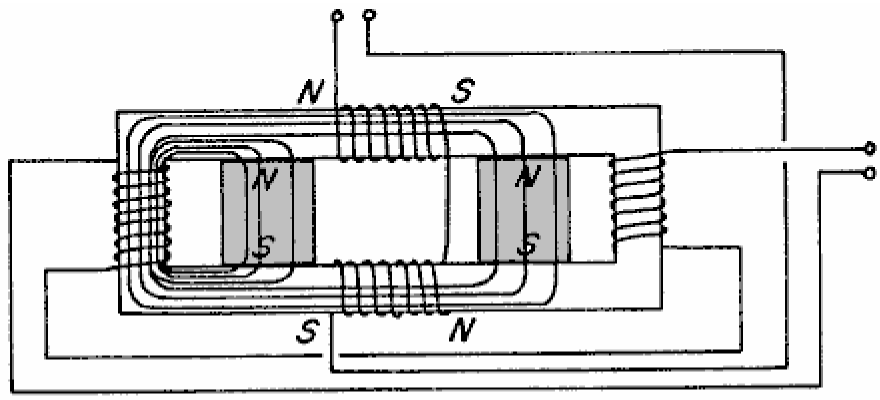


Fig. 45 Y

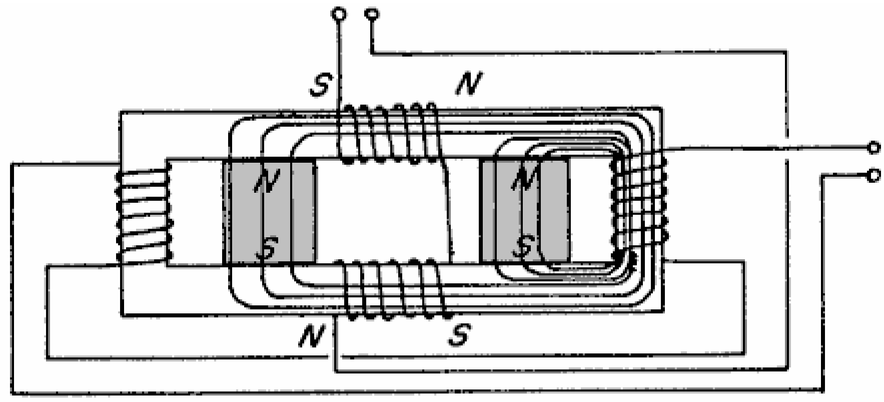


Fig. 45 Z

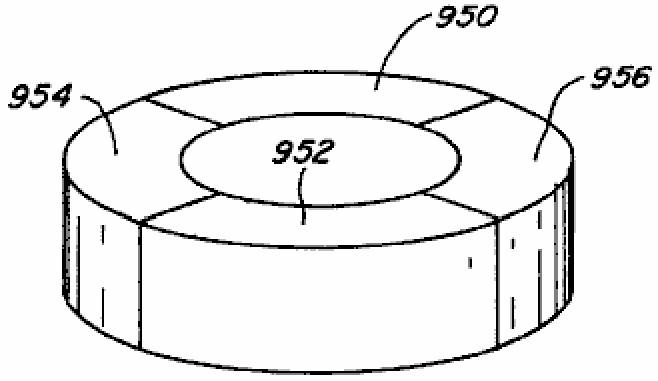


Fig. 46

Fig.46 is a schematic view of the permanent magnet portion of a rotor for use in some embodiments of the present device;

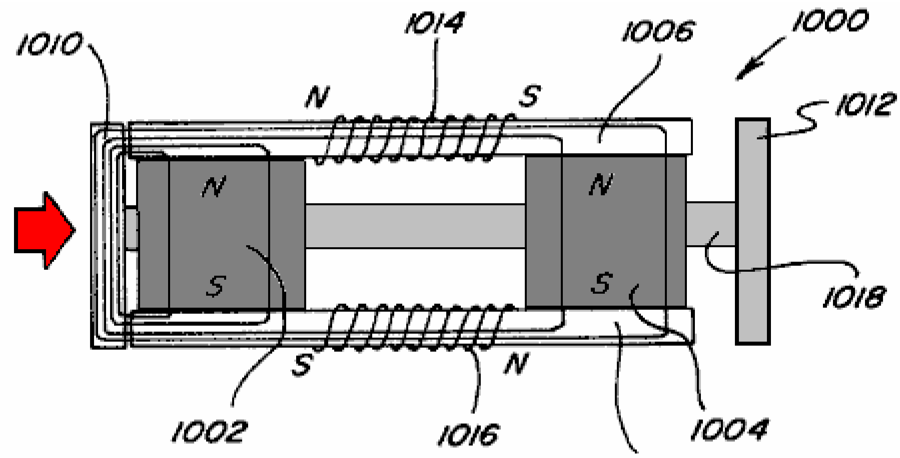


Fig. 47

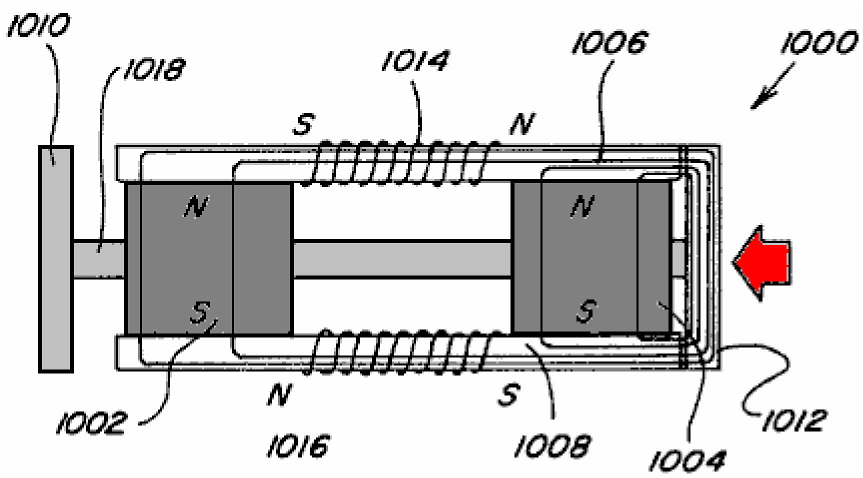


Fig. 48

Fig.47 and **Fig.48** show other embodiments of a linear motion device;

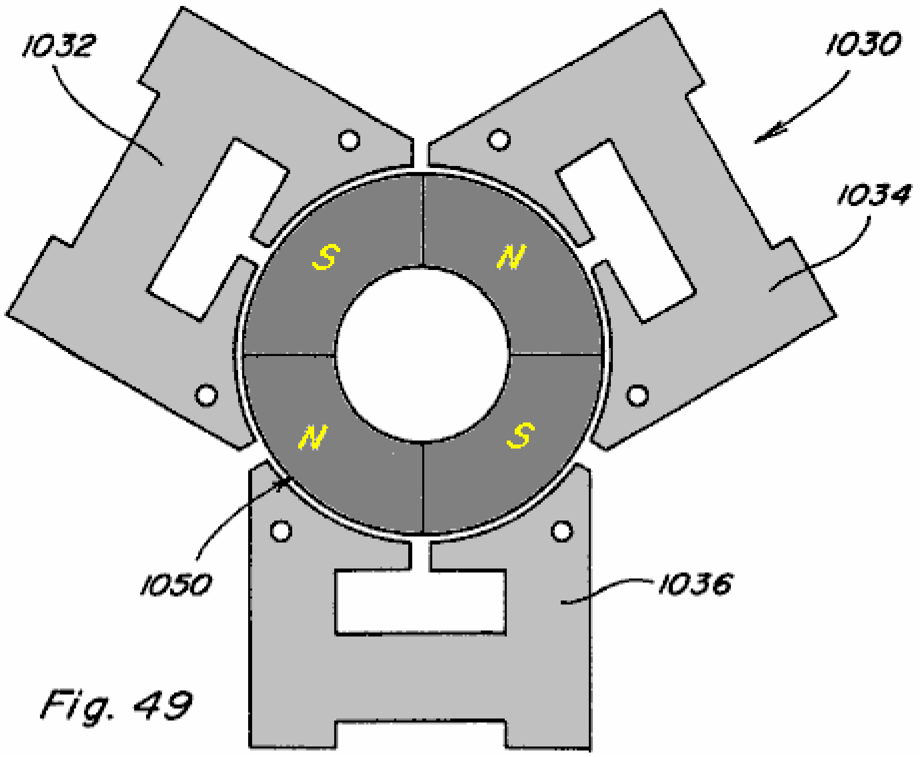


Fig. 49

Fig.49 is a top view of another embodiment of a rotating motor like construction; and

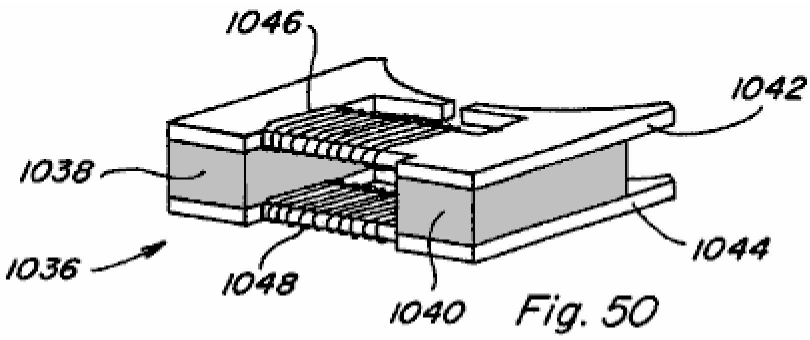


Fig. 50

Fig.50 is a schematic view of one of the three stator portions of the device shown in **Fig.49**.

DETAILED DESCRIPTION OF THE DRAWINGS

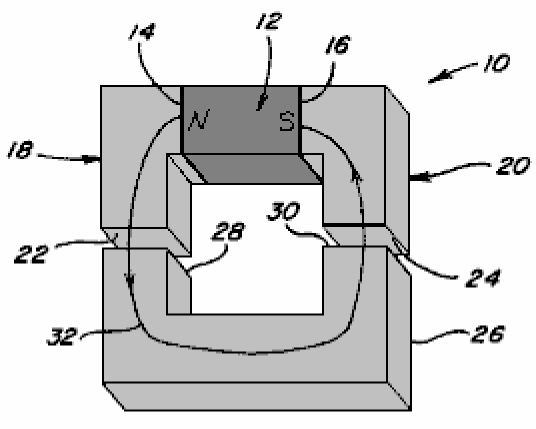


Fig. 1

Referring now to the drawings, Figs.1-4 are provided to facilitate an understanding of various aspects or features of the technology utilised in the present invention. **Fig.1** depicts a device **10** having a magnetic flux producing member **12** which may be a permanent magnet or electromagnet with magnetic poles **14** and **16** as shown. Pole pieces **18** and **20** are positioned adjacent respective poles **14** and **16** to provide a path for the magnetic flux of member **12**. Each pole piece **18** and **20** has a pole piece end face **22** and **24**. As used throughout this specification, it is understood that a pole piece, regardless of its shape or size, is preferably formed of soft iron, steel or some other magnetic material, with the preferred material being one which provides low reluctance, exhibits low hysterisis, and has a high magnetic flux density capability. Accordingly, the various pole pieces disclosed and described herein could likewise be of laminate type construction.

Referring again to **Fig.1** an armature **26**, also formed of magnetic material, is shown with end faces **28** and **30** which are positioned and sized for being placed adjacent pole piece end faces **22** and **24**, such that when so positioned a substantially continuous low reluctance path **32** is provided for magnetic flux from north pole **14**, through pole piece **18**, through armature **26**, through pole piece **16**, and to south pole **16**. The magnetic flux travelling along such path **32** results in a force which tends to hold armature **26** in position aligned with pole piece end faces **22** and **24**. The resulting magnetic coupling or holding force F provided between adjacent pole piece end face **22** and armature end face **28**, and between adjacent pole piece end face **24** and armature end face **30**, can be approximated by the following equation:

$$F = B^2 A / 2\mu_0,$$

where **B** is the magnetic flux density passing through the adjacent end faces and **A** is the surface area of the adjacent end faces. Assuming that if **B** is uniform throughout flux path **32** and that the area **A** of all end faces **22**, **24**, **28**, and **30** is the same, then the total holding force $\mathbf{F_{T26}}$ of armature **26** against pole pieces **18** and **20** will be:

$$F_{T26} = B^2 A / \mu_0.$$

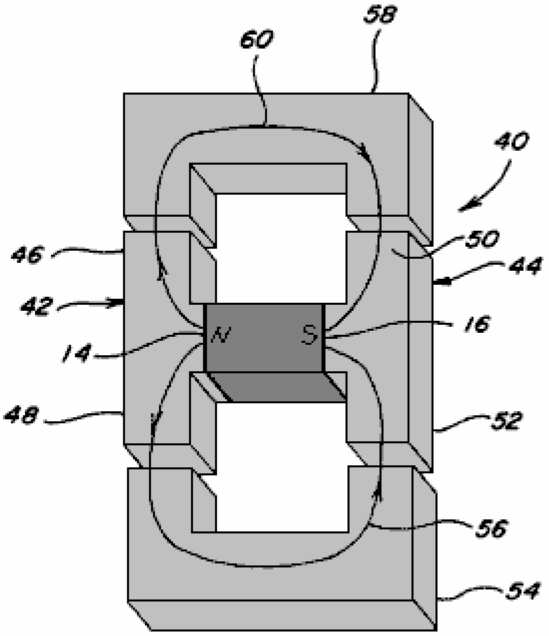


Fig. 2

In **Fig.2** a device **40** having the same magnetic flux producing member **12** with magnetic poles **14** and **16** is shown. Pole pieces **42** and **44** are positioned adjacent respective pole faces **14** and **16** to provide two paths, as opposed to one above, for the magnetic flux of member **12**. In particular, pole piece **42** includes a first path portion **46** extending beyond a perimeter of north pole face **14** in one direction and a second path portion **48** extending beyond the perimeter of north pole face **14** in another direction. Similarly, pole piece **44** includes a first path portion **50** extending beyond the perimeter of south pole face **16** in one direction and a second path portion **52** extending beyond the perimeter of south pole face **16** in another direction. Each pole piece path portion **46**, **48**, **50**, **52** includes a respective end face. A first armature **54** which can be positioned adjacent to the end faces of pole piece path components **48** and **52** provides a first magnetic flux path **56** and a second armature **58** is which can be positioned adjacent the end faces of pole piece path components **46** and **50** provides a second magnetic flux path **60**. If the flux carrying area along flux paths **56** and **60** is the same as the flux carrying area along flux path **32** of **Fig.1**, the magnetic flux density along each flux path **56** and **60** will be one-half the magnetic flux density along flux path **32** of **Fig.1** because the same amount of flux is split between two like paths. The effect of dividing a given amount of magnetic flux along two like flux paths instead of it passing along just one flux path can be seen by examining the holding force on armature **54** as compared to the holding force on armature **26** of **Fig.1**. As already noted the magnetic flux density along path **56** will be one-half that along flux path **32** and thus the total holding force F_{T54} can be determined as:

$$F_{T54}=(B/2)2A/,\mu_0=B^2A/4\mu_0=F_{T26}/4.$$

It is therefore seen that dividing the same amount of magnetic flux along two flux paths rather than along one flux path reduces the magnetic holding or coupling force on an armature to one-fourth rather than one-half as might have been expected. This unexpected magnetic holding or coupling force differential, resulting from multiple flux paths, can provide advantageous properties in linear, reciprocating, and rotary motion devices.

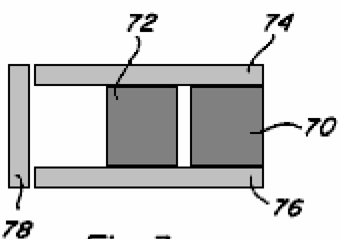


Fig. 3

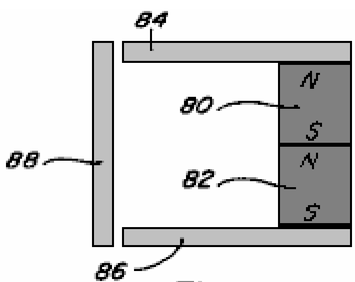


Fig. 4

Referring now to **Fig.3** and **Fig.4**, the behaviour of multiple magnetic flux sources arranged in parallel and series is described as compared to a single flux source. When identical flux sources or magnetic flux producing members **70** and **72** are positioned in parallel as shown in **Fig.3** with pole pieces **74** and **76** positioned adjacent the poles thereof to provide a flux path through armature **78**, the flux density B through armature **78** is double what the flux density would be if only one magnetic flux producing member were present. However, the field intensity H resulting from the two members **70** and **72** remains unchanged. This result holds true regardless of whether members **70** and **72** are both permanent magnets, are both electromagnets, or are a combination of one permanent magnet and one electromagnet. On the other hand, the properties resulting from magnetic flux producing members **80** and **82** arranged pole-to-pole in series between pole pieces **84** and **86**, with armature **88**, as shown in **Fig.4**, will vary depending on the nature of the members **80** and **82**.

In a first case, if both members **80** and **82** are permanent magnets, the magnetic field intensity H resulting from the two permanent magnets will be double that of one permanent magnet and the flux density B through armature **88** will be the same as what the flux density would be if only one permanent magnet type member were present.

In a second case, if both members **80** and **82** are electromagnets, the field intensity H again doubles and the flux density B increases according to the B/H curve or relationship of the pole piece **84**, **86** and armature **88** materials.

In a third case, if member **80** is a permanent magnet and member **82** is an electromagnet, the field intensity H again doubles, but, since the permanent magnet is near flux density saturation B_r the flux density can only be increased from B_r to B_{max} of the permanent magnet. At the point where electromagnet-type member **82** contacts permanent magnet-type member **80** the flux from the electromagnet-type member **82** couples with the flux of the permanent magnet-type member **82** until the flux density through permanent magnet-type member **80** reaches B_{max}. At that point additional flux from electromagnet-type member **82** does not contribute to the flux density along the flux path unless a bypass path around the permanent magnet-type member is provided. Use of such bypass paths will be described below.

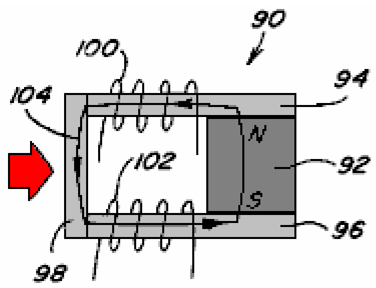


Fig. 5

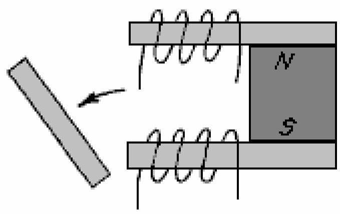


Fig. 6

Controlling the flow of flux along both one and multiple flux paths is best described with reference to **Figs.5-9**. In **Fig.5** and **Fig.6** a permanent magnet device **90** including a permanent magnet **92** having pole pieces **94** and **96** positioned adjacent to it's pole faces, and an armature **98** completing a low reluctance path **104** from pole to pole is shown. Control coils **100**, **102** are positioned along path **104**. When control coils **100**, **102** are not energised, the magnetic flux of permanent magnet **92** follows path **104** as shown and armature **98** is held in place against pole pieces **94**, **96** due to the resulting magnetic coupling forces. However, if coils **100**, **102** are energised to provide an equal but opposing magnetic flux to that of permanent magnet **92**, the result is that the magnetic flux of permanent magnet **92** is blocked and no magnetic flux traverses the path which includes armature **98** and therefore no magnetic coupling forces act on armature **98** allowing it to fall away as shown in **Fig.6**. The permanent magnet device **90** is useful, although as will become apparent below, it is more advantageous to provide multiple flux paths rather than one.

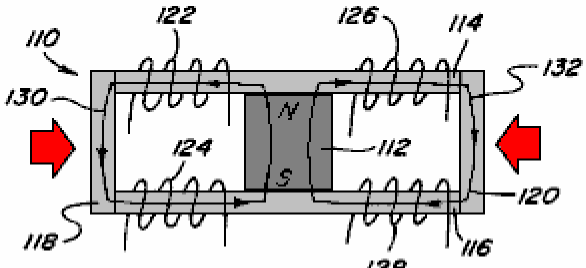


Fig. 7

In this regard, in **Fig.7** a permanent magnet device **110** includes a permanent magnet **112** having pole pieces **114**, **116** positioned adjacent the pole faces of it, with armatures **118**, **120** completing two low-reluctance paths **130**, **132** from pole to pole thereof. Control coils **122**, **124** are positioned along path **130** and control coils **126**, **128** are positioned along path **132**. The two paths provided are assumed to be of equal reluctance. With no coils energised, the magnetic flux of permanent magnet **112** divides equally along flux path **130** and flux path **132** such that both armatures **118**, **120** are subjected to a magnetic coupling force which holds them in place against pole pieces **114**, **116**.

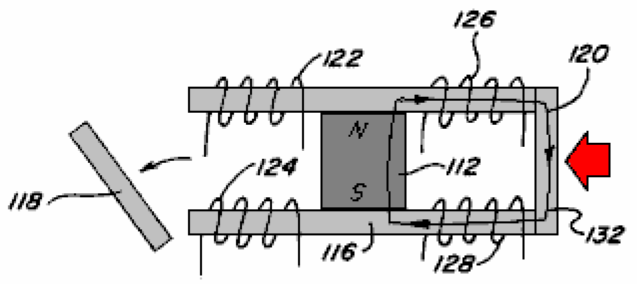


Fig. 8

If coils **122**, **124** are energised to provide a magnetic flux equal to but opposing the magnetic flux which travels along flux path **130** from permanent magnet **112** when no coils are energised, the result is that the magnetic flux of permanent magnet **112** is blocked and no magnetic flux traverses the path which includes armature **118** and therefore no magnetic coupling forces act on armature **118** allowing it to fall away as shown in **Fig.8**. Further, the magnetic flux traversing path **132** will be double that of when no coils are energised and therefore the magnetic coupling force on armature **120** will be about four (4) times that of when no coils are energised. By energising coils **126**, **128** in an opposing manner a similar result would be achieved such that armature **120** would fall away and such that the magnetic coupling force on armature **118** would be increased.

If coils **122**, **124** are energised to provide a magnetic flux equal to and aiding the magnetic flux which travels along flux path **130** when no coils are energised, the result is that the control coils couple completely with the magnetic flux of permanent magnet **112** and no magnetic flux traverses the path which includes armature **120** and therefore no magnetic coupling forces act on armature **120** allowing it to fall away as shown in **Fig.9**. Further, the magnetic flux traversing path **130** will be double that of when no coils are energised and therefore the magnetic coupling force on armature **118** will be about four (4) times that when no coils are energised. By energising coils **126**, **128** in an aiding manner a similar result would be achieved such that armature **118** would fall away and the magnetic coupling force on armature **120** would be increased.

Based on the foregoing, it is seen that the full magnetic coupling force available from the permanent magnet **112,** can be switched from one path to another path by the application of one half the power it would require for a coil alone to produce the same magnetic flux along one path. The ability to switch the full magnetic coupling force easily from one path to another, allows for efficient reciprocating, linear, and rotary motion and power conversion to be achieved.

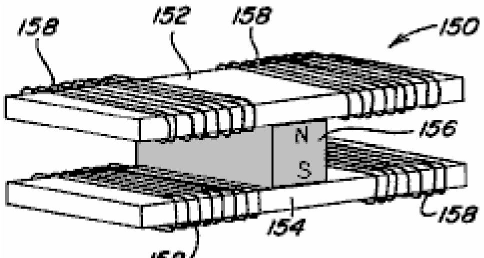


Fig. 10 A

The basic device utilised to achieve permanent magnet flux division and to control such permanent magnet flux division is defined herein as a "permanent magnet control component," various configurations of which are shown by way of example only, and not by way of limitation, in **Figs.10A-10F**. **Fig.10A** depicts a permanent magnet control component **150** in which pole pieces **152** and **154** are positioned adjacent to the pole faces of permanent magnet **156** to provide two magnetic flux paths extending from opposite sides of permanent magnet. Control coils **158** are positioned along each path.

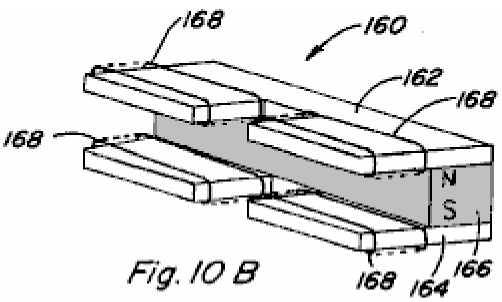


Fig. 10 B

Fig.10B depicts a permanent magnet control component **160** in which pole pieces **162** and **164** are positioned against the pole faces of permanent magnet **166** to provide two spaced, adjacent magnetic flux paths extending from the same side of permanent magnet **166**. Control coils **168** are positioned along each path.

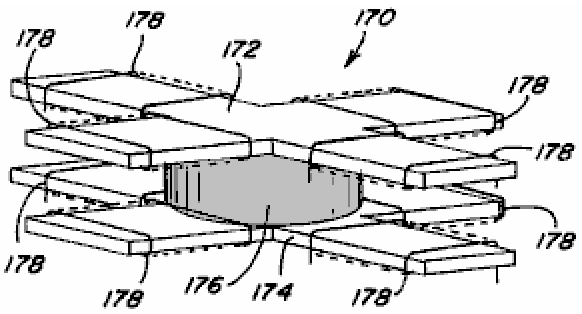


Fig. 10 C

Fig.10C depicts a permanent magnet control component **170** in which pole pieces **172** and **174** are configured so as to be positioned adjacent the pole faces of permanent magnet **176** so as to provide four flux paths, each flux path extending in a respective direction from permanent magnet **176**. Control coils **178** are also positioned along each path.

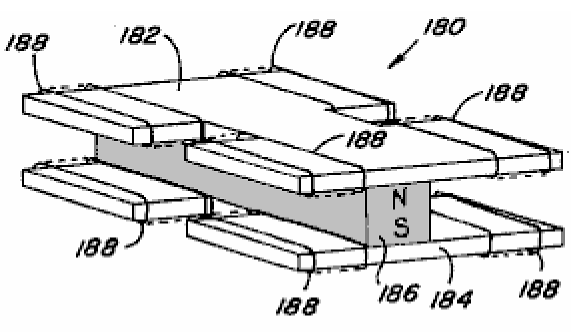


Fig. 10D

Fig.10D depicts another four-path configuration of a permanent magnet control component **180** in which pole pieces **182**, **184** are configured and positioned to provide four flux paths for permanent magnet **186**, with a pair of spaced, adjacent flux paths extending from each side of permanent magnet **186**. Control coils **188** are positioned along each path.

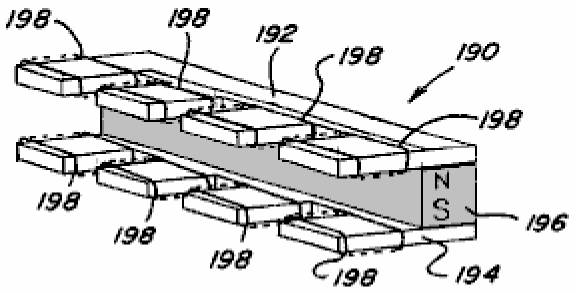


Fig. 10 E

Fig.10E depicts another four-path configuration of a permanent magnet control component **190** in which all four flux paths formed by pole pieces **192**, **194** extend from one side of permanent magnet **196**. Again, control coils **198** are positioned along each flux path.

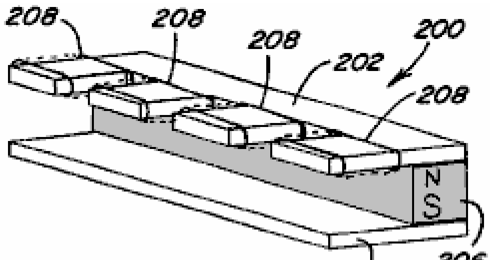


Fig. 10 F

Fig.10F still further depicts a four-path configuration of a permanent magnet control component **200** in which pole pieces **202**, **204** extend to one side of permanent magnet **206**, with pole piece **202** defining four flux paths and with pole piece **204** including a continuous return path. Control coils **208** are positioned along each path of pole piece **202**. Many other variations are possible.

Accordingly, it is seen that a variety of different configurations of permanent magnet control components are possible, in accordance with the present invention. The important considerations for division of permanent magnet flux in such permanent magnet control components include, extending each pole piece to, or beyond, the outer perimeter of the pole face of the permanent magnet in each region where a flux path is intended and assuring that the pole face of the permanent magnet intersects each of the flux paths. It is not necessary for each pole piece to include the same number of path portions extending beyond the perimeter of the respective permanent magnet pole face as noted with reference to permanent magnet control component **200**. Although two control coils are shown along each of the flux paths in **Figs.10A-10E**, it is apparent from component **200** in **Fig.10F** that one control coil positioned along a flux path is generally sufficient for purposes of the present invention. Further, although in the illustrated configurations each pole piece is positioned to contact a respective pole face of the permanent magnet, a small spacing between a pole piece and its adjacent permanent magnet pole face could be provided, particularly in applications where relative movement between the subject pole piece and the permanent magnet will occur.

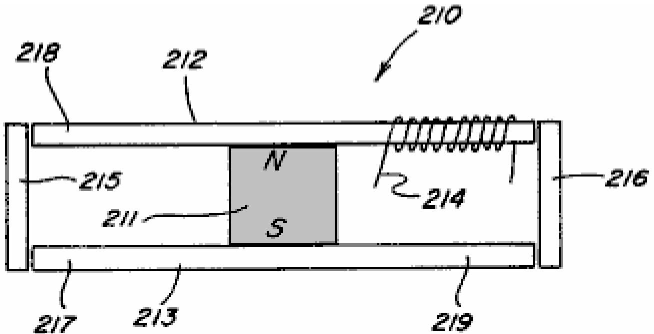


Fig. 10 G

In its simplest form a two path permanent magnet control component only requires one control coil positioned along one of the control paths to permit the magnetic flux of a permanent magnet to be switched between the two paths. In particular, a side view of such a two path component **210** is shown in **Fig.10G** and includes a permanent magnet **211** pole pieces **212** and **213**, and control coil **214** which may be connected to a suitable control circuit. By alternating energising control coil **214** in an opposing manner and an aiding manner the magnetic flux of permanent magnet can be switched between the path including armature **215** and the path including armature **216**. When control coil **214** is energised in an opposing manner the magnetic flux will traverse the path including armature **215** and when control coil **214** is energised in an aiding manner the magnetic flux will traverse the path including armature **216**. Control coil 214 could also be placed at any of the positions **217**, **218**, or **219** to achieve the flux path switching.

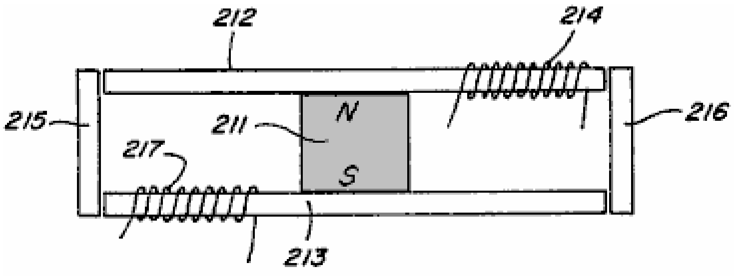


Fig. 10 H

Further, in the two coils embodiment shown in **Fig.10H** control coil **217** is added. In such a device, flux switching can be achieved by simultaneously energising control coil **214** in a flux aiding manner and control coil **217** in a flux opposing manner, and by then simultaneously reversing the energisation of the respective control coils **214** and **217**.

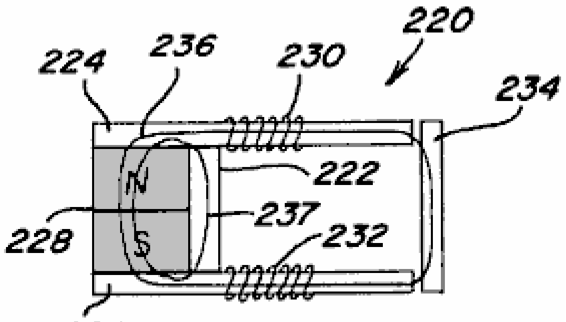


Fig. 11A

Reference is made to **Figs.11A-11F** which depict devices similar to that of **Figs.5-6** except that a bypass, formed of magnetic material, is provided in each case. In device **220** of **Figs.11A-11C** a bypass **222** is provided from pole piece **224** to pole piece **226** and is located between permanent magnet **228** and control coils **230**, **232**, with armature **234** located adjacent the ends of pole pieces **224**, **226**. In **Fig.11A** with no coil energisation, magnet flux components **236** and **237** travel as shown.

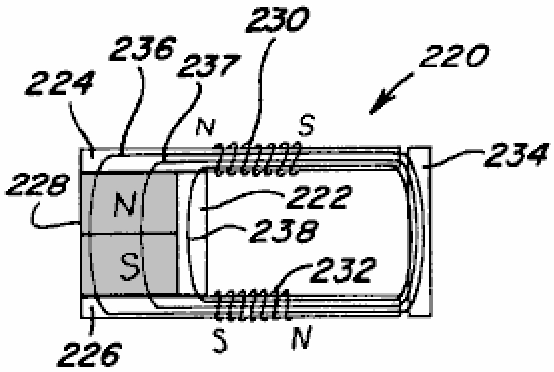


Fig. 11B

When coils **230** and **232** are energised in an aiding or adding manner as in **Fig.11B**, the result is permanent magnet magnetic flux components **236** and **237** travelling as shown, and with the added magnetic flux component **238** from coils **230** and **232** also travelling as shown. Thus, in device **220** energising the coils in an aiding manner results in an increased magnetic coupling force on armature **234**.

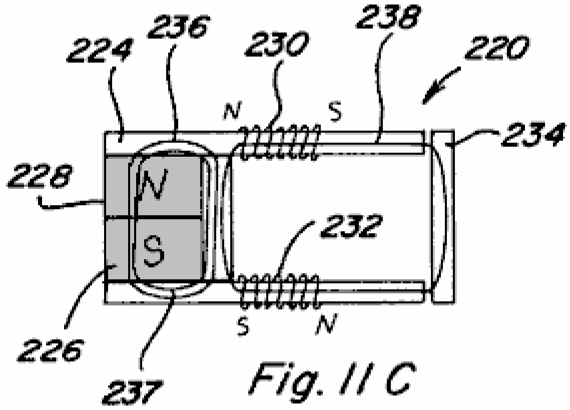


Fig. 11C

In **Fig.11C** coils **230**, **232** are energised in an opposing exceeding manner which results in permanent magnetic flux components **236** and **237** travelling as shown and excess magnetic flux component **238** travelling as shown. Thus, in device **220** energising the coils in an opposing exceeding manner results in magnetic coupling force on armature **234**, albeit smaller than that in the aiding exceeding case.

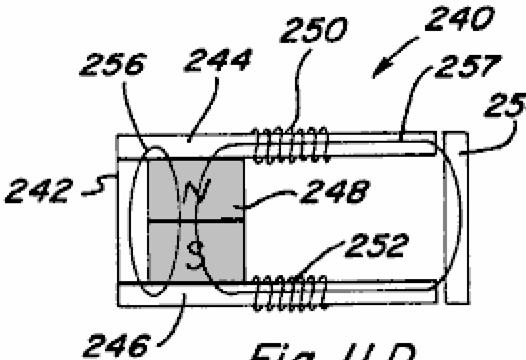


Fig. 11D

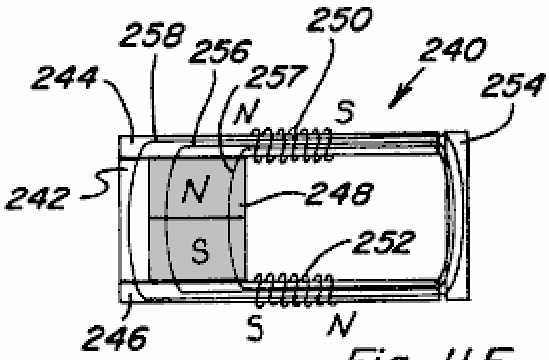


Fig. 11E

In device **240** of **Figs.11D-11F** a bypass **242** is provided between pole piece **244** and pole piece **246** but is located on an opposite side of permanent magnet **248** as compared to control coils **250**, **252** and armature **254**. Permanent magnet flux components **256** and **257** are shown for no coil energisation in **Fig.11D**. In **Fig.11E** the paths of permanent magnet flux components **256** and **257**, as well as excess coil magnetic flux **258**, are shown when coils **250**, **252** are energised in an aiding exceeding manner.

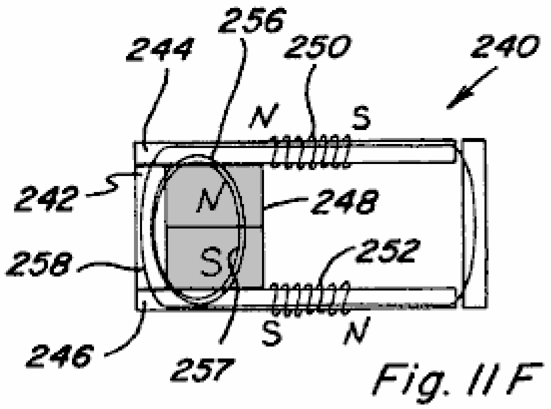


Fig. 11 F

In **Fig.11F** the path of each magnetic flux component **256**, **257**, and **258** is shown when coils **230**, **232** are energised in an opposed exceeding manner.

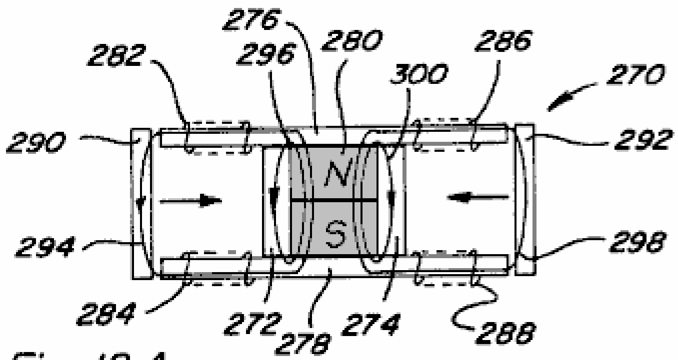


Fig. 12 A

Figs.12A-12E depict a device **270** similar to that shown in **Figs.7-9** except that bypasses **272** and **274** are provided from pole piece **276** to pole piece **278**. Bypass **272** is located between permanent magnet **280** and control coils **282**, **284** and bypass **274** is located between permanent magnet 280 and control coils **286**, **288**. Armatures **290** and **292** are also provided. When no coils are energised permanent magnet magnetic flux components **294**, **296**, **298**, and **300** travel as shown in **Fig.12A**.

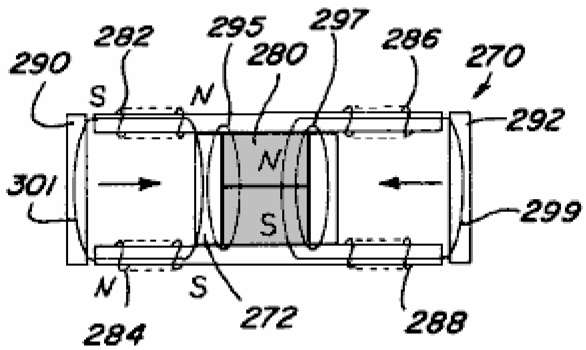


Fig. 12 C

If coils **282**, **284** are energised in an opposing manner permanent magnet flux components **295**, **297**, and **299** travel as shown, with no flux component traversing the path which includes armature **290** and therefore no magnetic coupling force acting thereon. This would be the case when coils **282**, **284** are energised to the level where the coils magnetic flux just blocks, but does not exceed, the magnetic flux component **294** (**Fig.12A**) from permanent magnet **280**. However, if coils **282**, **284** are energised in an opposed exceeding manner an excess coil magnetic flux component **301** is produced which travels a path including armature **290** and bypass **272** results as shown in **Fig.12C**.

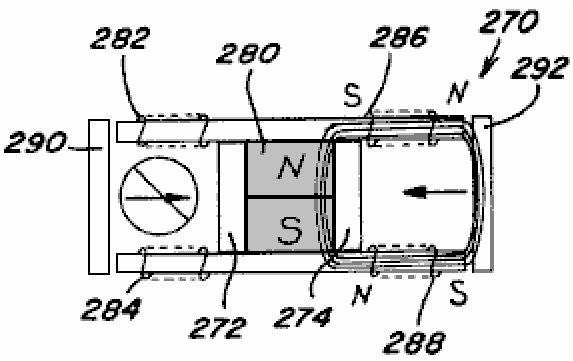


Fig. 12D

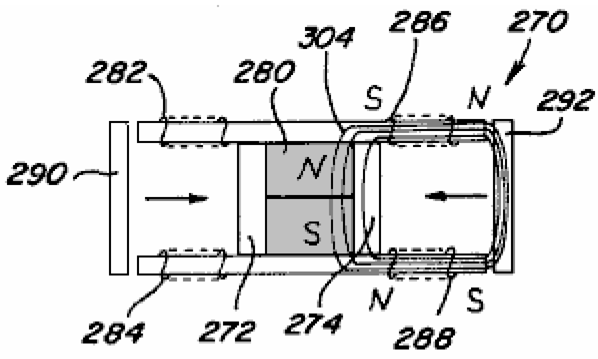


Fig. 12E

Coils **286**, **288** may be energised in an aiding manner such that all permanent magnet magnetic flux travels along the path which includes armature **292** as shown in **Fig.12D**. If coils **286**, **288** are energised in excess of the level of **Fig.12D** then the excess magnetic flux component **304** traverses the path which includes armature **292** and bypass **274** as shown in **Fig.12E**, thereby increasing the magnetic coupling force on armature **292** as compared to **Fig.12D**. The advantage of incorporating such bypasses into permanent magnet control components in certain applications will become apparent below.

