

# *A Practical Guide to 'Free Energy' Devices*

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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 10 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 15 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.

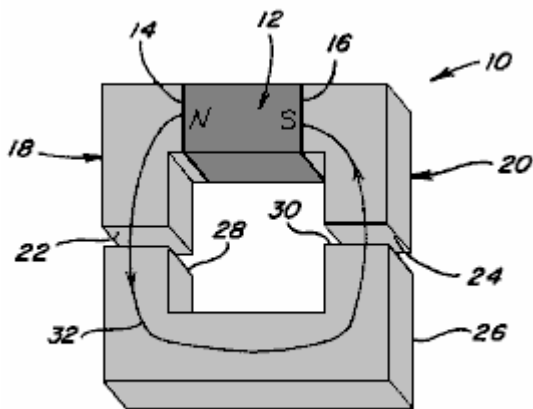
A further aspect of the present invention provides method for controlling the path of magnetic flux from a permanent magnet by placing a first pole piece adjacent a first pole face of the permanent magnet so as to have at least first and second path portions extending beyond a perimeter of the first 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.

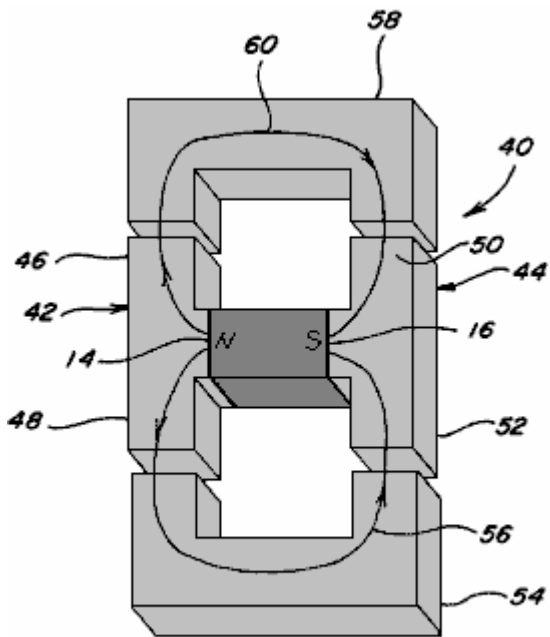
### BRIEF DESCRIPTION OF THE INVENTION

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



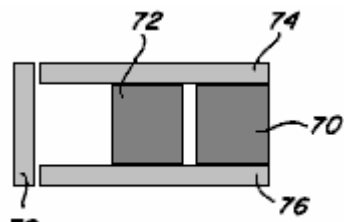
*Fig. 1*

**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;



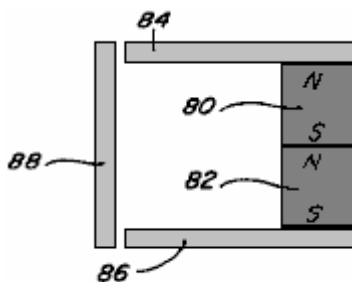
*Fig. 2*

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



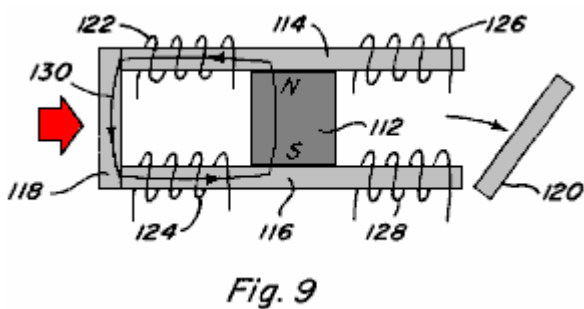
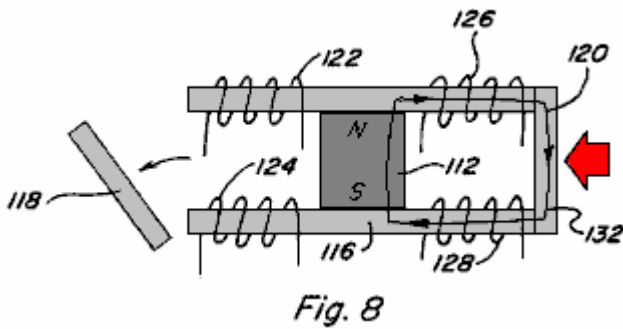
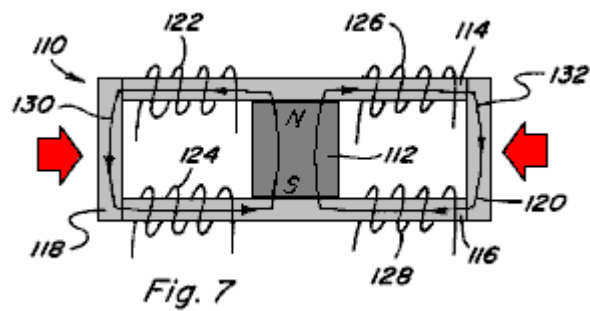
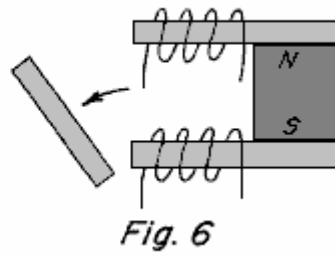
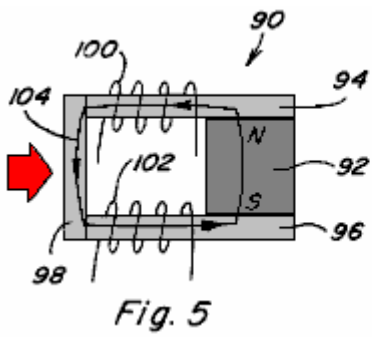
*Fig. 3*