Reciprocating Motion

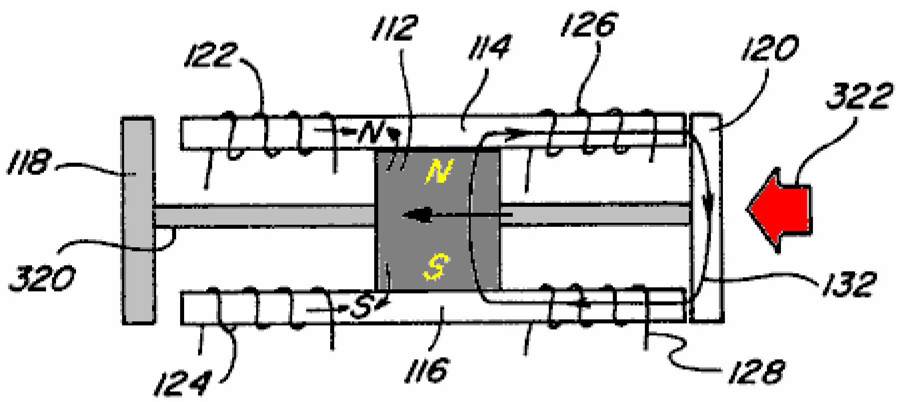


Fig. 13A

As mentioned above, controlling the path of magnetic flux from a permanent magnet can be useful in a variety of applications such as achieving reciprocating motion. In this regard, if the device **110** of **Figs.7-9** is modified such that armatures **118** and **120** are fixed to a sliding shaft **320** as shown in **Figs.13A-13C**, and if the distance between the armatures is greater than the end to end length of pole pieces **114**, **116**, limited linear motion in two directions (left and right in **Figs.13A-13C**), and therefore linear reciprocating motion, can be achieved by the timed, alternate delivery of electrical signals to control coils **122**, **124** and control coils **126**, **128**. By way of example, **Fig.13A** represents the position of shaft connected armatures **118**, **120** when coils **122**, **124** are energised in an opposing manner to block the flux of permanent magnet **112** such that all magnetic flux traverses path **132** as shown and such that the resulting magnetic coupling force acts to the left as indicated by arrow **322**.

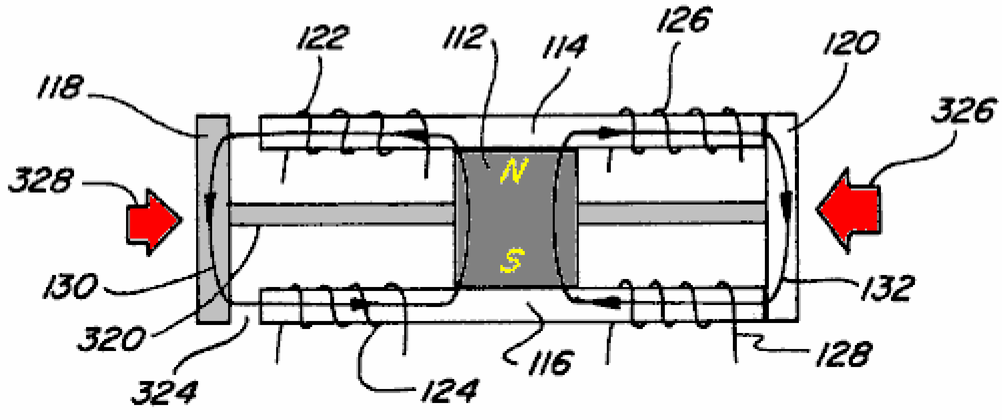


Fig. 13B

As shown in **Fig.13B** when coils **122**, **124** are de-energised the magnetic flux from permanent magnet **112** can again travel along path **130** through armature **118**. However, due to the air gap **324** between armature **118** and pole pieces **114**, **116** the reluctance along path **130** will be significantly greater than the reluctance along path **132**. Accordingly, the amount of magnetic flux which flows along path **130** will be less than the amount of magnetic flux which flows along path **132** such that the magnetic coupling force on armature **118** acting to the right will be significantly less than the magnetic coupling force on armature **120** acting to the left as shown by arrows **326** and **328**, which arrows are sized to represent the strength of the respective directional force.

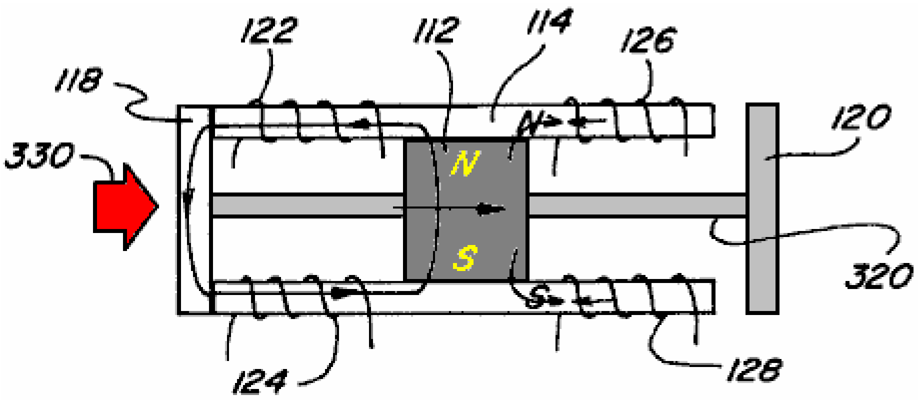
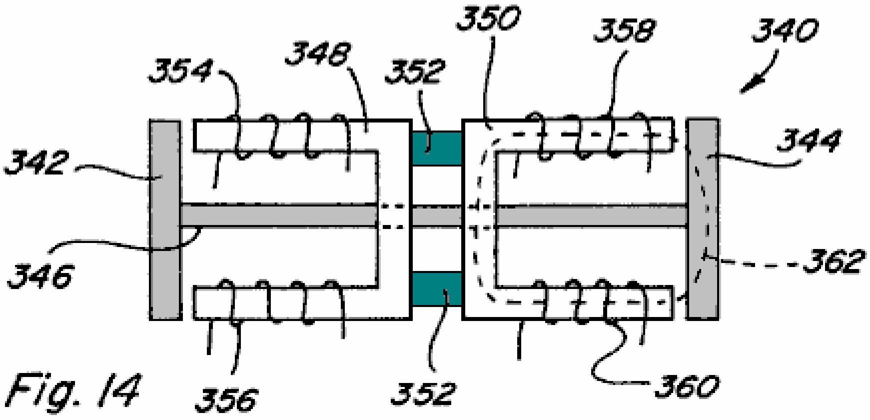


Fig. 13 C

Fig.13C represents the position of shaft connected armatures **118**, **120** after coils **126**, **128** are energised in a manner to oppose the flux of permanent magnet **112** such that all flux traverses path **130** and the resulting magnetic coupling force on armature **118**, depicted by arrow **330**, moves the shaft **10** connected armatures **118**, **120** to the right.

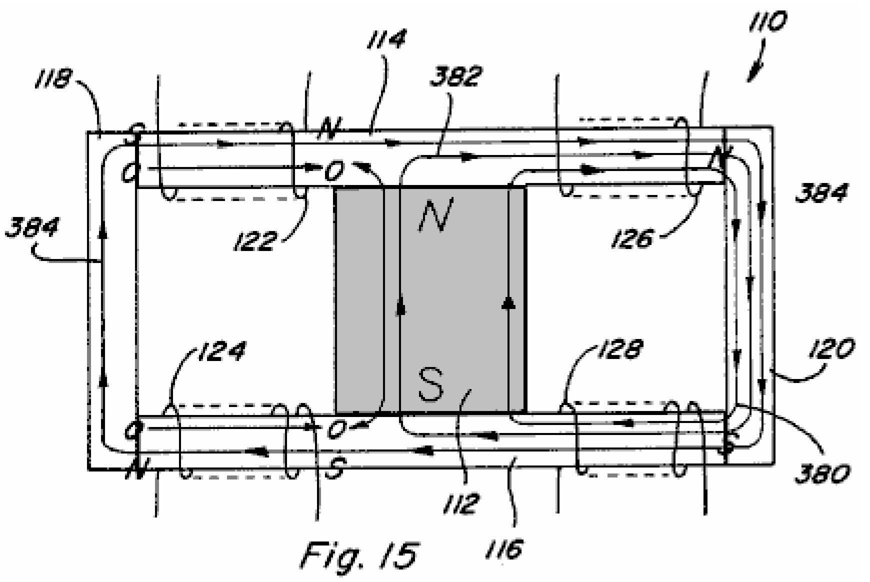
Control coils **122**, **124** and **126**, **128** could also be energised in a flux aiding manner to achieve the same result. In such a device, **Fig.13A** would represent coils **126**, **128** energised to aid magnetic flux along path **132**, **Fig.13B** would again represent no coils energised, and **Fig.13C** would represent coils **122**, **124** energised to aid magnetic flux along path **130**.

Thus, by alternately energising and de-energising control coils **122**, **124** and **126**, **128** a linear reciprocating motion of shaft connected armatures **118**, **120** may be achieved. Further, such reciprocating motion may be achieved by energising the coils in either an opposing or aiding manner. The magnetic coupling force exerted on a given armature when **20** the control coils are energised to establish all magnetic flux along a single path which includes that armature is significantly greater than the magnetic coupling force which would be exerted on such armature by an identical energisation of the control coils in the absence of the permanent magnet.



This is demonstrated with reference to **Fig.14** which depicts a reciprocating device **340** in which only coils or electromagnets are utilised. As shown armatures **342** and **344** are connected by shaft **346**, and each armature **342**, **344** includes a respective U-shaped pole path piece **348**, **350** which pole path pieces are mechanically connected by a non-magnetic material **352**. Each pole path piece **348** and **350** has respective control coils **354**, **356** and **358**, **360** positioned along them. By comparison with the device of **Figs.13A-13C**, if coils **358**, **360** of device **340** are energised to cause magnetic flux flow in either direction, clockwise or counterclockwise, along path **362**, the amount of electrical energy which would be required in order to achieve the same magnetic coupling force on armature **344** as achieved on armature **120** above in **Fig.13A** would be twice that delivered to coils **122**, **124** or **126**, **128** in **Fig.13A**. It is therefore demonstrated, that by controlling or switching the flow of magnetic flux from a permanent magnet between at least two different paths results in greater coupling forces per unit of input electrical energy, and therefore that such control or switching will enable more work to be achieved per unit of input electrical energy.

As described above, if a coil is energised beyond the point where the magnetic flux produced by the coil aiding the amount of the permanent magnet's flux that is either opposed or aided, the extra magnetic flux needs a low reluctance path between the poles of the coil that produces the excess magnetic flux. If a complete low-reluctance path is not provided for the excess magnetic flux, there is little potential for taking advantage of the excess magnetic flux in terms of producing additional magnetic coupling forces. The path for such excess flux cannot be through a permanent magnet member. In assemblies which include an armature on each path, the armature will provide the necessary low-reluctance path.



Referring to **Fig.15**, various components of the magnetic flux in device **110** (**Figs.7-9**) are depicted by numerals **380**, **382**, and **384** for the case when coils **122**, **124** are energised to oppose the magnetic flux of permanent magnet **112** in an amount which exceeds the level of magnetic flux which permanent magnet **112** would cause to flow through armature **118** when no coils are energised. **Fig.15** is likewise representative of the case when coils **126**, **128** are energised to aid the magnetic flux of permanent magnet **112** by an amount which exceeds the level of magnetic flux which permanent magnet **112** would cause to flow through armature **118** when no coils are energised. In particular, magnetic flux component **380** represents the magnetic flux of permanent magnet **112** which normally flows through the path including armature **120**; magnetic flux component **382** represents the magnetic flux of permanent magnet **112** which is diverted by the opposing field of coils **122**, **124** so as to traverse the path which includes armature **120**; and magnetic flux component **384** represents the magnetic flux produced by coils **122**, **124** which is in excess of the diverted magnetic flux **382**. As shown, the excess magnetic flux **384** produced by coils **122**, **124** traverses the path which includes armature **120** and bypasses permanent magnet **112** so as to also traverse the path which includes armature **118**. Thus, the excess magnetic flux produced by coils **122**, **124** adds to the permanent magnet flux traversing the path which includes armature **120**, thus increasing the magnetic coupling force on armature **120**, while at the same time providing a magnetic coupling force on armature **118**.

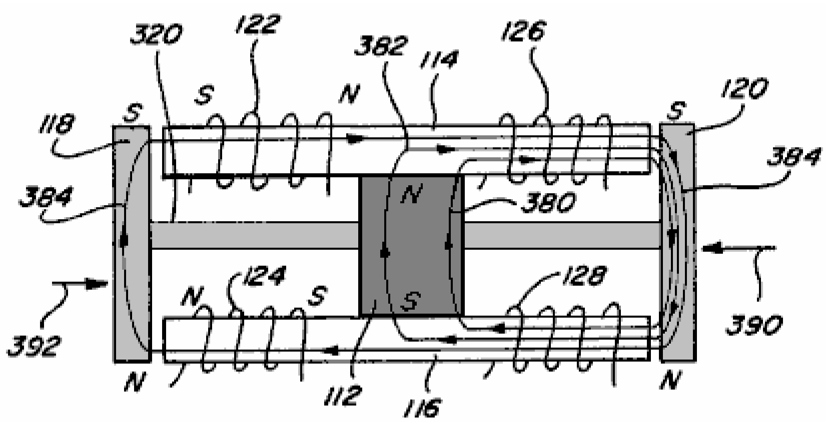


Fig. 16A

In a reciprocating device where armatures **118** and **120** are connected by shaft **320** as shown in **Figs.13A-13C** and again in **Fig.16A**, excess magnetic flux **384** will increase magnetic coupling force **390** on armature **120** acting to the left. However, because such excess flux **384** also traverses the path which includes armature **118**, such excess magnetic flux **384** also results in a magnetic coupling force **392** on armature **118** which acts to the right. Even though excess magnetic flux **384** traversing the path which includes an armature **118** has an opposite polarity to that which would traverse the path due to permanent magnet **112**, the magnetic coupling force on armature **118** still acts to the right because armature **118** is not polarity sensitive, that is, armature **118** will be attracted regardless of the direction of the magnetic flux traversing the path. The overall effect is that a resultant force which is the difference between force **390** and force **392** will act on the shaft-connected armatures **118**, **120**. However, if armatures **118** and **120** were formed by permanent magnets having polarities as shown at the top and bottom of such armatures, the force acting on each armature would be in the same direction and therefore additive.

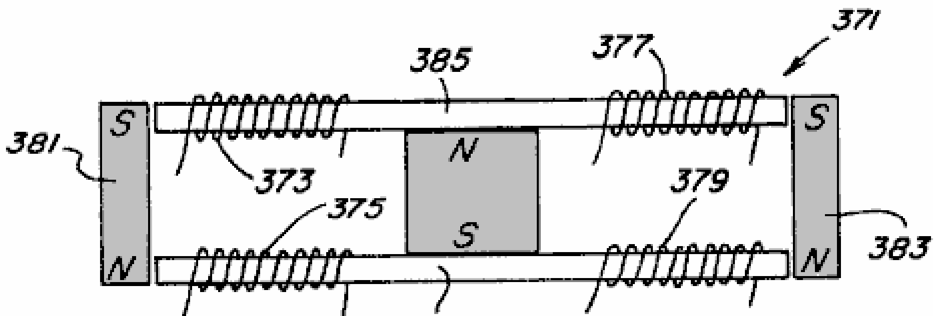


Fig. 16 B

In this regard reference is made to **Fig.16B** in which a two path device **371** having four control coils **373**, **375**, **377** and **379** is shown with the illustrated armatures being formed by permanent magnets **381** and **383** having polarities as shown. With no coils energised both permanent magnet armatures **381** and **383** are attracted to the ends of pole pieces **385** and **387**. With coils **373**, **375** energised in an opposing manner and coils **377**, **379** energised in an aiding manner, the attractive force on permanent magnet armature **383** will generally increase and the attractive force on permanent magnet armature **381** will generally decrease.

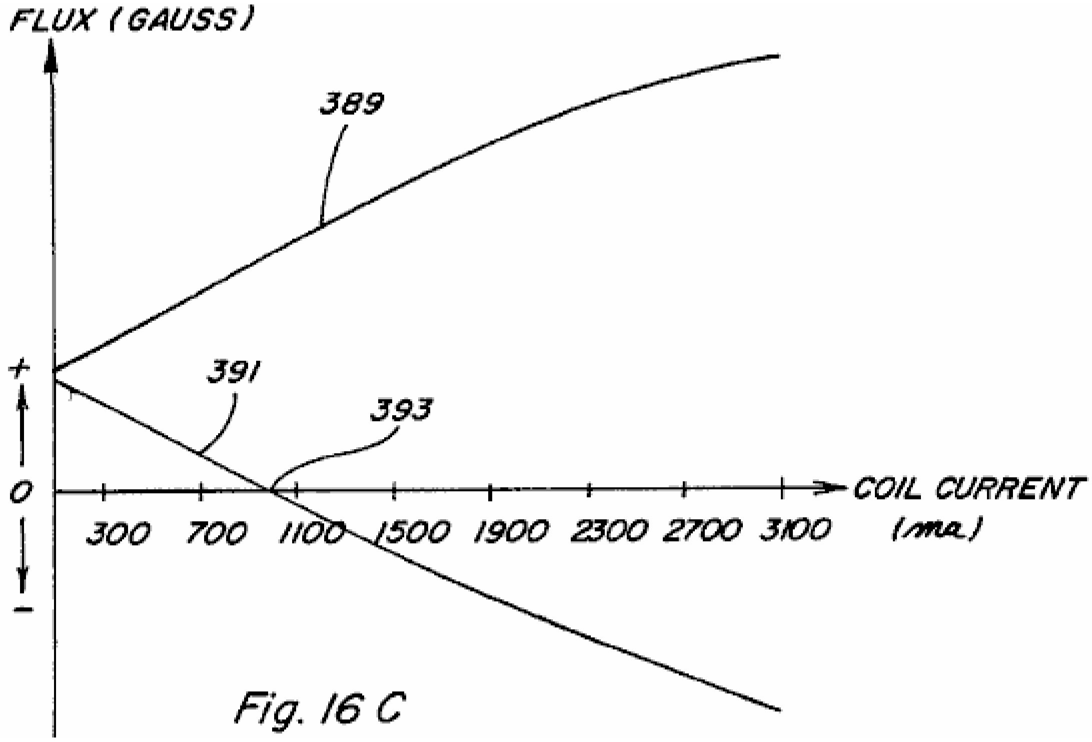


Fig. 16 C

This is demonstrated with reference to the graph of **Fig.16C** which depicts a graph of the current flowing in the control coils on the x-axis verses the magnetic flux in gauss on the y-axis with line **389** representing the flux along the aiding side of device **371** and line **391** representing the flux along the opposing side of device **371**. As shown, the magnetic flux on the coil opposing side decreases as the coil current increases and passes through zero at point **393**. After point **393**, reverse magnetic flux begins to be produced and would result in a repelling force on permanent magnet armature **381**. In some applications, particularly those where permanent magnet armatures and rotors are not utilised, it is critical to recognise point **393** so that reverse magnetic flux is not produced.

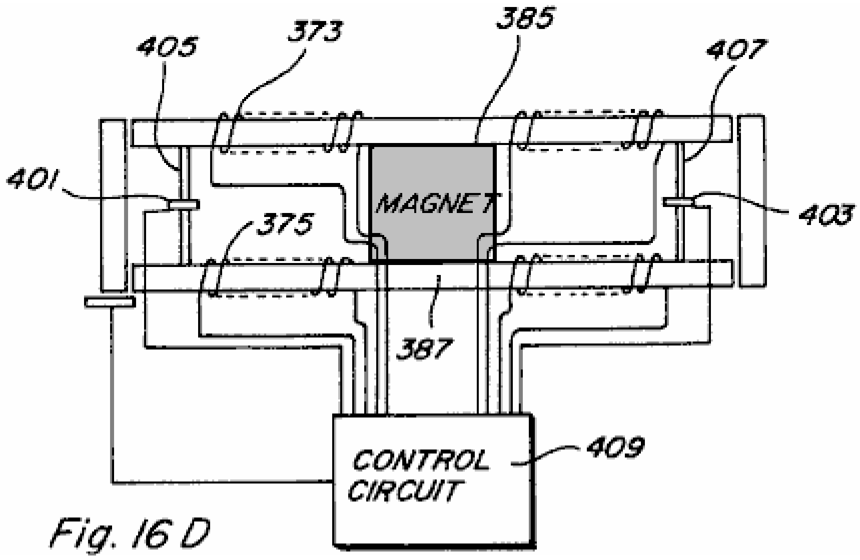


Fig. 16 D

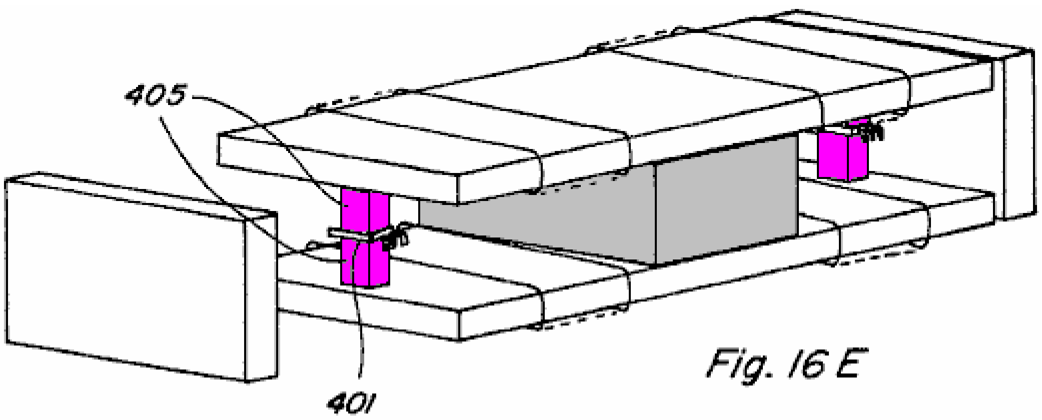


Fig. 16 E

In this regard, reference is made to **Fig.16D** and **Fig.16E**, in which use of Hall Effect switches **401** and **403** is made to enable control of the coil energising current in situations where it is desirable to prevent reverse magnetic flux. As shown, small bypasses **405** and **407** are provided with Hall Effect switches **401** and **403** positioned in gaps along them, the switches being connected to control circuit **409**. As the flux travelling along the bypass path falls to zero, the Hall Effect switch can be utilised to prevent further energisation of the control coils so that no reverse flux is created.

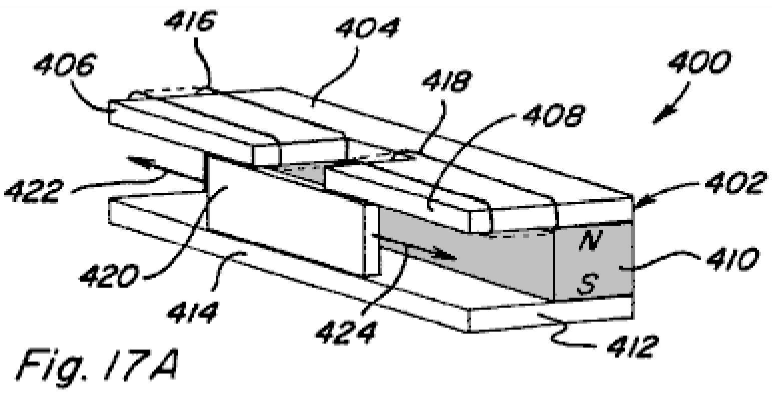


Fig. 17A

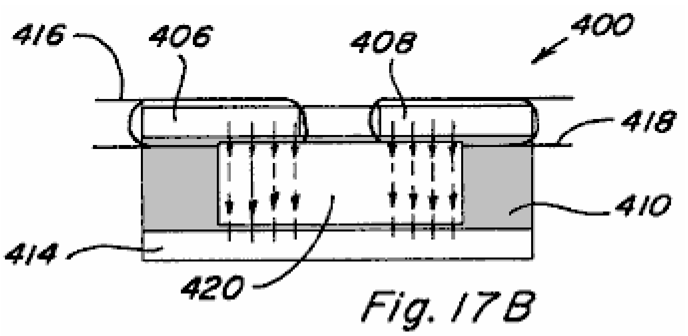


Fig. 17B

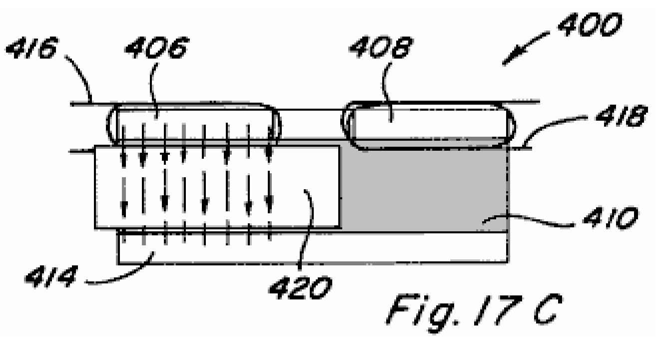


Fig. 17 C

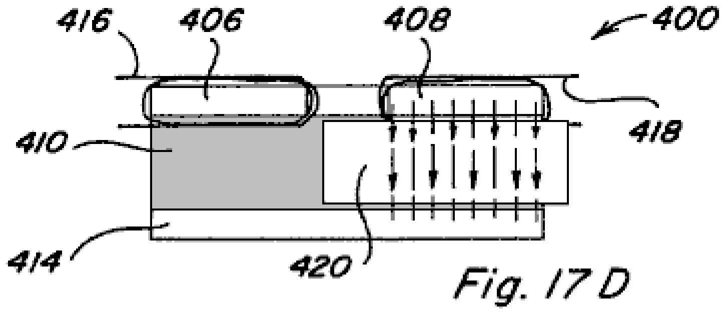


Fig. 17D

Another embodiment of a device **400** which would provide reciprocating motion is shown in **Figs.17A-17D** in which a permanent magnet control component **402** having two flux paths may is provided. A first pole piece **404**, has two spaced, adjacent path portions **406** and **408** extending beyond the perimeter of the pole face of permanent magnet **410**, and a second pole piece **412** includes only one continuous portion **414** extending beyond the perimeter of the pole face of permanent magnet **410**, each path portion **406** and **408** of pole piece **404** being substantially aligned with at least a part of portion **414** of pole piece **412**. Control coil **416** is positioned along pole piece path portion **406** and control coil **418** is positioned along pole piece portion **408**. An armature **420** is positioned in the region between pole piece path portions **404**, **406** and pole piece portion **414** and is free to slide from side to side as shown by arrows **422** and **424**.

A front view of component device **400** with no coils energised and armature **420** at a mid-point depicts flux flowing from the north pole face of permanent magnet **410**, through each of pole piece path portions **406** and **408**, through armature **420**, and returning to the south pole face through pole piece portion **414**. Thus, the magnetic flux divides equally along two paths. If coil **416** is energised in an aiding manner, or if coil **418** is energised in an opposing manner, all or a majority of the magnetic flux of the permanent magnets can be made to flow through pole piece portion **406** so that a resulting magnetic coupling force on armature **420** causes it to move to the left as shown in **Fig.17C**.

Likewise, if control coil **416** is energised in an opposing manner, or if control coil **418** is energised in an aiding manner, all or a majority of the permanent magnet flux can be made to flow through pole piece path portion **408** such that a resulting magnetic coupling force on armature **420** causes it to move to the right as shown in **Fig.17D**. Accordingly, by alternately energising and de-energising coils **416** and **418** a reciprocating motion of armature **420** may be achieved.

Linear Motion

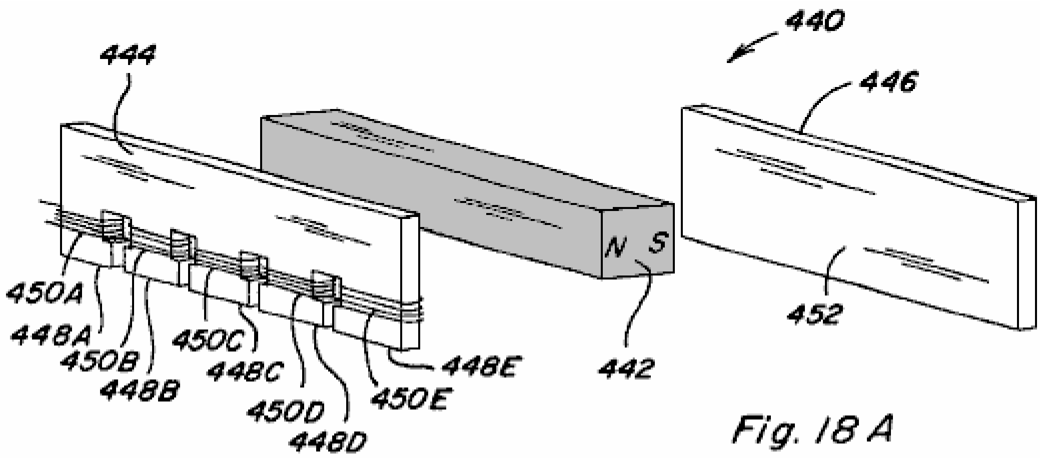


Fig. 18A

Referring now to **Figs.18A-18E**, linear motion in accordance with the present invention is described. In particular, a permanent magnet control component **440** including a permanent magnet **442** with a pole piece **444** positioned against it's north pole face and a pole piece **446** positioned against it's south pole face is shown in an exploded view in **Fig.18A** and assembled in **Fig.18B**.

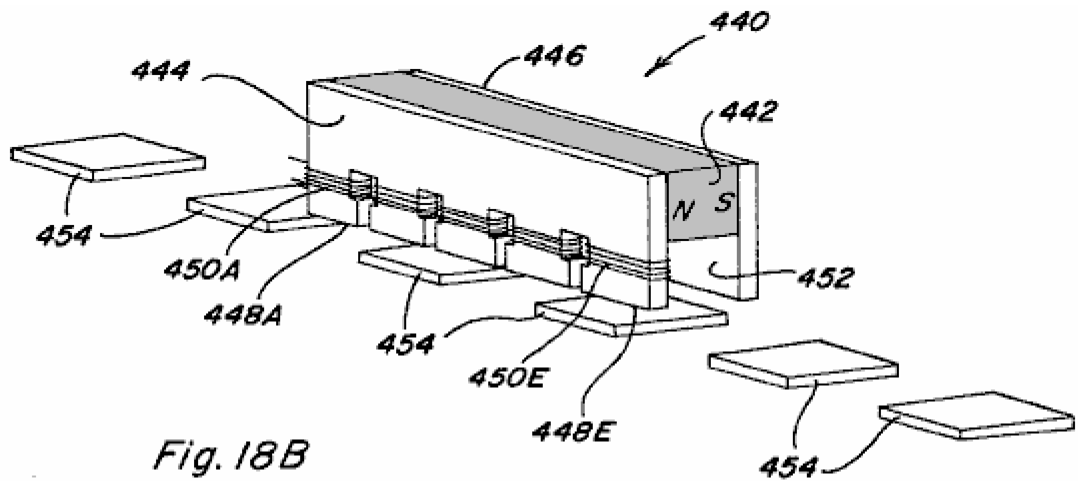


Fig. 18B

Pole piece **444** includes five path portions **448A-448E** which extend beyond the edge of the north pole face of permanent magnet **442** to one side of it and at respective positions along it's length, and it has path portion **448A-448E** each with a control coil **450A-450E** positioned around them. Pole piece **446** includes one portion **452** extending beyond the edge of the south pole face of permanent magnet **442** to the one side of it, and this portion **452** extends along the entire length of permanent magnet **442**. A number of armatures **454** define a path of relative movement between permanent magnet control component **440** and such armatures **454**, and by providing timed energisation of given control coils **450A-450E** such relative movement can be achieved.

Fig. 18C

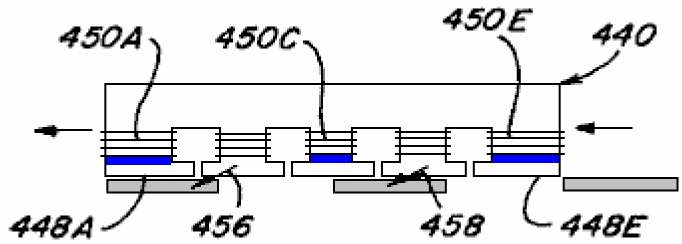


Fig. 18D

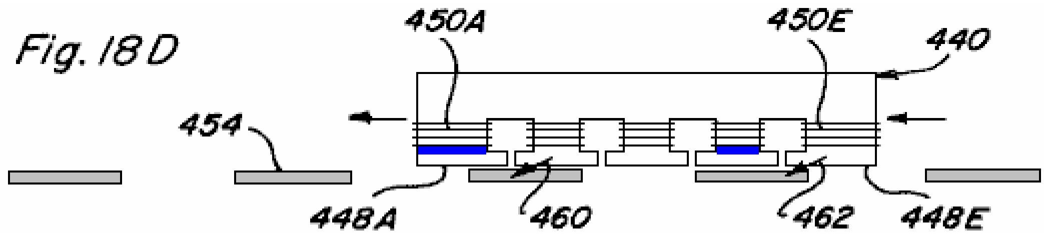
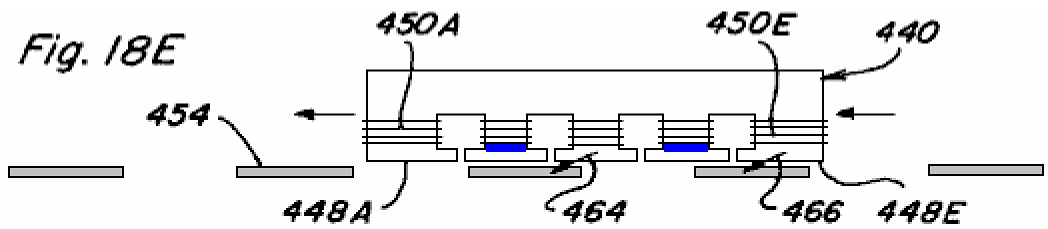


Fig. 18E

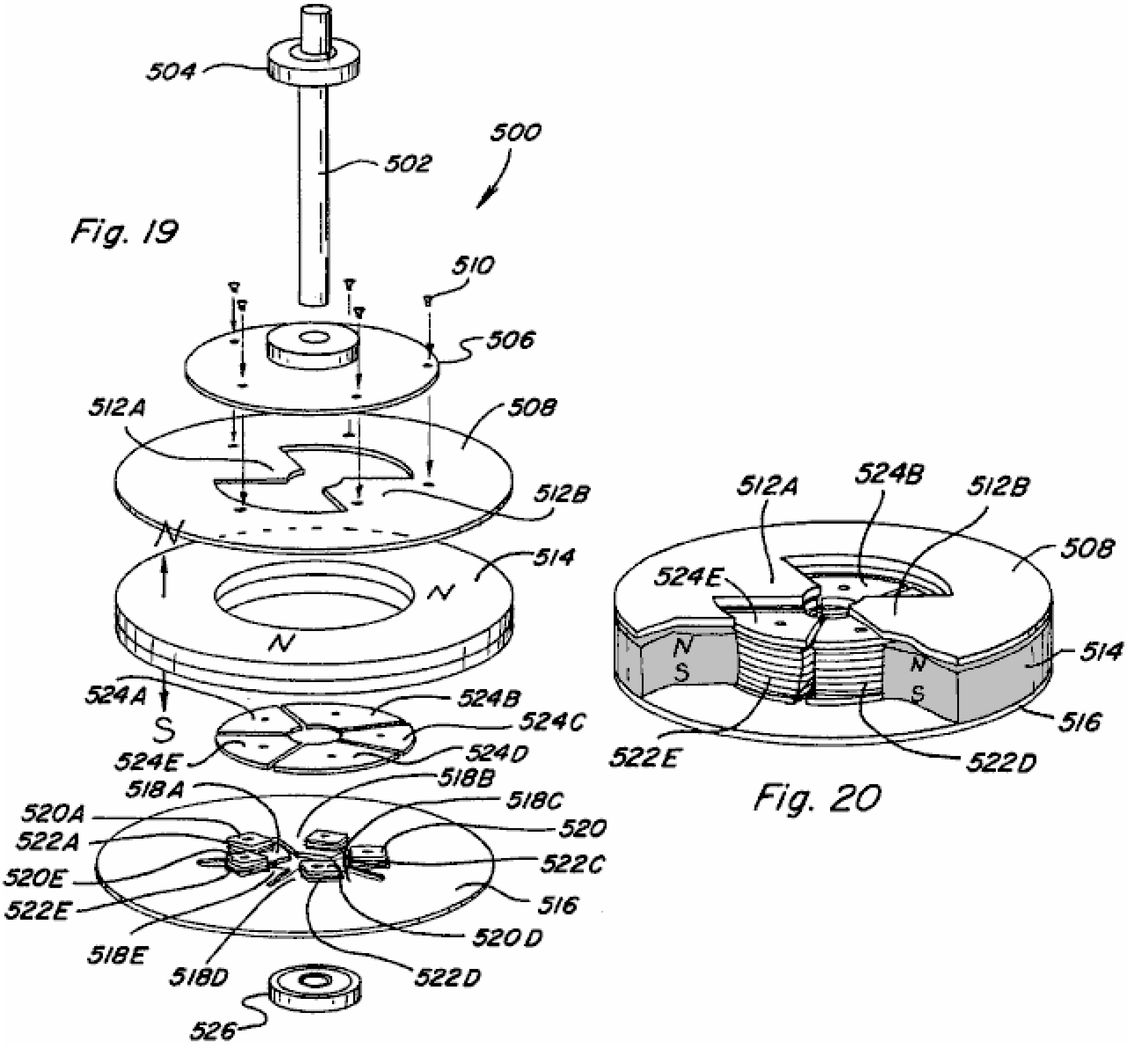


The sequence of side views depicted in **Figs.18C-18E** illustrate such relative movement,
with coils **450A**, **450C** and **450E** being **energised** in an opposing manner simultaneously in **Fig.18C**,
with coils **450A** and **450D** being **energised** simultaneously in an opposing manner in **Fig.18D**, and
with coils **450B** and **450D** being **energised** simultaneously in an opposing manner in **Fig.18E**.

In **Fig.18C**, magnetic flux will only flow along path portions **448B** and **448C** of pole piece **444** causing resultant magnetic coupling forces depicted by arrows **456**, **458** which act to move permanent magnet control component **440** to the left, assuming armatures **454** are fixed. Similarly, due to the timing of subsequent coil energisation resultant magnetic forces depicted by arrows **460**, **462** in **Fig.18D** and arrows **464**, **466** in **Fig.18E** act to continue movement of permanent magnet control component **440** to the left.

Thus, if permanent magnet control component **440** were fixed to a device or structure, controlled movement of the device or structure along the path defined by armatures **454** could be achieved. Conversely, if permanent magnet control component **440** were fixed and armatures **454** were located on a device or structure, controlled movement of the device or structure could also be achieved. It is also easily recognised that by varying the coil energisation sequence and timing relative movement in the opposite direction can be achieved. Further, if the permanent magnet was doughnut shaped and the armatures were arranged in a circumferential pattern, rotary motion would likewise be achievable.

Rotary Motion



One embodiment of a rotary motion device or motor **500** which incorporates various permanent magnet flux control aspects of the present invention is shown in the exploded view of **Fig.19** and in the partial assembled view of **Fig.20**. Motor **500** includes a rotor assembly which includes a shaft **502** and associated upper bearing **504**, a non-magnetic disk member **506** mounted for rotation with shaft **502**, and a rotor pole piece **508** which is mounted for rotation with disk member **506** such as by the use of screws **510**. Rotor pole piece **508** includes a ring-shaped portion having two inwardly extending magnetic flux path portions **512A** and **512B**. A stator assembly of motor **500** includes a doughnut or ring-shaped permanent magnet **514** having an upwardly directed north pole face positioned adjacent and in close proximity to rotor pole piece **508**, and a downward directed south pole face positioned adjacent and in contact with a stator pole piece **516**. Stator pole piece includes a ring-shaped portion having five inwardly projecting path portions **518A-518E**. Each path portion includes a respective winding post **520A-520E** extending therefrom and having a respective control coil **522A-522E** wound on it. Stator pole piece faces **524A-524E** are which can be positioned on respective winding posts **518A-518B** and, as shown in the partial assembly of **Fig.20**, are substantially aligned with the top surface of permanent magnet **514** so as to be which can be positioned adjacent rotor path portions **512A** and **512B** when aligned therewith. Each of winding posts **518A-518E** and stator pole piece faces are formed of magnetic material, and although shown as separate pieces, an integral, one piece stator could be formed with similar winding posts and pole piece faces machined on it. Lower bearing **526** is also shown.

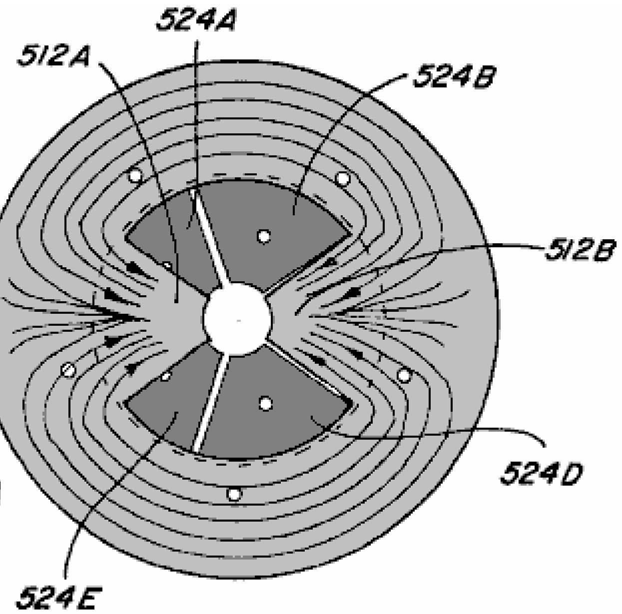


Fig. 21A

Figs.21A-21E illustrate top views of the partial assembly of **Fig.20** with magnetic flux shown. In **Fig.21A** magnetic flux travel when none of coils **522A-522E** are energised is depicted. Disregarding leakage flux, due to the low-reluctance path provided by rotor pole piece path portions **512A** and **512B**, the majority of magnetic flux from the north pole face of permanent magnet **514** will travel radially inward along one of such path portions before passing downward through the stator assembly and returning to the south pole face of permanent magnet **514**. It is noted that rotor pole piece **508** includes two path portions and stator pole piece **516** includes five path portions such that rotor pole piece path portions **512A** and **512B** will always be skewed relative to the stator pole piece faces **524A-524E**. Only one rotor pole piece path portion can directly align with a stator pole piece face at a given time. By alternately energising the control coils of each of the stator pole piece paths, rotary motion of the rotor may be achieved.

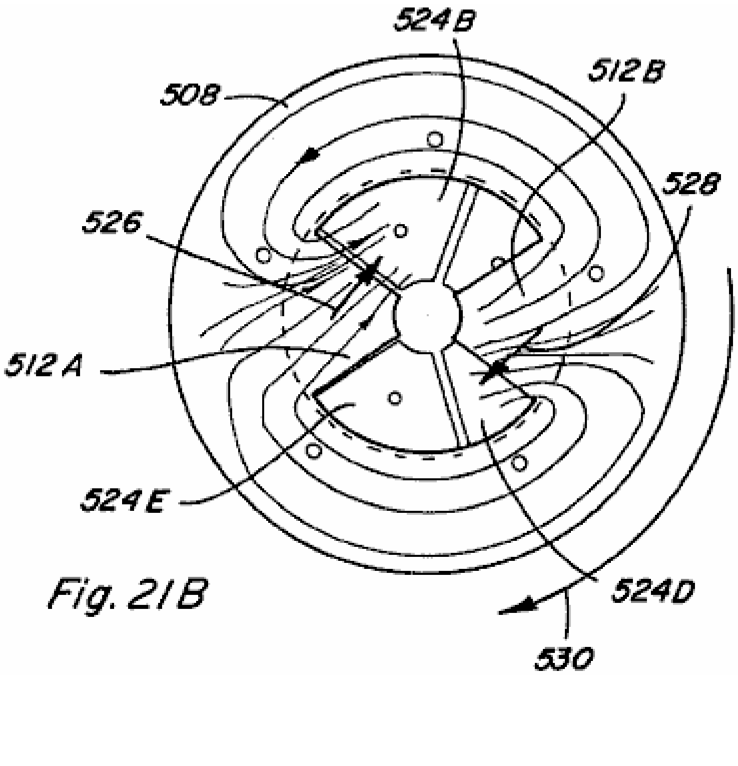


Fig. 21B

In particular, referring to **Figs.21B-21D**, an energising sequence which results in such rotary motion is described. In **Fig.21B**, control coils **522A** and **522C** are energised in a permanent magnet flux opposing manner. Permanent magnet magnetic flux travelling along rotor pole piece path portion **512A** tends to traverse to stator pole piece face **524B** causing a magnetic coupling force indicated by arrow **526**. Likewise, permanent magnet flux travelling along rotor pole piece path portion **512B** tends to traverse to stator pole piece face **524D** causing a magnetic coupling force indicated by arrow **528**. The result is rotation of rotor pole piece **508** in a clockwise direction as indicated by arrow **530**.

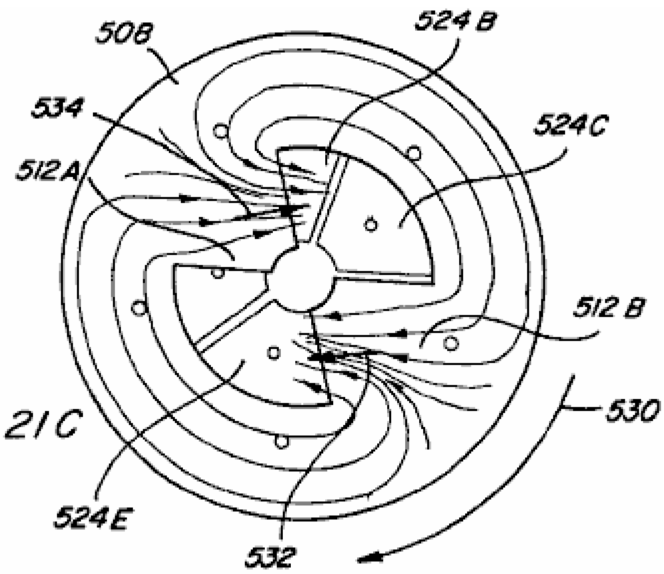


Fig.21C

Referring to **Fig.21C**, just after rotor pole piece path portion **512B** is no longer aligned with stator pole piece face **524D**, control coil **522C** is de-energised and control coil **522D** is energised in an opposing manner such that the permanent magnet flux travelling along rotor pole piece path **512B** tends to traverse to stator pole piece face **524E** resulting in magnetic coupling force indicated by arrow **532**. Control coil **522A** remains energised such that a magnetic coupling force indicated by arrow **534** results. Accordingly, clockwise rotation of rotor pole piece **508** is continued.

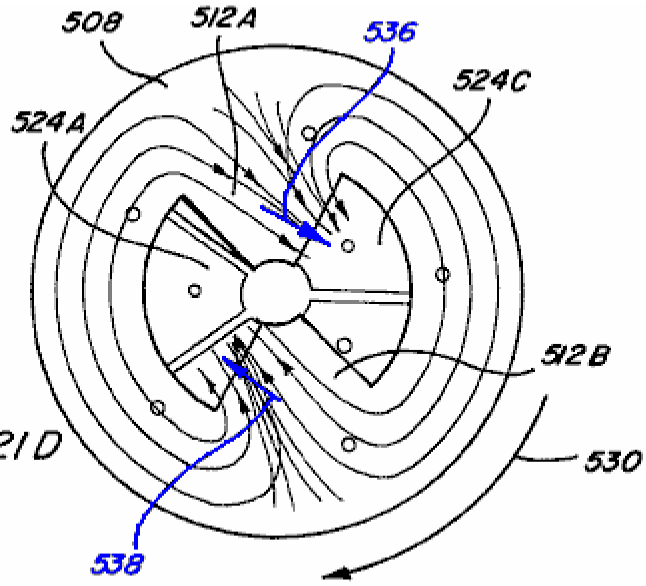


Fig. 21D

In **Fig.21D**, just after rotor pole piece path portion **512A** is no longer aligned with stator pole piece face **524B**, control coil **522A** is de-energised and control coil **522B** is energised in a permanent magnet magnetic flux opposing manner such that the permanent magnet magnetic flux travelling along rotor pole piece path **512A** tends to traverse to stator pole piece face **524C** such that a magnetic coupling force indicated by arrow **536** results. Control coil **522D** remains energised such that a magnetic coupling force indicated by arrow **538** results, and clockwise rotation of rotor pole piece **508** is continued.

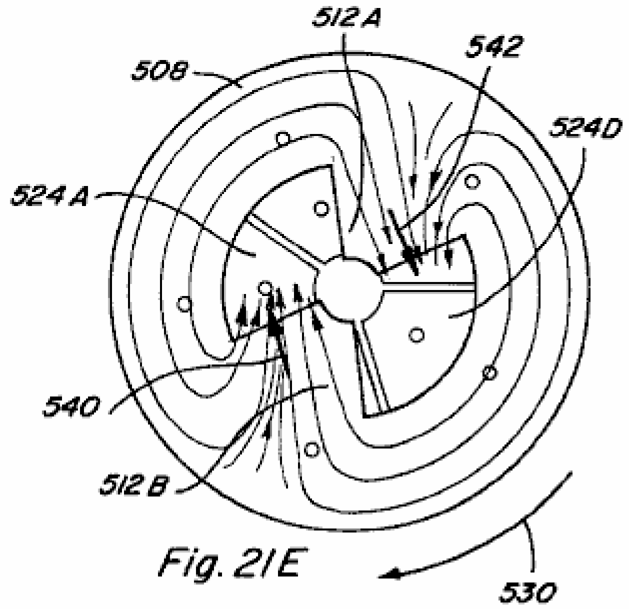


Fig. 21E

As shown in **Fig.21E**, just after rotor pole piece path portion **512B** is no longer aligned with stator pole piece face **524E**, control coil **522D** is de-energised and control coil **522E** is energised in a permanent magnet magnetic flux opposing manner such that the permanent magnet magnetic flux travelling along rotor pole piece path **512B** tends to traverse to stator pole piece face **524A** such that a magnetic coupling force indicated by arrow **540** results. Control coil **522B** remains energised such that a magnetic coupling force indicated by arrow **542** results, and clockwise rotation of rotor pole piece **508** is continued.

Thus, by alternating energising and de-energising control coils **522A-522E**, in a predetermined timed sequence based upon rotation of the rotor assembly, continued rotation movement of rotor pole piece **508** may be achieved. Such an energisation/de-energisation scheme can be achieved utilising circuitry common in the art, such as the control circuitry described in Applicant's U.S. Pat. Nos. 5,463,263 and 5,455,474, as well as various of the circuit configurations described below.

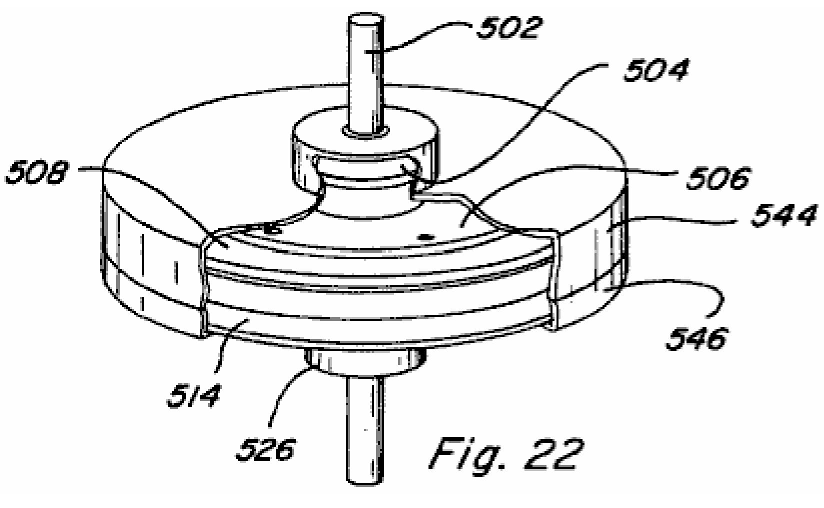


Fig. 22

Referring now to **Fig.22**, an assembled view of rotary motor **500** is shown including a housing or cover formed by an upper housing member **544** and a lower housing member **546**, with portions of each housing member cut away to expose motor structure described above. It is recognised that such housing members **544** and **546** should be constructed from a non-magnetic material, and likewise that motor shaft **502** and bearings **504**, **526** should be constructed from a non-magnetic material.

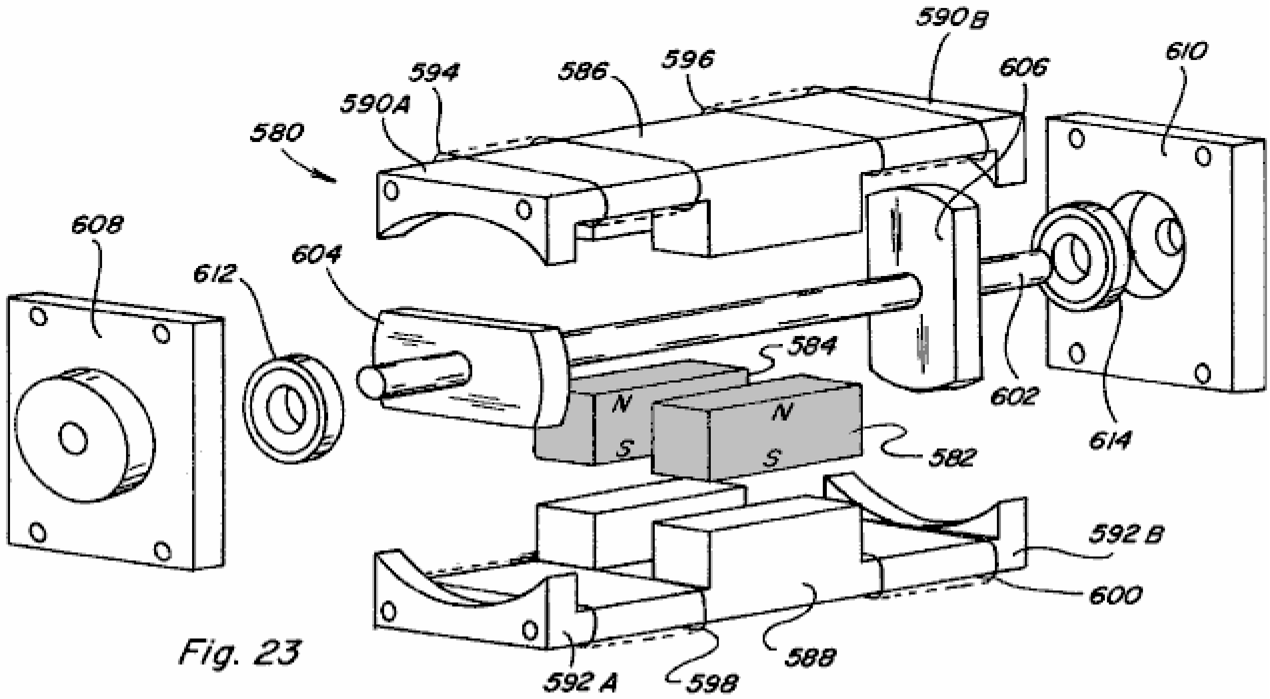


Fig. 23

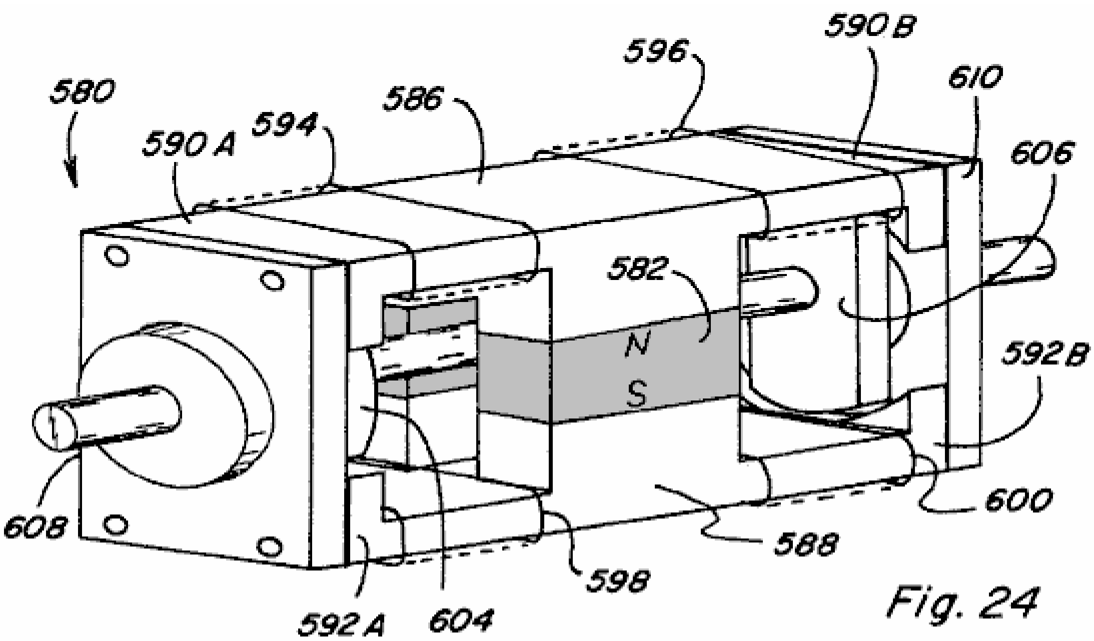


Fig. 24

In another embodiment, a rotary motion device or motor **580** in accordance with the present invention is shown in an exploded perspective view in **Fig.23** and in an assembled perspective view in **Fig.24**. Two spaced permanent magnets **582** and **584** are positioned between stator pole pieces **586** and **588**. Stator pole piece **586** includes two path portions **590A** and **590B** extending away from permanent magnets **582**, **584** in opposite directions. Likewise, stator pole piece **588** includes two path portions **592A** and **592B** extending away from permanent magnets **582**, **584** in opposite directions and which can be aligned with stator pole piece path portions **590A** and **590B**. Control coils **594**, **596**, **598**, and **600** are each positioned along a stator pole piece path portion as shown. A non-magnetic shaft **602** includes a pair of matching elongated rotor members **604** and **606**, formed of magnetic material, mounted at spaced locations on the shaft and being set at an angle to each other, shaft **602** passing between spaced permanent magnets **582** and **584**. Two end cap members **608** and **610**, made from non-magnetic material, are attached to the ends of stator pole pieces **586** and **588** and are configured for receiving shaft **602** and respective bearings **612** and **614**.

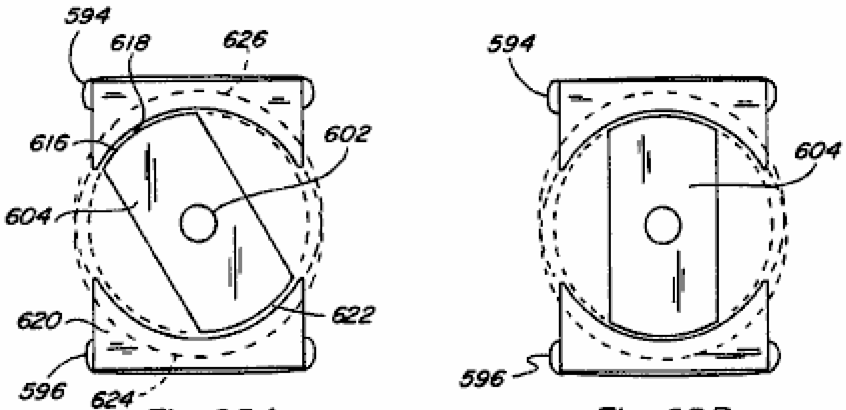


Fig. 25A Fig. 25B

The ends of the stator pole pieces **506** and **508** are configured for a given desired coupling relationship with rotor members **604** and **606**. For example, as shown in the exemplary end views of **Fig.25A** and **Fig.25B**, with end cap **608** removed, the end of stator pole piece **586** may include an curved portion **616** which is configured to create a variable-reluctance air gap **618** with elongated rotor member **604**. The end of stator pole piece **588** includes an curved portion **620** which is also configured to create a variable-reluctance air gap **622** with rotor member **604**.

In particular, portion **618** includes a circumferential curvature which has a centre point offset below the axis of rotation of shaft **602** and rotor member **604** as indicated by circle **624** shown in shadow. Similarly, portion **620** includes a circumferential radius of curvature which has a centre point offset above the axis of rotation of shaft **602** and rotor member **604**. When magnetic flux is passing along the path which includes a given end of the assembly, maximum coupling between the rotor member and stator pole pieces occurs when the rotor is positioned as shown in **Fig.25B**. Accordingly, the illustrated rotor member and stator pole piece configurations of themselves do not provide any skewing to the direction of rotation of the rotor assembly.

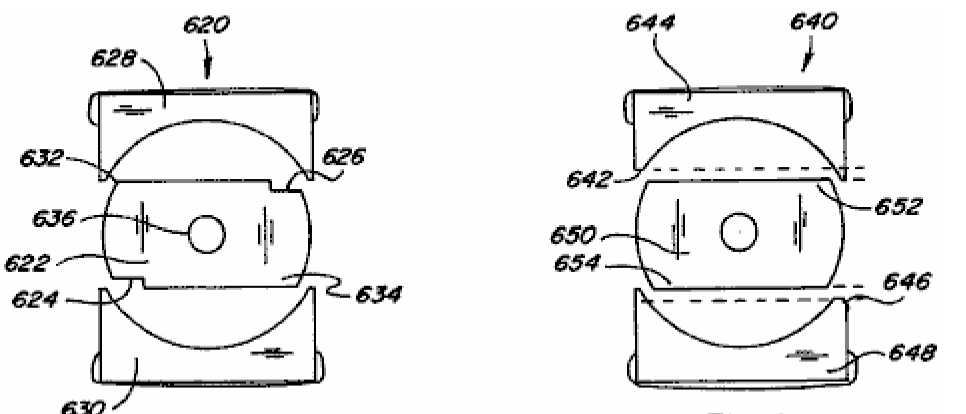


Fig. 26 Fig. 27

In this regard, various configurations for the rotor and ends of the stator pole pieces are shown in the end views of **Figs.26-28**, which configurations provide skewing the direction of rotation. In particular, in device **620** of **Fig.26** a rotor member **622** having notches **624** and **626**, which notches provide for greater magnetic coupling with the stator pole pieces **628** and **630** at corners **632** and **634** such that rotation is skewed in the clockwise direction. If notches were instead located at corners **632** and **634**, skewed rotation in the counterclockwise direction would be the result. In device **620** such counterclockwise rotation could also be achieved by removing rotor **622** from shaft **636**, flipping it end to end, and replacing it on shaft **636**.

In the device **640** of **Fig.27**, a portion **642** of the curved end portion of stator pole piece **644** is removed and a portion **646** of the curved end portion of stator pole piece **648** is removed. This configuration results in greater magnetic coupling between rotor member **650** and stator pole piece **644** at corner **652**, and greater magnetic coupling between rotor member **650** and stator pole piece **648** at corner **654**, such that rotation is skewed in the counterclockwise direction. Clockwise rotation could be achieved by instead modifying the opposite side of stator pole pieces **644** and **648**.

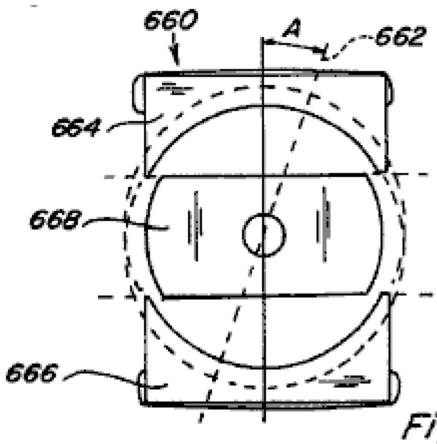


Fig. 28

Fig.28 depicts an end view of a device **660** in which the axis **662** of the curved end portion of upper stator pole piece **664** and lower stator pole piece **666** is placed at an angle **A** as shown. This configuration creates an unequal variable-reluctance air gap where opposite corners of rotor member **668** are closer to stator pole pieces **664** and **666**. Further, the angle at which maximum magnetic coupling between rotor member **668** and stator pole pieces **664** and **666** occurs is retarded by angle **A**. Rotation would be in the counterclockwise direction for the illustrated configuration.

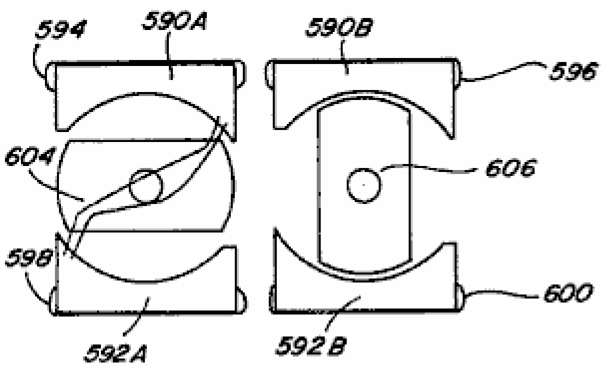


Fig. 29A

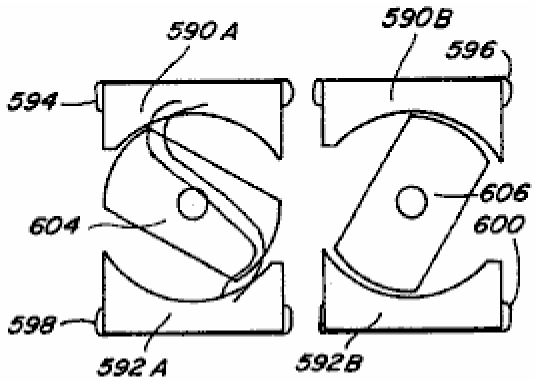


Fig. 29B

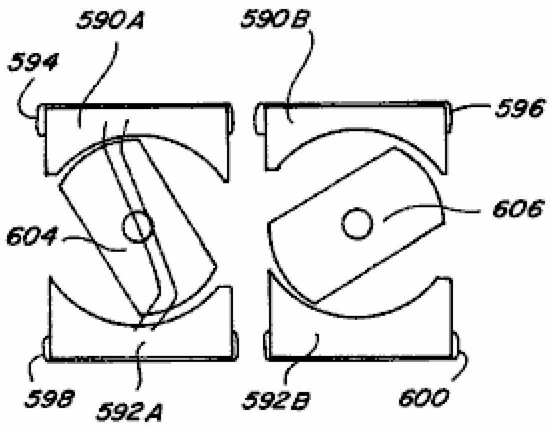


Fig.29C

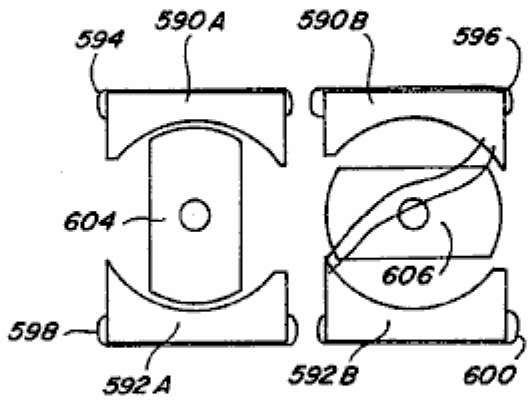
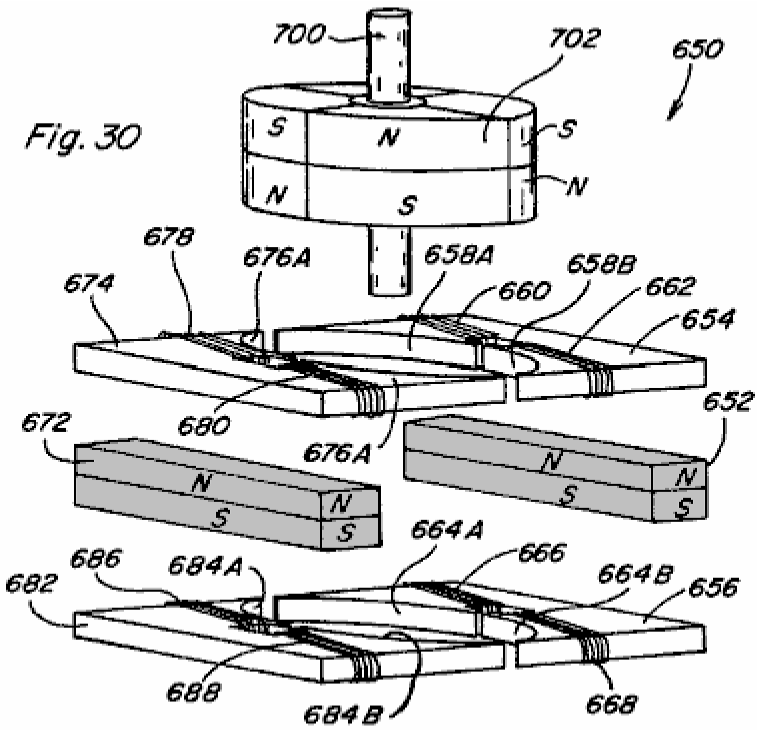


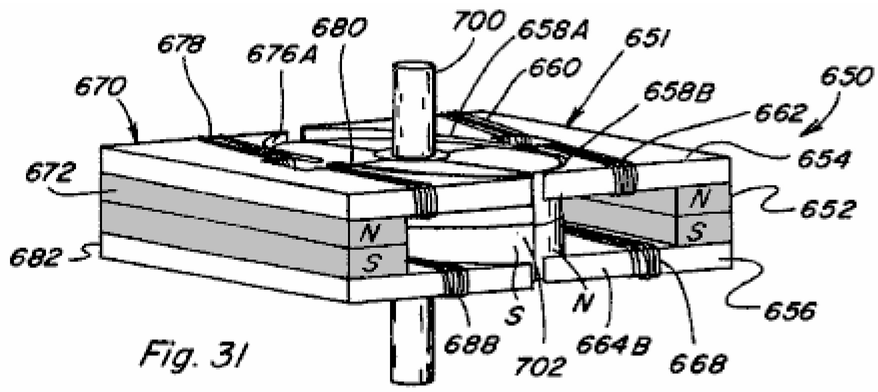
Fig.29 D

Referring again to motor **580** of **Figs.23-25**, rotary motion of such device is depicted in the end views of **Figs.29A-29D**. In each end view the end cap has been removed to show rotation of the rotor members and in each of **Figs.29A-29D** an end view depicting rotor member **604** and an end view depicting rotor member **606** are shown side-by-side. In **Fig.29A**, rotor member **604** is defined as being at zero degrees and rotor member **606** is defined as being at ninety degrees. Control coils **594**, **598** are energised in a permanent magnet magnetic flux aiding manner such that no magnetic flux passes through stator pole piece path portions **590B** and **592B**. This allows rotor member **606** to move out of its ninety degree position and the magnetic coupling between rotor member **604** and stator pole piece path portions **590A** and **592A** will cause rotation to the position shown in **Fig.29B** and then **Fig.29C**. When rotor member **604** reaches the ninety degree position shown in **Fig.29D** control coils **594**, **598** are de-energised and control coils **596**, **600** are energised in a permanent magnet magnetic flux aiding manner causing rotation to continue due to the magnetic coupling between rotor member **606** and stator pole piece path portions **590B** and **592B**. Thus, by alternately energising the control coils of each path with every ninety degree rotation of rotor members **604** and **606**, continuous rotary motion is achieved.

The initial direction of rotation can be controlled by the circuit means used to energise control coils **594**, **598** and **596**, **600**, which circuit means includes circuitry for detecting the angular position of the rotor members. In particular, if rotor members **604** and **606** are at rest in the position shown in **Fig.29A**, and coils **594**, **598** are energised in an aiding manner, rotation may be clockwise or counterclockwise. If the desired direction is clockwise but upon energisation of coils **594**, **598** the rotor members begin to move counterclockwise, the detection circuitry will immediately de-energise coils **594**, **598** and energise coils **596**, **600** so that the clockwise direction is achieved.

Further, bypasses around permanent magnets **582** and **584** could be provided in rotary motion device **580**, such as those shown in **Fig.12**, and rotor members **604** and **606** could be formed by permanent magnets so as to take advantage of energising the control coils in an exceeding manner.





A third embodiment of a rotary motion device or motor **650** is shown in the exploded partial perspective view of **Fig.30** and in the assembled partial perspective view of **Fig.31**. In motor **650** the stator assembly includes a control component **651** including a permanent magnet **652** having a stator pole piece **654** positioned adjacent to one pole face of the magnet and a stator pole piece **656** positioned adjacent to the opposite pole face. Stator pole piece **654** includes a path portion **658A** extending to one side of permanent magnet **652** and a path portion **658B** extending to the one side thereof and spaced from first path portion **658A**. Control coils **660** and **662** are positioned along respective stator pole piece path portions **658A** and **658B**.

In the same way, stator pole piece **656** includes path portions **664A** and **664B** which extend in a similar manner from it so as to be aligned with stator path portions **658A** and **658B** respectively. Control coils **666** and **668** are positioned along respective stator pole piece path portions **664A** and **664B**. Positioned opposite, and facing control component **651**, is a similar control component **670** including permanent magnet **672** stator pole piece **674** with path portions **676A** and **676B** having the control coils **678** and **680**, and stator pole piece **682** with path portions **684A** and **684B** having their control coils **686** and **688**. The end of each of the pole piece path portions **658A, 658B, 664A, 664B, 676A, 676B, 684A**, and **684B** is of a generally curved configuration.

A rotor assembly of motor **650** includes a non-magnetic shaft **700** having a permanent magnet rotor member **702** mounted on it and which rotates with it. Permanent magnet rotor member **702** is generally ring-shaped and segmented to include distinct north and south pole faces which reverse about every ninety degrees around them. When assembled, the top and bottom surfaces of permanent magnet rotor member **702** align with pole pieces **654, 656, 674**, and **682** of the stator assembly and are preferably configured so that there is a minimal gap between the outer surface of permanent magnet rotor member **702** and the curved surfaces of the pole piece path portions.

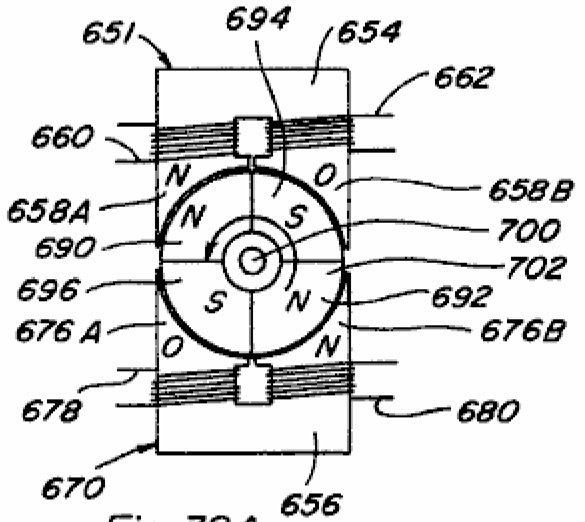


Fig. 32A

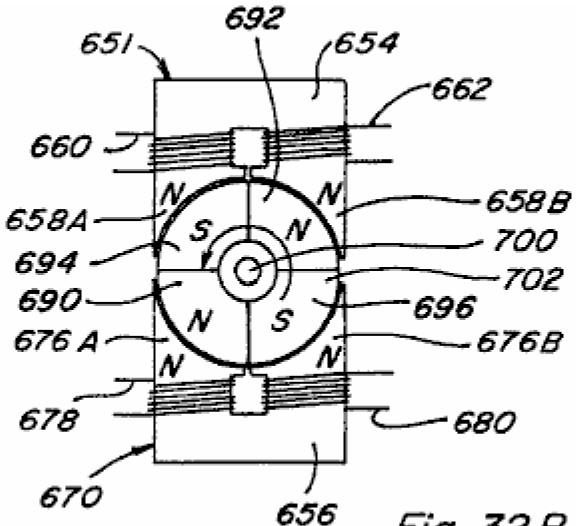


Fig. 32B

Rotation of device **650** can be achieved by controlled, timed energising and de-energising of control coils **660, 662, 666, 668, 678, 680, 686**, and **688**. Exemplary rotation is demonstrated with reference to the top views of **Figs.32A-32B** which depict counterclockwise rotation of permanent magnet rotor member **702** through one-hundred and eighty degrees. In **Fig.32A** stator pole piece path portion **658A** of component **651** is active and stator pole piece path portion **658B** is not active, which may be achieved by energising control coil **660** in a permanent magnet magnetic flux aiding manner or by energising control coil **662** in a permanent magnet magnetic flux opposing manner. Stator pole piece path portion **676B** of component **670** is active and stator pole piece path portion **676A** is not active, which may be achieved by energising control coil **680** in a permanent magnet magnetic flux aiding manner or by energising control coil **678** in a permanent magnet magnetic flux opposing manner.

Thus, portions **690** and **692** of permanent magnet rotor member **702**, which both have a north magnetic polarity, will be repelled by the north polarity of stator pole piece path portions **658A** and **676B** aligned with it. Portions **694** and **696** of permanent magnet rotor member **702**, both of which have a south magnetic polarity, will be attracted to the active path portions **658A** and **676B**. At the instant that rotor member portion **694** becomes aligned with stator pole piece path portion **658A**, as shown in **Fig.32B**, all coils are de-energised such that all pole piece path portions will be active as shown. Pole piece path portions **658B** and **676A** are then kept active while pole piece path portions **658A** and **676B** are made inactive. This is achieved by energising control coils **662** and **678** in a permanent magnet magnetic flux aiding manner or by energising control coils **660** and **680** in a permanent magnet magnetic flux opposing manner. Rotor member portions

690 and **692** will again be repelled by the north polarity of path portions **658B** and **676A** aligned with it so that rotation of permanent magnet rotor **702** is continued.

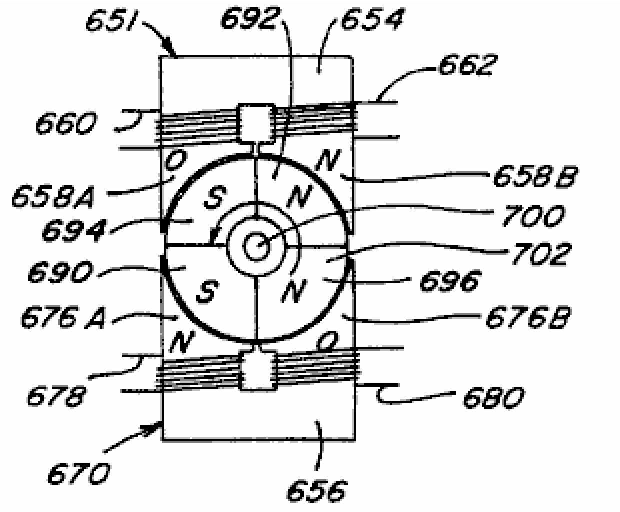


Fig. 32 C

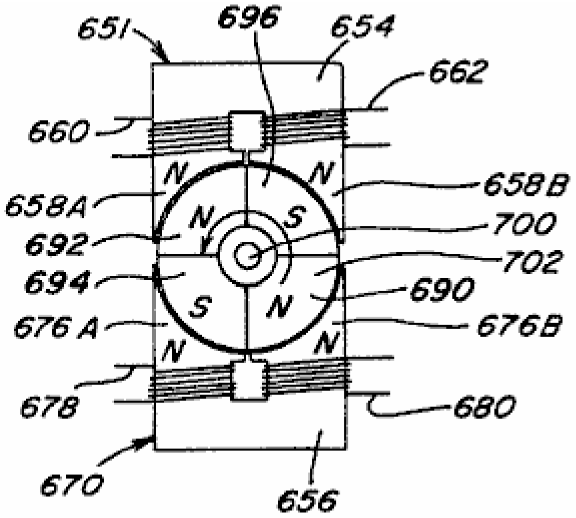


Fig. 32 D

In **Fig.32D** all coils are shown de-energised when rotor portion **692** aligns with pole piece path portion **658A**. By continuing this timed sequence of energisation and de-energisation of the control coils, continued rotary movement is achieved. As explained above, the initial direction of rotation can be controlled by circuit means which detects the initial direction of permanent magnet rotor **702** and immediately alters the coil energisation scheme if the initial direction is incorrect.

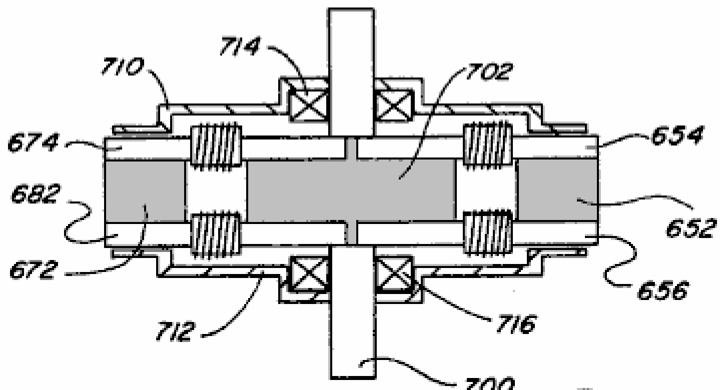


Fig. 33

A side view of assembled motor **650** is shown in **Fig.33** and includes an upper housing or enclosure portion **710**, a bottom housing portion **712**, upper bearing **714**, and a lower bearing **716**.

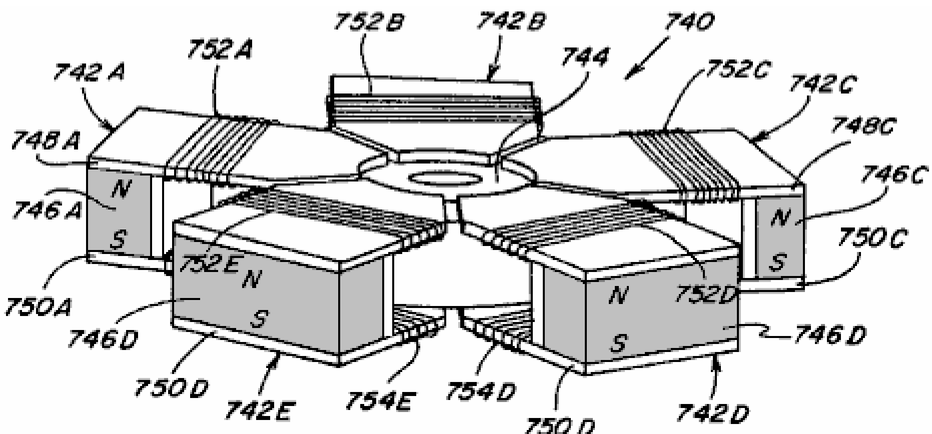


Fig. 34

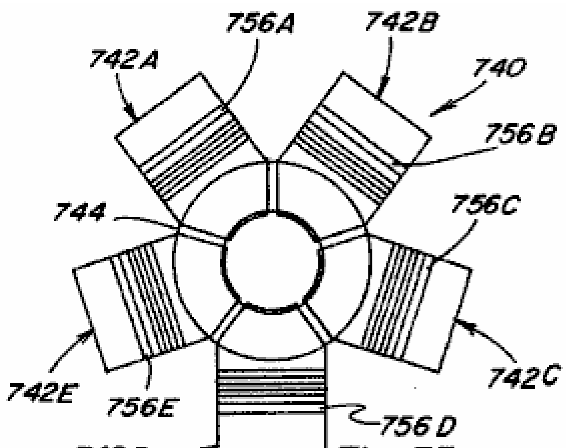


Fig. 35

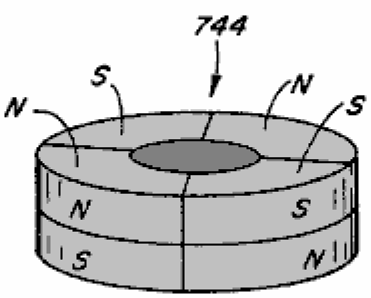


Fig. 36

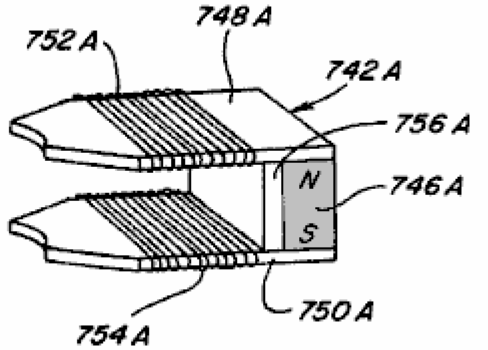


Fig. 37

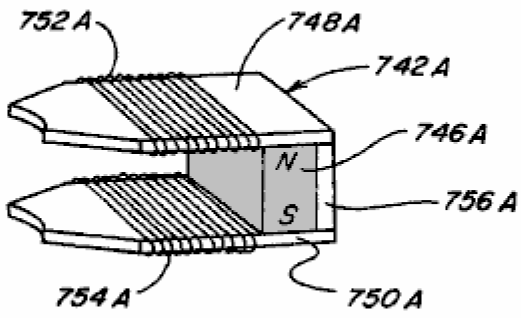


Fig. 38

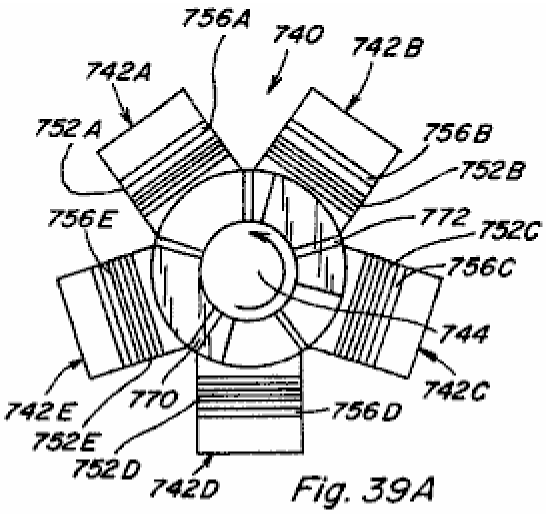


Fig. 39A

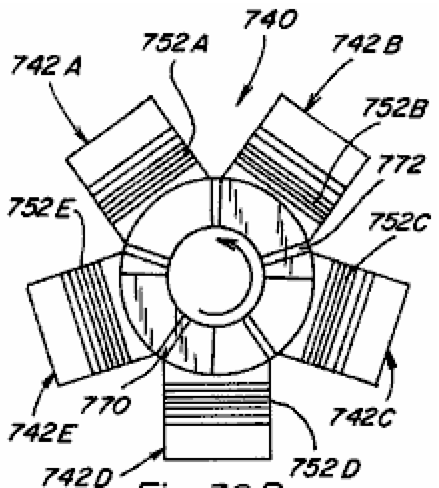


Fig. 39B

A fourth embodiment of a rotary motion device or motor **740** is illustrated in **Figs.34-39**. Motor **740** includes five stator control components **742A-742E** positioned around a ring shaped permanent magnet rotor member **744** (**Fig.36**). As shown with reference to component **742A** in **Fig.37**, each stator component **742A** includes a permanent magnet **746A** with an upper pole piece **748A** positioned adjacent to one pole face and a lower pole piece **750A** positioned adjacent to the opposite pole face. Control coils **752A**, **754A** are positioned along respective pole pieces **748A**, **750A**. A bypass **756A** extends from pole piece **748A** to pole piece **750A** and is positioned between permanent magnet **746A** and control coils **752A**, **754A**. Alternatively, bypass **756A** could be provided on the opposite side of permanent magnet **746A** as shown in **Fig.38**. Although not shown, it is anticipated that permanent magnet rotor member **744** would be mounted on an axis for rotation with it and that a motor housing or enclosure could be provided, such as shown in relation to motor **650** of **Fig.33**.