**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.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;

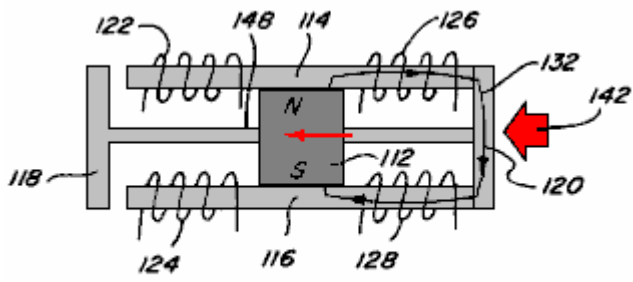


Fig. 10

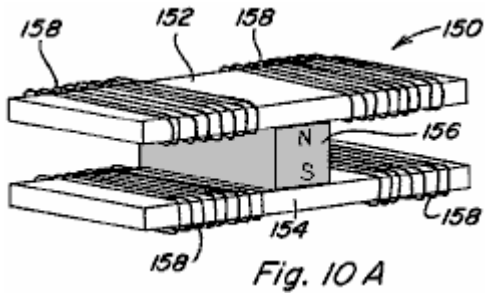


Fig. 10 A

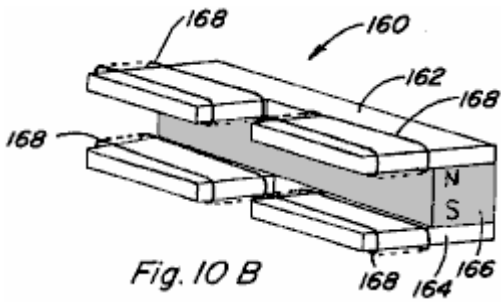


Fig. 10 B

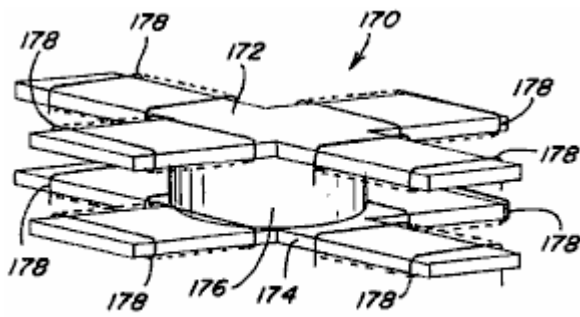


Fig. 10 C

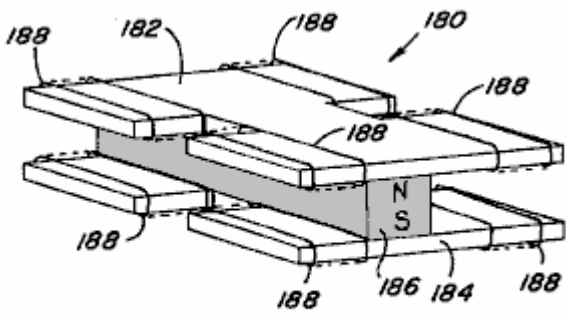


Fig. 10D

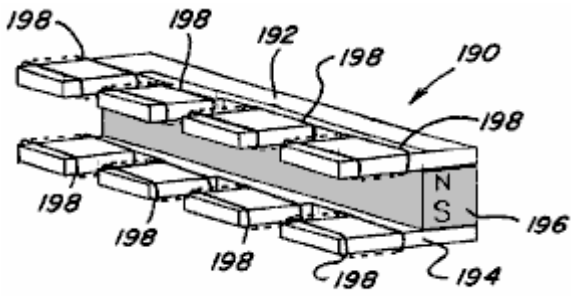


Fig. 10E

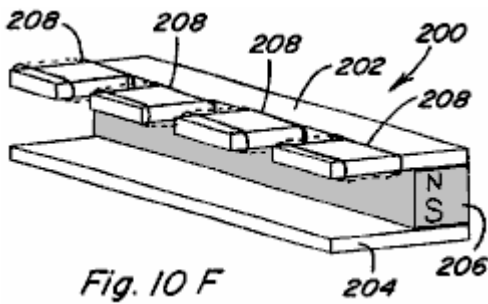


Fig. 10F

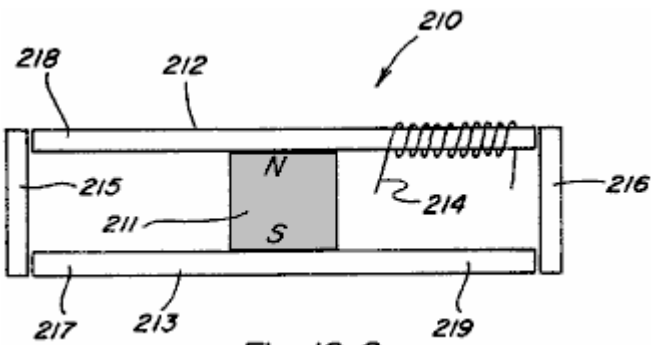


Fig. 10G

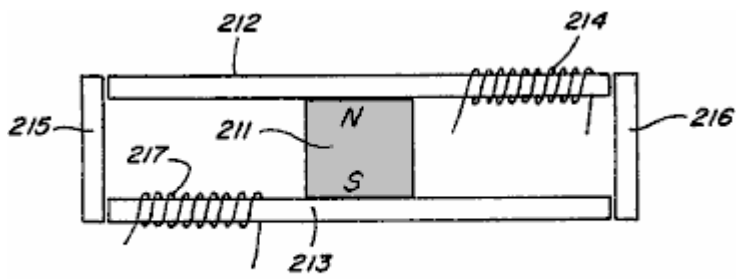


Fig. 10 H

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

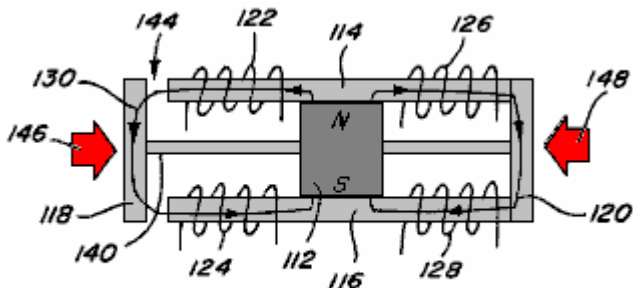


Fig. 11

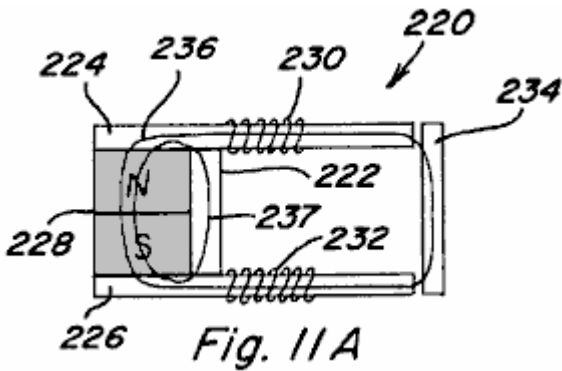


Fig. 11 A

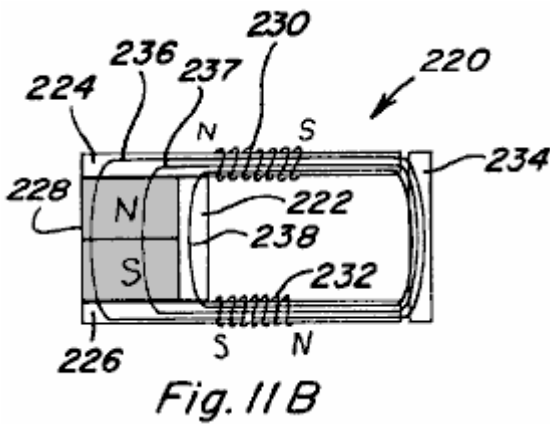
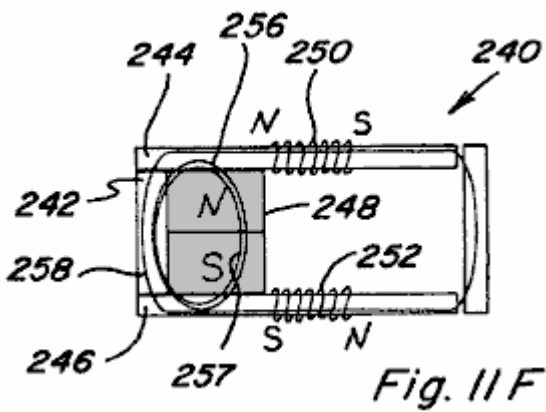
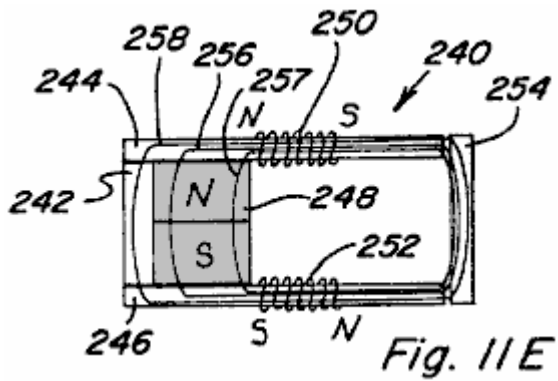
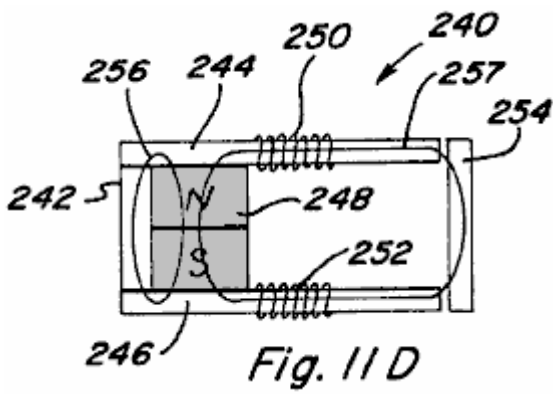
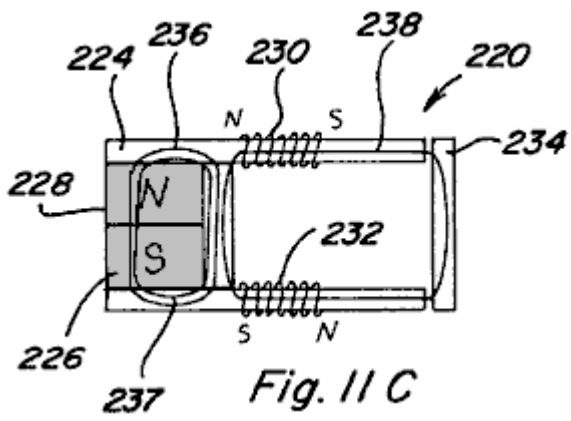