Referring to the top views of **Figs.39A-39D**, rotary motion of rotor member **744** is depicted by the sequence of views. Regions **770** and **772** in **Figs.39A-39D** represent the magnetic north regions of the top of permanent magnet rotor **744**. In **Fig.39A** control coils **752E** and **752C** are energised in a permanent magnet aiding and exceeding manner such that regions **770** and **772** of permanent magnet rotor **744** are repulsed by components **742E** and **742C** while permanent magnet motor regions **774** and **776** are attracted by components **742E** and **742C**. The resultant coupling forces act to move permanent magnet rotor in a counterclockwise direction to the location shown in **Fig.39B**. Just after permanent magnet rotor region **772** passes the point shown in **Fig.39C**, control coil **752B** is energised in a permanent magnet aiding and exceeding manner, while control coils **752E** and **752C** also remain energised, and counterclockwise rotation of permanent magnet rotor **744** is continued. Just after permanent magnet rotor region **772** passes by control component **742C** control coil **752C** is de-energised, while control coils **752E** and **752B** remain energised, so as to continue counterclockwise rotation. Then, just after permanent magnet rotor region **770** reaches the location shown in **Fig.39D** control coil **752D** is energised in a permanent magnet flux aiding and exceeding manner, while coils **752E** and **752B** remain energised, so as to continue counterclockwise rotation. Thus, as in the other embodiments, repeated and timed energisation and de-energisation of the control coils produces the desired rotational movement.

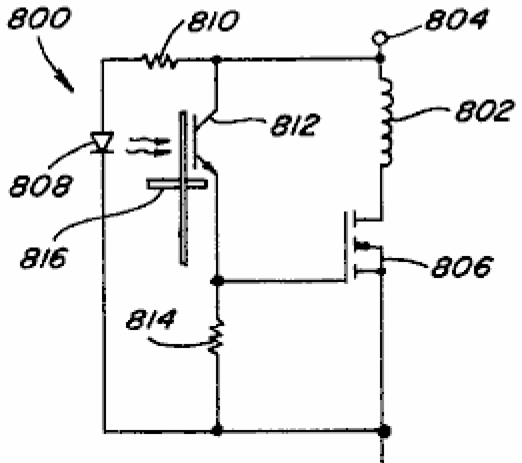


Fig. 40

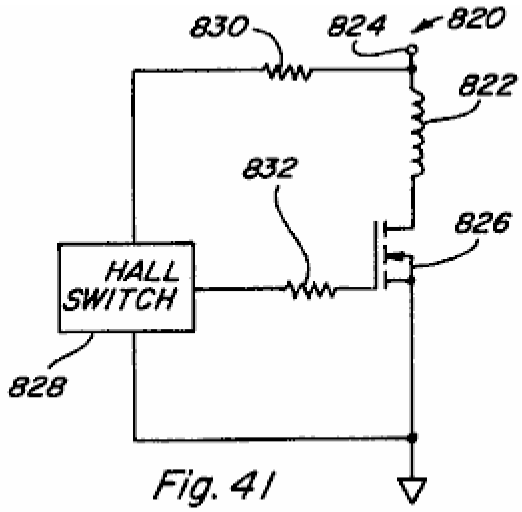


Fig. 41

In terms of controlling the energisation of coils in the devices described above, various electronic control circuit/switching means and electromechanical control circuit/switching machines are depicted in **Figs.40-44**. In circuit **800** of **Fig.40** a given coil **802** is placed in series between an electrical energy source **804** and a power MOSFET **806**. An LED **808** is connected to electrical energy source **804** through resistor **810** and is positioned to impinge upon a phototransistor **812** which is connected in series with resistor **814**. A control input of MOSFET **806** is connected between phototransistor **812** and resistor. Accordingly, when LED **808** activates phototransistor **812** the voltage drop across resistor **814** activates, or turns ON, MOSFET **806** and coil **802** is energised. Timed energisation of coil **802** is provided by mounting an interrupter **816**, such as shown in **Fig.42**, to the shaft **816** of the motor device to be controlled, such that as interrupter **814** rotates with shaft **816** coil **802** is alternately energised and de-energised. In a device with a plurality of coils a corresponding plurality of LED/photoresistor pairs may be provided.

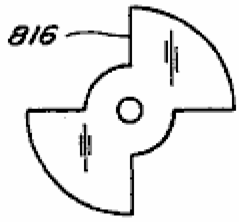


Fig. 42

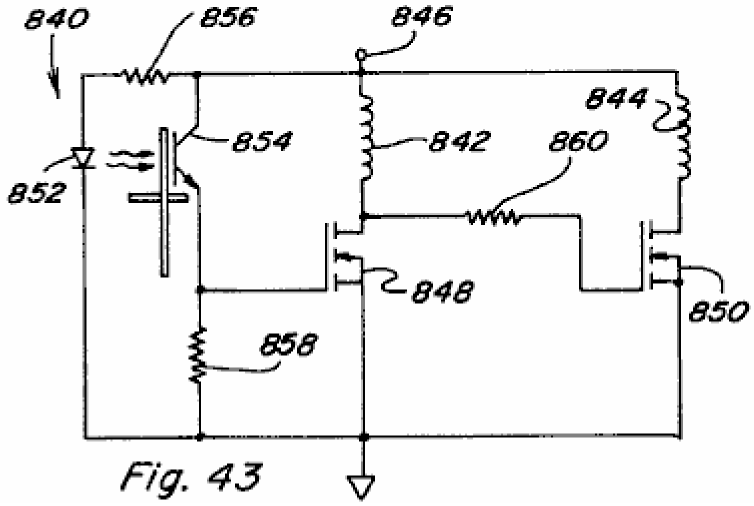


Fig. 43

In circuit **820** of **Fig.41** a coil **822** is positioned between electrical energy source **824** and power MOSFET **826**. A hall switch **828** is connected in series with resistor **830**. Hall switch **828** is also connected to the control input of MOSFET **826** through resistor **832**. In a given device hall switch **828** would be positioned to react to a change in magnetic flux so as to control the ON/OFF switching of MOSFET **826**, and thus the alternate energisation and de-energisation of coil **822**.

In **Fig.43** a circuit **840** for controlling two coils in an opposite manner is provided such that when coil **842** is energised coil **844** is de-energised, and such that when coil **842** is de-energised coil **844** is energised. Both coils **842** and **844** are connected in series between electrical energy source **846** and respective power MOSFETs **848** and **850**. An LED **852** and phototransistor **854** arrangement is provided, LED connected in series with resistor **856** and phototransistor connected in series with resistor **858**. When LED **852** turns phototransistor **854** ON the voltage drop across resistor **858** turns MOSFET **848** ON and coil **842** is energised. At that time the voltage applied at the control input of MOSFET **850** will be low and therefore MOSFET **850** will be OFF and coil **844** will be de-energised. When interrupter **814** blocks LED 852, phototransistor **854** is turned OFF and MOSFET **848** is likewise turned OFF. The control input of MOSFET **850** is therefore pulled high through resistor **860** and MOSFET **850** is turned ON such that coil **844** is energised.

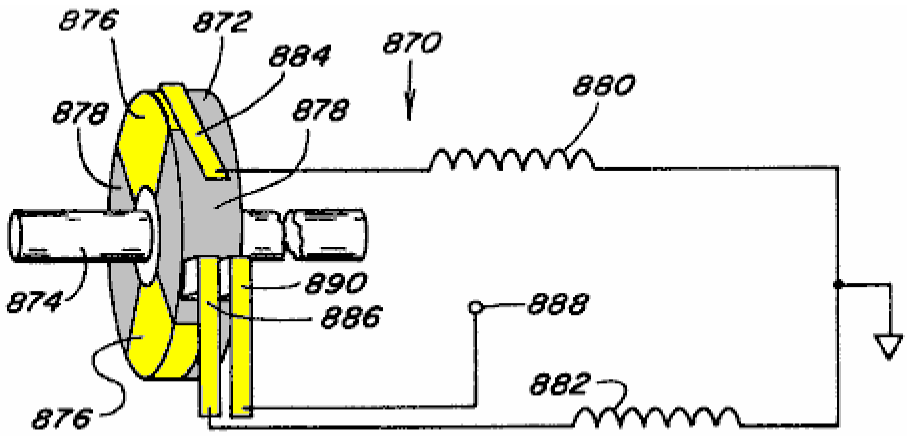


Fig. 44

In **Fig.44** a system **870** including member **872** mounted on rotating shaft **874** is provided, with the left side of member **872** being alternately conductive at **876** and non-conductive at **878**. Coils **880** and **882** are connected to respective brushes **884** and **886** which are positioned to contact member **872** during each rotation of the shaft. Member **872** is connected through brush **890** to power supply **888**. Thus, coils **880** and **882** will alternately be energised and de-energised as the respective brushes thereof contact the conductive and non-conductive portions of member **872**.

Any of such circuit means, variations thereof, or other circuit means may be used to provide the timed energisation of the control coils in the various embodiments of the present invention.

From the preceding description of the illustrated embodiments, it is evident that the objects of the invention are attained. Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is intended by way of illustration and example only and is not to be taken by way of limitation.

For example, although the magnetic flux control techniques of the present invention have been discussed as applicable mainly to various motive applications, such magnetic flux control techniques are also useful in static applications.

Power Conversion

Referring to **Figs.45A-45C** there is shown the permanent magnet device **900** of **Figs.45A-45C** which has two magnetic flux paths provided by rectangular pole piece **902** which includes upper portion **904** and lower portion **906** each positioned against a respective pole face of permanent magnet **910**. Unlike the device of **Figs.7-9**, fall away armatures are not provided. Instead, fixed armatures in the form of integral pole piece portions **912** and **914** extend from upper portion **904** to lower portion **906** completing the two flux paths in a permanent manner. Control coils **916**, **918** are provided along one flux path and control coils **920**, **922** are provided along the other flux path, such control coils acting as primary windings in device **900**. One coil **924** is positioned around pole piece portion **912** and another coil **926** is positioned around pole piece portion **914**, such coils **924**, **926** acting as secondary windings in device **900**.

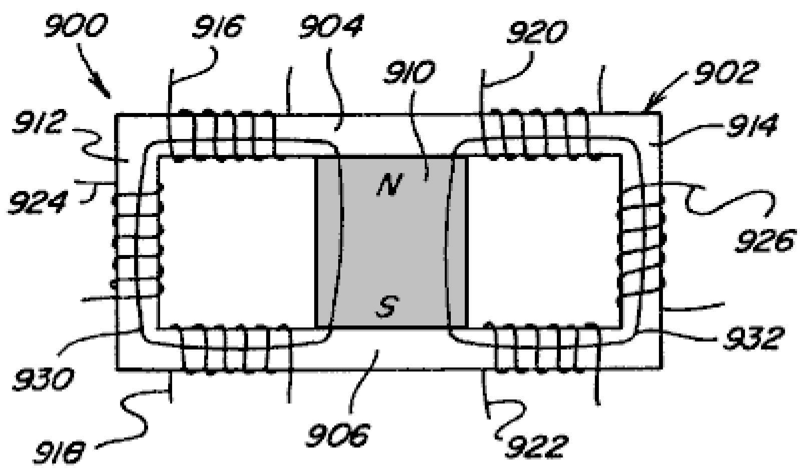


Fig. 45A

In **Fig.45A** no coils are energised and the permanent magnet magnetic flux splits evenly between paths **930** and **932**, coupling with both coil **924** and coil **926**.

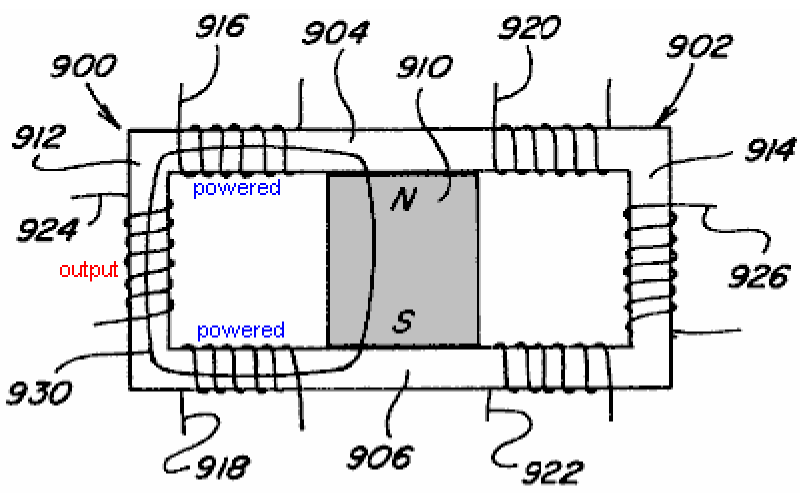


Fig. 45B

In **Fig.45B** coils **916**, **918** are energised in a permanent magnet magnetic flux aiding manner so as to couple with all the magnetic flux of permanent magnet **910**. All magnetic flux flows along path **930** as shown and thus couples with coil **924**.

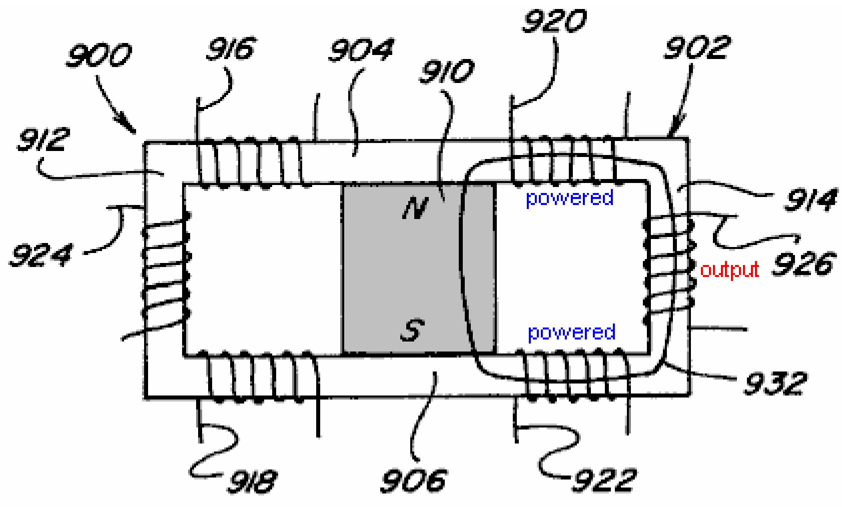


Fig. 45C

In **Fig.45C** coils **920**, **922** are energised in a permanent magnet magnetic flux aiding manner such that all magnetic flux traverses path **932** and couples with coil **926**. By continuously alternately energising and de-energising coils **916**, **918** and **920**, **922** in such a manner energy conversion is achieved due to the coupling with coils **924** and **926**. The magnetic flux in the integral pole piece portions **912** and **914**, and thus the flux coupling with respective coils **924** and **926**, varies by a factor of twice the amount of magnetic flux generated by energising coils **916**, **918** and **920**, **922**.

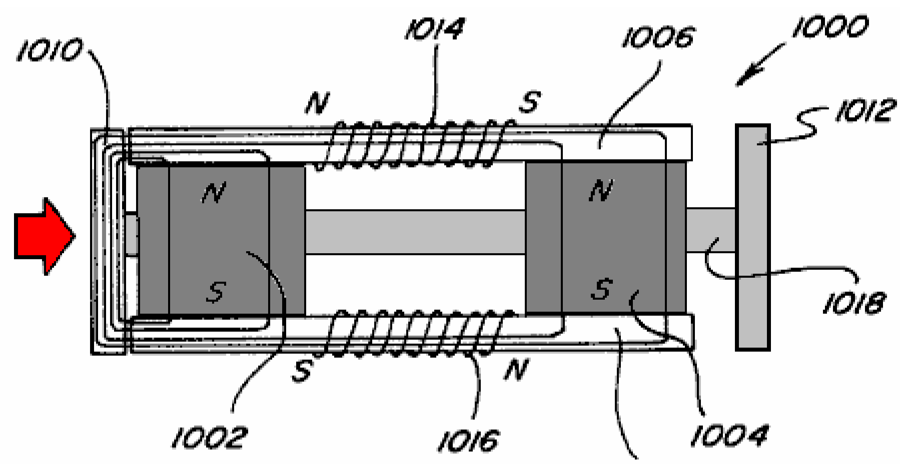


Fig. 47

The construction shown in **Fig.45A** and **Fig.45X** are similar to the construction shown in **Fig.7** and **Fig.47**. The difference in both cases relates to replacing the two flux paths and armatures with one continues flux path. The arrangement in **Fig.7** has one permanent magnet and four coils and the arrangement in **Fig.47** has two permanent magnets and two coils. Although the physical aspects of the two arrangements and the details of the flux control vary, the control method for varying the permanent magnets flux are similar and will be described simultaneously and only differences will be pointed out.

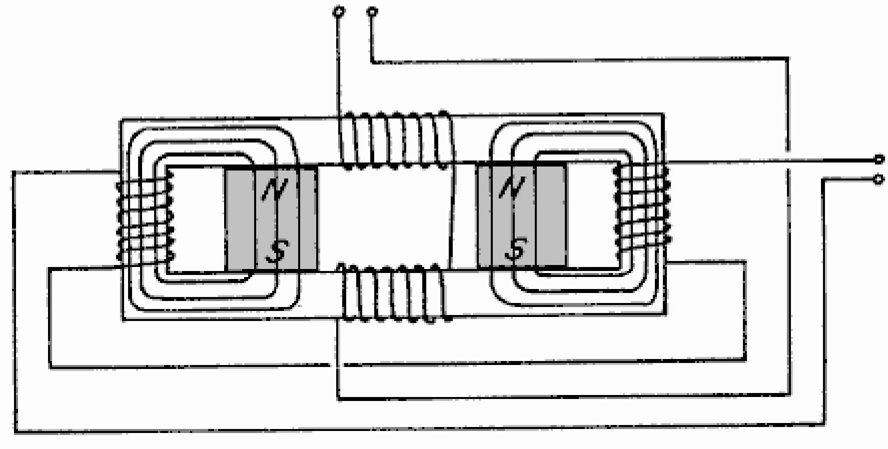


Fig. 45 X

With continuous flux paths the static flux from the permanent magnet or magnets is useless. However, if the static flux of the permanent magnet confined to the flux paths were modified to be time varying it would have utility for electromagnetic induction devices for power conversion like transformers and power inverters. However, the same basic method for controlling the flux of a permanent magnet to provide linear and rotary motion can also be applied to time varying the static flux from the permanent magnet. The construction shown in **Fig.45X** utilises four control coils and a single permanent magnet while the construction shown in **Fig.45A** uses two control coils and two permanent magnets. The flux that would normally be supplied by a primary winding is supplied by the static flux of the permanent magnet or magnets and the control coils convert this static flux into a time varying flux in a novel way. Both arrangements use two secondary coils, the secondary coils are placed in the region of the continuous flux path that would be occupied by an armature or rotor in the linear or rotary arrangements. The regions of the flux paths that perform work are the same in all cases.

In all cases the control coils can either be wired in series or parallel and the secondary coils can be either wound in series or parallel. More than one secondary coil or secondary coils with multiple taps can be placed in the working regions and further multiple flux paths can be utilised with one or more secondary coils placed in each of the working regions. This is made obvious by the disclosures of the linear and rotary devices herein and based on the fact that the working regions of the flux paths are identical.

Fig.45X and **Fig.45A** also show the paths of the static flux of the permanent magnet or magnets when no current is flowing in the control coils. In the arrangement shown in **Fig.45X** the flux from the single permanent magnet divides between the two working areas of the flux path. In the arrangement of **Fig.45A** all of the flux of one of the permanent magnets passes through one of the working regions and all of the flux of the second permanent magnet passes through the other working region. Each of the working regions in both cases are occupied by secondary coils.

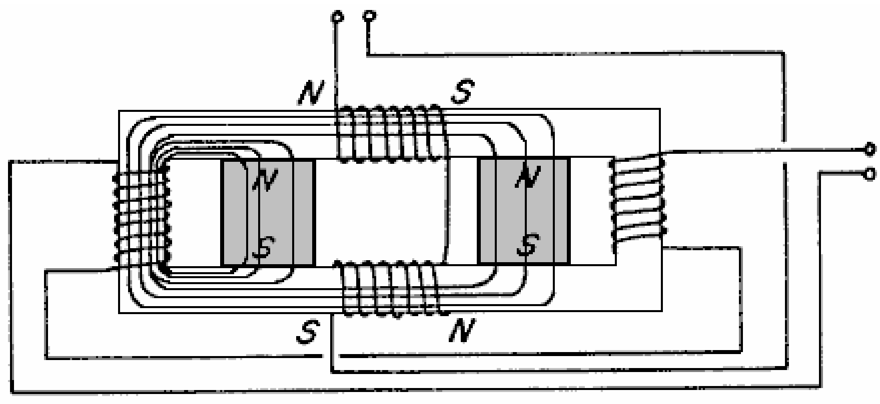


Fig. 45 Y

Fig.45Y and **Fig.45B** show the control coils energised with the polarity shown with respect to the polarity of the permanent magnet or magnets included. In **Fig.45Y** the opposing coil, blocks the passage of flux from the permanent magnet, and the aiding coil couples with the flux of the permanent magnet and therefore all of the flux of the permanent magnet passes through one working region as shown. In **Fig.45B** the opposing side of the coil blocks the passage of flux from the permanent magnet on the opposing side of the coil and the aiding side of the coil couples with the flux of the other permanent magnet and therefore all of the flux of both the permanent magnets passes through the working region as shown.

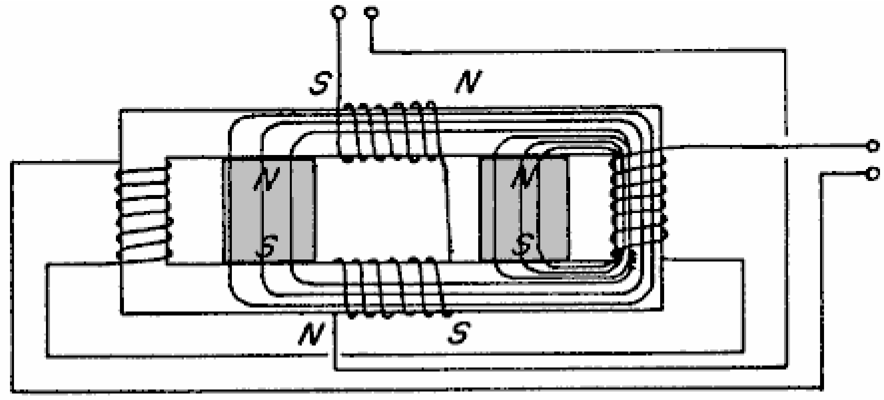


Fig. 45 Z

Fig.45Z and **Fig.45C** show the control coils energised with a polarity opposite of that shown in **Fig.45Y** and **Fig.45B**. The same action occurs and results in all of the permanent magnet or magnets path flux passing through the opposite working regions.

By alternating the polarity of the control coils during one cycle, one working region experiences an increasing flux and the opposite region experiences a decreasing flux and during the next cycle the opposite occurs. This results in the induction of a voltage in the secondary coils that is decided by the magnitude of the change in flux in the working region and the time in which this change occurs. The novelty of this discovery is that the primary flux inducing the voltage in the secondary coils is supplied by the permanent magnet or magnets and is far greater than the flux supplied by the control coils.

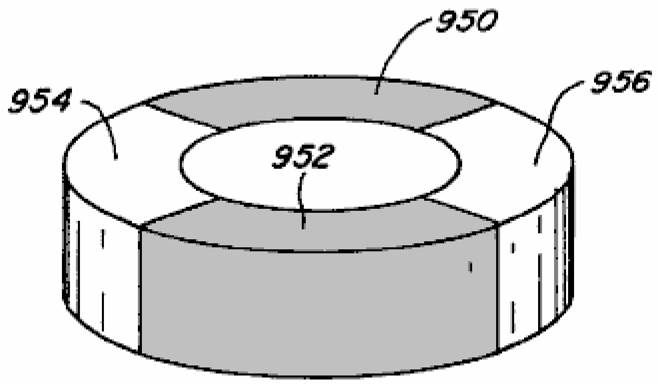


Fig. 46

Further, in the rotary motion devices of **Fig.31** and **Fig.34**, it is not necessary that respective rotor members **702** and **744** be formed of permanent magnets. Each could take the form shown in **Fig.46** where sections **950** and **952** are formed of magnetic material such as soft iron and sections **954** and **956** are formed by a non-magnetic filler material.

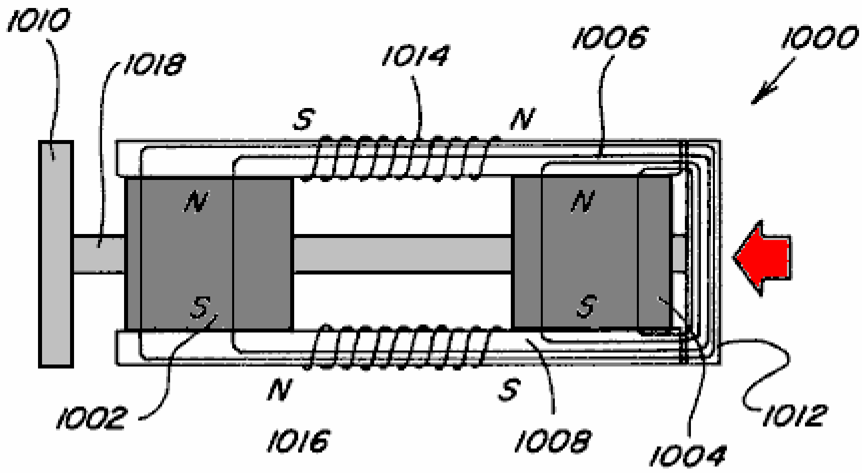


Fig. 48

Fig.47 and **Fig.48** show another embodiment **1000** of the subject device. The embodiment **1000** includes two spaced permanent magnets **1002** and **1004** each of which has its north pole adjacent to the upper surface and its south pole adjacent to the lower surface. A magnetisable bridging member **1006** extends across and makes contact with the north magnetic poles of the magnets **1002** and **1004** and another magnetisable bridging member **1008** makes contact with the south magnetic poles of the two permanent magnets **1002** and **1004**.

The members **1006** and **1008** extend slightly beyond the opposite sides of the respective permanent magnets **1002** and **1004** and a pair of spaced armature members **1010** and **1012** are positioned to move into and out of engagement with the ends of the members **1006** and **1008**. Coils **1014** and **1016** are mounted respectively on the members **1006** and **1008** in the space between the permanent magnets **1002** and **1004**, and the armatures **1010** and **1012** are shown connected together by a rod **1018** which enables them to move backwards and forwards into engagement with the respective members **1006** and **1008** when different voltages are applied to the respective coils **1014** and **1016**.

In **Fig.47**, the coils **1014** and **1016** are energised as shown with the coil **1014** having its north magnetic end to the left and its south magnetic end to the right and the opposite is true of the coil **1016**. In **Fig.48**, the voltage applied to the respective coils **1014** and **1016** is reversed so that the polarity of the left end of coil **1014** is south and the polarity of the opposite end of the same coil **1014** is a north magnetic pole. The reverse is true of the coil **1016**. In **Fig.47** and **Fig.48** it should be noted that the relationship of aiding and opposing is indicated on the figures to indicate the relationship when the coils are energised. For example, in **Fig.47** when the coils are energised as shown the relationship is opposing for the permanent magnet **1002** and is aiding with respect to the permanent magnet **1004**. The reverse is true when the voltage on the coils is reversed as shown in **Fig.48**. The movement of the armature is therefore controlled by the proper timing of the voltage on these coils. The same principles can be applied to produce rotating movement as shown in **Fig.42**.

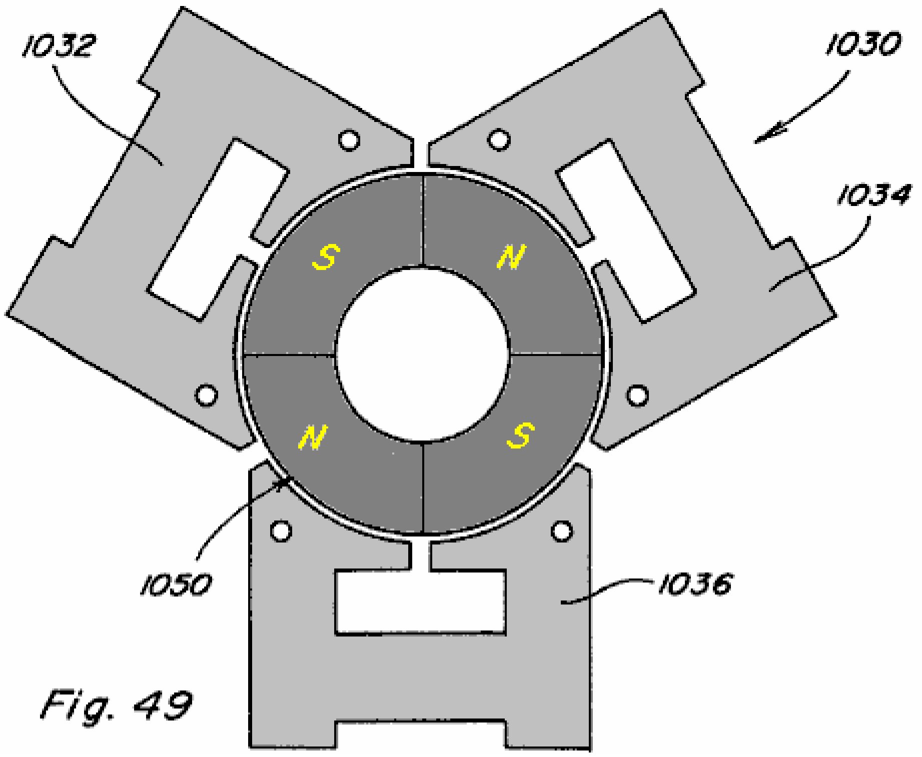


Fig. 49

Fig.49 shows another embodiment **1030** of the subject invention using principles similar to those described in connection with **Fig.47** and **Fig.48**. The embodiment **1030** includes a plurality, three being shown, of stationary members **1032**, **1034** and **1036**.

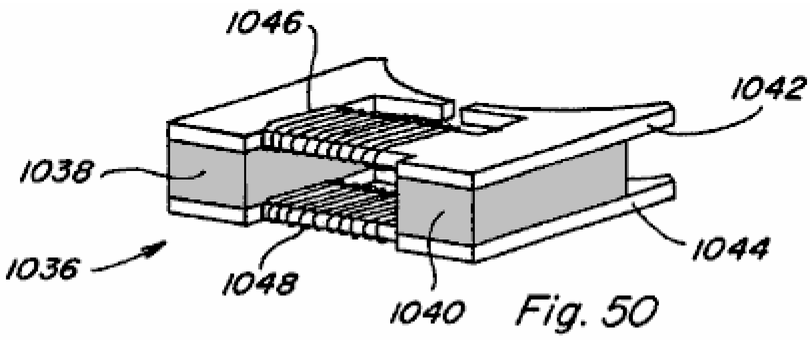


Fig. 50

The details of these members are better shown in **Fig.50** which shows the details of the member **1036**. This member includes a pair of permanent magnets **1038** and **1040**, each of which has magnetisable members mounted adjacent to it's opposite sides, as in the previous construction. The members **1042** and **1044** also have coils **1046** and **1048**, respectively, and the coils are energised as described in connection with **Fig.47** and **Fig.48** to produce aiding and opposing magnetism. The construction shown in **Fig.49** may have three stator portions as shown or it may have more stator portions as desired. The rotor **1050** is positioned in the space between the members **1032**, **1034** and **1036** and includes a permanent magnet portion part of which has its north magnetic pole on the surface as shown and the other parts has its south magnetic pole in the same surface as shown. The permanent magnets **1038** and **1040** on the stators interact with the permanent magnets on the rotor to produce the rotating motion and is controlled by the energising of the coils.

Other applications and advantages of the devices and methods of the present invention exist and various modifications are possible, and therefore the present invention is not intended to be limited to the specific examples disclosed herein. Accordingly, the spirit and scope of the invention are to be limited only by the terms of the appended claims.

CLAIMS

What is claimed is:

1. A permanent magnet device, comprising a permanent magnet having north and south pole faces, a first pole piece, a second pole piece, a first control coil, a second control coil, and circuit means, the first pole piece positioned adjacent the north pole face of the permanent magnet and including a first path portion, a second path portion and a third portion, the first path portion extending beyond a perimeter of the north pole face in one direction and the second path portion extending beyond the perimeter of the north pole face in another direction to define first and second flux paths for magnetic flux emanating from the north pole face of the permanent magnet, the first path portion of the first pole piece connected to the second path portion of the first pole piece by the third portion which extends across the north pole face of the permanent magnet, the second pole piece positioned adjacent the south pole face and including a first path portion and a second path portion, the first path portion extending beyond a perimeter of the south pole face and substantially aligned with the first path portion of the first pole piece, the second path portion extending beyond the perimeter of the south pole face and substantially aligned with the second path portion of the first pole piece, the first control coil positioned around the first path portion of the first pole piece, the second control coil positioned around the second path portion of the first pole piece, the circuit means connected to each of the first control coil and the second control coil to alternately energise the first coil and the second coil in a timed sequential manner.

2. The permanent magnet device as set forth in claim 1, wherein the first control coil and the second control coil are alternately energised in a permanent magnet magnetic flux aiding manner.

3. The permanent magnet device as set forth in claim 1, wherein the first control coil and the second control coil are alternately energised in a permanent magnet magnetic flux opposing manner.

4. The permanent magnet device as set forth in claim 1, further comprising a rotor member mounted on a shaft for rotation therewith, the rotor member sized, shaped, and positioned to extend substantially from the first path portion of the first pole piece to the first path portion of the second pole piece during at least some part of its rotation.

5. The permanent magnet device as set forth in claim 4, wherein the rotor member is formed by at least one permanent magnet.

6. The permanent magnet device as set forth in claim 1, wherein the second path portion of the first pole piece and the second path portion of the second pole piece are positioned alongside the first path portion of the first pole piece and the first path portion of the first pole piece.

7. The permanent magnet device as set forth in claim 1, further comprising a first bypass extending from the first path portion of the first pole piece to the first path portion of the second pole piece, one end of the first bypass positioned adjacent the first path portion of the first pole piece and between the permanent magnet and the first control coil.

8. The permanent magnet device as set forth in claim 6, further comprising a second bypass extending from the second path portion of the first pole piece to the second path portion of the second pole piece, one end of the second bypass positioned adjacent the second path portion of the first pole piece and between the permanent magnet and the second control coil.

9. The permanent magnet device as set forth in claim 1, further comprising a plurality of armatures arranged to define a path of movement, wherein the second path portion of the first pole piece and the second path portion of the second pole piece are positioned alongside the first path portion of the first pole piece and the first path portion of the second pole piece, and wherein all of such pole piece path portions include an end face positioned adjacent the path of movement defined by the plurality of armatures.

10. The permanent magnet device as set forth in claim 1, wherein the first control coil and the second control coil are simultaneously energised one in a permanent magnet magnetic flux aiding manner and one in a permanent magnet magnetic flux opposing manner.

11. The permanent magnet device as set forth in claim 1, further comprising two shaft connected armatures which can be positioned adjacent the ends of the first and second pole pieces, wherein each of the armatures is formed by a permanent magnet.

12. The permanent magnet device of claim 1 further comprising a first fixed armature extending between the first path portion of the first pole piece to the first path portion of the second pole piece and a second fixed armature extending between the second path portion on the first pole piece to the second path portion of the second pole piece.

13. The permanent magnet device of claim 12 where a first secondary coil is wrapped around the first fixed armature and a second secondary coil is wrapped around the second fixed armature.

14. The permanent magnet device of claim 13 including circuit means connected to the control coils to control the energising thereof to produce a varying flux in the armatures and to induce voltage in the secondary coils.

15. The permanent magnet device of claim 1 wherein there are at least two permanent magnets each having north and south pole faces, the first pole piece being positioned extending between the north pole faces of the permanent magnets and the second pole piece positioned extending between adjacent south pole faces of the permanent magnets.

16. A method for controlling the path of magnetic flux from a permanent magnet, the method comprising the steps of:

(**a**) placing a first pole piece adjacent a first pole face of the permanent magnet so as to have at least first and second path portions extending beyond a perimeter of the first pole face;

(**b**) placing a second pole piece adjacent a second pole face of the permanent magnet so as to include at least one portion which substantially aligns with the first and second path portions of the first pole piece;

(**c**) placing a first control coil along and around the first path portion of the first pole piece;

(**d**) placing a second control coil along and around the second path portion of the first pole piece;

(**e**) repeatedly energising the first control coil in a permanent magnet magnetic flux opposing manner so as to prevent magnetic flux of the permanent magnet from traversing the first path portion of the first pole piece; and

(**f**) repeatedly energising the second control coil in a permanent magnet magnetic flux opposing manner so as to prevent magnetic flux of the permanent magnet from traversing the second path portion of the first pole piece.

17. The method as set forth in claim 16 wherein the energisation of steps (e) and (t) take place in a simultaneous manner.

18. A method for controlling the path of magnetic flux from a permanent magnet, the method comprising the steps of:

(**a**) placing a first pole piece adjacent a first pole face of the permanent magnet so as to have at least first and second path portions extending beyond a perimeter of the first pole face;

(**b**) placing a second pole piece adjacent a second pole face of the permanent magnet so as to include at least one portion which substantially aligns with the first and second path portions of the first pole piece;

(**c**) placing a first control coil along and around the first path portion of the first pole piece;

(**d**) placing a second control coil along and around the second path portion of the first pole piece; and

(**e**) alternately performing the following steps in a repeated manner:

(**i**) energising the first control coil in a permanent magnet magnetic flux aiding manner so as to couple with substantially all magnetic flux of the permanent magnet such that substantially no magnetic flux of the permanent magnet traverses the second path portion of the first pole piece when the first control coil is so energised; and (**ii**) energising the second control coil in a permanent magnet magnetic flux opposing manner so as to couple with substantially all magnetic flux of the permanent magnet such that substantially no magnetic flux of the permanent magnet traverses the first path portion of the first pole piece when the second control coil is so energised.

19. A method for controlling the path of magnetic flux from a permanent magnet the method comprising the steps of:

(**a**) placing a first pole piece adjacent a first pole face of the permanent magnet so as to have at least first and second path portions extending beyond a perimeter of the first pole face;

(**b**) placing a second pole piece adjacent a second pole face of the permanent magnet so as to include at least one portion which substantially aligns with the first and second path portions of the first pole piece;

(**c**) placing a first control coil along and around the first path portion of the first pole piece;

(**d**) placing a second control coil along and around the second path portion of the first pole piece; and

(**e**) alternately performing the following steps in a repeated manner:

(**i**) simultaneously energising the first control coil in a permanent magnet magnetic flux aiding manner and the second control coil in a permanent magnet flux opposing manner; and

(**ii**) simultaneously energising the first control coil in a permanent magnet flux opposing manner and the second control coil in a permanent magnet magnetic flux aiding manner.

20. A rotary motion device, comprising a rotor assembly including a shaft which defines an axis of rotation of the assembly, a rotor pole piece mounted for rotation with the shaft, the rotor pole piece including an outer ring portion having at least two path portions extending inwardly from a periphery of the outer ring portion;

a stator assembly including a permanent magnet having a generally ring-shaped configuration, a first pole face of the permanent magnet positioned adjacent the outer ring portion of the rotor pole piece, the stator assembly further comprising a stator pole piece including an outer ring portion positioned adjacent a second pole face of the permanent magnet and having a plurality of path portions extending inwardly from the periphery, each path portion further including a respective portion which extends toward a plane defined by the first pole face of the permanent magnet and capable of being aligned with each of the rotor pole piece path portions at certain rotational positions of the rotor pole piece, each path portion including a control coil positioned along it;

and circuit means connected to each of the coils and including a source of electrical energy and switch means for energising respective ones of the control coils in a predetermined timed sequence based upon rotation of the rotor assembly.

21. A rotary motion device, comprising:

a rotor assembly including a shaft which defines an axis of rotation of the assembly, a pair of spaced elongated rotor members mounted on the shaft at spaced locations thereon and angularity oriented with respect to each other, each of the elongated rotor members formed of a magnetic material;

a stator assembly including a permanent magnet having opposed first and second pole faces, a first pole piece positioned adjacent the first pole face and a second pole piece positioned adjacent the second pole face, each pole piece including a respective first path portion extending beyond a perimeter of its adjacent pole face and having an curved shaped end portion, the first path portion of the first pole piece aligned with the first path portion of the second pole piece, each pole piece further including a respective second path portion extending beyond the perimeter of its adjacent pole face in a direction opposite to that of the first path portions and having an curved shaped end portion, the second path portion of the first pole piece aligned with the second path portion of the second pole piece, at least one of the first path portions of the first pole piece and the first path portion of the second pole piece including a control coil mounted on at least one of the pole pieces, at least one of the second path portions of the first pole piece and the second path portion of the second pole piece including a control coil mounted on at least one of the pole pieces,

wherein the rotor assembly extends from end to end of the stator assembly such that the elongate members are aligned with the curved shaped end portions of the path portions of the pole pieces;

and circuit means connected to each of the coils and including a source of electrical energy and switch means for energising respective ones of the control coils in a predetermined timed sequence based upon rotation of the rotor assembly.

22. A rotary motion device comprising:

a rotor assembly including a shaft which defines an axis of rotation of the assembly, a ring-shaped rotor member mounted for rotation with the shaft, the ring-shaped rotor member including a plurality of distinct circumferential regions;

a stator assembly including a first permanent magnet, a first pole piece positioned against a first pole face and a second pole piece positioned against a second pole face, the first pole piece including at least a first path portion extending beyond a perimeter of the first pole face, the second pole piece including at least a first path portion extending beyond a perimeter of the second pole face, the first path portion of the first pole piece aligned with the first path portion of the second pole piece, at least a portion of the ring-shaped rotor member positioned between the first path portion of the first pole piece and the first path portion of the second pole piece, at least one of the first path portions of the first pole piece and the first path portion of the second pole piece including a first control coil positioned at a point intermediate the first permanent magnet and the ring-shaped rotor member;

and circuit means connected to the first control coil and including a source of electrical energy and switch means for energising the first control coil in a predetermined timed manner based upon rotation of the rotor assembly.

23. The rotary motion device as set forth in claim 22, wherein the ring-shaped rotor member is formed by a permanent magnet having distinct circumferential regions of opposite polarity.

24. The rotary motion device as set forth in claim 23, wherein the first pole piece includes a second path portion spaced from and extending adjacent to the first path portion, the second pole piece including a second path portion spaced from and extending adjacent to the first path portion such that the second path portion of the first pole piece is aligned with the second path portion of the second pole piece, at least a portion of the ring-shaped permanent magnet rotor member positioned between the second path portion of the first pole piece and the second path portion of the second pole piece, at least one of the second path portions of the first pole piece and the second path portion of the second pole piece having a second control coil mounted on at least one of the pole pieces at a point intermediate the first permanent magnet and the ring-shaped permanent magnet rotor member, the second control coil connected to the circuit means so as to be energised in a predetermined timed manner based upon rotation of the rotor assembly.

25. The rotary motion device as set forth in claim 22, wherein the stator assembly further comprises a second permanent magnet, a third pole piece positioned adjacent a first pole face of the second permanent magnet and a fourth pole piece positioned adjacent a second pole face of the second permanent magnet, the third pole piece including at least a first path portion extending beyond a perimeter of the second permanent magnet first pole face, the fourth pole piece including at least a first path portion extending beyond a perimeter of the second permanent magnet second pole face, the first path portion of the third pole face aligned with the first path portion of the fourth pole piece, at least a portion of the ring-shaped permanent magnet rotor member positioned between the first path portion of the third pole piece and the first path portion of the fourth pole piece, at least one of the first path portions of the third pole piece and the first path portion of the fourth pole piece including a third control coil mounted on at least one of the pole pieces at a point intermediate the second permanent magnet and the ring-shaped permanent magnet rotor member, the third pole piece including a second path portion spaced from and extending adjacent to the first path portion the fourth pole piece including a second path portion spaced from and extending adjacent to the first path portion thereof such that the second path portion of the third pole piece is aligned with the second path portion of the fourth pole piece, at least a portion of the ring-shaped permanent magnet rotor member positioned between the second path portion of the third pole piece and the second path portion of the fourth pole piece, at least one of the second path portions of the third pole piece and the second path portion of the fourth pole piece including a fourth control coil mounted on at least one of the pole pieces at a point intermediate the second permanent magnet and the ring-shaped permanent magnet rotor member, wherein each of the third and fourth control coils are connected to the circuit means so as to be energised in a predetermined timed manner based upon rotation of the rotor assembly.

26. A device for producing rotary motion comprising:

a rotor assembly including a shaft which defines an axis of rotation for the assembly, a ring-shaped rotor member mounted for rotation with the shaft, the ring-shaped rotor member having a plurality of distinct circumferentially positioned regions extending around the axis, a stator assembly including a first permanent magnet, a first pole piece positioned against the first pole face of the first pole piece and a second pole piece positioned against a second pole face of the first pole piece, the first pole piece including at least a first path portion extending beyond a perimeter of the first pole face, the second pole piece including at least a first path portion extending beyond the perimeter of the second pole face, the first path portion of the first pole piece aligned with the first path portion of the second pole piece, at least a portion of the ring-shaped rotor member positioned between the first path portion of the first pole piece and the first path portion of the second pole piece, at least one of the first path portions of the first pole piece and the first path portion of the second pole piece including a first control coil mounted on at least one of the pole pieces at a point intermediate the first permanent magnet and the ring-shaped rotor member; and circuit means connected to the first control coil and including a source of electrical energy and switch means for energising the first control coil in a predetermined timed manner based upon position of the rotor assembly during rotation of the rotor assembly.

27. The device for producing rotary motion of claim 26 wherein the circuit means includes means for timing the energising of the first control coil includes means for adjusting the timing thereof.

28. The device for producing rotor motion of claim 26 including means to vary the flux generated in the first and second pole pieces.

29. A device for handling the flux between two separate permanent magnets each of which has a north magnetic pole adjacent one side face and the south magnetic pole adjacent to the opposite side face, the north and south side pole faces respectively of both magnets being substantially in alignment, a first member in surface-to-surface contact with the north magnetic faces of the spaced permanent magnets, a second member in surface-to-surface contact with the south magnetic faces of the spaced permanent magnets, first and second armatures each positioned adjacent opposite ends of the first and second permanent magnets and adjacent to opposite ends of the spaced members, a coil mounted on each of the members in the space between the adjacent permanent magnets, and means for applying voltages of predetermined polarities across the respective coils to change the magnetic coupling between the permanent magnets and between the armatures.

30. A device for producing rotational movement comprising:

a rotor having a shaft rotatable about the axis thereof, a member constructed of permanent magnets mounted on the shaft, said member having circumferential portions some of which have a north magnetic pole and others a south magnetic pole adjacent to the same side thereof, the opposite surface of the permanent magnet member having north magnetic poles opposite the south magnetic poles and south magnetic poles opposite the north magnetic poles, a stator having a plurality of circumferentially spaced portions each of which includes at least one permanent magnet and a pair of members mounted adjacent opposite sides of the permanent magnets, the members being positioned adjacent to the periphery of the rotor permanent magnet member and means on the member adjacent each opposite side of the stator permanent magnet for mounting a coil, and means for energising the coil on each stator portion in sequence to produce magnetic coupling force between the stator and the rotor in a direction to produce rotating motion of the rotor.

31. A device including a rotating member and a stationary member, each having a permanent magnet portion positioned to produce magnetic coupling force between them in predetermined positions thereof, the rotor including a shaft rotatable about its axis and the permanent magnet extending around the shaft and formed by a plurality of adjacent portions of permanent magnet material whereby adjacent portions have their north and south magnetic pole faces on opposite sides of the rotor permanent magnet, a plurality of stator members each stator member having at least one permanent magnet having a north magnetic pole adjacent one side and a south magnetic pole adjacent to the opposite side, a pair of members positioned adjacent respective opposite sides of the stator permanent magnet in position to extend to adjacent the rotor permanent magnet whereby a flux path is formed between the members and the stator and rotor permanent magnets, a coil mounted on each member of the stator and means for applying a voltage of predetermined polarity to each of said coils to control the flux through a path between the permanent magnets and to control the coupling force between the permanent magnets on the stator and the permanent magnets on the rotor.

32. A motion producing device comprising at least one permanent magnet having a north pole opposite and spaced from a south pole, a pair of spaced substantially parallel members adjacent respectively the north and south poles of the at least one permanent magnet and extending outwardly to substantially aligned opposite edges, a flux supporting member positioned adjacent the respective opposite edges of each pair of parallel members, a coil on selected ones of the parallel members, and a source of electrical energy connected to each of the coils for energising the coils to change the flux in the parallel members and in the flux supporting members.

33. The motion producing device of claim 32 wherein there are at least two spaced permanent magnets extending between the parallel members.

34. The motion producing device of claim 32 wherein one of said pair of parallel members is subdivided into a plurality of sidewardly extending portions extending to one of said opposite side edges, at least one of said coils being positioned on at least one of said sidewardly extending portions.

35. The motion producing device of claim 34 wherein there are coils on a plurality of respective ones of the sidewardly extending portions.

36. The motion producing device of claim 32 wherein the permanent magnet and the parallel members are annular in shape.

37. The motion producing device of claim 32 including a by-pass member extending between the pair of spaced substantial parallel members adjacent one side of the permanent magnet.

38. A permanent magnet device comprising at least two permanent magnets each having north and south pole faces, a first pole piece, a second pole piece, a first control coil, a second control coil and circuit means, the first pole piece positioned adjacent the north pole faces of the at least two permanent magnets and including a first path portion, a second path portion and a third path portion, the first path portion extending beyond the perimeter of the north pole faces and the second path portion extending beyond the perimeter of the north pole faces to define first and second flux paths for magnetic flux emitting from the north pole faces of the at least two permanent magnets, the first path portion of the first pole piece connected to the second path portion of the first pole piece by a third portion which extends across the north pole face of the at least two permanent magnets, the second pole piece positioned adjacent to the south pole faces of the at least two permanent magnets and including a first path portion and a second path portion, the first path portion extending beyond a perimeter of the south pole faces and substantially aligned with the first path portion of the first pole piece, the second path portion extending beyond the perimeter of the south pole faces and substantially aligned with the second path portion of the first pole piece, the first control coil positioned around the first path portion of the first pole piece, the second control coil positioned around the second path portion of the first pole piece, and the circuit means connected to each of the first control coil and the second control coil to alternately energise the first coil and the second coil in a timed sequential manner.

39. The permanent magnet device of claim 38 further comprising a first fixed armature extending between the first path portion of the first pole piece to the first path portion of the second pole piece and a second fixed armature extending between the second path portion of the first pole piece to the second path portion of the second pole piece.

40. The permanent magnet device of claim 39 where a first secondary coil is wrapped around the first fixed armature and a second secondary coil is wrapped around the second fixed armature.

41. The permanent magnet device of claim 40 including circuit means connected to the control coils to control the energising thereof to produce a varying flux in the armatures and to induce voltage in the secondary coils.

42. The permanent magnet device of claim 38 wherein there are at least two permanent magnets each having north and south pole faces, the first pole piece being positioned extending between the north pole faces of the permanent magnets and the second pole piece positioned extending between the south pole faces of the permanent magnets.

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United States Patent [19]

Flynn

[11] **Patent Number: 5,455,474**

[45] **Date of Patent: Oct. 3, 1995**

[54] **MAGNETIC MOTOR CONSTRUCTION**

[75] Inventor: **Charles J. Flynn**, Kansas City, Mo.

[73] Assignee: **Magnetic Revolutions Limited L.L.C.**, St. Louis, Mo.

[21] Appl. No.: **902,952**

[22] Filed: **Jun. 23, 1992**

[51] **Int. Cl.**^{6} **H02K 1/17**; H02K 1/27; H02K 11/00; H02K 29/10

[52] **U.S. Cl.** .... **310/181**; 310/152; 310/154; 310/156; 310/268; 310/68 B

[58] **Field of Search** .... 310/68 B, 152, 310/154, 156, 181, 268; 335/126, 131, 272; 318/254

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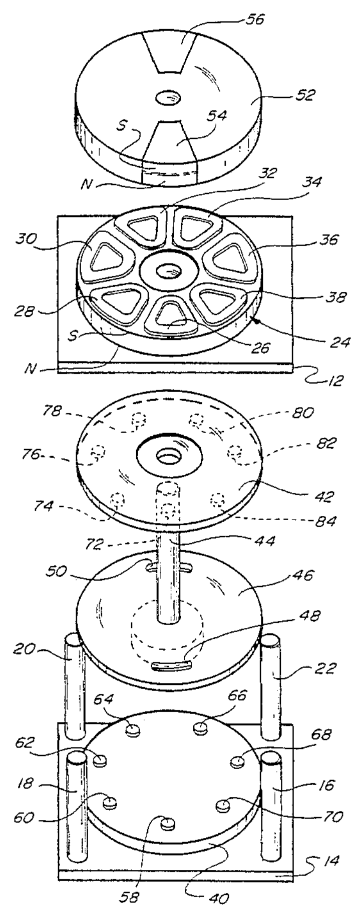
Primary Examiner—Clayton E. LaBalle
Attorney, Agent, or Firm—Haverstock, Garrett & Roberts

[57] **ABSTRACT**

The present invention relates to an apparatus having spaced permanent magnets positioned so that there is magnetic interaction between them, and controlling the interaction by having a coil in the space between the permanent magnets connected to a source of electric potential and a controllable switch in series such that closing the switch places a voltage across the coil and predeterminately affects the magnetic interaction between the spaced permanent magnets. The invention also teaches mounting one of the permanent magnets on a rotatable structure so that the spaced permanent magnets can move relative to each other, the controllable switch operating to control the application of electric potential across the coil in such a manner as to produce relative rotational movement between the spaced permanent magnets.

25 Claims, 7 Drawing Sheets



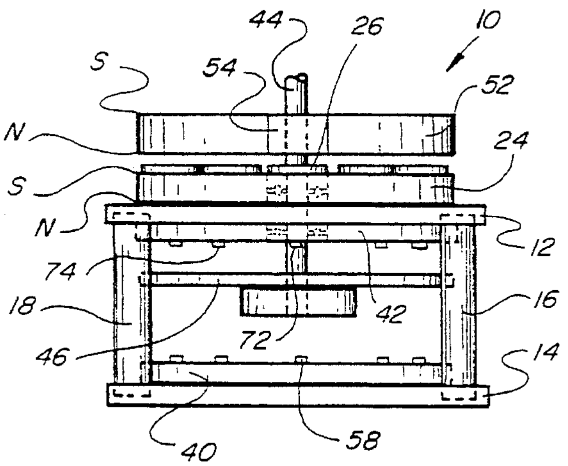


Fig. 1

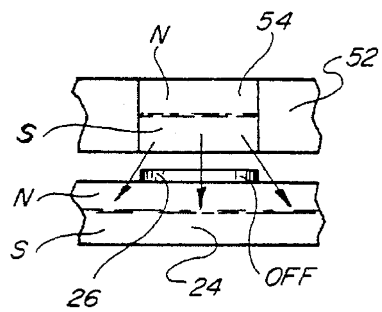


Fig. 3

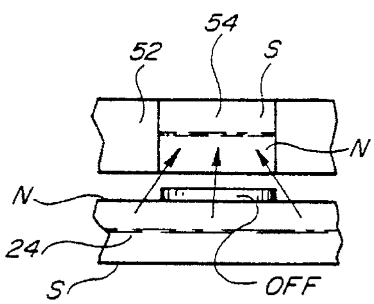


Fig. 5

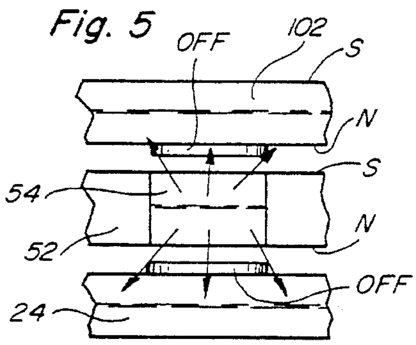


Fig. 8

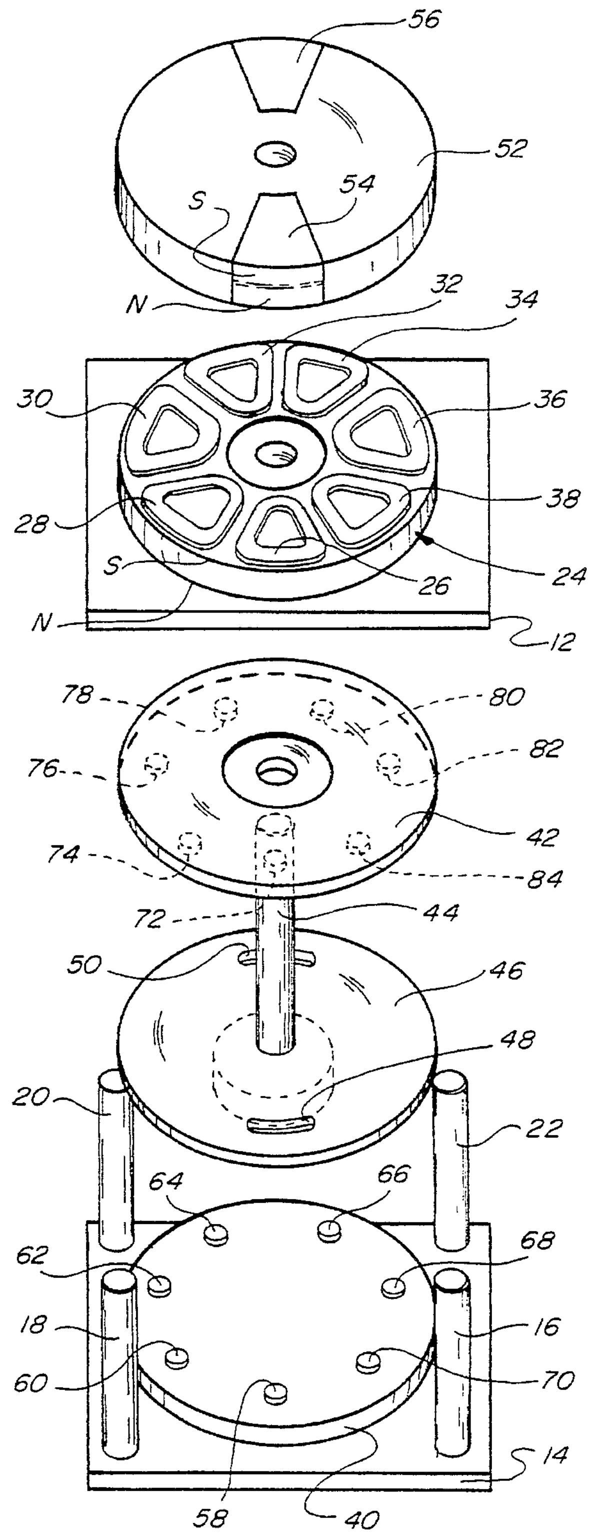


Fig. 2

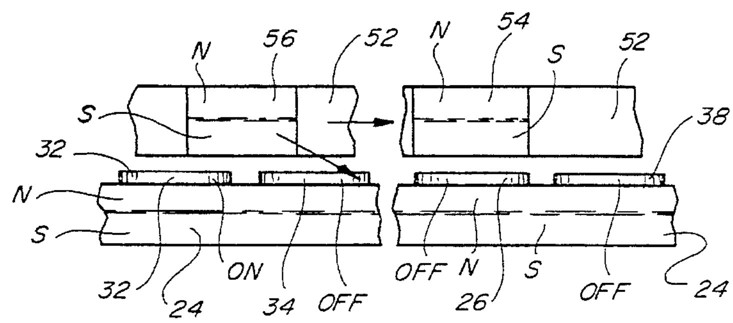


Fig. 4

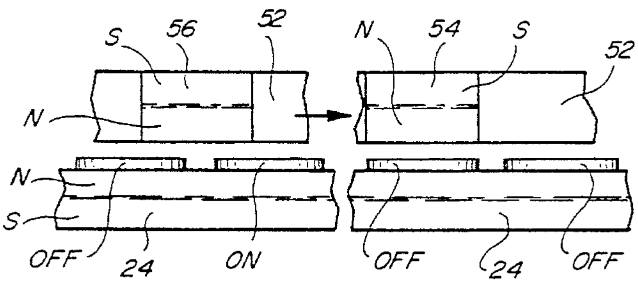


Fig. 6

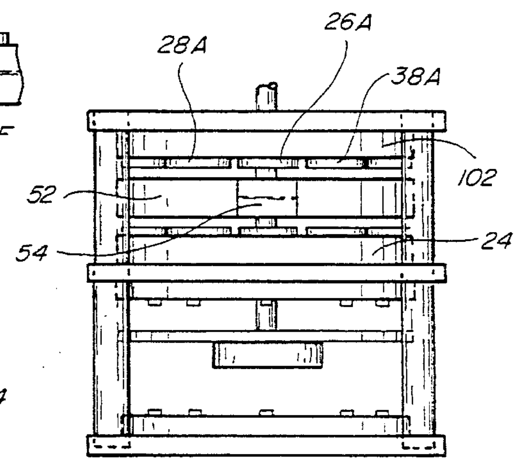


Fig. 7

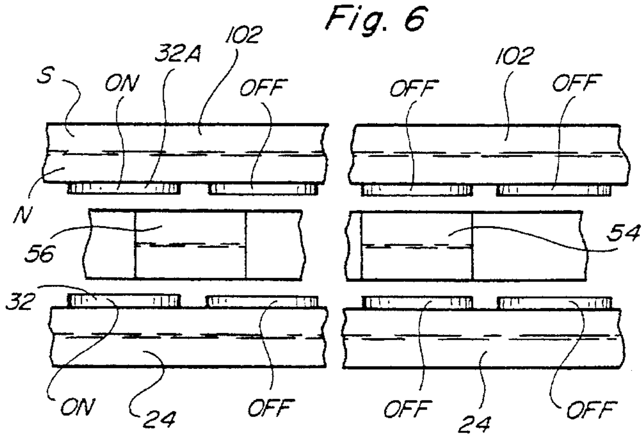


Fig. 9

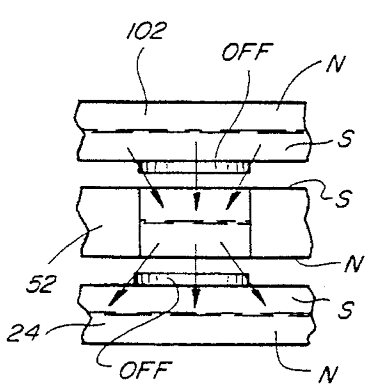


Fig. 10

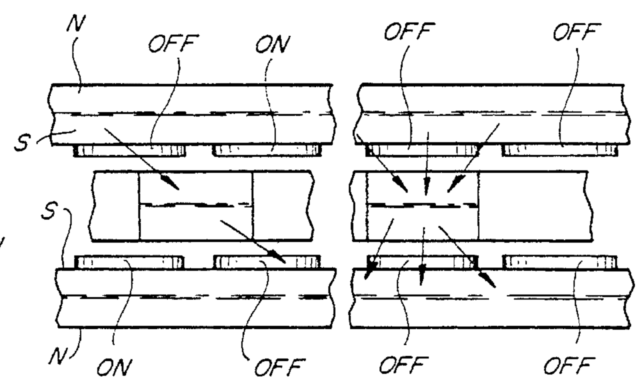


Fig. 11

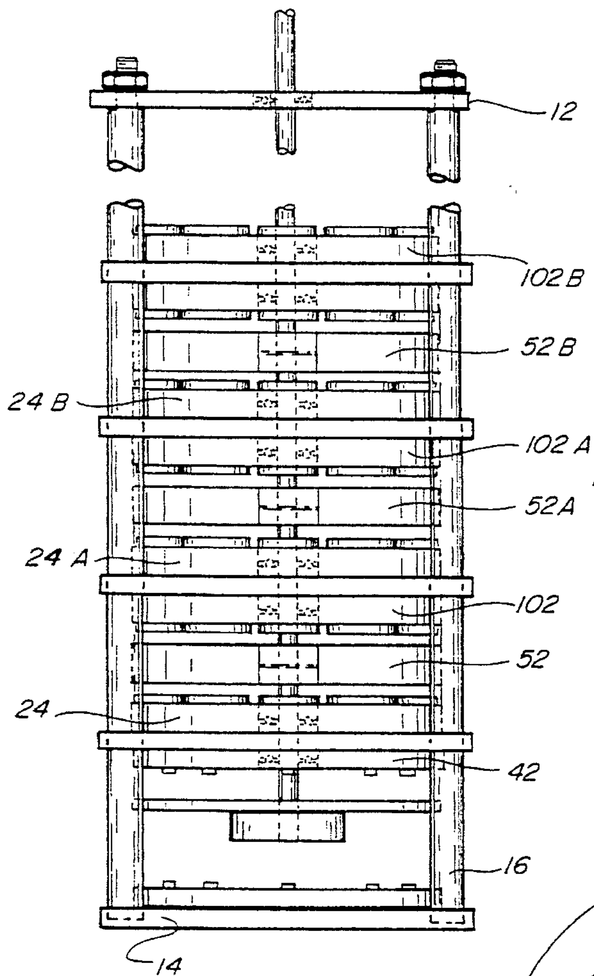

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Fig. 12

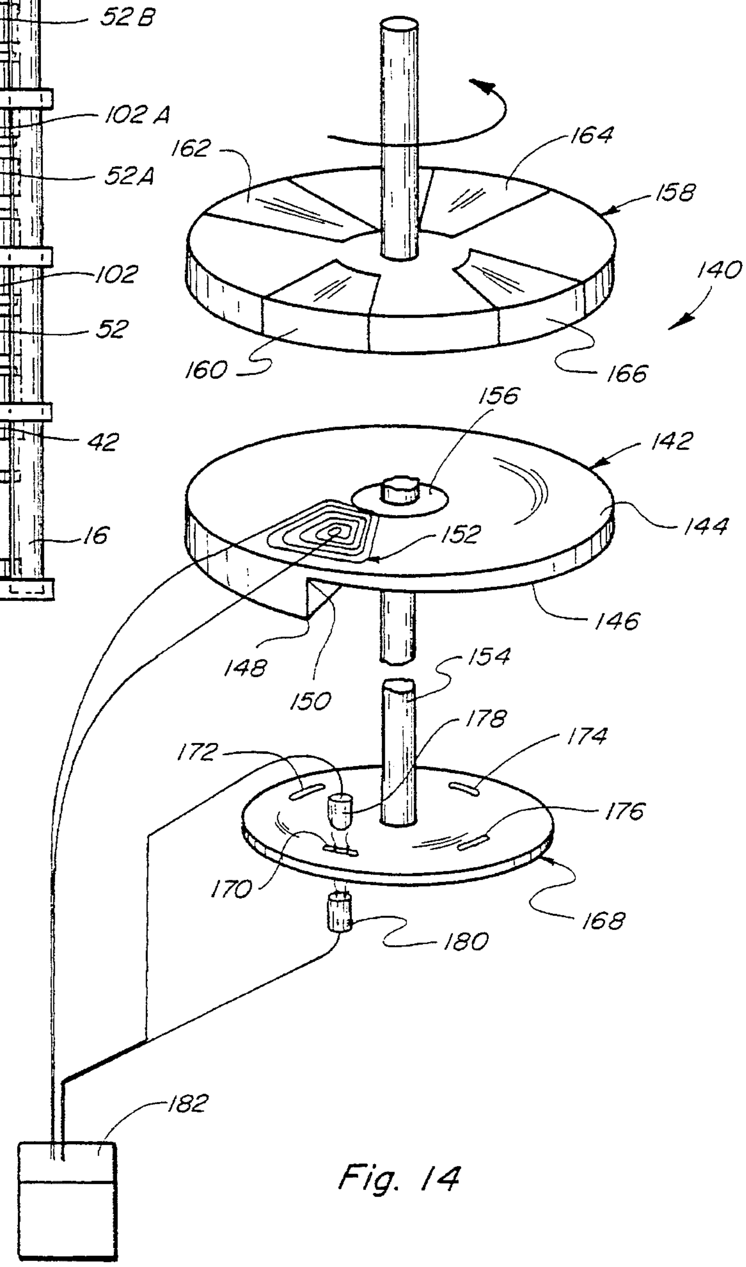
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Fig. 14