Fig. 11 B





**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;

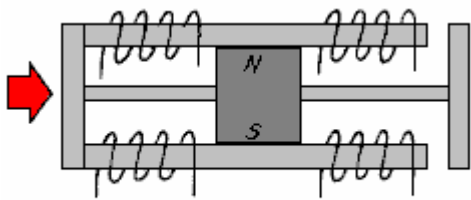


Fig. 12

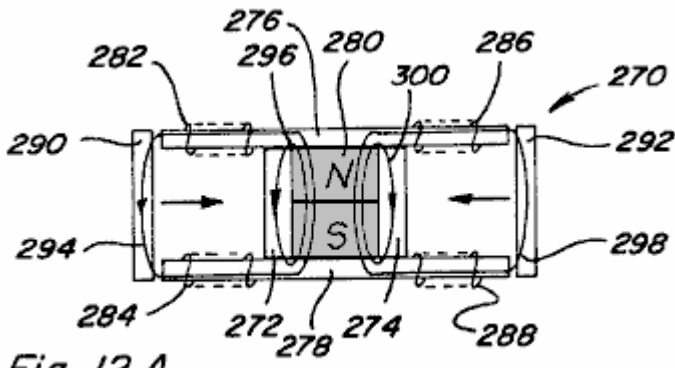


Fig. 12 A

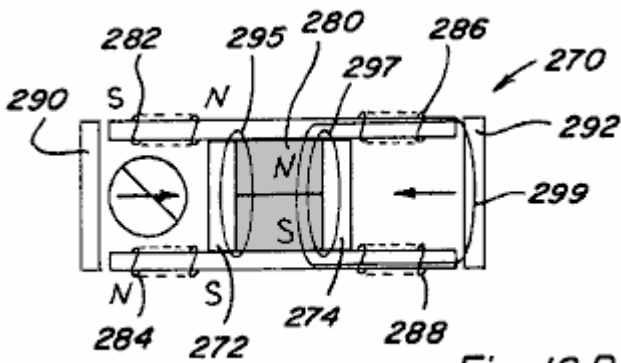


Fig. 12 B

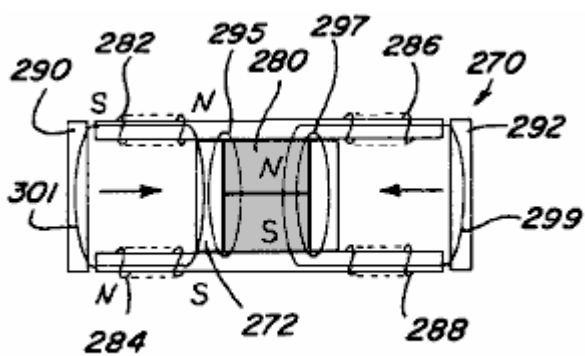


Fig. 12 C

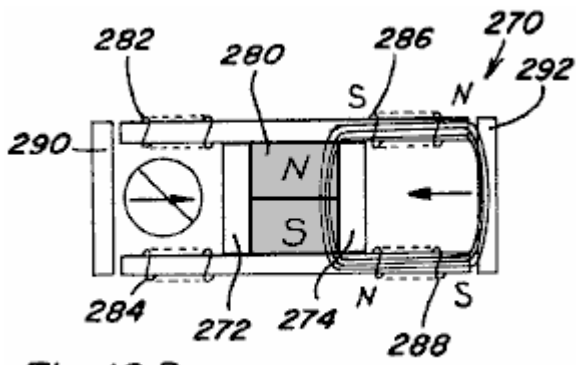


Fig. 12 D

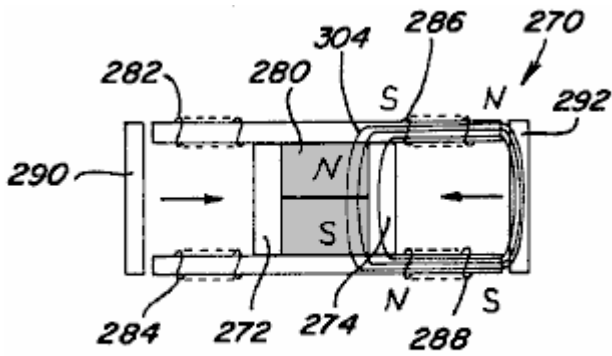


Fig. 12 E

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

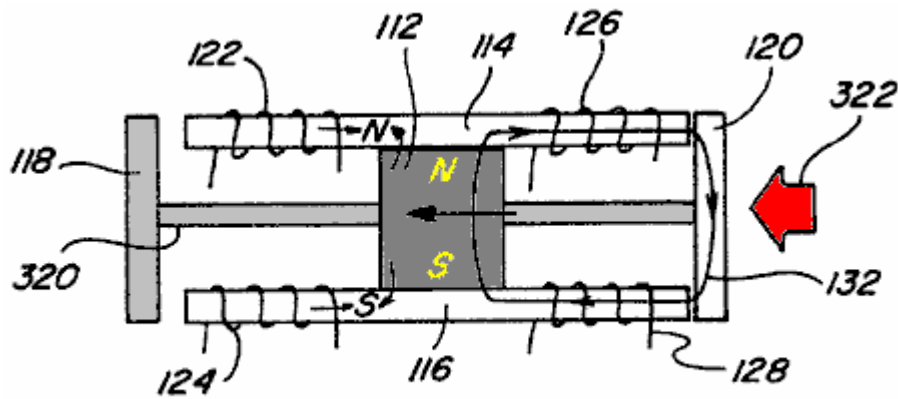


Fig. 13 A

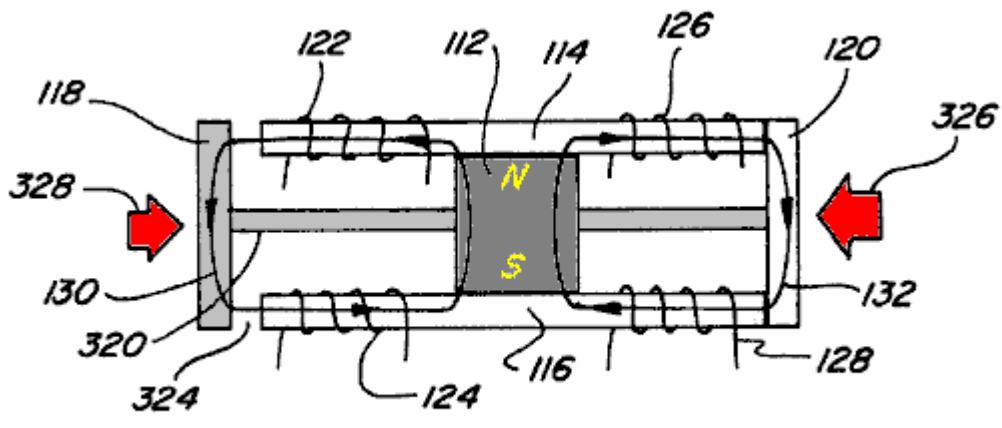


Fig. 13 B

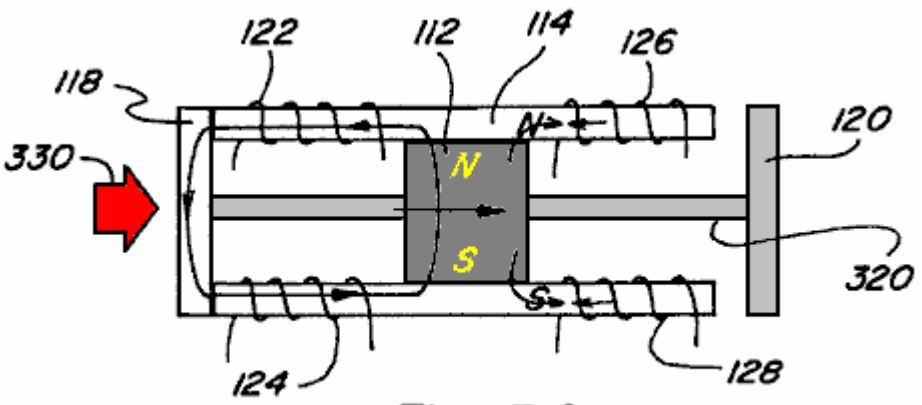


Fig. 13 C

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

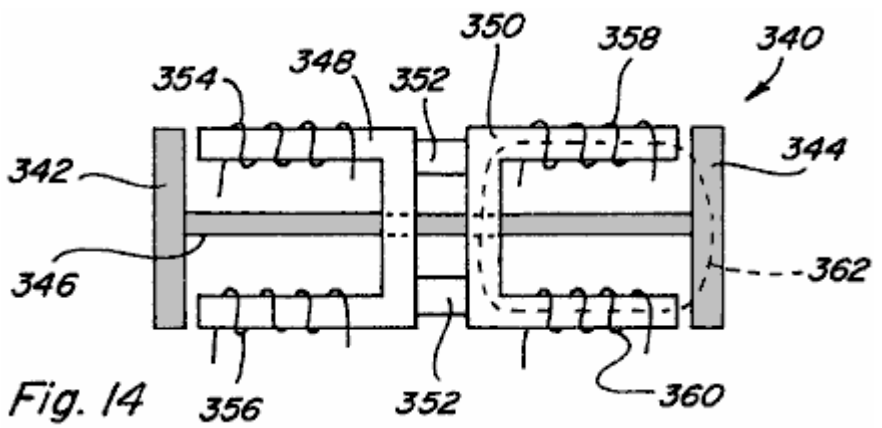


Fig. 14

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

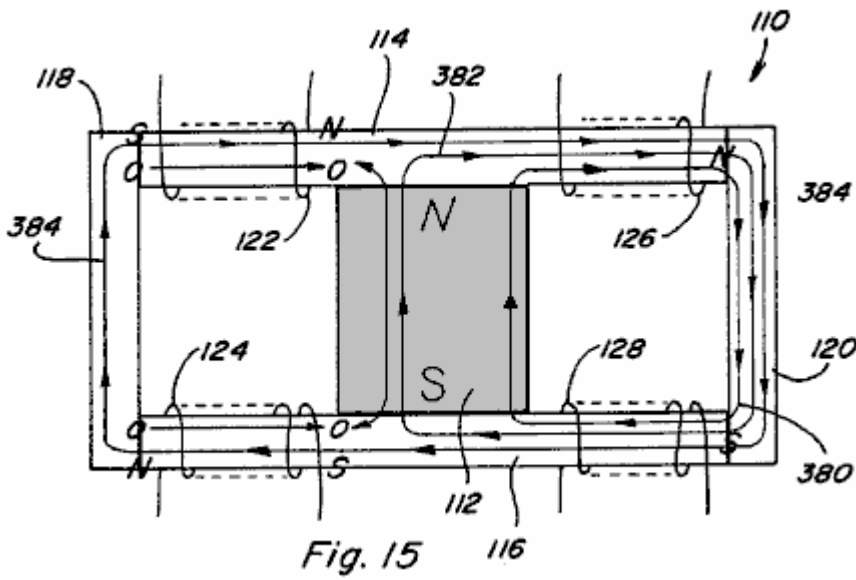
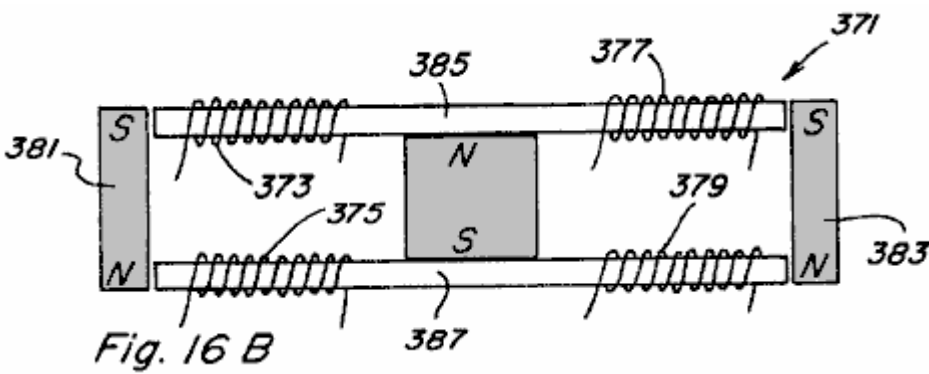
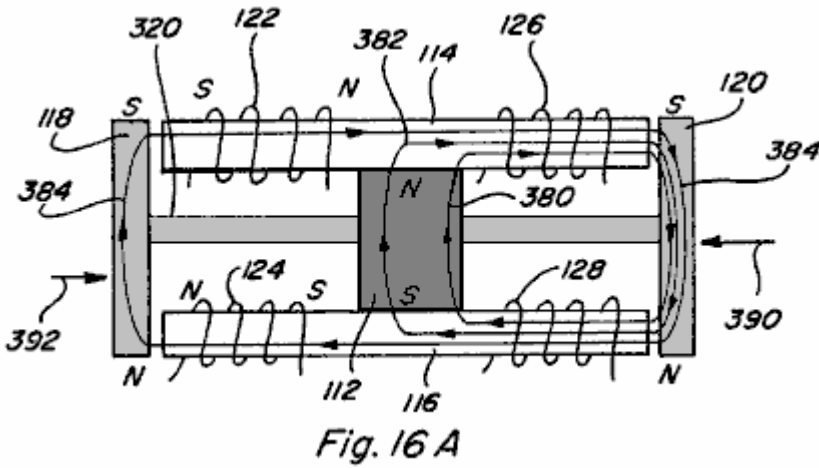


Fig.15 is a side view of a two path permanent magnet device showing control coils energised in an exceeding manner;