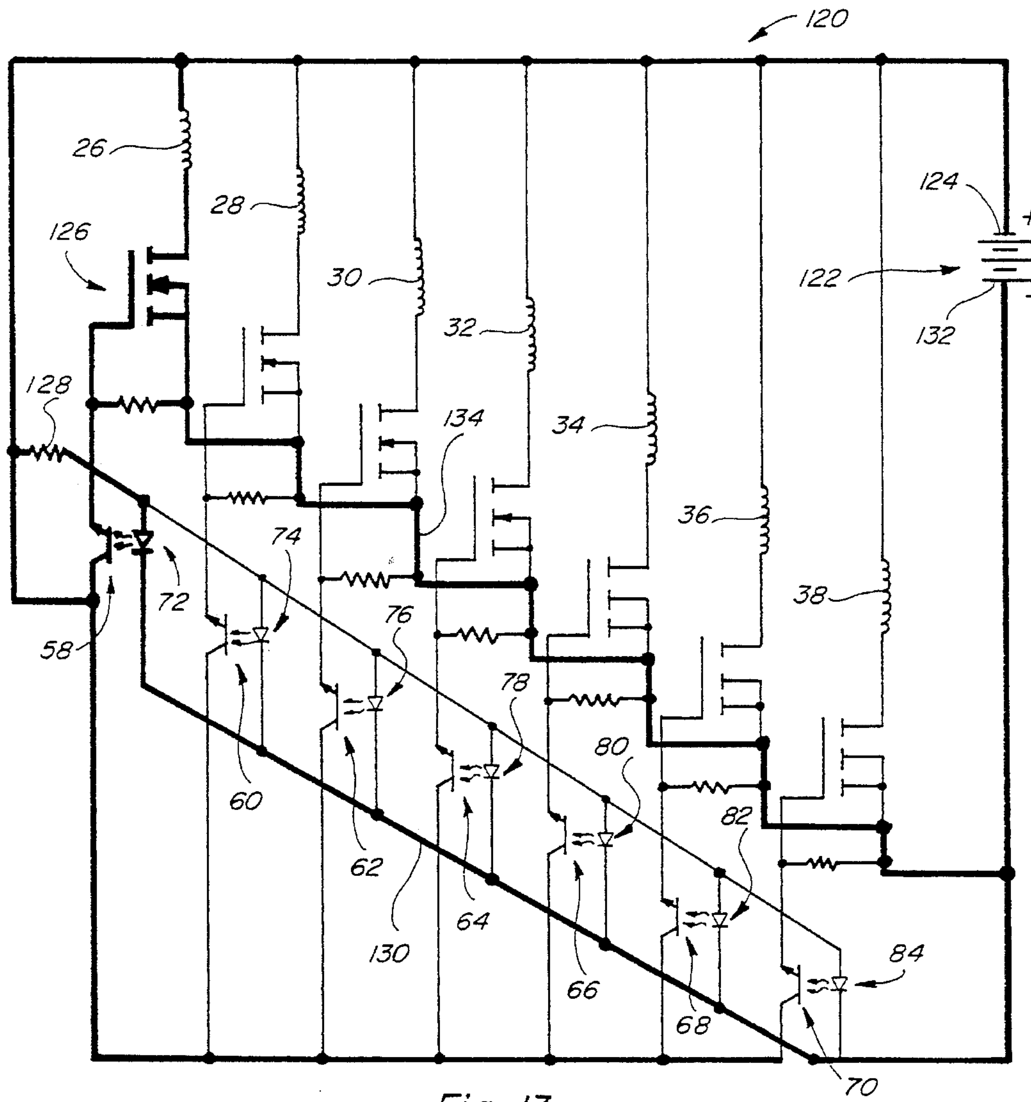

Fig. 13

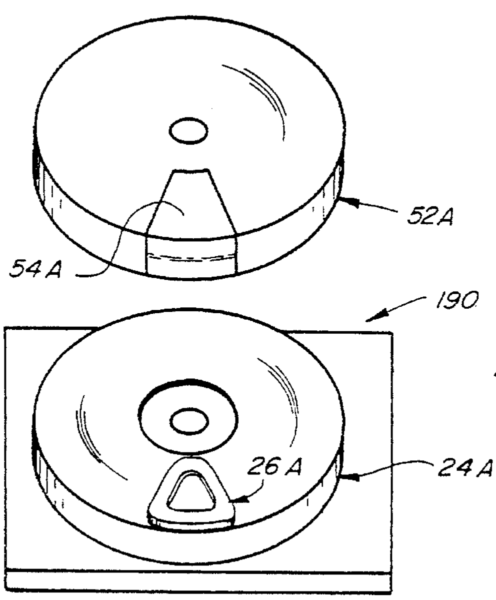

Fig. 15

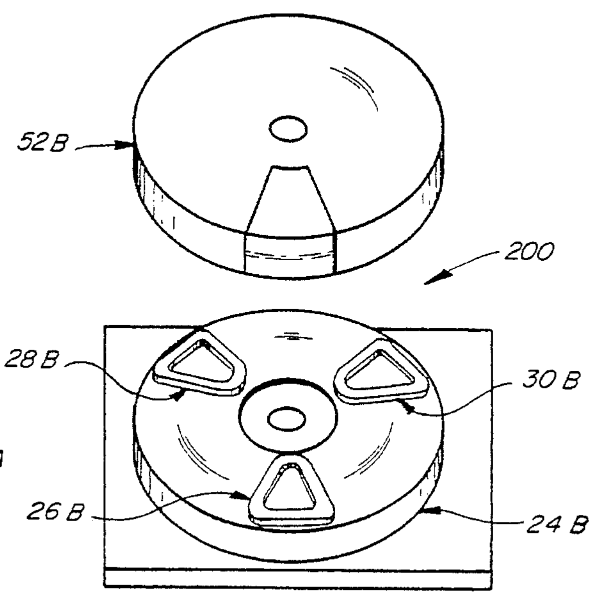

Fig. 16

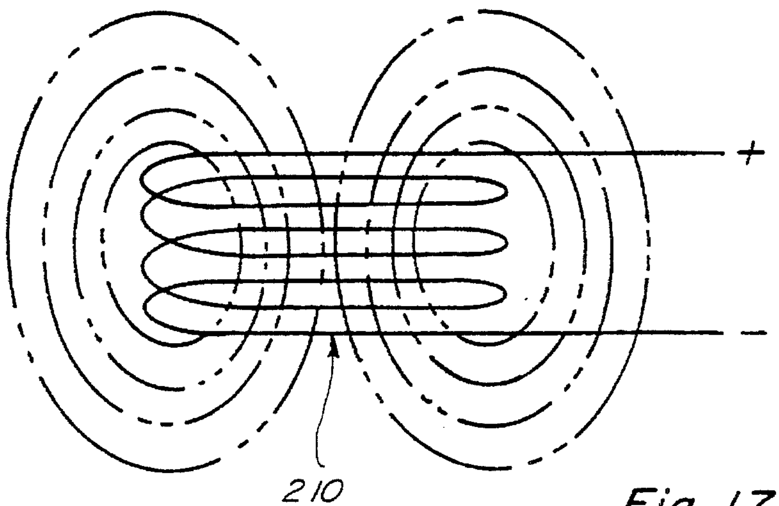

Fig. 17

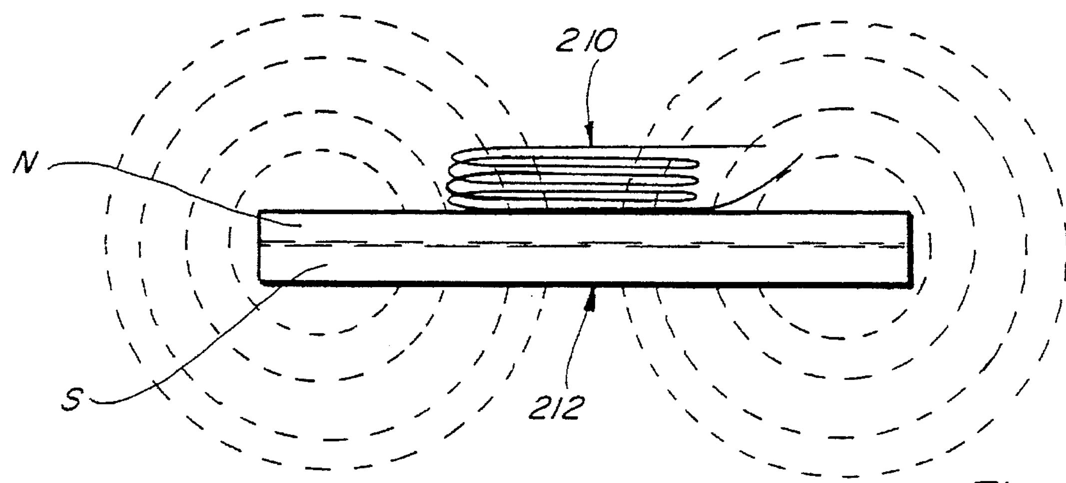

Fig. 18

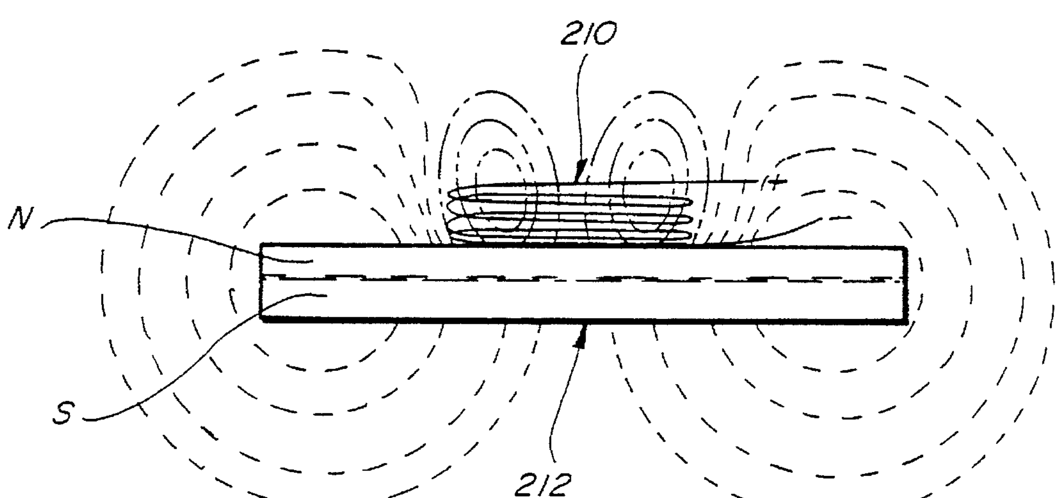

Fig. 19

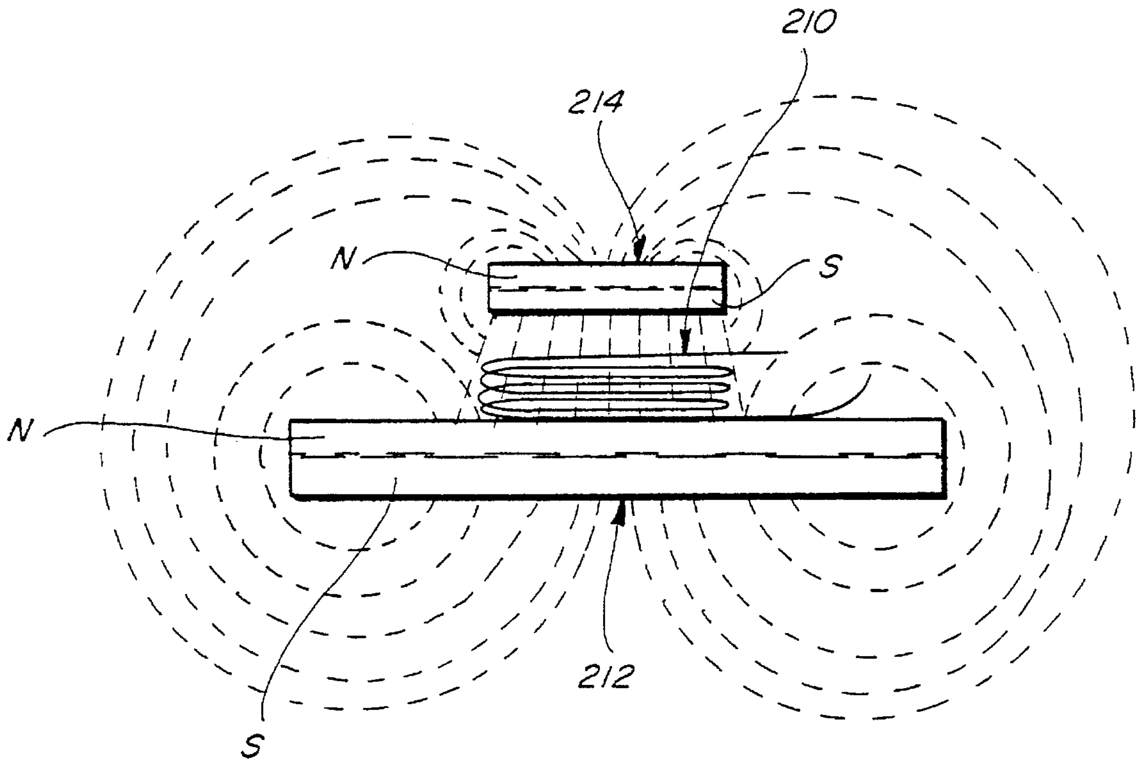

Fig. 20

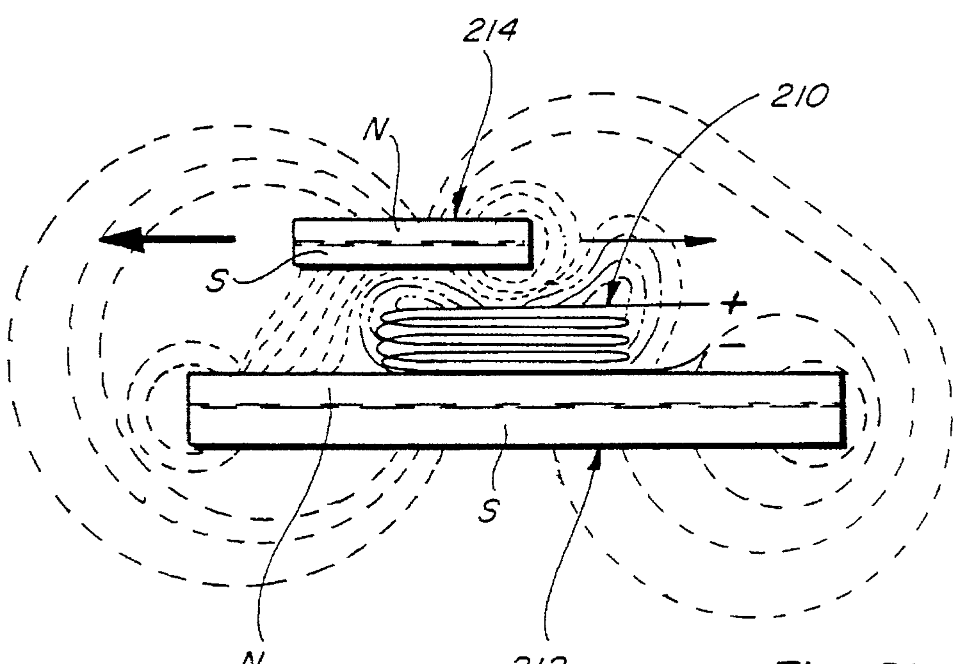

Fig. 21

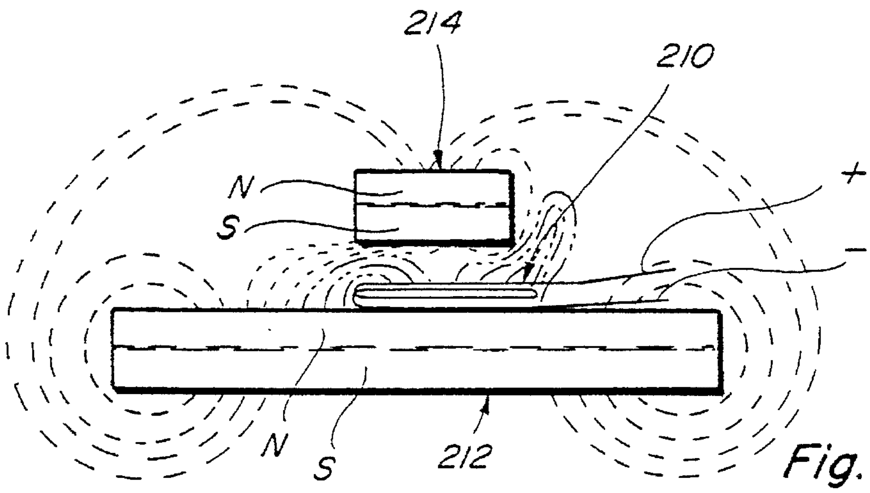

Fig. 22

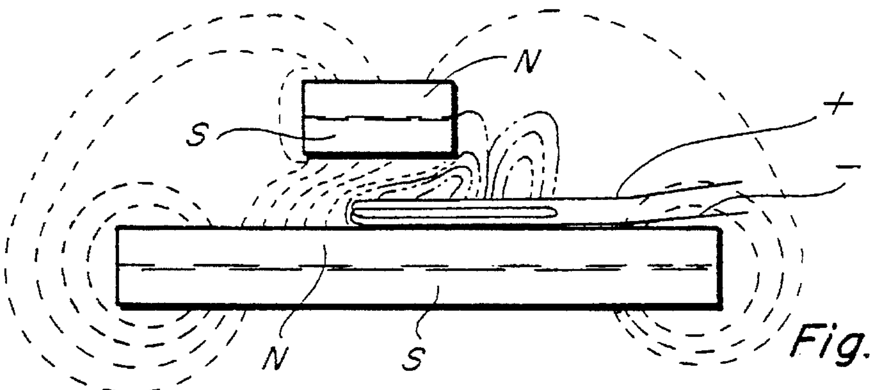

Fig. 23

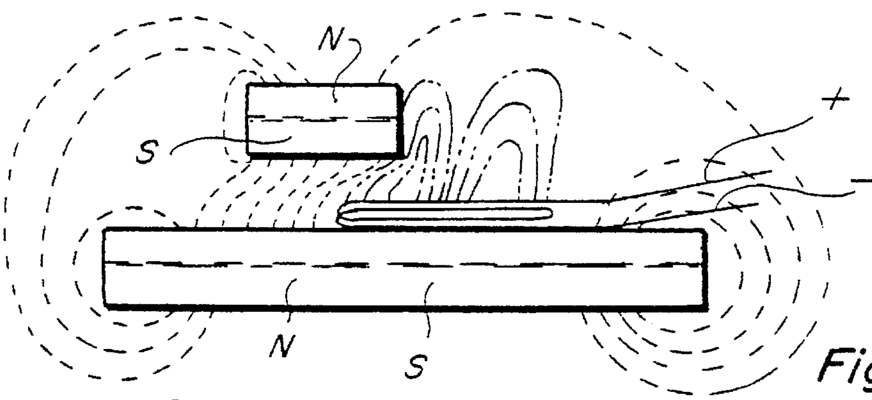

Fig. 24

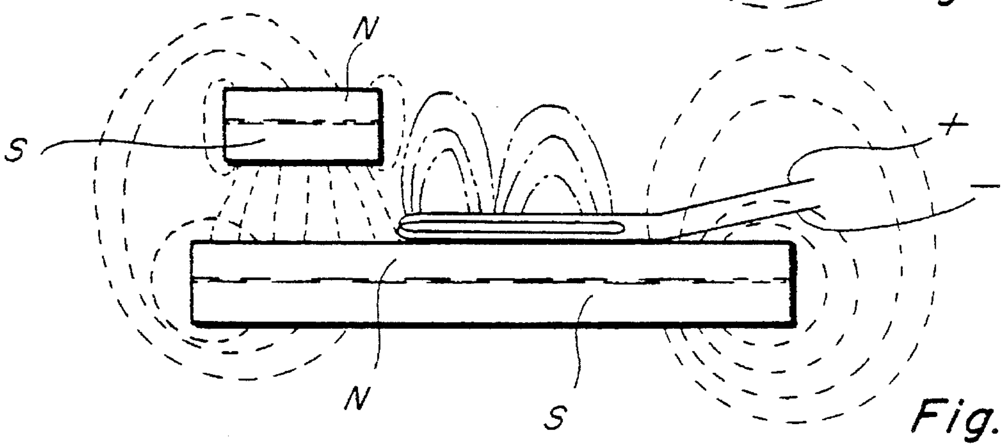

Fig. 25

MAGNETIC MOTOR CONSTRUCTION

BACKGROUND OF THE INVENTION

The present invention is an improvement over the inventions disclosed in Flynn et al and Flynn pending patent applications Ser. Nos. 07/322,121 and 07/828,703, filed Mar. 13, 1988 and Jan. 31, 1992 respectively. The devices disclosed in the pending applications relate to means to produce useful energy using permanent magnets as the driving source. This is also true of the present invention which represents an important improvement over the known constructions and one which is simpler to construct, can be made to be self starting, is easier to adjust, and is less likely to get out of adjustment. The present construction is also relatively easy to control, is relatively stable and produces an amazing amount of output energy considering the source of driving energy that is used. The present construction, like the constructions disclose in the earlier applications, makes use of permanent magnets as the source of driving energy but teaches a novel means of controlling the magnetic interaction or coupling between the magnet members and in a manner which is relatively rugged, produces a substantial amount of output energy and torque, and in a device capable of being used to generate substantial amounts of energy that is useful for many different purposes.

The present invention resides in a fixed support structure having one or more fixed permanent magnets such as an annular permanent magnet mounted thereon with the pole faces of the permanent magnet located adjacent opposite faces thereof. The device has one or a plurality of relatively flat coils arranged in a coplanar manner about the periphery on one of the opposite faces of the fixed permanent magnet, and it has means for journaling a shaft member that extends through the permanent magnet with one or more other permanent magnet members attached thereto at spaced locations, each of the one or more spaced magnets having one of its magnetic poles positioned adjacent to the fixed permanent magnet with the plane of the coils positioned therebetween, the spaced permanent magnets and the fixed permanent magnet having their polarities arranged to produce a magnetic interaction such as magnetic coupling or magnetic repulsion therebetween. The device also includes journal means for supporting the shaft member and the spaced permanent magnet members for rotation relative to the fixed magnet and to the coils thereon, and means for selectively and sequentially energizing the coils located in a plane or space between fixed and movable magnets to predeterminately control the magnetic interaction forces between the respective spaced permanent magnet members and the fixed magnet in such a manner as to produce relative rotation therebetween. Various means can be used to control the application of energy to the coils including timer means under control of means mounted on the shaft for rotation therewith and a source of energy. The present construction can be made to be self starting or to be started with some initial help to establish rotation.

OBJECTS OF THE INVENTION

It is a principal object of the present invention to teach the construction and operation of a relatively simple, motor-like device using permanent magnets in an unique manner to generate rotational or other forms of movement.

Another object is to teach the construction and operation of a relatively simple, motor-like device having novel means for coupling and/or decoupling relatively moveable permanent magnets to produce motion.

Another object is to provide novel means for controlling the coupling and decoupling of relatively moveable permanent magnets.

Another object is to make the generation of rotational energy less expensive and more reliable.

Another object is to teach a novel way of generating energy by varying magnetic interaction forces between permanent magnets.

Another object is to provide an inexpensive way of producing energy.

Another object is to provide a substitute source of energy for use in places where conventional motors, generators and engines are used.

These and other objects and advantages of the present invention will become apparent after considering the following detailed specification of preferred embodiments in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevational view of a magnetically powered device constructed according to the present invention;

FIG. **2** is an exploded view of the device shown in FIG. **1**;

FIG. **3** is a fragmentary elevational view showing a relationship between one of the movable magnet members and the non-movable magnet member in one position of the device;

FIG. **4** is a view similar to FIG. **3** but showing the relationship between the other of the movable magnet members and the non-movable magnet member in the same position of the device;

FIG. **5** is a fragmentary view similar to FIG. **3** but showing a repulsion interaction between the relatively movable permanent magnet members;

FIG. **6** is a view similar to FIG. **4** for the condition shown in FIG. **5**;

FIG. **7** is a side elevational view showing another embodiment of the subject device which is capable of producing even greater energy and torque;

FIG. **8** is a fragmentary elevational view similar to FIG. **3** for the device of FIG. **7**;

FIG. **9** is a view similar to FIG. **4** for the construction shown in FIG. **7**;

FIG. **10** is a view similar to FIG. **3** for the device shown in FIG. **7** but with the polarity of one of the fixed permanent magnet members reversed relative thereto;

FIG. **11** is a fragmentary view similar to FIG. **4** for the device as shown in FIGS. **7** and **10**;

FIG. **12** is a side elevational view of another embodiment of the device;

FIG. **13** is a schematic circuit diagram of the circuit for the devices of FIGS. **1**, **7** and **12**;

FIG. **14** is a perspective view of another embodiment of the subject device;

FIG. **15** is a simplified embodiment of the device showing the use of one rotating magnetic member and one coil positioned in the plane between the rotating and stationary magnetic members;

FIG. **16** is a simplified embodiment of the device showing use of one movable magnetic member and three coils arranged to be in a plane between the rotating and stationary magnets.

FIG. 17 is a side elevational view of an air coil with a voltage applied thereacross and showing in dotted outline the field of the coil;

FIG. 18 is a view similar to FIG. 17 but showing the air coil positioned adjacent to one side of a permanent magnet showing in dotted outline the magnetic field of the permanent magnet with no electric potential applied across the air coil;

FIG. 19 is a side elevational view similar to FIG. 18 with an electric potential applied across the air coil, said view showing in dotted outline the shapes of the electric field of the air coil and the magnetic field of the permanent magnet;

FIG. 20 is a side elevational view similar to FIG. 19 but showing a second permanent magnet spaced above first permanent magnet and showing in dotted outline the magnetic fields of the two permanent magnets when no electric potential is connected across the air coil;

FIG. 21 is a view similar to FIG. 20 but with the permanent magnets in an different relative position and with a voltage applied across the air coil, said view showing the shapes of the electro-magnetic field of the air coil and the modified shapes of the magnetic fields of the two permanent magnets; and

FIGS. 22–25 are similar to FIG. 21 and show the electromagnetic field of the air coil and the magnetic fields of the magnets in four different relative positions of the permanent magnets.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings more particularly by reference numbers, number **10** refers to a device constructed according to the present invention. The device **10** includes a stationary base structure including an upper plate member **12**, a lower plate member **14**, and spaced posts **16–22** connected therebetween. Mounted on the upper plate **12** is a fixed permanent magnet member **24** shown annular in shape which has one of its poles (its North pole) adjacent the upper surface thereof and its opposite pole (its South pole) spaced above the plate **12**.

Referring to FIG. **2**, the permanent magnet member **24** is shown having a plurality of coils **26–38** mounted in a coplanar relationship on the upper surface thereof. Seven coils are shown, and the coils **26–38** have electrical connections made through the plate **12** to other circuit members which will be described later in connection with FIG. **13**. Another member **40** is mounted on the upper surface of the lower plate **14** and a similar member **42** is mounted on the underside of the plate **12**.

A shaft **44**, (shown oriented vertically for convenience) extends through aligned bores in the members **42**, **12** and **24**. The lower end of the shaft **44** is connected to a disk member **46** which has a pair of spaced arcuate openings **48** and **50** shown located in diametrically opposite positions inwardly from the edge of the disk **46**. The purpose for the openings **48** and **50** will be explained hereinafter.

The shaft **44** is also connected to another annular member **52** which is located on the shaft so as to be positioned adjacent to the coils **26–38**. The member **52** is shown as disk shaped and it has a pair of spaced permanent magnet members **54** and **56** mounted on or in it at spaced locations shown diameterically opposite to one another (see FIG. **2**). The magnetic members **54** and **56** have their north and south poles oriented as shown in FIG. **2**, that is with north poles shown on their lower sides and their south poles on the upper sides. This is done so that there will be mutual magnetic attraction and coupling between the magnets **54** and **56** and the fixed magnetic member **24**. The polarity of the magnets **54** and **56** and/or of the magnet **24** can also be reversed if desired for some purposes to produce relative magnetic repulsion therebetween.

Referring again to FIG. **2**, the lower plate member **40** is shown having a plurality of phototransistors **58–70** mounted on the upper surface thereof at spaced locations therearound. The number and locations of the phototransistors **58–70** are such as to be in alignment substantially with the centers of the respective coils **26–38** that are mounted on the member **24**. A similar number of infrared emitters **72–84** are mounted on the undersurface of the member **42** in alignment with the respective phototransistors. There are seven infrared emitters **72–84** shown, each of which is in alignment with a respective one of the seven phototransistors **58–70** and a respective one of the seven coils **26–38**. This arrangement is such that when the shaft **44** and the members attached thereto, including the disk **46** and the member **52**, rotate relative to the other members including the member **24**, the arcuate openings **48** and **50** will pass between the respective pairs of infrared emitters and in so doing will cause the phototransistors periodically to be in optical communication with the respective infrared emitters for predetermined time intervals. The purpose of this communication is to establish a sequence of energizing circuits to energize the respective coils **26–38**, one at a time, so that each coil in turn will cause a momentary interruption of the magnetic interaction or a portion thereof between respective ones of the permanent magnets **54** and **56** and the magnet member **24**.

When a coil is mounted on top of a permanent magnet such as permanent magnet **24** and energized it acts to concentrate the flux in a symmetrical magnetic field resulting in a non symmetrical field when another permanent magnet is placed above the coil that is located on the first permanent magnet **24**. This will result in uneven or non-uniform forces being produced when the coil is energized causing a torque between the two permanent magnets, which torque will be in the direction to try to move one of the permanent magnets relative to the other.

Referring to FIG. **3** there is shown the position of one of the magnet members **54** located immediately adjacent to one of the coils such as the coil **26**. In this position there would be magnetic coupling between the magnets **54** and **24** so long as there is no voltage across the coil **26**. However, if a voltage is placed across the coil **26** it will interrupt the magnetic coupling between the magnets **54** and **24** where the coil resides. This means that if there is any torque developed, it will be developed to either side of the coil **26**. Without energizing the coil **26** there will be full attraction between the magnets **24** and **54** and no rotational force will be produced.

Referring to FIG. 4 there is shown the relative positions of the movable magnets **54** and **56** for one position of the member **52**. For example, the magnet **54** is shown located immediately above the coil **26** while the magnet **56** is shown straddling portions of the coils **32** and **34**. If, in this position of the members, the coil **32** is energized but the coils **34** and **26** are not energized then the magnetic coupling between the magnet **56** and the magnet **24** will be oriented at an angle shown illustrated by the arrow in FIG. **4**, and this attractive coupling will tend to move the member **52** to the right as shown in FIG. 4. Since there is no energizing of the coil **26** there will be full coupling between the magnet **54** and the member **24** but this will have no effect since it will neither be in a direction to rotate the member **52** or to stop it. At this same time the coil **38** which is the next coil over which the magnet **54** will move is likewise deenergized and will therefore have no effect to produce rotational moment of the member **52**.

As the member **52** continues to rotate different ones of the coils **26–38** will be energized in sequence to continue producing magnetic coupling force between the members **52** and **24** in a direction to produce relative rotation therebetween. It is to be noted, however that all of the rotational force is produced by interaction between permanent magnet members and none of the rotational force is produced by the coils or by any other means. The coils are merely energized in sequence to control where the magnetic interaction occurs, and this is done in a manner to cause the member **52** to rotate. It should also be understood that one or more, including more than two, permanent magnets such as the permanent magnets **54** and **56** can be mounted on the rotating member **52**, and the shape and size of the rotating member **52** can be adjusted accordingly to accommodate the number of permanent magnets mounted therein. Also, the member **52** can be constructed of a non magnetic material, the only requirement being that sufficient structure be provided to support the permanent magnets during rotation. This means that the member **52** need not necessarily be constructed to be round as shown in the drawing.

FIGS. **5** and **6** are similar to FIGS. **3** and **4** but show a construction wherein the permanent magnets **54** and **56** are overturned so that instead of having their north poles adjacent to the member **24** they have their south poles adjacent to the magnet **24** but on the opposite side of the coils such as coils **26–38**. The construction and operation of the modified device illustrated by FIGS. **5** and **6** is similar to that described above except that instead of producing magnetic attraction forces between the magnet members **54** and **56** and the magnet **24**, magnetic repulsion forces are produced, and these repulsion forces can likewise be used in a similar manner to produce rotation of the member **52**, whatever its construction.

FIG. **7** shows a modified embodiment **100** of the subject device which includes all of the elements shown in FIGS. **1** and **2** but in addition has a second stationary permanent magnet member **102** which is mounted above rather than below the member **52** and has its coil members such as coil members **26**A–**38**A mounted on its underside. The magnetic member **102** operates with the magnets **54** and **56** similarly to the member **24** and can operate in precisely the same manner, that is by producing attraction force between the magnet members or by producing repulsion forces therebetween, each being used to produce relative rotational movement between the rotary portions of the device and the stationary portions. It is also contemplated to make the construction shown in FIG. **7** so as to produce attraction forces between the magnets **54** and **56** on one side thereof and cooperating repulsion forces which add to the rotation generating forces produced on the opposite sides thereof.

FIGS. **8** and **9** are similar to FIGS. **3** and **4** but show the relationship between the magnets **54** and **56** and the members **24** and **102** located on opposite thereof. FIG. **9** shows arrows used to indicate the direction of the rotational forces produced that are necessary for rotating the rotatable portions of the device. These figures show one form of interaction between the rotating magnets **54** and **56** and the stationary magnets **24** and **102** located as shown in FIG. **7**. In this construction the device produces attractive rotating force only.

FIGS. **10** and **11** are similar to FIGS. **8** and **9** except that in these figures both attraction and repulsion forces are shown being produced in association with the stationary magnets on opposite sides of the rotating magnets. Note also that the coils being energized on opposite sides of the member **52** are energized in a different arrangement.

FIG. **12** is a side elevational view similar to FIG. **7** but illustrating the way in which a plurality of stationary and rotatable magnetic members such as the members **24** and **102** can be mounted on the same shaft, in almost any number of repetitive groups to increase the amount of torque produced by the device. In FIG. **12** the same power source and the same circuit arrangement can be used to energize the phototransistors and the infrared emitters. However, depending upon whether attraction or repulsion forces are used to produce the rotation or some combination thereof will depend upon the order in which the coils associated with the stationary magnetic members are energized.

FIG. **13** is a circuit diagram for the device shown in FIGS. **1** and **2**, showing the circuit connections for the coils **26–38** and for the circuit elements associated therewith. A similar circuit can be used for the construction shown in FIGS. **7** and **12**. The circuit also includes connections to the various phototransistors and infrared emitters.

In FIG. **13**, the circuit **120** is shown including a power supply **122** which may be a battery power supply, a rectified AC power supply or an AC or pulsed power supply. The positive side **124** of the power supply **122** is shown connected to one side of each of the coils **26–38**, coil **26** and the circuits associated therewith being shown in bold outline and including connections to one side of a resistor **128** and to one side of the photo transistors **58–70**. The opposite side of the coil **26** is connected to one terminal of Mosfet **126**. The opposite side of the resistor **128** is connected to one side of the infrared emitter **72**, as well as to the corresponding sides of all of the other infrared emitters **74–84**. The opposite sides of the infrared emitters **72–84** are connected by lead **130** to the negative terminal side **132** of the power supply **122**. With the circuit as shown, the infrared emitters **72–84** are all continuously energized and produce light which can be seen by the respective phototransistors **58–70** when one of the openings **48** or **50** passes therebetween. When this happens, the respective phototransistor **58** will conduct and in so doing will apply positive voltage on the associated Mosfet **126**, turning the Mosfet on, and causing the voltage of the source **122** to also be applied across the coil **26**. The circuit for this is from the source **122** through the coil **26**, through the Mosfet **126** to and through the lead **134** to the opposite side of the source **122**. When the supply voltage is applied across the coil **26**, the coil **26** operates to limit or prevent magnetic communication between whichever one of the magnets **54** or **56** happens to be positioned adjacent to the coil **26** which is in the space between that magnet **54** or **56** and the magnet **24**. This circuit is shown darkened in FIG. **13**. By properly timing and controlling the application of voltage to the various coils **26–38** in the manner described, the magnetic coupling between the magnets **54** and **56** and the magnet **24** can be accurately controlled and in a manner to cause angular magnetic attraction between the magnet **54** (or **56**) and the magnet **24**, which angular attraction (or repulsion) is in a direction to cause rotation of the rotating parts of the structure shown in FIGS. **1**, **2**, **7** and **12**. It is to be understood that each of the coils **26–38** will be controlled in the same manner, that is, will have a voltage appearing across it at the proper time to control the direction of the magnetic coupling in a manner to produce rotation. The rotating portions will continue to rotate and the speed of rotation can be maintained at any desired speed. Various means can be used to control the speed of rotation such as by controlling the timing of the DC or other voltage applied to the various coils, such as by using an alternating or pulsed current source instead of a direct current source or by loading the device to limit its rotational speed.

It is especially important to note that the energy required to operate the subject device is minimal since very little electrical energy is drawn when voltage is applied across the various coils when they are energized.

A well known equation used for conventional motor art, is:

$$\frac{\text{Speed} \times \text{Torque}}{9.55} = \text{Power (in watts). Hence,}$$

$$\frac{S \times T}{9.55} = W.$$

This equation has limited application to the present device because in the present device the torque is believed to be constant while the speed is the variable. The same equation can be rewritten:

$$T = \frac{9.55 \times W}{S} \text{ or } S = \frac{9.55 \times W}{T}$$

These equations, if applicable mean that as the speed increases, the watts divided by the torque must also increase but by a factor of 9.55. Thus if torque is constant or nearly constant, as speed increases, the power output must increase and at a very rapid rate.

It should be understood that the present device can be made to have any number of stationary and rotating magnets arranged in stacked relationship to increase the power output, (see FIG. 12) and it is also possible to use any desired number of coils mounted on the various stationary magnets. In the constructions shown in FIGS. **1**, **7**, and **12** seven coils are shown mounted on each of the stationary magnets but more or fewer coils could be used on each of stationary magnet depending upon the power and other requirements of the device. If the number of coils is changed the number of light sources and photodetectors or transistors will change accordingly. It is also important to note that the timing of the turning on of the various phototransistors is important. The timing should be such as that illustrated in FIG. **4**, for example, when one of the coils such as coil **32** is energized to prevent coupling in one direction between the magnet **56** and the magnet **24** the adjacent coil **34** will not be energized. The reasons for this have already been explained.

Referring to FIG. **14**, there is shown another embodiment **140** of the subject device. The embodiment **140** includes a stationary permanent magnet **142** which has a flat upper surface **144** and a lower surface **146** that is circumferentially helical so that the member **142** varies in thickness from a location of maximum thickness at **148** to a location of minimum thickness at **150**. The thickness of the member **142** is shown varying uniformly therearound. Near the location of the thickest portion **148** of the permanent magnet **142** and adjacent to the surface **144** is an air coil **152** shown formed by a plurality of windings. A shaft member **154** is journalled by bearing means **156** for rotation relative to the stationary permanent magnet **142** and is connected to a rotating member **158**. The member is shown annular in shape and includes four spaced permanent magnets **160**, **162**, **164** and **166** mounted on or in it. The permanent magnets **160–166** are positioned to rotate in closely spaced relation to the stationary permanent magnet **142** but with the coil **152** positioned therebetween. The coil **152** is connected into a circuit similar to that shown in FIG. **13** and the circuit will not be described further.

The principals of operation of the device **140** shown in FIG. **14** are similar to that described above in connection with FIGS. **1** and other figures. It is important to note, however, that the permanent magnets **160–166** rotate relative to the permanent magnet **142** because of the increasing coupling between them and the permanent magnet due to the increasing peripheral thickness of the permanent magnet. Thus the member **158** will rotate in a counterclockwise direction as shown, and each time one of the magnets **160–166** moves into a position adjacent to the thickest portion **148** of the fixed permanent magnet **142** the coil **152** will have voltage applied across it, otherwise there would be a tendency for the member **158** to stop or reduce the rotational force. In order to overcome this the coil **152** is energized each time one of the permanent magnets **160–166** is in the position shown. The rotating disc **158** is connected through the shaft **154** to rotating disc **168** which has four openings **170**, **172**, **174** and **176** corresponding to the locations of the permanent magnets **160–166** so that each time one of the permanent magnets moves to a position adjacent to the thickest portion **148** of the stationary permanent magnet **142** the coil **152** will be energized and this will reduce or eliminate the coupling between the rotating and stationary magnets that would otherwise slow the rotating portions down. The circuit connected to the coil **152** includes the same basic elements described above in connection with FIG. **13** including varying a photocell **178**, an infrared emitter **180** and a Mosfet **182** connected into a circuit such as that shown in FIG. **13**. The timing of the energizing of the coil **152** is important and should be such that the coil will be energized as the respective permanent magnets **160–166** move to a position in alignment or substantial alignment with the thickened portion **148** of the stationary permanent magnet **142**.

FIG. **15** shows a basic simplified form **190** of the present device which includes a rotary member **52**A having a single permanent magnet portion **54**A mounted thereon. The device also has a stationary permanent magnet **24**A with a single air coil **26**A positioned in the space between the members **52**A and **24**A in the manner already described. The construction **190** is not self-starting as are the preferred embodiments such as embodiment **10** but the rotary portions will rotate continuously once the device is started as by manually rotating the rotary portions. The construction **190** will have other portions as described above but the output from the construction will be less than the output produced by the other constructions.

FIG. **16** shows another simplified version **200** of the device wherein the member **52**B is similar to the corresponding rotatable member **52**A shown in FIG. **15**. However, the fixed structure including the permanent magnet **24**B has three windings **26**B, **28**B and **30**B located at spaced intervals adjacent to the upper surface thereof. The construction shown in FIG. **16** will produce more output than the construction shown in FIG. **15** but less than that of the other constructions such as that shown in FIGS. **1**, **2**, **7** and **12**. Obviously many other variations of the constructions shown in the application are also possible including constructions having more or fewer coils, more or fewer rotating magnetic portions, more or fewer rotary members such as the member **52** and more or fewer stationary members such as the members **24** and **142**.

FIGS. **17–25** illustrate some of the underline principles of the present invention.

FIGS. **17** shows an air coil **210**, positioned in space, with an electric potential applied thereacross. With the energizing voltage applied the electro-magnetic field of the air coil **210** extends substantially equally in the space above and below the coil as shown in dotted outlined.

FIG. **18** shows the air coil **210** positioned adjacent to one side (the north side) of permanent magnet **212**. In FIG. **18** no voltage is applied across the air coil **210** and therefore the air coil **210** does not produce an electro-magnetic field as in FIG. **17**. Under these circumstances the air coil **210** has no effect on the magnetic field of the permanent magnet **212** and the field of the permanent magnet is substantially as shown by the dotted outlines in FIG. **18**.

FIG. **19** is similar to FIG. **18** except that in FIG. **19** the air coil **210** has an electric potential applied across it and therefore has an established electro-magnetic field shown again by dotted outline.

The electro-magnetic field of the air coil **210** modifies the magnetic field of the permanent magnet **212** in the manner shown. If the coil **210** is placed in contact with or close to the surface of the permanent magnet and it is energized so that its polarity is opposite to that of the permanent magnet then the field produced is similar to that shown in FIG. **19**. Note that the field of the air coil **210** and the field of the permanent magnet **212** directly beneath the air coil **210** are in opposition and therefore act to cancel one another. The air coil **210** would be defined to produce a counter magnetomotive force which acts to cancel the field of the permanent magnet **212** in the region where the air coil **210** exists and the amount of the field in that region of the permanent magnet **212** that is canceled is the remainder of the difference in magnetomotive force between the region of the permanent magnet **212** and the counter magnetomotive force of the air coil **210**. Note that since the field of permanent magnet **212** is only altered in the region of the air coil **210**, the geometric magnetic field characteristics of the permanent magnet **212** can be altered selectively based upon the size of the coil **210**, the number of air coils **210** and the amount of counter magnetomotive force being produced by the air coil **210**.

FIG. **20** is similar to FIG. **19** except that a second permanent magnet **214** is positioned at a location spaced above the air coil **210**. In FIG. **20** no voltage is applied across the air coil **210** and therefore the air coil **210** does not have an electro-magnetic field. Thus FIG. **20** shows only the combined affect of the fields of the permanent magnets **212** and **214**. Since the permanent magnets **212** and **214** are oriented so that their respective north and south poles are close together, there will be a strong attractive force between them at the location of the air coil **210**.

FIG. **21** is a view similar FIG. **20** but with an electric potential applied across the air coil **210** and with the upper permanent magnet **214** displaced to the left relative to its position in FIG. **20**. Note that in FIG. **21** the shape of the electro-magnetic field of the air coil **210** is concentrated and shifted somewhat to the right and upward. This shift of the electro-magnetic field concentrates the magnetic coupling between the magnets **212** and **214** to the left thereby increasing the tendency of the upper permanent magnet **214** to move to the left. A much smaller magnetic coupling occurs between the right end of the permanent magnets **212** and **214** and thus the force tending to move the permanent magnet **214** to the right is much less than the force tending to move it to the left. This is illustrated by the size of the arrows shown in FIG. **21**.

FIGS. **22–25** show four different positions of the upper permanent magnet **214** relative to the lower permanent magnet **212**. In FIG. **22** because of the position of the upper permanent magnet **214** relative to the air coil **210** there is a concentration of the magnetic coupling force tending to move the upper permanent magnet **214** to the left. This force increases in FIGS. **23** and **24** until the upper permanent magnet **214** reaches the position shown in FIG. **25** where all of the magnetic coupling is directed substantially vertically between the permanent magnets **212** and **214** and in this position there is little or no torque as a result of coupling energy between the permanent magnets **212** and **214** tending to move them relative to one another.

The principles illustrated in FIGS. **17–25** are at the heart of the present invention and explain where the energy comes from to produce relative movement between the relatively moveable permanent magnets.

The present device has application for very many different purposes and applications including almost any purpose where a motor or engine drive is required and where the amount of energy available and/or required to produce the driving force may vary little to nil. Applicant has produced devices of the type described herein capable of rotating at very high speed in the order of magnitude of 20,000 RPMs and with substantial torque. Other lesser speeds can also be produced, and the subject device can be made to be self starting as is true of the constructions shown in FIGS. **1**, **2**, **7** and **12**. Because of the low power required to operate the device applicant has been able to operate same using a commerically available battery such as a nine volt battery.

Thus there has been shown and described a novel magnetic motor or motor-like construction which fulfills all of the objects and advantages sought therefor. It will be apparent to those skilled in the art, however, that many changes, variations, modifications and other uses in applications for the subject device are possible. All such changes, variations, modifications and other uses in applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the claims which follow.

What is claimed is:

1. A device to control the magnetic interaction between spaced permanent magnets comprising:

a first permanent magnet having opposite surfaces with north and south poles respectively,

a second permanent magnet spaced from and movable relative to the first permanent magnet and having opposite surfaces with north and south poles respectively, one of which is positioned in close enough proximity to one of the surfaces of the first permanent magnet to produce magnetic interaction therebetween,

a coil of conductive metal positioned in the space between the first and second permanent magnets,

a source of electrical energy and switch means connected in series therewith across the coil whereby when the switch means are closed the electrical energy from said source is applied across the coil whereby the magnetic interaction between the first and second permanent magnets is changed, and

means to control the opening and closing of the switch means.

2. A device for producing rotational movement and torque comprising:

a member journaled for rotational movement about an axis of rotation, the rotatable member having at least a portion adjacent the periphery thereof formed of a permanently magnetized material,

a stationary member formed of permanently magnetized material mounted adjacent to the peripheral portion of the rotatable member axially spaced therefrom whereby a magnetic interaction is produced between the stationary and the rotatable members in predetermined positions of the rotatable member,

at least one coil positioned extending into the space between the stationary and rotatable members,

means including a source of electric potential and switch means connected in series across the coil, and

means to predeterminately control the opening and closing of the switch means during rotation of the rotatable member to vary the magnetic interaction in a way to produce rotation of the rotatable member.

3. Means to predeterminately vary the magnetic interaction between first and second spaced permanent magnet members comprising a first permanent magnet member having north and south poles, a second permanent magnet member having north and south poles spaced from the first permanent magnet member by a gap therebetween, a coil positioned extending into the gap between the first and second permanent magnet members, means connecting the coil across a circuit that includes a source of voltage and switch means connected in series therewith so that when the voltage source is connected across the coil it effects the magnetic interaction between the first and second permanent magnet members, and means for mounting the first permanent magnet member for movement relative to the second permanent magnet member and relative to the coil in the gap therebetween.

4. The device of claim **3** wherein the first and second permanent magnet members are mounted to produce magnetic attraction therebetween.

5. The device of claim **3** wherein the first and second permanent magnet members are mounted to produce magnetic repulsion therebetween.

6. The device of claim **3** wherein the means mounting the first permanent magnet member includes means mounting the first permanent magnet member for rotational movement relative to the second permanent magnet member and the switch means includes cooperative optical means having a first portion mounted for movement with the first permanent magnet member and a second portion associated with the second permanent magnet member.

7. The device of claim **6** wherein the switch means includes a light source and a light sensitive member associated respectively with the first and second permanent magnet members, and control means therefor mounted for movement with the first permanent magnet.

8. The device of claim **3** wherein the second permanent magnet member is an annular permanent magnet member having one of its poles on one side of the gap and the other of its poles opposite thereto, means mounting the first permanent magnet member for rotational movement relative to the second permanent magnet member, said first permanent magnet member having one of its poles on one side of the gap, and a plurality of circumferentially spaced coils mounted in the gap between the first and second permanent magnet members.

9. The device of claim **8** wherein the first permanent magnet member includes two circumferentially spaced portions.

10. Means for producing rotational movement comprising:

a support structure having a first permanent magnet mounted thereon, said first permanent magnet having a north pole adjacent one surface and a south pole adjacent to the opposite surface,

means for mounting a second permanent magnet for rotational movement in a plane parallel to the first permanent magnet, the second permanent magnet occupying an arcuate portion of said mounting means less than the entire circumference of said mounting means and having a north pole adjacent to the opposite surface and positioned so that there is a magnetic interaction between the spaced first and second permanent magnets across a gap therebetween in at least one position thereof,

at least one air coil positioned in the gap between the first and second permanent magnets,

a source of electric potential and switch means for controlling the application of the electric potential from said source across the air coil, the application of voltage across the air coil effecting the magnetic interaction between the first and second permanent magnet members in certain positions of the second permanent magnet relative to the first permanent magnet and in such a manner as to produce rotational movement of the second permanent magnet.

11. The device for producing rotational movement of claim **10** wherein a third permanent magnet is mounted on the support structure on the opposite side of the second permanent magnet from the first permanent magnet so as to establish a second gap therebetween and so that there is magnetic interaction between the second and third permanent magnets, and at least one second coil mounted in the gap between the second and third permanent magnets to predeterminately effect the magnetic interaction therebetween in certain positions of the second permanent magnet relative to the third permanent magnet thereby to contribute to the production of rotational movement of the second permanent magnet member relative to the first and third permanent magnets.

12. The device for producing rotational movement defined in claim **11** wherein the switch means for applying voltage from the source across the coils includes a light source and light sensor one mounted on the support structure and the other on the rotatable means to produce a switching action to apply and remove voltage from across the coils in predetermined positions of the second permanent magnet relative to the first and third permanent magnets.

13. Means for producing rotary motion using magnetic energy from permanent magnets comprising:

a fixed permanent magnet having opposite surfaces with north and south poles respectively adjacent thereto,

a shaft having an axis and means journaling the shaft for rotation in a position extending normal to the opposite surfaces of the fixed permanent magnet,

a movable permanent magnet and means mounting the movable permanent magnet on the shaft for rotation therewith, the movable permanent magnet occupying an arcuate portion of said mounting means less than the entire circumference of said mounting means and having opposite surfaces with associated north and south poles respectively, one pole of said movable permanent magnet being positioned to move in close enough proximity to one of the opposite surfaces of the fixed permanent magnet to produce magnetic interaction therebetween,

at least one coil mounted in the space between the fixed permanent magnet and the movable permanent magnet, energizing of the coil effecting the magnetic interaction between the fixed and the movable permanent magnets when positioned therebetween, and

means connecting the coil to a source of energizing potential in selected positions of the movable permanent magnet relative to the fixed permanent magnet.

14. The device for producing rotary motion of claim **13** wherein a plurality of coils are mounted in a coplanar relationship in the space between the fixed permanent magnet and the movable permanent magnet, the means connecting the coils to a source of energizing potential including means for energizing the respective coils in a predetermined sequence.

15. The device for producing rotary motion of claim **13** including a second movable permanent magnet mounted on the means mounting the movable permanent magnet for movement therewith, said second movable permanent magnet being spaced circumferentially from the aforesaid movable permanent magnet.

16. The device for producing rotary motion of claim **13** wherein a second fixed permanent magnet has opposite surfaces with north and south poles respectively adjacent thereto and is mounted on the opposite side of the movable permanent magnet from the aforesaid fixed permanent magnet and at least one coil mounted in the space between the second fixed permanent magnet, and the movable permanent magnet.

17. A device for producing rotary motion defined in claim **13** wherein the means connecting the coil to a source of energizing potential includes a fixed light source and a fixed light sensitive member mounted in spaced relationship and means on the mounting means for the movable permanent magnet for predeterminately controlling communication between the light source and the light sensitive member during rotation of the movable permanent magnet.

18. A magnetic motor-like device comprising:

a fixed support structure having a permanent magnet member mounted thereon, said member having opposite side faces with a north magnetic pole adjacent one side face and a south magnetic pole adjacent the opposite side face,

a plurality of coils mounted adjacent to and arranged about one of the opposite side faces,

an orifice through the permanent magnet member at a location intermediate the coils,

a shaft extending through the orifice for rotation about the axis thereof,

a member attached to the shaft for rotation therewith and spaced from the one opposite magnet side faces,

at least one magnet member attached to a segment of said rotating member for rotation therewith, each of said rotating magnetic members having a magnetic pole face positioned in spaced relation to the one opposite pole side face of the fixed permanent magnet member, the plurality of coils being in the space formed by and between the fixed permanent magnet member and the at least one rotatable magnet member, and

means to selectively and sequentially energize the coils as the shaft rotates to predeterminately control the magnetic interaction between the at least one magnetic member and that fixed permanent magnet member.

19. The magnetic device of claim **18** wherein there is an odd number of coils mounted in the space between the permanent magnet member and the at least one rotatable magnetic member.

20. The magnetic device of claim **18** wherein the at least one magnetic member attached to the rotating member for rotation therewith includes two circumferentially spaced rotatable magnet portions.

21. A device for producing rotary motion comprising:

a support structure having a wall member,

a shaft and means journaling the shaft for rotation in the wall member about its axis,

a permanent magnet member mounted on the wall member extending about at least a portion of the shaft, said permanent magnet member having one pole adjacent to the wall member and an opposite pole spaced therefrom,

a member mounted on the shaft having at least two magnetic members oriented to produce magnetic interaction with the permanent magnet member,

a plurality of coils mounted in coplanar relation extending into the space formed by and between the permanent magnet member and the at least two magnetic members and

means to sequentially apply a voltage across the respective coils to vary the magnetic interaction between the permanent magnet member mounted on the wall member and selected ones of the at least two magnetic members.

22. A device for producing rotary motion using magnetic energy from permanent magnets comprising

a fixed permanent magnet having opposite surfaces with north and south poles respectively adjacent thereto,

a shaft and means for journaling the shaft for rotation extending normal to the opposite surfaces of the fixed permanent magnet,

at least two rotatable permanent magnets and means mounting them for rotation with the shaft, the rotatable permanent magnets having opposite surfaces with associated north and south poles respectively, one pole of each rotatable permanent magnet being positioned close enough to one of the opposite surfaces of the fixed permanent magnet to produce magnetic interaction therebetween,

a plurality of spaced coils arranged to be coplanar and positioned in the space formed by and between the fixed permanent magnet and the rotatable permanent magnets, and

means to apply a voltage across respective ones of the coils in a sequence so as to predeterminately affect the interaction between the fixed permanent magnet and the rotatable permanent magnets in a manner to produce rotation of the at least two permanent magnets.

23. A device for producing rotary motion using magnetic energy from permanent magnets comprising:

a fixed annular permanent magnet having a flat surface on one side and an opposite surface of helical shape extending therearound from a location of minimum thickness to a location of maximum thickness approximately adjacent thereto, the annular permanent magnet having one of its poles adjacent to the flat surface and its opposite pole adjacent to the helical opposite surface,

a shaft and means for journaling the shaft for rotation extending substantially normal to the flat surface of the fixed permanent magnet,

a permanent magnet and means mounting it on the shaft for rotation therewith, said permanent magnet having opposite pole faces and being positioned so that there is magnetic interaction between said permanent magnet and the fixed annular permanent magnet,

at least one air coil positioned in the space between the fixed and rotatable permanent magnets, and

means to apply a voltage across the air coil when the rotatable permanent magnet is adjacent to the thickest portion of the fixed permanent magnet to change the magnetic interaction therebetween, said last name means including a source of voltage and switch means in series with the source for controlling the application of voltage across the air coil.

24. The device for producing rotary motion of claim **23** wherein a plurality of rotatable permanent magnets are mounted at circumferentially spaced locations about the

shaft for magnetic interaction with the fixed annular permanent magnet, the switch means controlling the application of voltage from the source to the air coil when one of the rotatable permanent magnets is positioned adjacent to the thickest portion of the fixed annular permanent magnet.

25. The means for producing rotary motion of claim **23** wherein the switch means includes cooperative optical means having a first portion associated with the fixed annular permanent magnet and a second portion associated with the rotatable annular permanent magnet.

* * * * *

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United States Patent [19]

Flynn

[11] Patent Number: 5,463,263

[45] Date of Patent: Oct. 31, 1995

[54] **PERMANENT MAGNET CONTROL MEANS**

[75] Inventor: **Charles J. Flynn**, Kansas City, Mo.

[73] Assignee: **Magnetic Revolutions Limited L.L.I.**, St. Louis, Mo.

[21] Appl. No.: **104,783**

[22] Filed: **Aug. 11, 1993**

Related U.S. Application Data

[62] Division of Ser. No. 828,703, Jan. 31, 1992, Pat. No. 5,254,925.

[51] **Int. Cl.**^{6} **H02K 23/04**; H02K 29/10; H02K 11/00; H02K 1/27

[52] **U.S. Cl.** .... **310/181**; 310/156; 310/68 B

[58] **Field of Search** .... 310/46, 68 B, 310/20, 24, 152, 156, 181, 268; 335/229, 230, 231, 232, 233, 234, 272; 318/135

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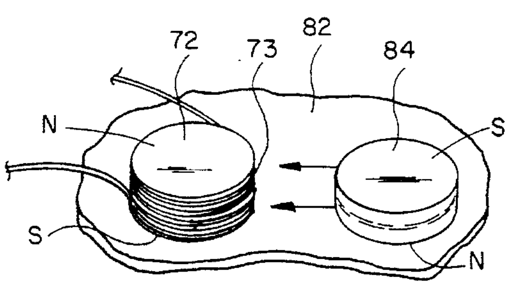
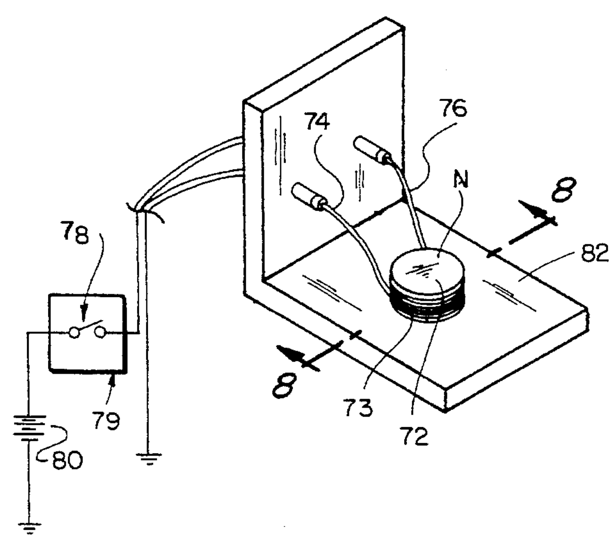
Primary Examiner—Clayton E. LaBalle
Attorney, Agent, or Firm—Haverstock, Garrett and Roberts

[57] **ABSTRACT**

A motion producing device using permanent magnets as the source of energy including one or more permanent magnets at least one having a coil mounted on it, and an electric circuit for connecting the coil to a source of electric energy whereby application of the energy to the coil changes or modifies the magnetic characteristics of the permanent magnet on which it is mounted in such a manner that when another permanent magnet is in the field of the controlled permanent magnet, the interaction between the permanent magnets will be modified so as to change the coupling force therebetween. The present device can be used to produce rotational motion, linear motion, oscillating motion, and combinations of these.

14 Claims, 8 Drawing Sheets





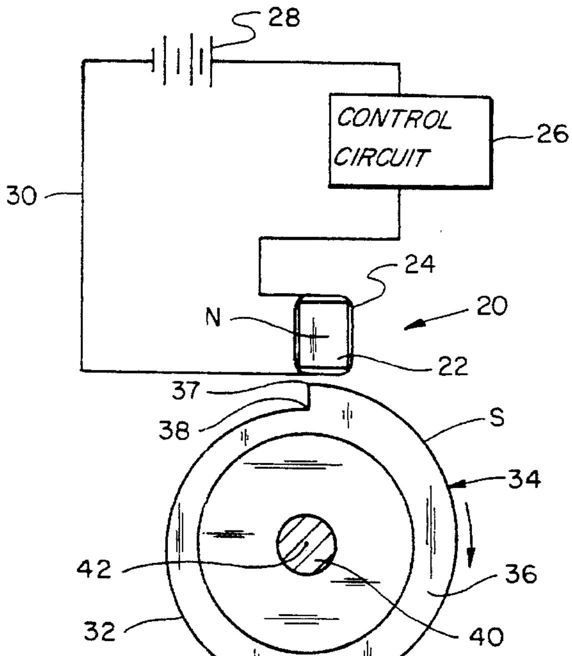


Fig. 1

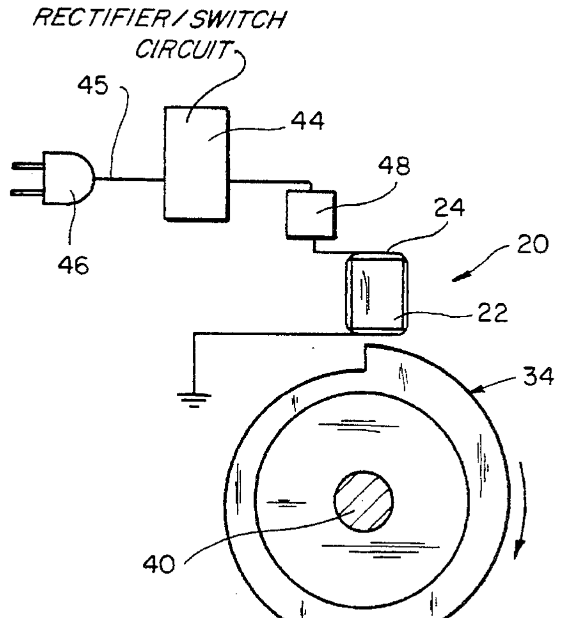


Fig. 2

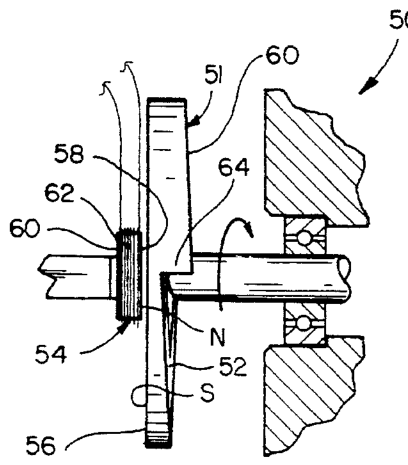
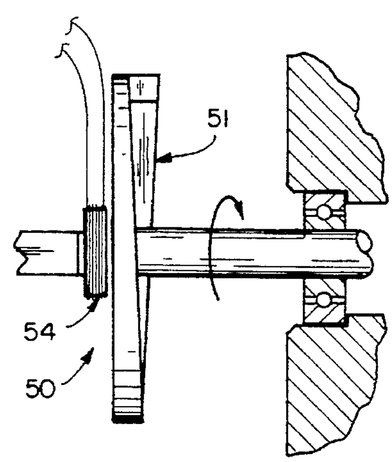


Fig. 3



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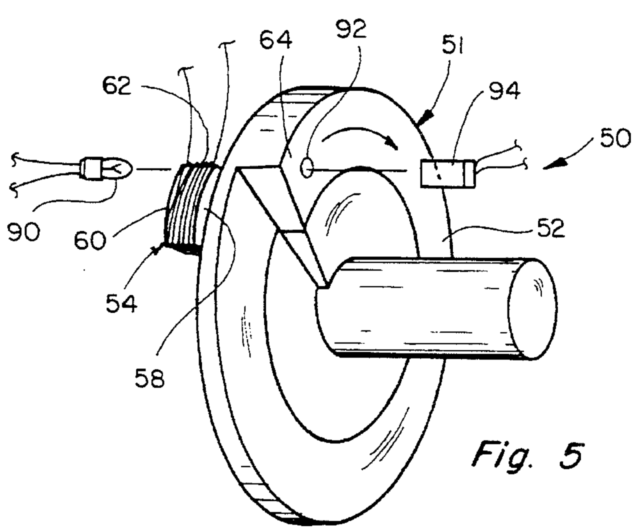


Fig. 5

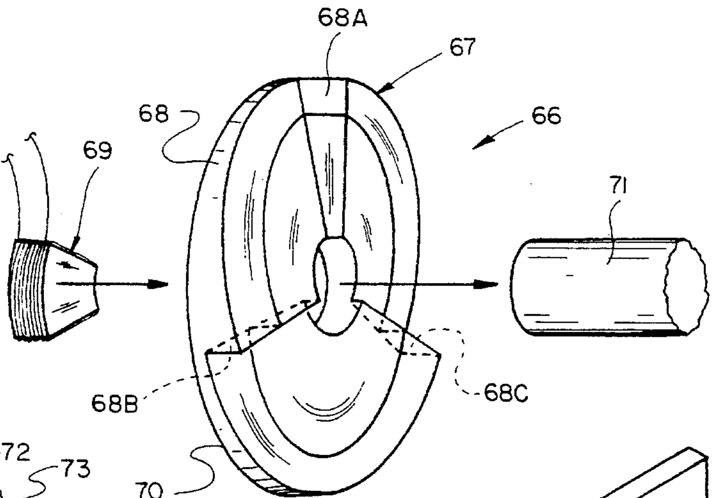


Fig. 6

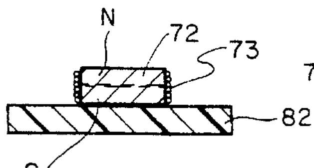


Fig. 8

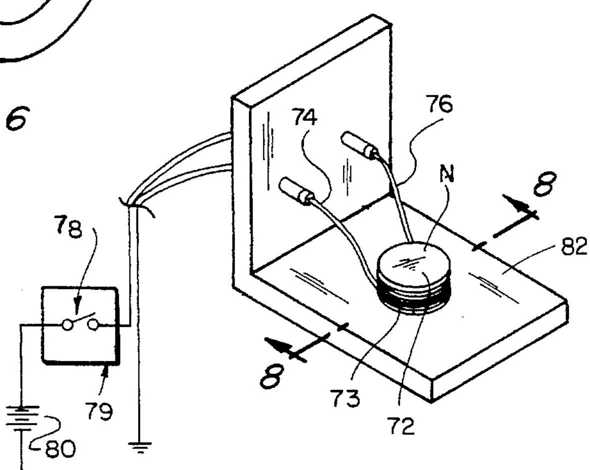


Fig. 7

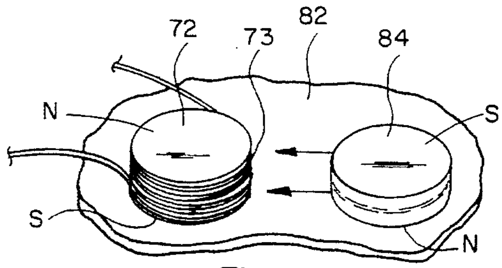


Fig. 9

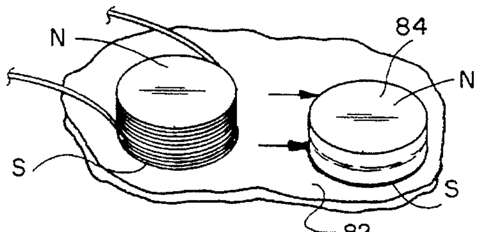


Fig. 10

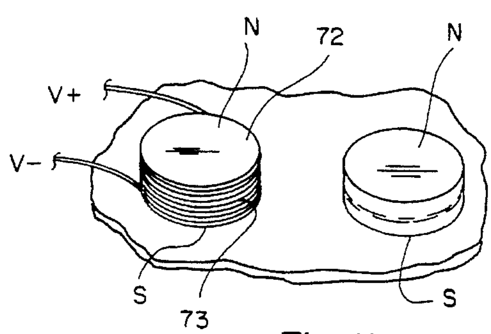
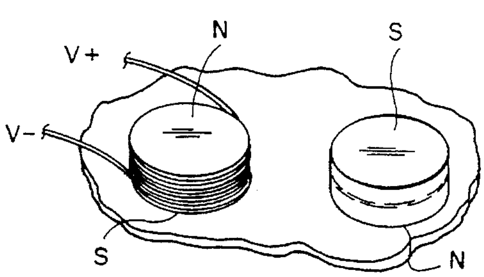


Fig. 11



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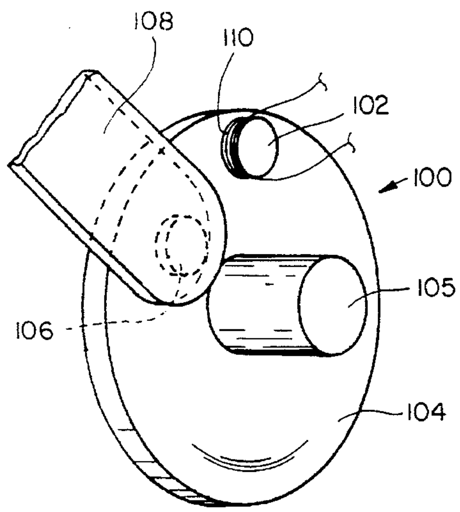


Fig. 13

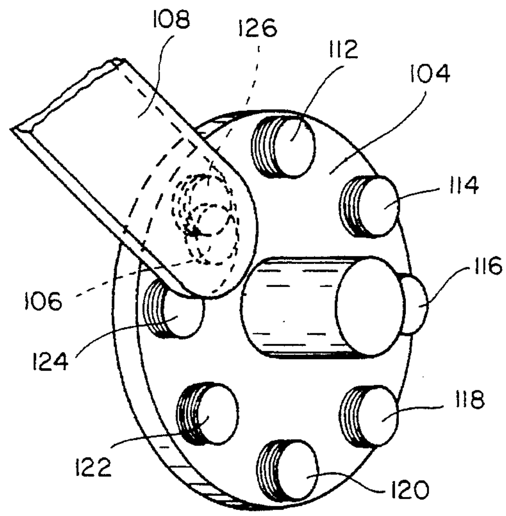


Fig. 14

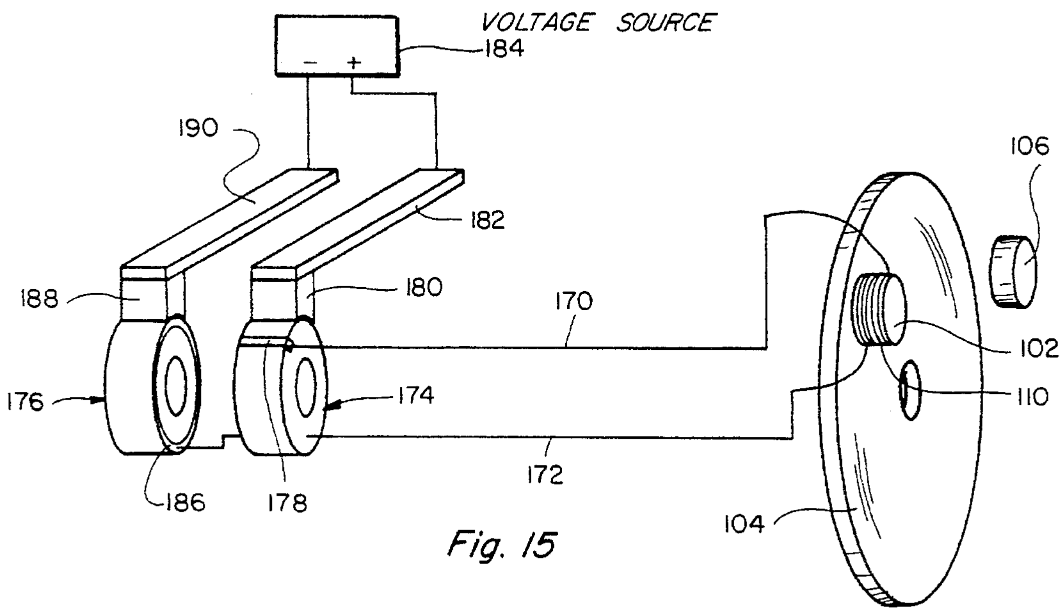
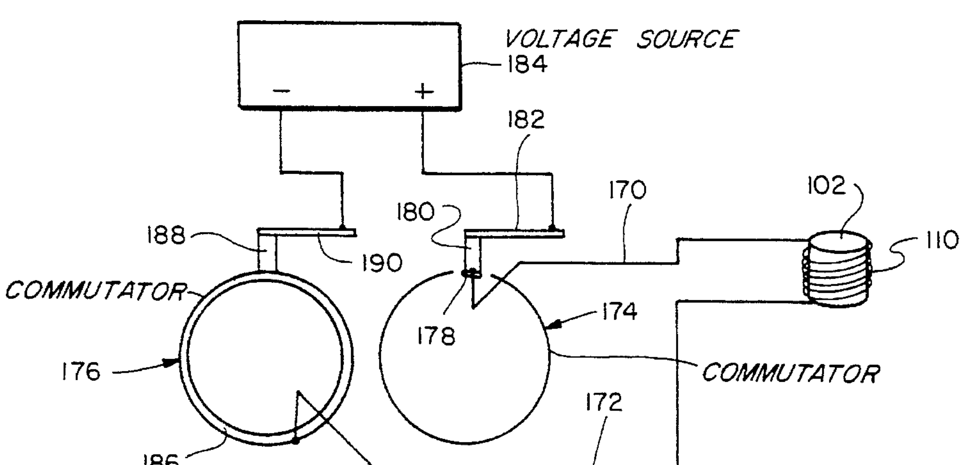


Fig. 15



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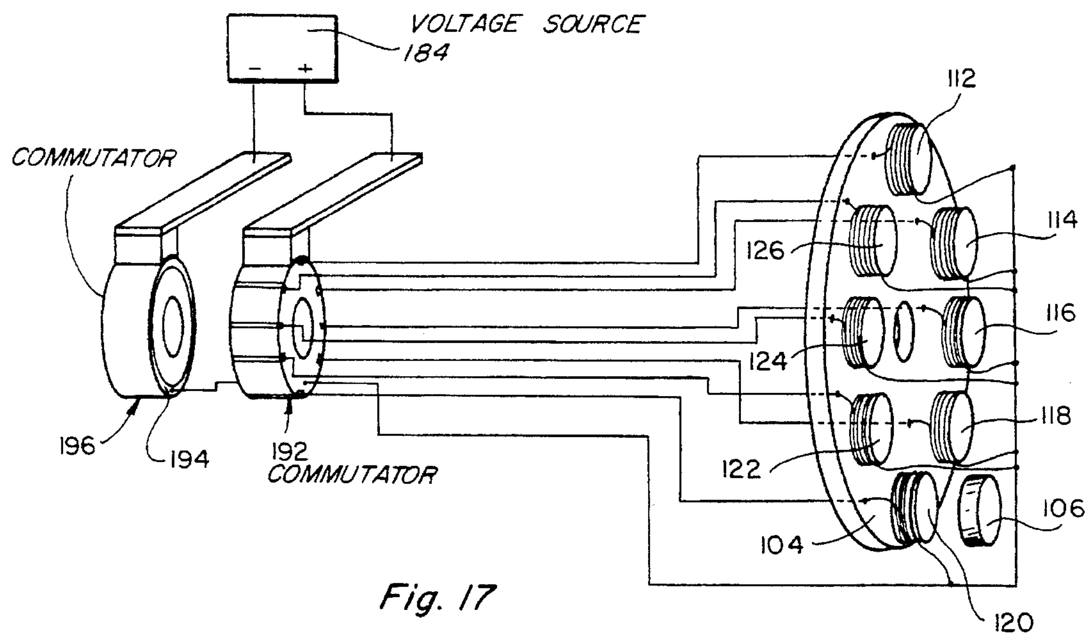
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Fig. 17

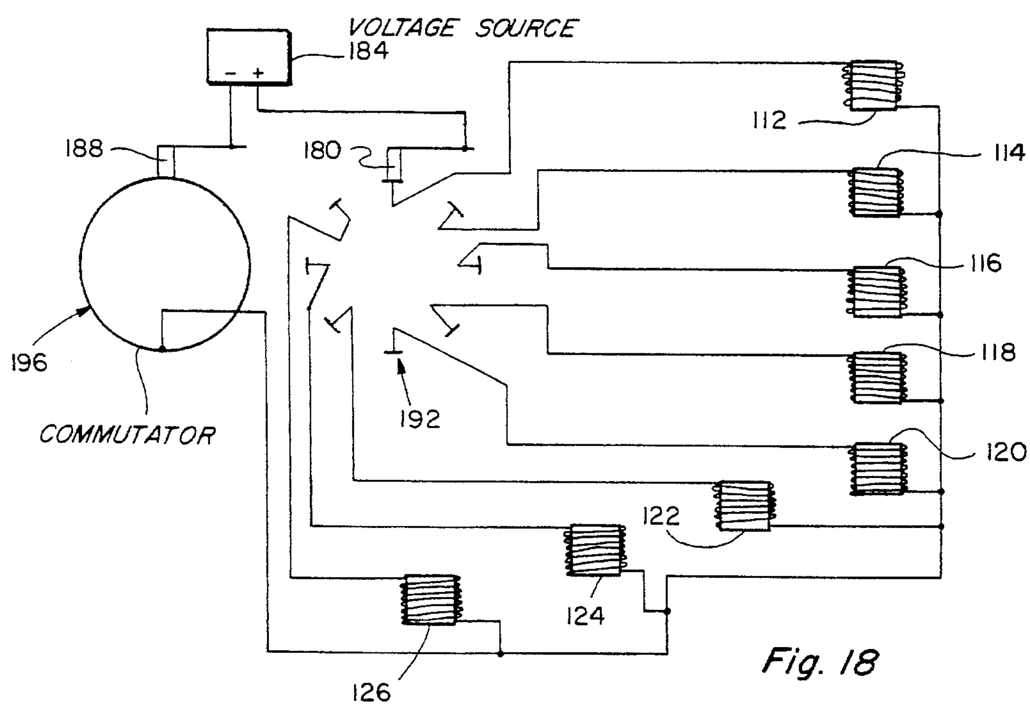
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Fig. 18

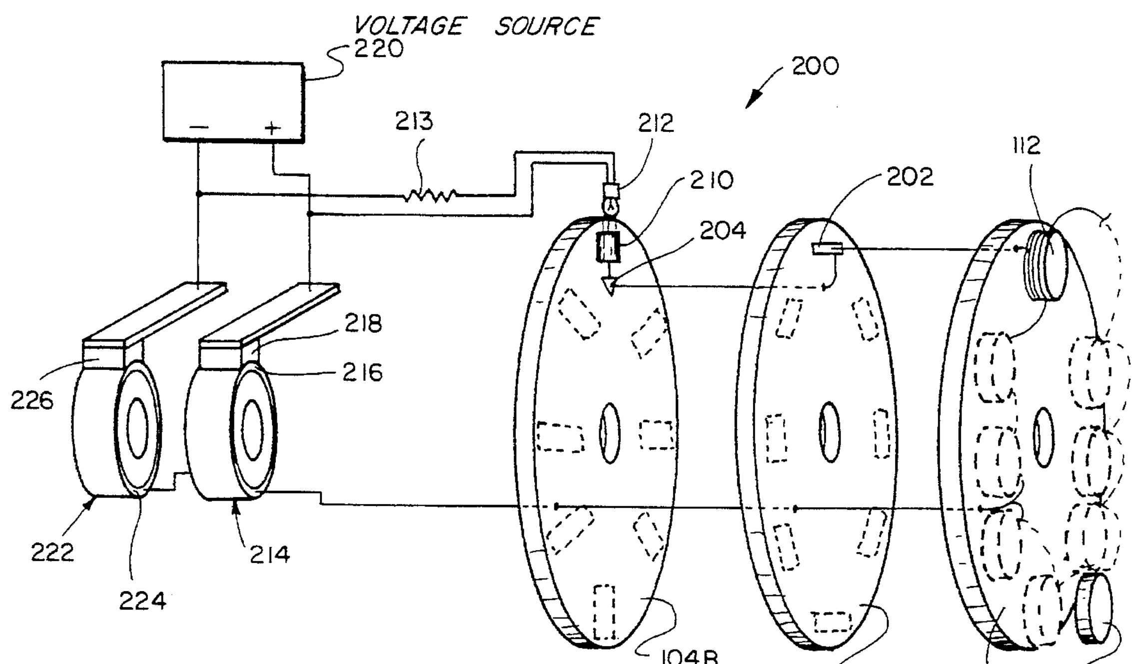
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Fig. 19

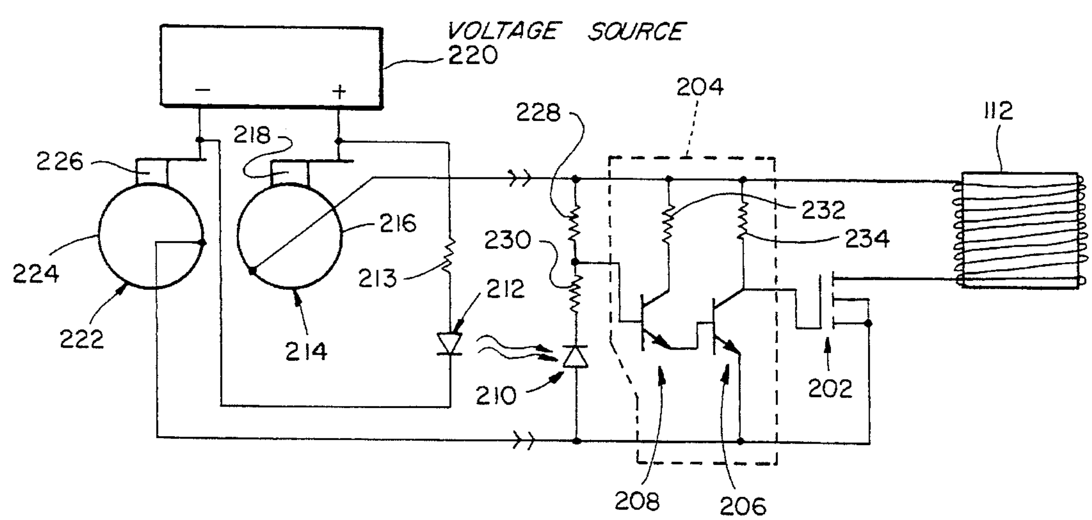
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Fig. 20

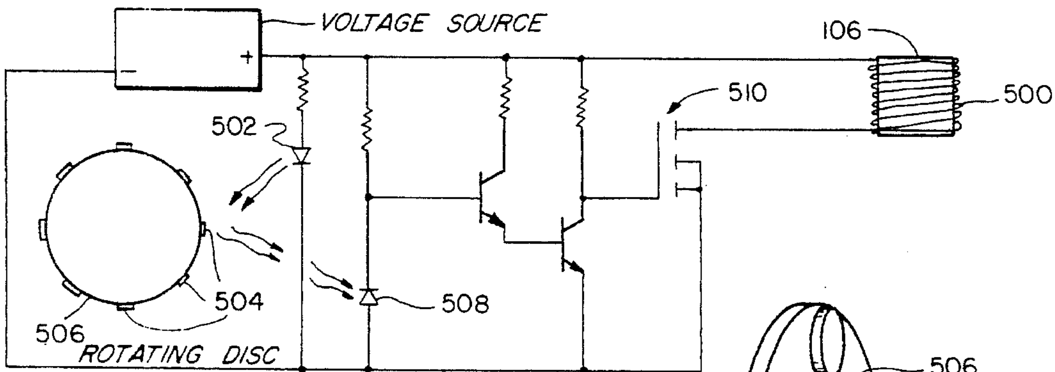
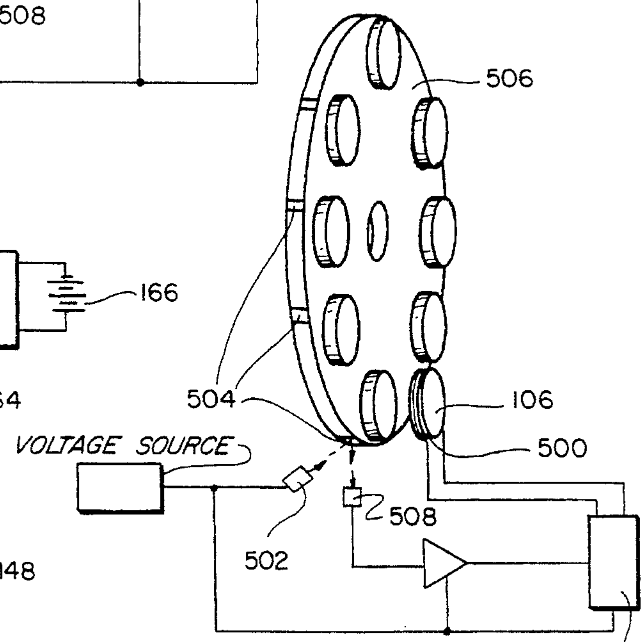


Fig. 22



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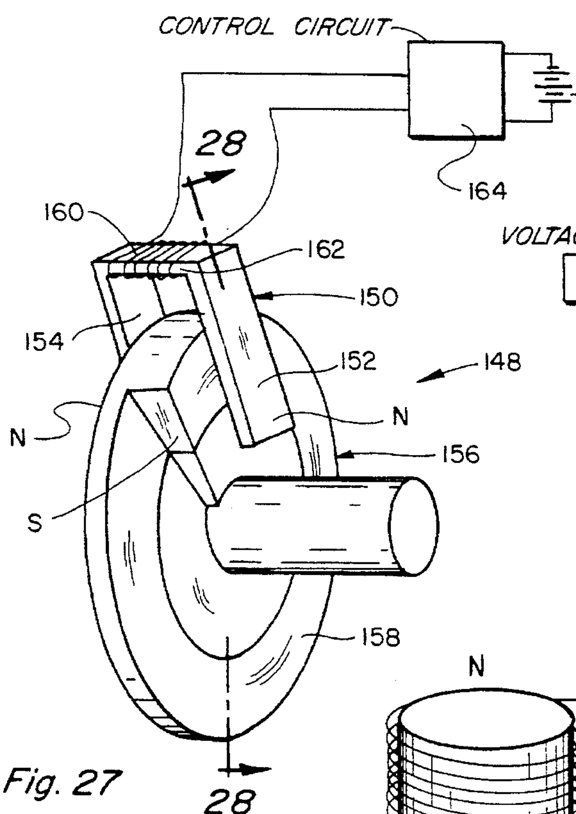


Fig. 27

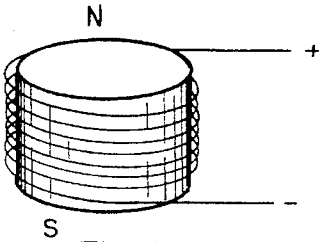
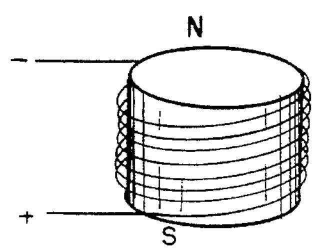


Fig. 23



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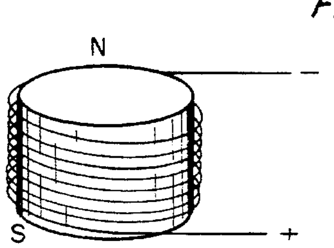

Fig. 25

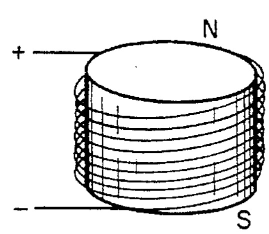

Fig. 26

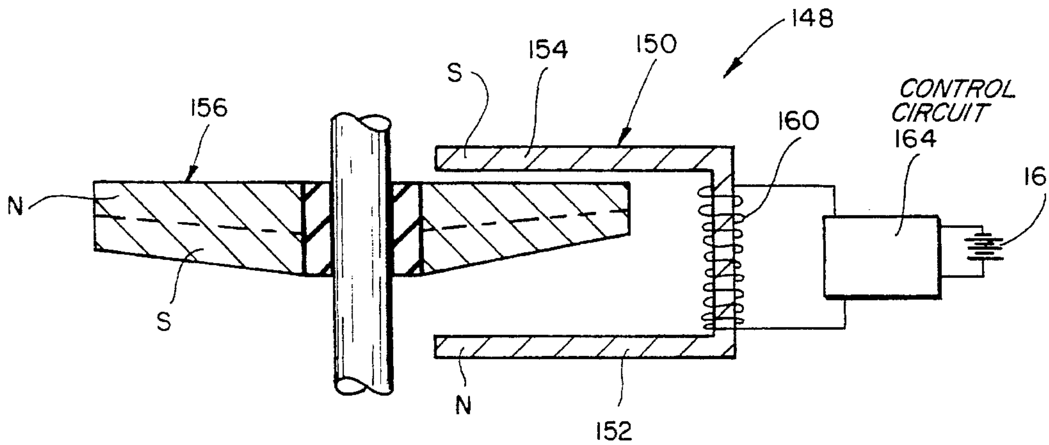
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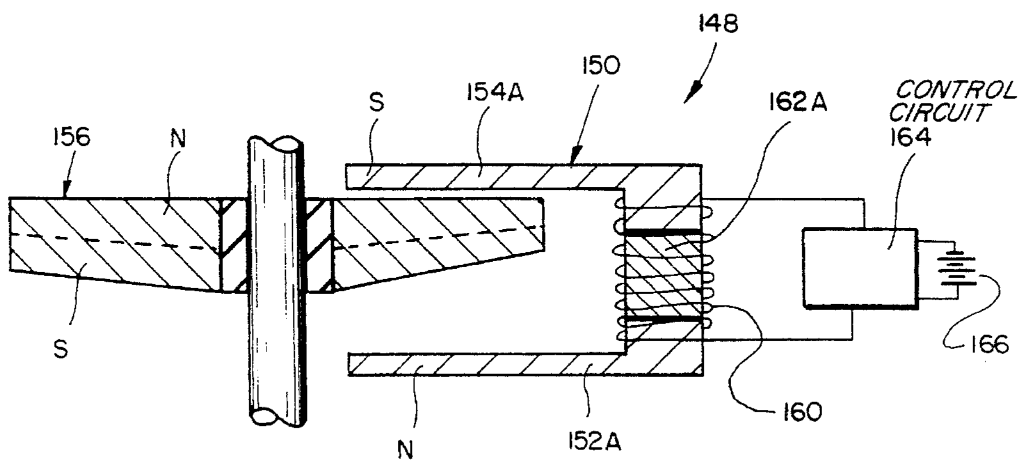
Fig. 28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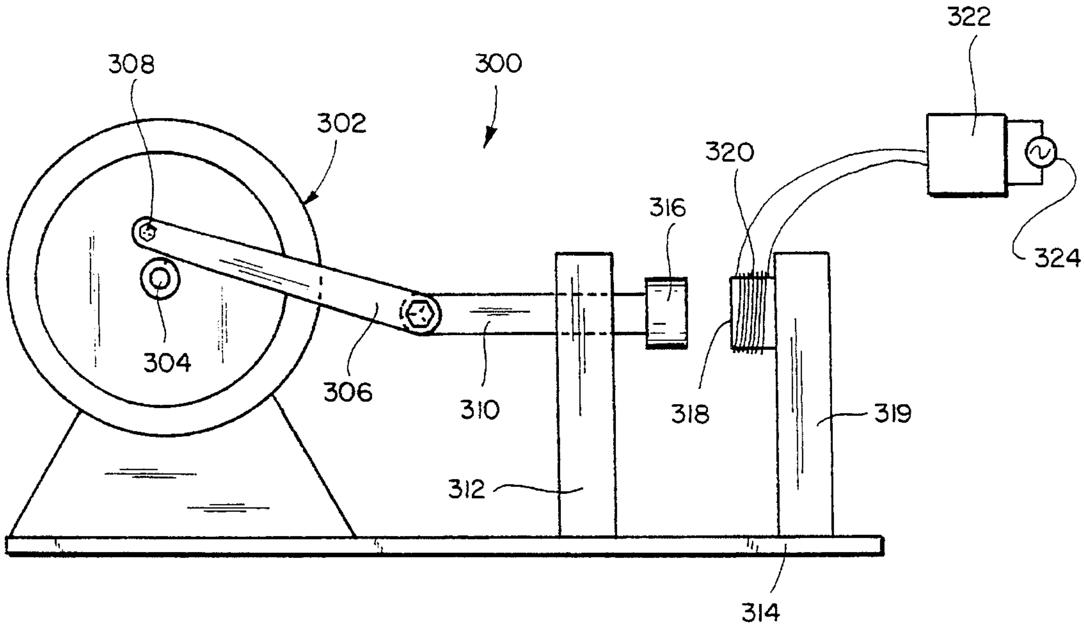
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Fig. 30

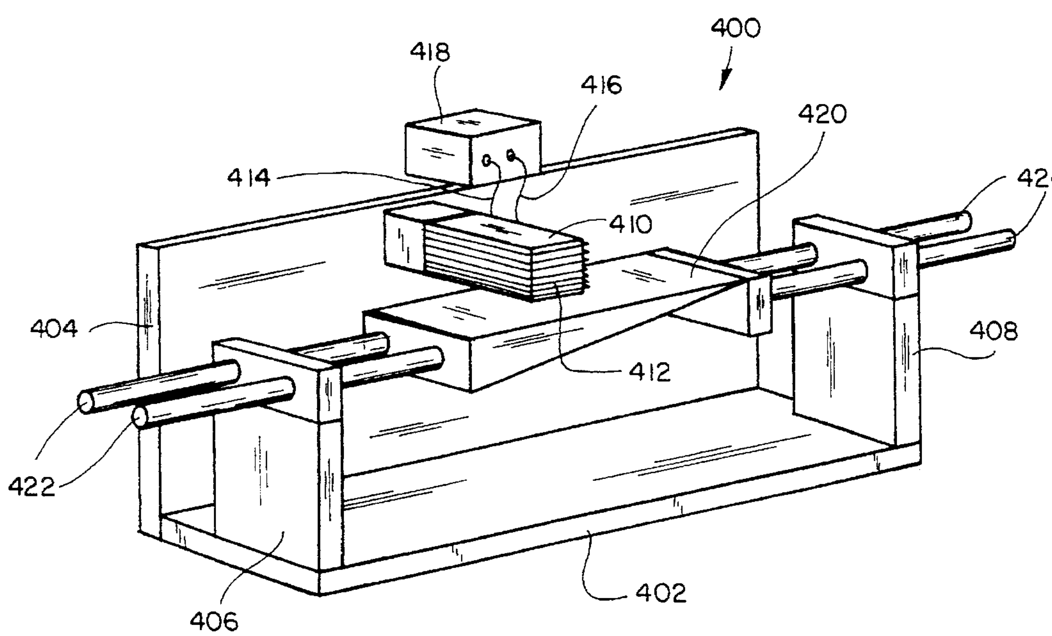
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Fig. 31

PERMANENT MAGNET CONTROL MEANS

This is a divisional of copending application Ser. No. 07/828,703, filed on Jan. 31, 1993, now U.S. Pat. No. 5,254,925.

BACKGROUND OF THE INVENTION

The present invention relates to novel means for producing rotary and other types of motion using a controllable permanent magnet. The closest known prior art to the present construction is disclosed in Applicants' co-pending U.S. patent application Ser. No. 322,121, filed Mar. 13, 1988, and entitled MEANS FOR PRODUCING ROTARY MOTION. The prior art listed in the file of application Ser. No. 322,121, is also incorporated herein by reference.

DESCRIPTION OF THE INVENTION

There are many devices that require a rotating member for some purpose. For the most part the known devices have included electric motors of various types, certain types of mechanically driven rotating members, and there are some devices that use permanent magnets which produce limited amounts of rotating motion. The present invention resides in means capable of producing continuous rotating motion using one or more controllable permanent magnets positioned adjacent to and magnetically coupled to a portion of a rotating member having predetermined magnetic properties that vary in a particular way around the circumference thereof. In a like manner the controllable permanent magnets are mounted on a non-magnetic rotatable member positioned adjacent to and magnetically coupled to a portion of a stationary member having predetermined magnetic properties that vary in a particular way around the circumference thereof. The subject magnetic means are able to produce continuous rotary motion of the rotating member if the magnetic coupling between the field of the permanent magnet is interrupted at a predetermined position during each cycle of rotation of the rotating member.