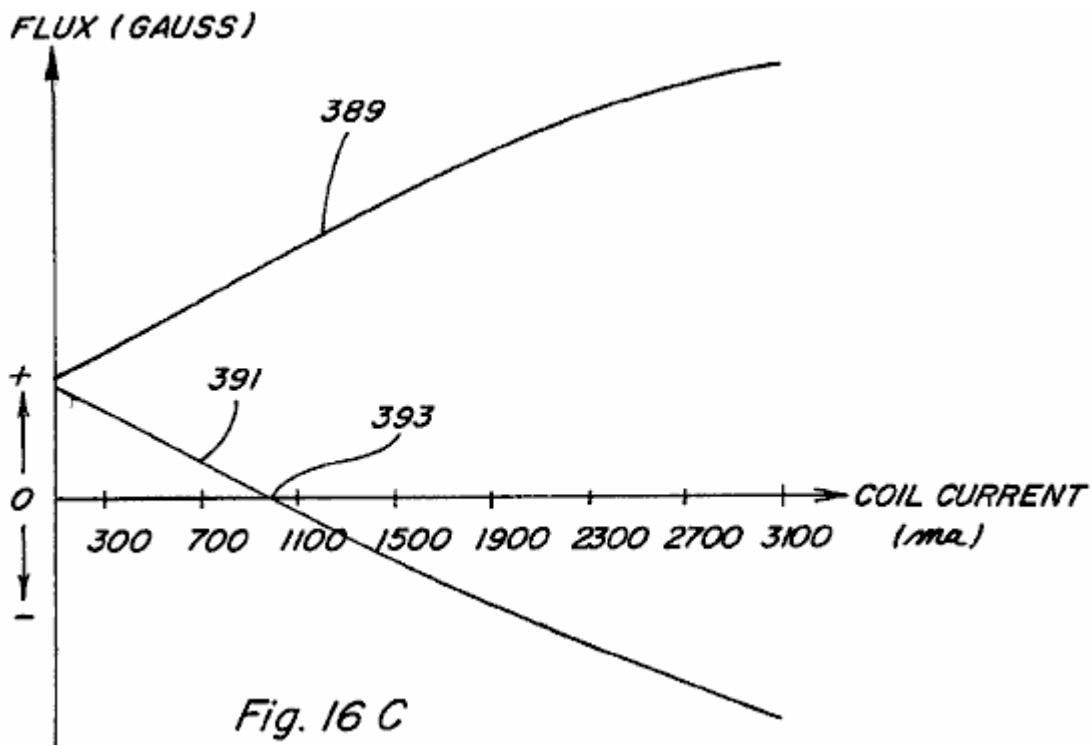


Fig. 16 C

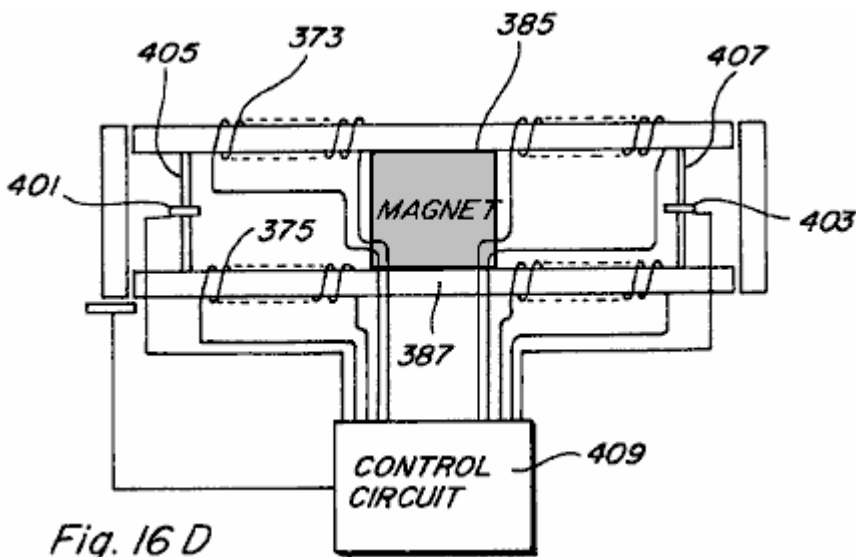


Fig. 16 D

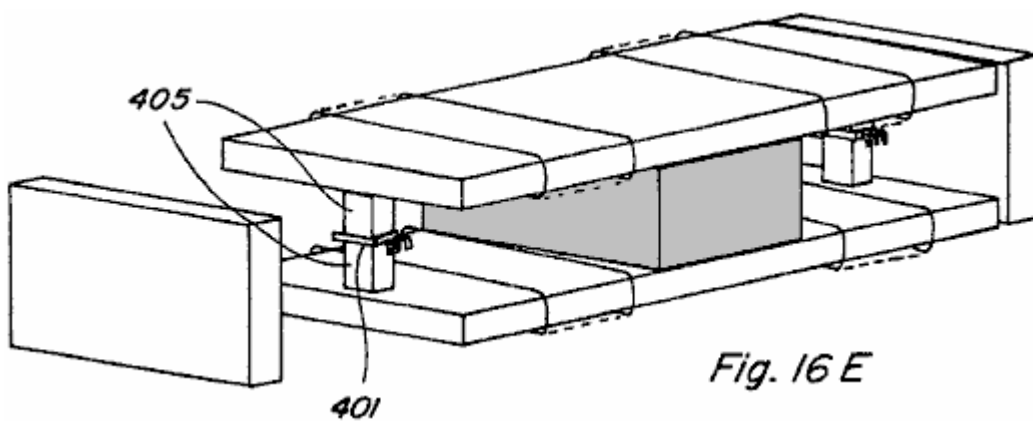


Fig. 16 E

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

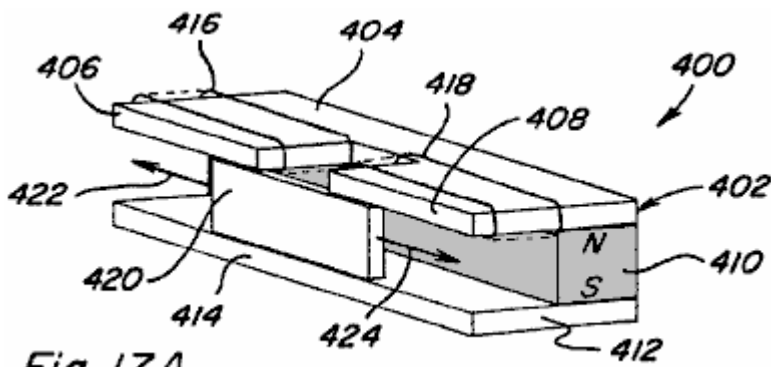


Fig. 17A

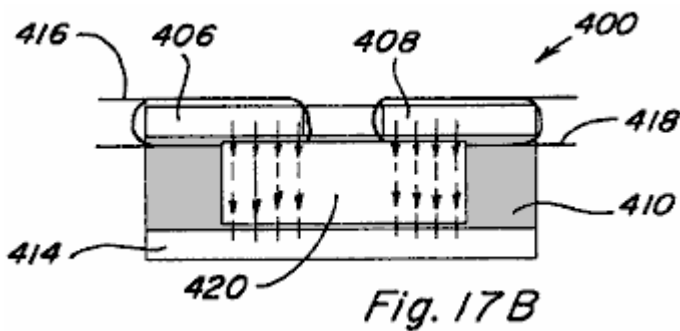


Fig. 17 B

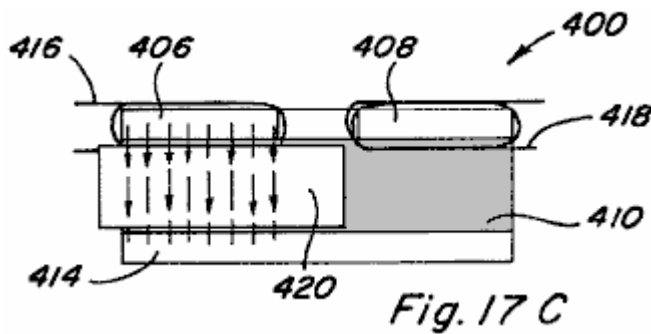


Fig. 17 C

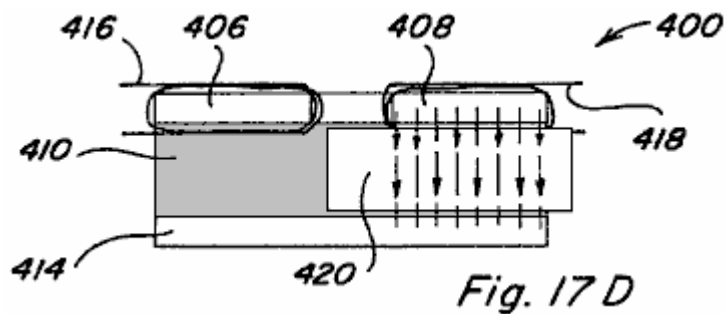


Fig. 17 D

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

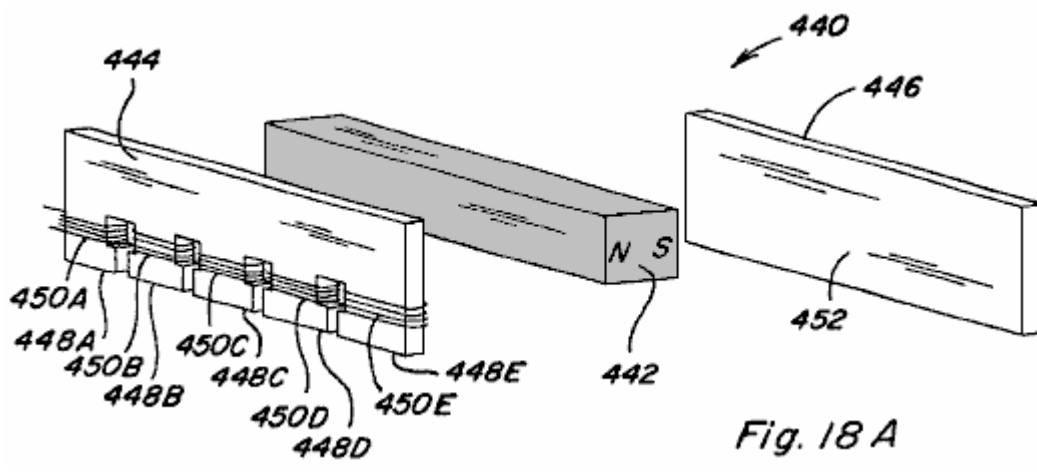


Fig. 18 A

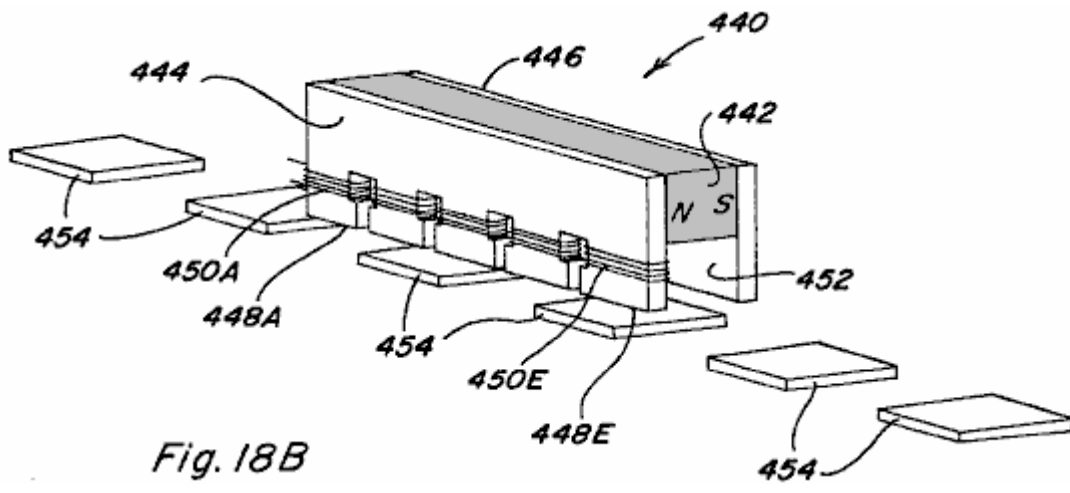


Fig. 18B

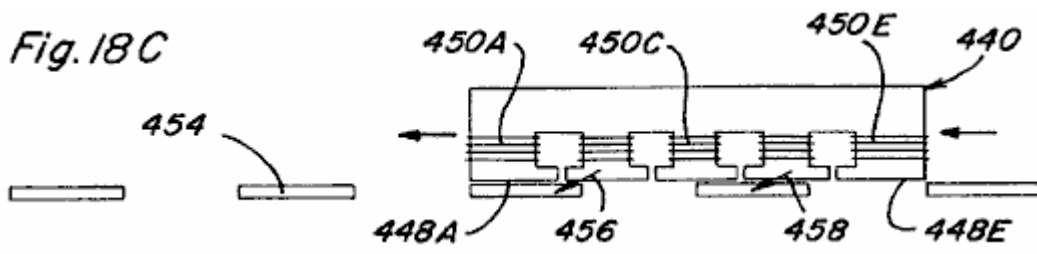


Fig. 18C

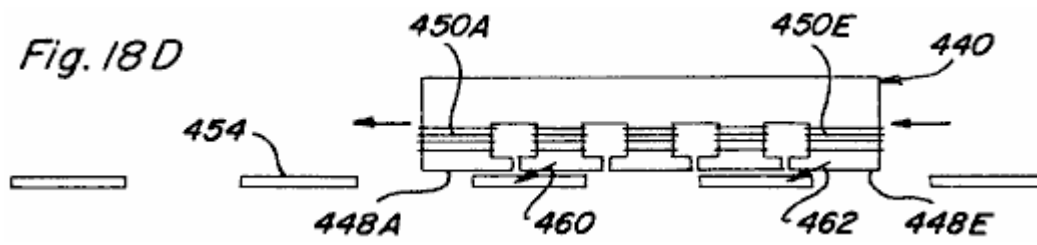
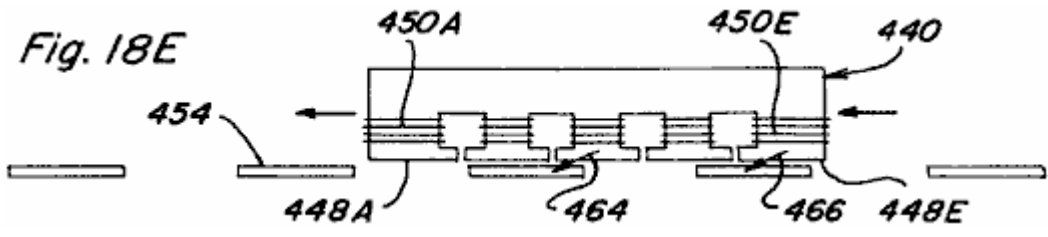


Fig. 18D





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

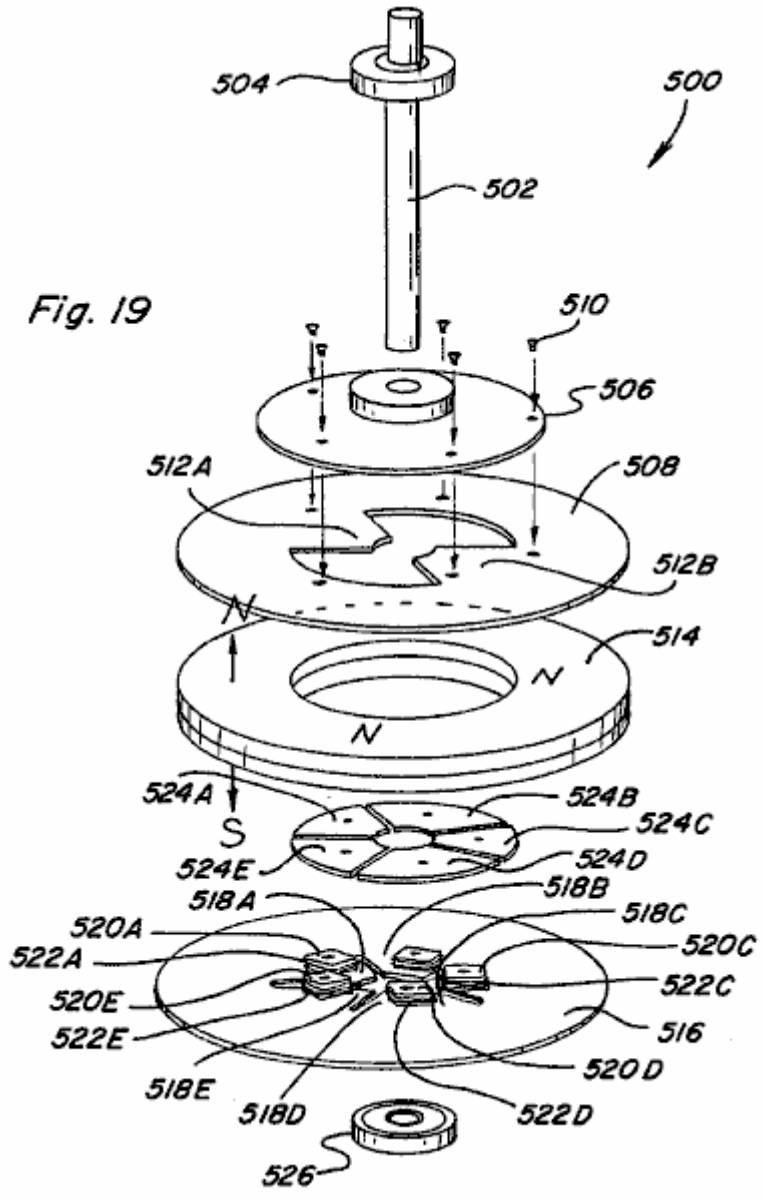


Fig.19 is an exploded perspective view of a rotary motion device;