The present invention also teaches controlling the field of a permanent magnet and the use of such a device to produce rotational or other motion. One embodiment of the present invention includes a disc or disc-like members journaled for rotation about the axis thereof. The disc is constructed to have a band of magnetic or magnetizable material extending around the periphery thereof, and the band is such that its magnetic properties vary, from a minimum to a maximum condition adjacent to the same location or locations about the circumference. The device also includes a controllable permanent magnet mounted adjacent to the band of magnetic material on the rotating disc and magnetically coupled thereto such that the magnetic coupling force therebetween varies in a direction to continuously increase (or possible continously decrease in the repelling direction) and to thereby cause the disc to rotate. An electric winding is mounted on the permanent magnet and extends therearound between the opposite poles thereof. The winding is connected across a source of DC potential through controllable switch means. When the switch means are closed DC potential is applied to the coil to interrupt the magnetic field thereof and these interruptions are timed to occur at predetermined positions during rotation of the disc, namely at times when the maximum and minimum magnetic portions of the band of magnetic material on the rotating disc are moving adjacent to the permanent magnet. By so doing the field strength of the permanent magnet and hence its coupling to the disc, is substantially reduced or eliminated altogether and this occurs precisely when there otherwise would be maximum coupling therebetween in a direction to retard rotation. This means that the effect of the permanent magnet on the rotating disc is maintained in force during most of the rotation of the rotating disc to cause the rotation of the disc to occur but is effectively decoupled from the rotating disc during those times when maximum magnetic coupling would otherwise occur. This is done to prevent the rotating disc from being stopped by the force of the magnetic coupling.

The present invention also relates to the means for controlling and particularly interrupting the magnetic characteristics of a permanent magnet as well as means to make use of this control to produce rotary motion. There are in existence various devices that produce rotation due to the action or coupling between magnetic members. However so far as known, except for applicants copending application Ser. No. 322,121, there are no devices capable of producing continuous rotating motion of a rotating member where the force to do so is produced by magnetically coupling a permanent magnet to a portion of the rotating member and wherein the device includes means for predeterminately controlling or temporarily interrupting the field of the permanent magnet in the manner taught by the present invention. The present invention therefore resides in the use of a controllable permanent magnet having a north and a south pole and a winding mounted on or wound around the permanent magnet in the region between the poles, and the invention resides in mounting such a permanent magnet adjacent to the magnetic portion of the rotatable member. The device also includes a switch type circuit connected across the winding and controllable as by electronic switch means sychronized to the position of the rotary member such that when the switch means are in their open condition the field of the permanent magnet will be relatively uneffected and will be magnetically coupled to the rotating member but when the switch means are closed, the field of the permanent will be substantially modified and effectively eliminated so that no magnetic coupling will occur. The timing of the elimination of the field of the permanent magnet is important to the present invention. The physical shape and orientation of the magnetic poles of the magnetic portion of the rotating member are also important to the invention and several of many possible embodiments thereof are disclosed herein. The shape of the magnetic or magnetizable portion of the rotating member is also important and should be such that the magnetic coupling force changes (increases or decreases) continuously as the disc rotates.

OBJECTS OF THE INVENTION

It is a principal object of the present invention to use the energy of a permanent magnet to produce rotational or some other movement of a member.

Another principal object is to provide means to predeterminately temporarily modify or eliminate or isolate the magnetic field produced by a permanent magnet.

Another object is to use a permanent magnet having a controllable magnetic field to produce rotating or other motion of a member having a portion constructed of magnetic material.

Another object is to reduce the amount of energy required to produce rotational or other motion.

Another object is to control the magnetic coupling between a permanent magnet and a magnetic portion of a rotating member in a way so as to produce continuous rotation of the rotating member.

Another object is to modify or eliminate or isolate the field produced by a permanent magnet by the application of a DC field to a coil wound around the permanent magnet.

Another object is to provide a means, where the amount of energy that would be produced in the form of back EMF in a conventional wire wound iron rotor/stator, is returned to the system directly as magnetic energy.

Another object is to provide relatively inexpensive means for producing rotational motion of a rotatable member.

Another object is to provide means where all output torque is produced solely from the interactation of permanent magnets.

Another object is to produce continuous motion without the production of eddy current losses which is not possible with any known electro-magnetic system prior to the present invention.

Another object is to predeterminately time the interruptions of the magnetic field of a permanent magnet used to produce rotational movement of a rotatable member.

Another object is to use the magnetic force of a permanent magnet to produce rotational, oscillatory, linear and/or reciprocating motion.

Another object is to produce rotational speed and output torque that are not related to input power.

These and other objects and advantages of the present invention will become apparent after considering the following detailed specification in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagramatic view showing a battery operated embodiment of a device capable of producing rotational motion of a rotatable member;

FIG. **2** is a view of a device similar to the device of FIG. **1** but showing the device using a rectified alternating current energy source;

FIGS. **3** and **4** are side elevational views of another embodiment of the subject device;

FIG. **5** is a perspective view of the embodiment of the device shown in FIGS. **3**–**4**;

FIG. **6** is a perspective view showing another embodiment of the present device;

FIG. **7** is a perspective view of a controllable magnetic device constructed to illustrate certain teachings of the present invention;

FIG. **8** is an enlarged cross sectional view taken on lines **8**—**8** of FIG. **7**;

FIG. **9** is a fragmentary view of the device shown in FIGS. **7** and **8** showing the device coupled magnetically to another permanent magnet positioned adjacent thereto, the device being shown with no DC voltage applied to the coil wound around one of the permanent magnets;

FIG. **10** is a perspective view similar to FIG. **9** showing the other associated permanent magnet in an overturned position relative to the controllable permanent magnet and with no DC voltage applied to the coil;

FIGS. **11** and **12** are perspective views similar to FIGS. **9** and **10** showing the absence of any magnetic force between the two permanent magnets which are shown in different relative positions when the controllable permanent magnet has a DC voltage applied across the winding wound therearound;

FIGS. **13** and **14** are perspective views showing other alternative embodiments of the present invention;

FIG. **15** is a perspective view partly in diagramatic form showing another embodiment of the subject device using commutator means to control and time the application of direct current to a coil wound around a permanent magnet on a rotating disc;

FIG. **16** is a schematic diagram of the circuit for the device shown in FIG. **15**;

FIG. **17** is a perspective view similar to FIG. **15** but showing a rotating disc having a plurality of permanent magnets with coils wound around them and associated commutator and DC source means;

FIG. **18** is a schematic circuit diagram of the construction shown in FIG. **17**;

FIG. **19** is a perspective view similar to FIGS. **15** and **17** but showing the use of electronic-optical timing means;

FIG. **20** is a schematic diagram of the control circuit for one of the coils mounted on the rotatable disc in the construction shown in FIG. **19**;

FIG. **21** is a perspective view showing another embodiment of a rotating disc with permanent magnets mounted thereon and with a stationary permanent magnet with a coil mounted on it and with optically controlled circuit means connected thereto;

FIG. **22** is a schematic circuit diagram of the control circuit for the construction shown in FIG. **21**;

FIG. **23** is a perspective view of a permanent magnet with a coil wound thereon in a counterclockwise direction as viewed from the north pole of the permanent magnet;

FIG. **24** is a permanent magnet with a coil wound thereon similar to that shown in FIG. **23** except that the coil is wound clockwise when viewed from the north pole;

FIG. **25** is a view similar to FIG. **23** except that the coil is wound counterclockwise with the south pole of the coil located adjacent to the north pole of the permanent magnet;

FIG. **26** is a view similar to FIG. **25** except that the coil is wound clockwise when viewed from the north pole of the permanent magnet;

FIG. **27** is a perspective view of another embodiment of the invention;

FIG. **28** is a cross-sectional view taken on line **28**—**28** of FIG. **27**;

FIG. **29** is a cross-sectional view similar to FIG. **28** but showing another construction for the C-shaped member;

FIG. **30** is a side elevational view of another embodiment of the invention specifically constructed to produce reciprocating motion; and

FIG. **31** is a perspective view showing yet another embodiment specificially for producing linear motion.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings more particularly by reference numbers, number twenty 20 in FIG. **1** refers to a magnet assembly including a permanent magnet **22** shown having a north (N) pole which is visible and a south (S) pole at its opposite end which ends are oriented as shown. The permanent magnet **22** also has a winding **24** wound around it in the area between the north and south poles. The winding **24** is connected into a series circuit which includes a control circuit **26** that includes switch means in series with a DC source shown as battery **28**. The grounded or negative side of the battery **28** is connected by lead **30** to the other side of winding **24**. The magnet assembly **20** is positioned adjacent to the peripheral edge **32** of a rotating disc member **34** which has a spiral shaped peripheral edge portion **36** formed of a magnetized or magnetizable material shown as having a south (S) pole aligned with the north (N) pole and a north (N) pole aligned with the south (S) pole of the magnet **22**. This will produce magnetic attraction between the members **22** and **34** and clockwise rotation of the disc **34**. If the magnetic poles of one of the members **22** and **36** is reversed, repelling force will be produced and the member **34** will rotate in a counterclockwise direction. Either case will work with the present invention. In the embodiment shown, the assembly **20** is magnetically coupled with or attracted to the magnetic edge portion **36** of the disc **34**. In the construction shown in FIG. **1** the edge portion **36** extends from a radially outermost location **37** to an innermost location **38**, both locations being located circumferentially at the same location. The disc **34** is mounted for rotation on shaft **40** which has an axis of rotation **42**, and the shaft **40** is supported by suitable journal or bearing means, not shown.

The peripheral portion **36** of the disc **34** is shown being formed of magnetized material and is oriented as stated so that its south pole is closely adjacent to the north pole of the permanent magnet **22**, and its north pole is on the side adjacent to the south pole of the magnet **22**. This orientation produces maximum magnetic attraction or magnetic coupling between the members. The reasons for this will become apparent.

With the construction shown in FIG. **1**, as the disc member **34** rotates, except for when the high spot **37** is adjacent to the permanent magnet **22**, the edge portion **36** will move progressively closer to the magnet assemblies **20** increasing the magnetic coupling between the magnet assembly **20** and the peripheral portion **36** of the disc member **34**. This increasing coupling is the force that produces the rotating movement of the disc **34**. However, when the disc **34** rotates to the position as shown in FIG. **1**, the coupling between the assembly **20** and the disc **34** reaches a maximum, and if nothing is done to reduce or eliminate the magnetic coupling at this place the disc will not continue to rotate but will stop. In order to reduce or eliminate the magnetic coupling force between the assembly **20** and the disc **34** at this point it is necessary to apply a DC potential across the winding **24**. This is done for a long enough time for the high spot **37** to move past the magnet **22** as will be explained so that little or no retarding magnetic coupling will occur. The application of DC to the coil **24** will temporarily (as opposed to permanently) alter or eliminate or isolate during its application the magnet field of the permanent magnet **22** from the disc **34**, and there will be little or no coupling therebetween. This condition will persist for as long as the DC is applied. Eliminating or isolating the magnetic field of the permanent magnet assembly **20** at and adjacent to movements of high spot **37** of the disc **34** past the assembly **20** means that the disc **34** will be able to continue to rotate indefinitely. Elimination of the magnetic field during this portion of each rotation of the disc **34** is under control of the control circuit **26** and the associated switch means which will be described later.

FIG. **2** shows a device that is similar to the device of FIG. **1** except that in the FIG. **2** construction the DC source is derived using a rectified AC source that includes a rectifier/switch circuit **44** which has a connection by cord **45** to a wall

plug **46** or any other means of producing AC such as to an alternator and another connection to a switch control circuit **48** and from there to one side of the coil **24**. The advantage of using the circuit of FIG. **2** over that of FIG. **1** is that the DC source is not dependant on a battery for controlling the switch means.

FIGS. **3–5** show another embodiment **50** of the subject construction wherein disc member **51** has a variable thickness magnetized or magnetic peripheral portion **52** which extends around the circumference thereof. In this construction controlled permanent magnet assembly **54** is mounted adjacent to flat side **56** of the magnetic disc portion **52** and has one of its poles, shown as north (N) pole **58**, positioned closely adjacent to the flat south pole side **56** of the rotating member **51**. In this construction the distance between the flat side **56** of the disc **51** and the magnet **54** remains constant but the magnetic coupling between the members varies with the thickness of the magnetic portion **52** of the disc **51**. The opposite or south pole side **60** of the permanent magnet **54** and the north pole side of magnetic portion **52** of the disc **51** are spaced from each other on opposite sides of the respective members. The magnet assembly **54** has a winding **62** mounted thereon as shown and is connected to a circuit which may be similar to the circuits shown in FIGS. **1** and **2** to provide DC potential across the winding **62** whenever the permanent magnet assembly **54** is adjacent to, in this case, the thickest portion **64** of the rotating magnetic disc portion **52**.

FIG. **4** is another view of the same construction **50** shown in FIG. **3** showing the permanent magnetic assembly **54** positioned adjacent to a different location of the magnetic peripheral portion **52** of the disc member **51**, and FIG. **5** is a perspective view of the same construction **50** with an arrow to indicate the direction of rotation of the rotatable disc member **51**. The direction of rotation would be in the opposite direction if the polarity of either magnet **52** or **54** were reversed.

FIG. **6** is an exploded view showing another embodiment **66** of the device which includes stepped rotating disc member **67**. In this case the disc **67** has an annular magnetic or magnetizable portion **68** shown divided into three equal length helical segments or steps each of which has a thickest and a thinnest portion adjacent to respective transverse faces **68A**, **68B** and **68C**. One or more spaced permanent magnet assemblies such as permanent magnet assembly **69** is located adjacent to the flat side **70** of the disc **67**. Circuit means such as those described above with FIGS. **1** and **2** are provided to interrupt the magnetic field of the respective permanent magnets as they move adjacent to the thickest disc portions in the manner already described. In the construction shown in FIG. **6**, the same or separate circuits can be provided to apply DC voltage to the coils wound on the various permanent magnet assemblies **69**. The device **66** includes a shaft **71** and suitable journal or bearings means (not shown) to support the disc **67** for rotation.

FIGS. **7–12** are included to illustrate the effect of applying a DC potential across a winding mounted on or wound around a permanent magnet. In the construction as shown in FIGS. **7** and **8**, permanent magnet **72**, in the area between its north and south poles, has a winding **73** mounted thereon. Leads **74** and **76** are connected to opposite ends of the winding **73** and are also connected to a circuit such as shown in FIGS. **1** and **2** which includes a switch **78** in a timer or like control circuit **79** in series with battery **80** or other DC source. The magnet **72** is shown positioned on or attached to a non-conductive, non-magnetic platform or support member **82**, see FIGS. **7** and **8**.

In FIG. **9** a second magnet member **84** is shown positioned on the platform **82** in spaced relationship to the magnet **72** and arranged thereon to have its south pole in the plane of the north pole of the magnet **72** and its north pole in the plane of the south pole of the magnet **72**. When no DC potential is applied to the coil **73**, the magnet **84** will be attracted to and therefore will move toward the magnet **72** as indicated by the arrows and will remain against the magnet **72** unless forceably restrained or pulled away.

In FIG. **10** the same second magnet **84** is shown overturned on the platform **82** so that its north pole is in the plane of the north pole of the magnet **72** and its south pole is in the plane of the south pole of the magnet **72**. In this situation the magnet **84** will be repelled by the magnet **72** and will therefore move away from it as indicated by the arrows.

Referring to FIGS. **11** and **12**, the same structure is shown as in FIGS. **7–10** except that a DC potential is applied across the coil **73** in a direction to oppose and cancel the field of the permanent magnet **72**. Under these circumstances the magnetic field of the member **72** and its coupling to the magnet **84** is effectively eliminated or isolated so that the magnet **84** will neither be attracted to nor repelled by the magnet **72**. This is true regardless of whether the magnet **84** has its north pole up or down. Furthermore, the fact the magnet **84** has no winding on it will not enable its own magnetic force to be able to magnetically couple to the magnet **72**. FIGS. **7–12** illustrate some of the principles that are made use of in connection with the present invention, and are used to controllably couple or decouple the permanent magnet such as magnets **22**, **54** and **69** to the magnetic or magnetizable portions **36**, **52** or **68** of the rotatable member such as of the disc members **51** and **67**.

Various means can be used to control the closing of the switch means associated with the control circuit **26**, **48** and **79** to eliminate or prevent coupling between the magnet assembly **20**, **54** or **69** and the respective rotating disc **34**, **51** or **67**. Keep in mind, however, that the rotation of the disc member in all cases is produced by the increasing of the magnetic coupling force when attracting or decreasing the coupling when repelling between the permanent magnet and the magnetic portion of the disc during most of each cycle of disc rotation. The control of the switch means can take place by timing means controlled by rotation of the disc such as by light from an electric light **90** shining through an opening such as opening **92** in the disc **51**, FIG. **5**, to a sensor **94** or by various other means as will be described.

It is important to an understanding of the invention that the principles of applying DC to a coil wound or mounted on a permanent magnet, be it the stationary or rotating magnet, affects the field, only of that magnet and only for as long as the DC is applied, but does not generally permanently alter or affect the magnetism of the permanent magnet especially if the permanent magnet is a ceramic or like type magnet.

Referring again to the construction shown in FIGS. **7–12**, the question arises as to what happens to the magnetic field of a permanent magnet when the coil that encircles it is energized. If the coil is energized in a manner such that the magnetic field of the coil opposes the field of the permanent magnet on which it is mounted, then the north pole of the permanent magnet will short to the south pole of the coil and the south pole of the permanent magnet short to the north pole of the coil. In other words the coil will produce a counter magnetomotive force that opposes, and therefore cancels all or a predetermined portion of the magnetic force surrounding the permanent magnet. If the opposing magnetic field of the coil equals or nearly equals the field surrounding the permanent magnet, the effect is to neutralize or make the effective field of the permanent magnet equal to zero. If it has been reduced to zero in the manner indicted then even if another permanent magnet if brought into close proximity to that magnet it will not be attracted or be magnetically coupled to the permanent magnet whose field has been cancelled and in effect the magnets will be isolated from each other. This happens in much the same way as putting an iron keeper on a horseshoe magnet. Cancelling the field of a permanent magnet has the further effect of blocking outside magnetic fields from reaching or coupling to the permanent magnet whose fields has been cancelled in this way. Therefore, not only does the coil cancel the effect of the permanent magnet but it also blocks or prevents other magnets including other permanent magnets brought into the vicinity thereof from having their fields reach the field of the magnet whose field has been cancelled. In other words the magnet whose field is cancelled is magnetically isolated from other magnets. It is this phenomenon of the present invention that enables interrupting the coupling between the magnets including between a stationary magnet and a rotating magnet, and this condition exists even when relatively large and powerful magnets are used. This also enables a relatively small device to be able to produce substantial rotational force and torque.

If the coil on the permanent magnet is oriented so that when energized the field of the coil is in aiding relation to the field of the permanent magnet, the resultant magnetic force will be increased to at or near the combined fields of the permanent magnet plus the field due to the energized coil. Under these circumstances the permanent magnet will attract (or repel) a second permanent magnet brought into the field thereof such as a rotating magnetic member, and will produce even greater coupling force between the members and at even greater distances between the magnets. This fact can be made use of in the present device to increase the torque generated in some embodiments.

It has been discovered that by energizing the coil on the permanent magnet for a relatively large portion of each cycle of rotation of the rotating magnetic member, except during the area of greatest attraction, as when the two members are closest together, will cause the rotating member to rotate at even greater speeds, even at several thousand RPM and at substantial torque. If, under these circumstances the magnetic field of the permanent magnet is interrupted during those portions of the rotational movement when there is the greatest attraction between the members, and during the remainder of the rotation the two magnets are fully magnetically coupled as aforesaid, then at no time will the rotation be interrupted. In this as in other embodiments the total rotational force is produced by the coupled magnets. With this construction the pole magnet will have a continuous magnetic field which will be increased during most of the time the rotating member or disc is rotating, but the field of the pole magnet will not be increased (and likewise will not be isolated) during that portion of each cycle of rotation when the pole magnet is closest to or has the most magnetic attraction to the rotating magnet or rotor. During these time the coupling will be reduced by eliminating the DC applied to the winding but not by enough to slow down or stop the rotation. Experiment has shown that increasing the field of the stationary permanent pole magnet for even a few degrees of the total 360° of rotation while returning it to its unaltered or permanent magnet state (no current through coil) for a short time during each cycle will cause the rotating member to continue to rotate indefinitely being limited only by the bearings used to support it. It has also been discovered that by adding energy by way of the coil to cancel the effect of the pole piece for as little as 18° of the total 360° of rotation is sufficient to overcome any tendency for the rotary member to stop. Such a construction will accelerate at a fast rate and maintain a high rotational speed even in a construction having only one rotating and one stationary pole piece. Applicant has produced such a device in which the rotating member rotated at several thousand RPM and with appreciable torque.

FIG. **13** shows a relatively simple embodiment **100** of the present device utilizing a permanent magnet control means that includes one permanent magnet pole piece **102** having no special shape but which is mounted adjacent to one side of a non-magnetic rotatable disc such as plastic disc **104**. The disc **104** is mounted for rotation on a journaled shaft **105**. A stationary permanent magnet pole piece **106** is mounted adjacent to one side of the disc **104** on a fixed support **108** in position to produce magnetic attraction with the rotating magnet **102** in certain positions of the disc **104**. The rotating pole piece **102** has a coil **110** mounted on it as shown, and the coil **110** can be connected to a source of voltage and control circuit through commutation means (not shown). Once the disc **104** starts to rotate, and this may be done by mechanical means such as by starting it to rotate with a finger, each time the rotating pole piece **102** approaches the stationary pole piece **106** the speed of rotation of the disc **104** will speed up until the pole pieces **102** and **106** are adjacent to each other. In this position it would be expected that the disc **104** would stop. However, as the rotating magnet **102** moves to align itself with the stationary pole magnet **106**, the coil **110** will be energized by applying a DC voltage thereacross which produces a field in opposition to the field of the permanent magnet **102** so as to cancel the field. The coupling force between the magnets **102** and **106** is therefore interrupted or blocked at this time and this enables the rotating disc **104** to continue to rotate past the point of closest proximity and enables the rotating magnet **102** to again reach the area where magnetic attraction between the magnets again occurs to produce the energy for the succeeding cycle of rotation.

The rotating member **104** can be a plastic or other non magnetic member or it can be a member constructed of a magnetizable material such as of soft iron. To further increase the rotational coupling force between the stationary and rotational pole pieces several stationary magnets and/or several rotational pole pieces such as the pole pieces **112–126** (FIG. **14**) can be provided, the rotating pole pieces being mounted at arcuately spaced locations on the rotating disc **104**. In this construction each of the stationary or rotating magnets and the coils thereon must be individually controlled as aforesaid and at the proper times in order to produce continuous rotational motion.

Schematic circuit diagrams for timing the application of DC to the coil **110** on the permanent magnet **102** is shown in FIGS. **15** and **16**. Similar control circuits can be provided for each magnets **112–126** when a plurality of controlled magnets are used as shown in FIGS. **17** and **18**.

If a piece of a magnetizable material, such as a piece of soft iron, is placed in the magnetic field of a permanent magnet it will to some extent take on the characteristics of the permanent magnet. Also by wrapping or winding a coil of wire around the magnetizable member, the field of the material can be either strengthened, reduced in strength or cancelled by passing current through the winding as aforesaid. Consider, for example, the construction **148** shown in FIG. **27** which has a U-shaped iron pole piece **150** positioned to have its spaced leg **152** and **154** straddling a rotor or disc member **156** also formed of magnetized material. The disc **156** has a peripheral portion **158** of magnetized material that has north and south poles positioned as shown. The magnetic field of the rotor **156** will be such that a magnetic field is established in the magnetizable material or iron in the same manner as in any permanent magnet. In other words when the magnetizable material is in the magnetic field of the U-shaped permanent magnet **150** it takes on the characteristics of the permanent magnet and has its own north and south poles. In this way the rotating member **156** creates its own adjacent poles. A coil **160** is mounted on the center portion **162** of the U-shaped member **150** and is connected to a circuit **164** that controls the connection of the winding **160** to a source of DC voltage shown as battery **166**. The source of energy **166** is arranged in the circuit in a direction to oppose and cancel the magnetic field in the U-shaped member **150**, but the source is not strong enough to produce in the member **150** its own electro-magnetic field. When this is done the winding **160** on the U-shaped member **150** causes the member **150** to become an electro-magnet in which only enough energy flows to produce a counter magnetomotive force equal to and in opposition to the magnetic flux that is established in the member **150** by the peripheral permanent magnet portion **158** of the rotor or disc **156**. By energizing the coil **160** to the point where it cancels the effect of the field of the permanent magnet **150** on the U-shaped member, the pole piece will produce a magnetic field that is equal to the amount of flux it has been cancelling. The construction **148** operates basically the same as the other embodiments such as those shown in FIGS. **13** and **14** except that in the FIG. **27** construction the winding **160** is energized instead of being deenergized at the point where greatest attraction occurs so as to eliminate the effect of the field of the magnetizable material. In this construction as in the other constructions all of the force or torque to produce the rotational movement is produced by a permanent magnet. FIGS. **28** and **29** show the same device **148**, FIG. **28** showing use of a soft iron pole piece **150** while FIG. **29** shows use of two steel or like pole pieces **152A** and **154A** connected by permanent magnet pole piece **162A** therebetween.

The constructions shown in FIGS. **15–26** are based on the constructions shown in FIGS. **13** and **14** and show various ways of controlling the application of voltage to the control winding or windings. In the construction shown in FIGS. **15**, **17** and **19**, the control is of the voltage that is applied to the coils mounted on the permanent magnet or magnets on the insulated disc member **104**. In the construction shown in FIGS. **21** and **22** the control is of the winding mounted on the stationary permanent magnet **106**.

Referring to FIG. **15** the magnet **102** has the coil **110** mounted on it, and the coil is connected by leads **170** and **172** to conductive portions of respective commutator members **174** and **176**. The commutators **174** and **176** are mounted for rotation with the disc member **104**. The commutator member **174** has a cooper segment **178** which spans a predetermined arcuate portion of the circumference corresponding to the time when DC power source should be applied to the winding **110**. The commutator **174** is engaged by a brush **180** which is connected to arm **182** that has an electrical connection to the positive side of voltage source **184**. The lead **172** extends through a hole in the commutator **174** and is connected to an annular conductive ring **186** that extends around the periphery of the commutator **176**. The ring **186** makes electrical contact at all times with a brush **188** connected by arm **190** to the negative terminal of the DC voltage source **184**. When the disc **104** and the commutators

174 and 176 are rotating, DC voltage will be applied to the coil 110 for short periods of time which occur when the magnet 106 is in close proximity to the magnet 102. This is done to prevent magnetic coupling therebetween. This is also the time when the magnetic coupling otherwise would be maximum and therefore would cause the disc 104 to stop. By magnetically isolating the magnets 102 and 106 from each other at this time, the disc 104 will continue to rotate without stopping. FIG. 16 shows the equivalent electrical circuit for the construction shown in FIG. 15.

FIG. 17 shows a construction similar to that shown in FIG. 14 including having a rotatable disc member 104 with a plurality of magnetic members such as the magnetic members 112–126 mounted thereon. The stationary permanent magnet in this construction is similar to the magnet 106 and is mounted adjacent to the disc 104 to move in close proximity with the magnets 112–126, one at a time. In the construction shown in FIG. 17 each of the permanent magnets 112–126 has its own coil and the coils are connected to respective conductive segment strips on commutator 192 positioned or timed to correspond to the positions when each of the respective magnets 112–126 moves adjacent to the fixed magnet 106. The opposite side of each of the coils on the magnets 112–126 are connected in common and to the annular conductive layer 194 on the other commutator 196. The construction shown in FIG. 17 operates similarly to the construction shown in FIGS. 13 and 16 except that each of the rotatable magnets is individually controlled by having a DC potential applied across it at the time that it is moving adjacent to the stationary coil 106. Such a construction provides more continuous magnetic coupling between the stationary magnet and the magnets on the rotatable structure and will therefore provide additional energy for rotating the disc 104 and anything connected thereto.

FIG. 18 is a schematic circuit diagram for the construction shown in FIG. 17, and the parts shown therein are similarly identified.

FIG. 19 shows another embodiment 200 of a construction similar to that shown in FIG. 14 except that the rotating disc structure 104 has more circuitry including optical means on it to control the application of DC voltage to the respective rotating coils. FIG. 20 shows the details of the circuitry associated with one of the rotating coils, the others having similar circuitry.

Referring to FIG. 19 and 20 in detail, and using numbers similar to the numbers used above where applicable, the device 200 includes a rotating disc member 104 which has connected rotating portions 104A and 104B. The rotating permanent magnets 112–126 are mounted on the disc 104 in the matter already described and rotate adjacent to a fixed permanent magnet 106. The magnets 112–126 have coils mounted on them and the coils are connected into circuitry which controls them in the manner illustrated above. The controls for the coils on the magnets 112–126 are connected through respective power MOSFET transistor switches 202 which in turn are connected to amplifier circuits 204 which include transistors members 206 and 208 connected as shown in FIG. 20. The input to the transistor 208 is connected through a circuit which includes resistor elements and a phototransistor 210. A similar phototransistor and associated amplifier circuits is provided for each of the coils. The phototransistor 210 is mounted on the rotatable member 104B and is exposed during a portion of each cycle of rotation of the rotatable structure 104, 104A and 104B to the light from a stationary light source 212. The light source 212 is connected in series with a resistor 213 across a voltage source. The circuit of the phototransistor 210 and the associated amplifier circuit 204 and element 202 are connected to commutator means including a first commutator 214 having a conductive peripheral portion 216 which makes sliding engagement at all times with a brush member 218 that is connected to the positive side of voltage source 220. A second similar commutator structure including commutator member 222 having a conductive peripheral portion 224 slidably engages another brush 226 connected to the other side of the circuit that includes the phototransistor 210 and the amplifier circuit 204. The brush 226 is connected the negative terminal of the voltage source 220.

The amplifier circuit 204 is formed by the transistors 206 and 208 and forms a darlington amplifier pair which switches on and off the current flowing through the magnet control coil on the respective permanent magnet 112–126. Timing is accomplished by the number of degrees of rotation of the phototransistors such as phototransistor 210 in the field of the light given off by the light source 212. The circuit for each of the permanent magnets 212–126 are similar and each of the phototransistors such as phototransistor 210 is reverse biased and its output is fed to the base of the transistor 208 of the Darlington amplifier. The sensitivity or switching point of the transistor 208 is determined by the proportional values of the biasing resistors 228 and 230 and the resistor 232 determines the gain of the transistor 208. The transistor 206 is an emitter follower whose gain is controlled and determined by another resistor 234. The transistors 206 and 208 may be of the NPN general purpose type.

The light source 212 for each of the circuits may be a light emitting diode (LED) whose radiation would be in the infrared region of the electro-magnetic spectrum. The resistor 213 provides current limiting control for the light source 212.

The number of turns and the gage of the wire wound on the rotating magnets 112–126 is determined by the size and strength of the permanent magnet to be controlled and by the strength of the voltage source. A typical magnet assembly using ⅜ inch diameter, ¼ thick button magnets would have a coil consisting of about 152 turns of 28 copper wire and use a 12 volt power supply.

The direction of winding of the turns and the polarity of the coils in relation to the permanent magnet on which they are mounted is illustrated in FIGS. 25–26. The direction of the windings and the polarities thereof are such as to oppose the permeability of the air surrounding the permanent magnet so as to decrease the permeability by an amount determined by the ampere turns of the respective coil. FIGS. 23 and 24 show the direction of the turns and the polarity of the coils wound in the manner to produce an aiding permeability condition with respect to the permeability of the permanent magnet, and therefor, if used, would increase the strength of the permanent magnet by the amount of ampere turns of the respective coil. Such an embodiment could be used to impart energy to a rotational member by increasing the coupling between the stationary permanent magnet and the magnet on the rotating structure, preferrably as the rotating magnet approaches the stationary magnet, and just at the angular position where lock up would occur due to the maximum coupling therebetween, whereupon the coupling between stationary permanent magnet and the rotating magnet would be returned to normal. In this case enough energy would be imparted to the rotating member to continue to carry the magnet of the rotating member past the stationary magnet. It is thus apparent that both increasing the magnetic coupling and decreasing the magnetic coupling at the proper time and by the proper amount can be incorporated within the same embodiment, and it is also possible, rather than returning the coupling force to normal by removing the voltage across the winding the field of the coil it could be reversed to cancel or substantially reduce the coupling altogether.

FIGS. **21** and **22** show an embodiment that is similar to that described above except that the stationary magnetic member rather than the rotatable permanent magnets has a control winding **500** mounted thereon. Such as embodiment is preferred over some of the other embodiments because only one permanent magnet, namely the stationary magnets needs to have a control winding mounted on it. The circuit for the embodiments shown in FIGS. **21** and **22** may be similar to the circuit shown in connection with the construction of FIGS. **19** and **20**. However, in the construction shown FIGS. **21** the light emitting diode **502** projects onto a reflective surface **504** on the edge of the rotating disc **506** and is reflected back onto a phototransistor or a phototransducer **508** and the signal produced is amplified. The circuit of FIG. **22** is not substantially different in construction and operation from the circuit shown in FIG. **20**. However, an advantage of the construction shown in FIGS. **21** and **22** is that because of the manner in which the light from the light source is directed to the reflective surfaces on the rotating member **506** and then back to the phototransistor **508**, it is not necessary to have a commutator such as are included in the other constructions. In this regard note that the MOSFET 510 is controlled in such a manner as to control application of dc power across the winding **500** on the magnet **106**. Since the coil **500** is on the stationary permanent magnet **106**, no commutators are necessary as in the other constructions. The timing of the energizing of the coil **500** under control of the MOSFET 510 is determined by the angular length of the reflective segment **504** plus the field of view of the phototransistor **508** and the beam divergence of the light emitted by the light source **502**.

FIG. **30** shows another embodiment **300** of the present device designed to produce reciprocating rather than rotational motion. The device includes a rotating member or flywheel **302** rotatably mounted on a shaft **304**, the flywheel **302** being pivotally connected by a crank arm **306** to one end of a reciprocating rod **310** mounted for reciprocating movement in a support member **312**. The support member **312** is attached to a base member **314** as shown. The opposite or free end of the rod **310** has a magnetic member **316** mounted on it, and the member **316** is positioned in spaced relationship to a second fixed permanent magnet member **318** attached to support member **319**. The magnet **318** has a winding **320** mounted thereon. The winding **320** is connected to a control circuit **322** which in turn is connected to a source of power such as AC source **324**. The control circuit may include timer means and rectifier means along the lines already disclosed in connection with the other embodiments. The circuit **322** operates to cancel and isolate the field of the magnet **318** from the magnet **316** as the inertia of the flywheel moves the member **310** and the magnet **316** to its closest position to the magnet **318**. During the rest of the cycle the opposite condition occurs and the coil **320** is deenergized. Once the rotating member **302** is placed in motion, the rod **310** will move back and forth being urged in one or the other direction by the magnetic coupling or repelling force between the magnets **316** and **318**. The winding **320** can be timed to produce a field around the magnet **318** which will either enhance the magnetism thereof and therefore increase the magnetic attraction between the magnets **316** and **318** or to reduce and/or isolate the magnetism of the magnet **318** so that no magnetic coupling will be produced between the magnets **316** and **318** during a portion of each cycle of operation. By properly timing the voltage applied to the winding **320**, the rotation of the rotating member **302** and the reciprocating motion of the rod **310** can be sustained.

FIG. **31** shows another embodiment **400** which uses the teaching of the present invention to produce linear as distinguished from reciprocal or rotational motion. The construction shown in FIG. **31** includes a support stand having a lower wall **402**, a back wall **404**, and two spaced upstanding end walls **406** and **408**. A stationary permanent magnet **410** is attached extending outwardly from the rear wall **404**, and the magnet **410** has a winding **412** mounted on it as shown. The winding **412** is connected by leads **414** and **416** to a control circuit **418** and associated power source which may be similar to the control circuits and power sources shown in the other drawings. The permanent magnet **410** is positioned above elongated permanent magnet **420** which is shown being tapered from end to end so that its magnetic strength also varies from end.

It is possible to incorporate a return spring feature in the constructions shown in FIGS. **30** and **31**. If a spring is incorporated, the spring can be arranged to act in opposition both on attract or on repel, or one can be provided to operate on attract and one on repel so long as they are pulling in opposite directions. Furthermore, by applying direct current to the coil in an amount that does not completely cancel the field of the permanent magnet, it is possible to change the position of the movable member. The position of the moveable member can also be varied by varying the current. Such devices can be used with disk drives, robotic devices, and in other places where it is desired to control the position of the movable member for some purpose.

The member **420** is shown connected at its opposite ends to rods **422** and **424** which are slidably mounted in openings in the end wall members or bearing blocks **406** and **408**. This construction as in the others can use increasing magnetic coupling or increasing magnetic repulsion to produce the desired linear sliding movement of the rods **422** and **424** and of the attached member **420**. In this construction as in the others the member **420** has a north pole on one side (top or bottom as shown) and a south pole on the opposite side. Therefore it has been shown that the teachings of the present invention can be used to produce rotational, reciprocating, oscillating as well as linear motion.

Thus there has been shown and described several different embodiments of a device capable of producing motion generated by permanent magnets and in some cases permanent magnets with control windings wound around or mounted on them. It will be apparent to those skilled in the art, however, that many changes, modifications, variations and other uses and applications of the present invention are possible and contemplated and all such changes, modifications, alterations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the claims which follow.

What is claimed is:

1. A device to control the magnetic properties of a permanent magnet including the ability of the permanent magnet to magnetically interact with another permanent magnet comprising:

first and second permanent magnets having north and south poles,

a coil of conductive metal wound about the first permanent magnet intermediate the north and south poles, the first permanent magnet having north and south poles lying in a first plane, the second permanent magnet having north and south poles lying in a second plane that is substantially parallel to the first plane,

means to control the linear movement of the second permanent magnet in a plane perpendicular to the first and second planes caused by the magnetic interaction between the first permanent magnet and the second permanent magnet including

a source of direct current energy and switch means connected in series therewith across the coil whereby when the switch means are closed the direct current source is applied across the coil whereby the magnetic flux of the first permanent magnet changes the ability of the first permanent magnet to interact with the second permanent magnet.

2. A device to produce reciprocating motion comprising a rotatable member of flywheel construction having an arm pivotally connected thereto at a location spaced radially from the axis of rotation, said arm having an opposite end pivotally connected to a second arm mounted for reciprocating motion, said second arm having a free end with a first permanent magnet mounted thereon, one of the poles of the first permanent magnet forming the end surface of the reciprocating member, a fixed support member positioned in close promixity to said first permanent magnet, a second permanent magnet mounted on said fixed support member in alignment with the first permanent magnet whereby the first permanent magnet moves toward and away from the second permanent magnet when the flywheel is rotated, a winding mounted on one of said first and second permanent magnets, and circuit means connected to said winding to control the magnetic characteristics thereof, said circuit being timed to energize the winding in such a way as to change the magnetic interaction between the first and second permanent magnets and to apply force on the first permanent magnet in a direction to maintain rotation of the flywheel.

3. A device to produce linear motion of a first member relative to a second member, the first member being a permanent magnet having a north pole on one side and a south pole on the opposite side, said first member being constructed so that the magnetic characteristics thereof vary from end to end, means for supporting the first member for linear movement in a direction normal to the direction through the magnet poles thereof, a second member having magnetic characteristics mounted adjacent one side of said first member, a winding mounted on the second member, and means to control the application of electric energy to said winding to modify the magnetic flux emanating from the second magnet member and the coupling between the first and second members.

4. A device to modify the magnetic flux emanating from a first permanent magnet including the ability of the first permanent magnet to magnetically interact with a second permanent magnet comprising:

a first permanent magnet having opposed north and south poles lying in a first plane, a winding of electrically conductive material mounted on the first permanent magnet,

a second permanent magnet having north and south poles lying in a second plane that is substantially parallel to the first plane and positioned to magnetically interact with the first permanent magnet, and

means to control the linear movement of the second permanent magnet in a plane perpendicular to the first and second planes caused by the magnetic interaction between the first and second permanent magnets, said means including an electric energy source and switch means connected across the winding of electrically conductive material whereby closing of the switch means establishes a voltage across the winding of electrically conductive material that modifies the magnetic characteristics of the first permanent magnet by changing the flux emanating therefrom and the ability of the first permanent magnet to interact with the second permanent magnet.

5. The device of claim **4** wherein the electrically conductive winding is mounted on the first permanent magnet between the north and south poles thereof.

6. The device of claim **4** wherein the energy source is a DC energy source polarized relative to the winding of conductive material to increase the magnetic force of the permanent magnet when the energy source is connected across the winding.

7. The device of claim **4** wherein the polarity of the energy source is oriented to reduce the magnetic force of the first permanent magnet when the energy source is connected across the winding of conductive material.

8. The device of claim **4** wherein the means to modify the flux emanating from the first permanent magnet reduces the magnetic interaction between the first permanent magnet and the second permanent magnet when the energy source is connected across the winding of conductive material.

9. The device of claim **4** wherein the switch means include optical switch means.

10. The device of claim **4** wherein the switch means include reed switch means.

11. A device to control the magnetic properties of a permanent magnet including the ability of the permanent magnet to magnetically interact with another member having magnetic characteristics comprising:

a permanent magnet having north and south poles,

a coil of conductive metal wound about the permanent magnet intermediate the north and south poles,

a member having magnetic characteristics mounted on a rotatable member having an axis of rotation, the member having magnetic characteristics including a circumferentially extending portion of the rotatable member, means mounting the permanent magnet adjacent to the circumferentially extending portion of the rotatable member whereby the permanent magnet is magnetically coupled thereto, the circumferentially extending portion of the rotatable member having portions of greater magnetic characteristics than others, and

a source of direct current energy and switch means connected in series across the coil whereby when the switch means are closed the direct current source is applied across the coil whereby the magnetic permeability of the permanent magnet changes the ability of the permanent magnet to interact with the member having magnetic characteristics, the circumferentially extending portion of the rotatable member having a circumferentially extending helical shaped portion.

12. The device of claim **11** wherein the helical shaped portion extends circumferentially around the peripheral edge portion of the rotatable member going from a point of maximum diameter to a point of minimum diameter adjacent to the same circumferential location.

13. The device of claim **11** wherein the circumferentially extending portion of the rotatable member varies in thickness circumferentially around the rotatable member, the thickest and thinnest portions thereof being adjacent to one another.

14. The device of claim **13** wherein one side surface of the rotatable member is relatively flat, and means mounting the permanent magnet adjacent to said flat side surface.

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