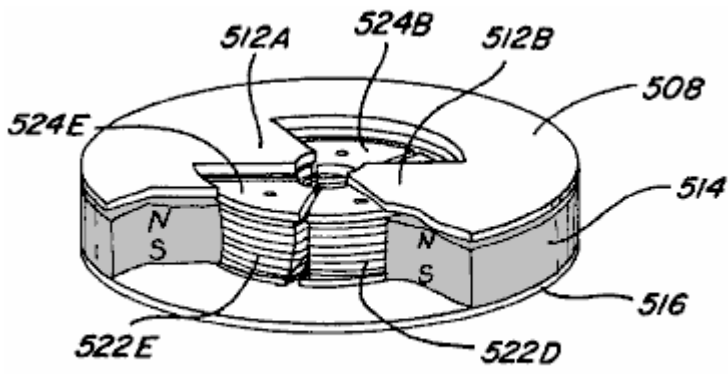


Fig. 20

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

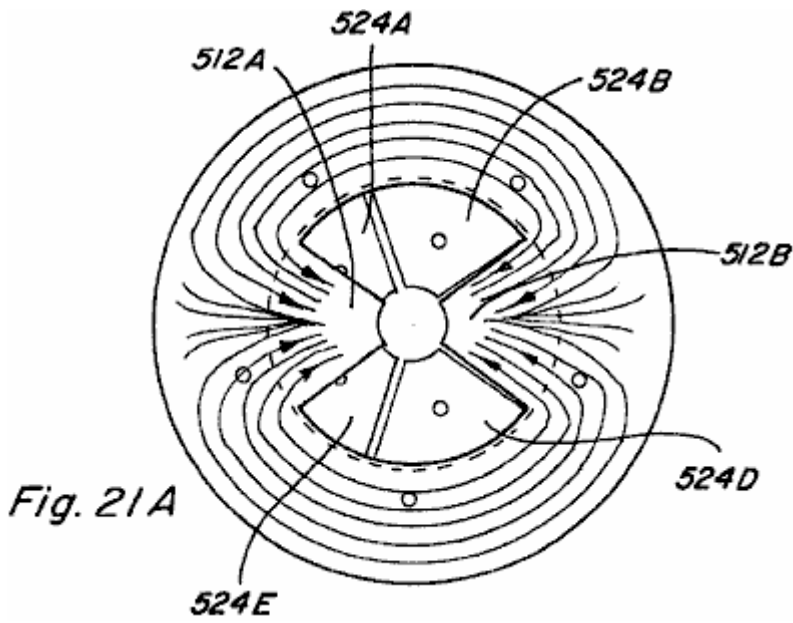


Fig. 21A

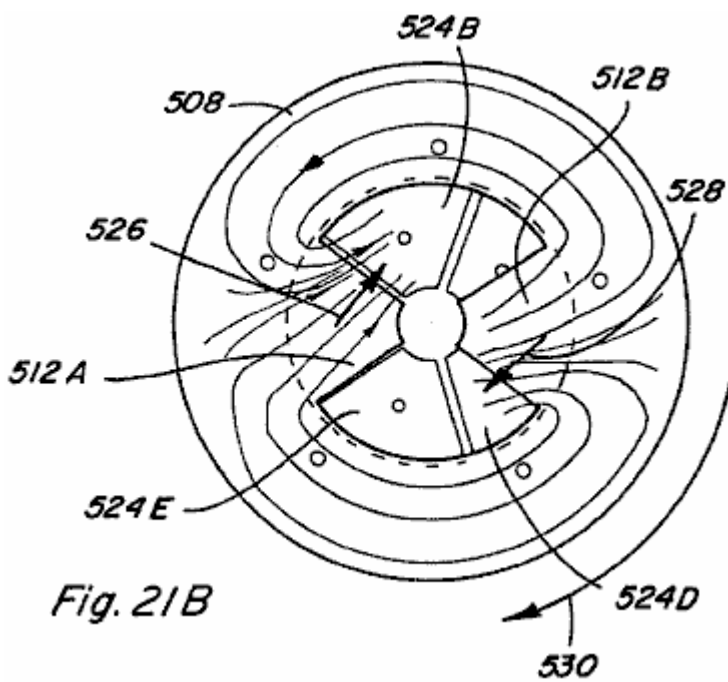
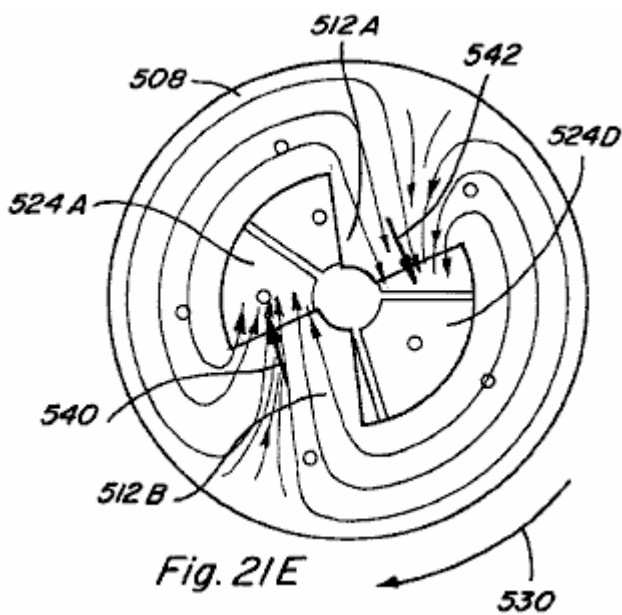
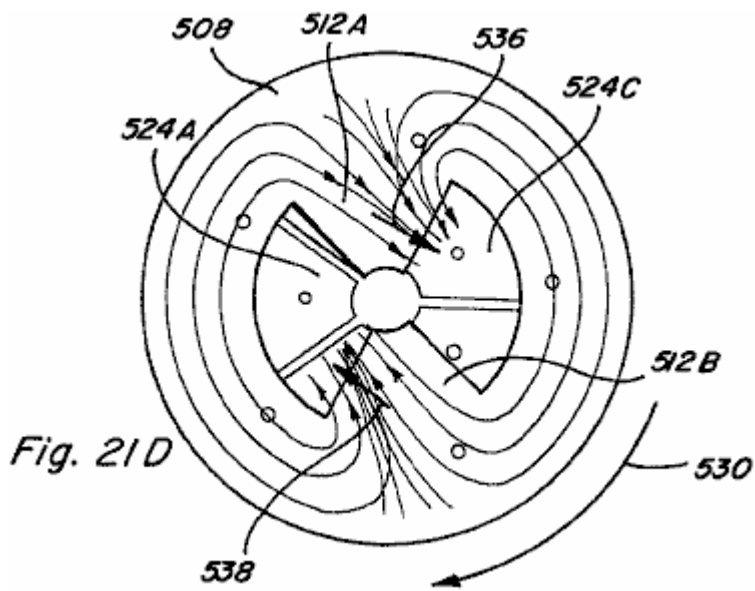
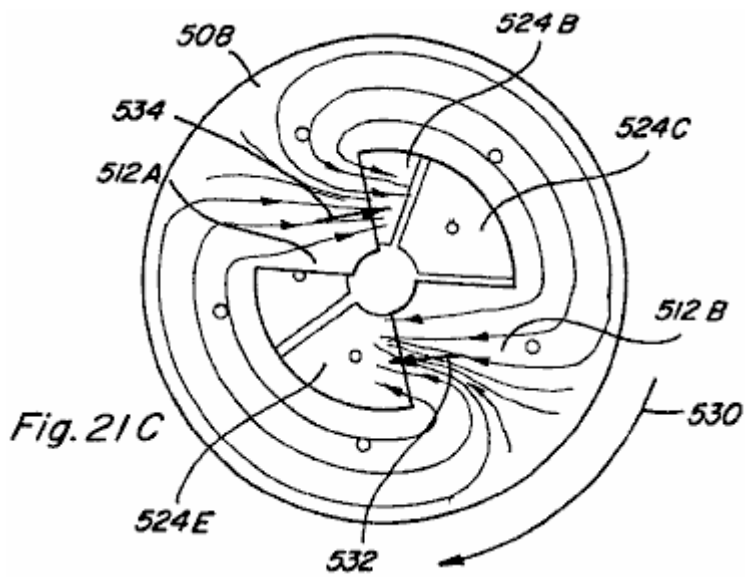


Fig. 21B



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

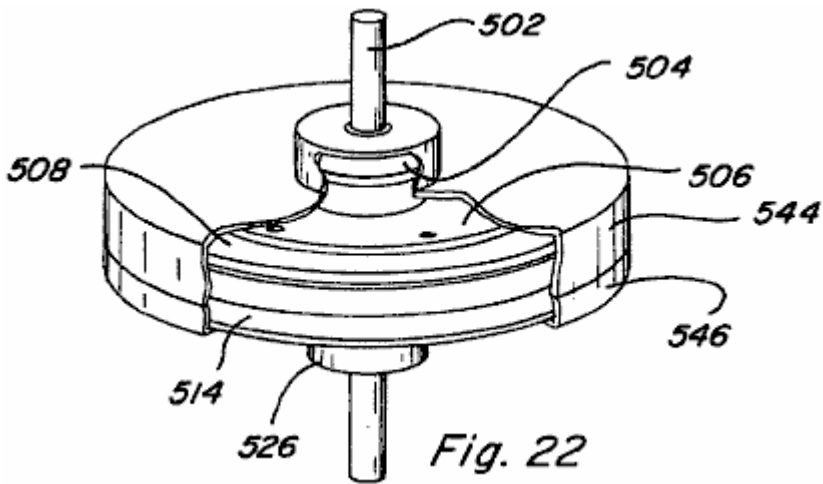


Fig. 22

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

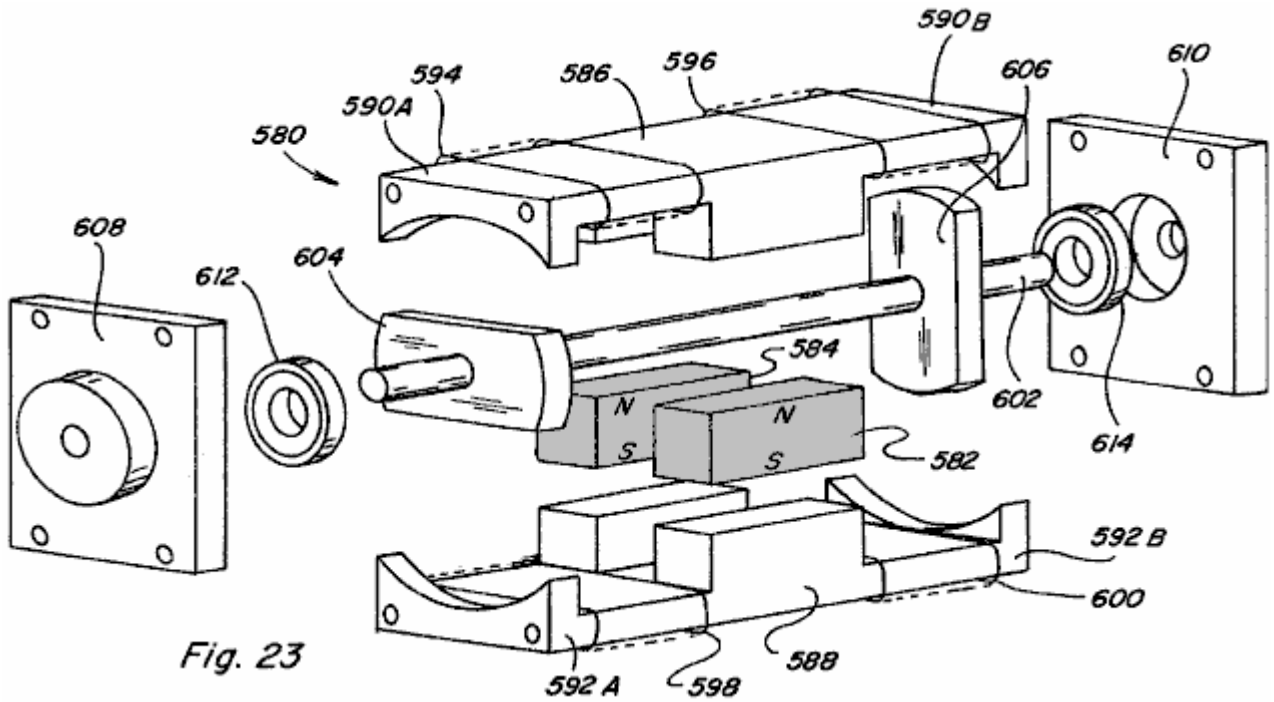


Fig. 23

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

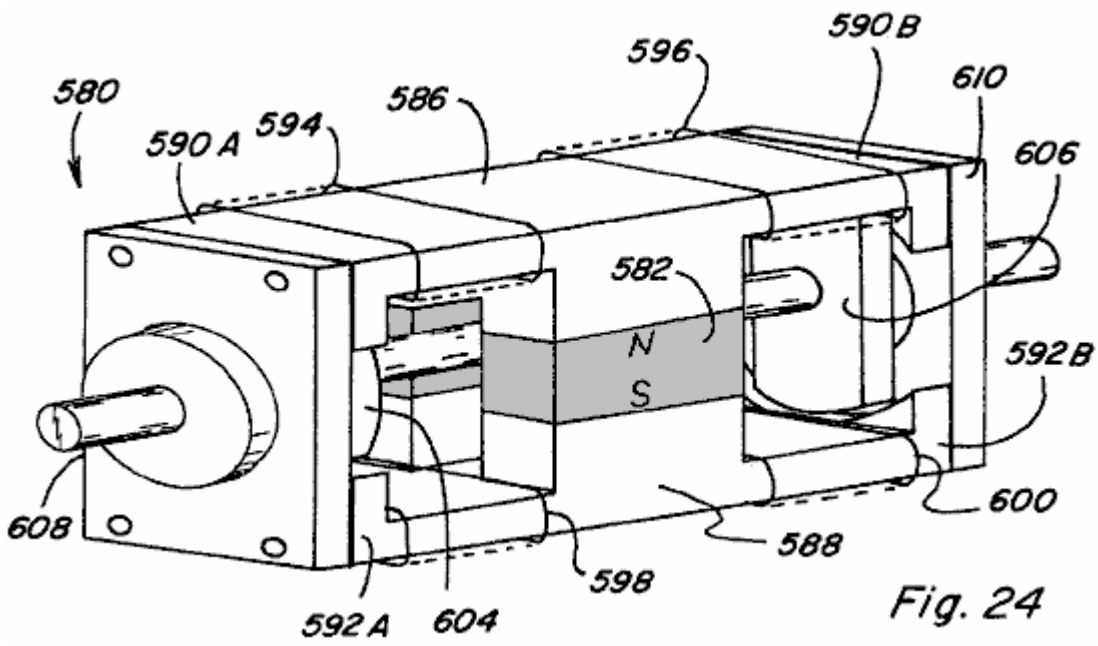


Fig. 24

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

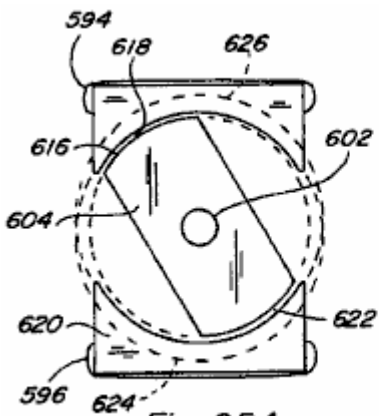


Fig. 25A

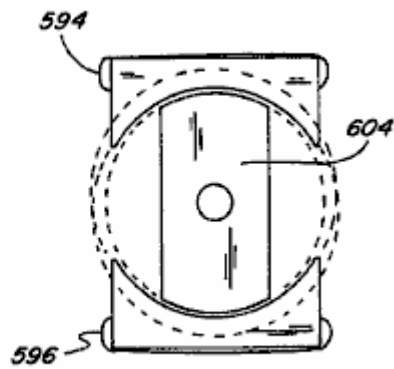


Fig. 25B

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

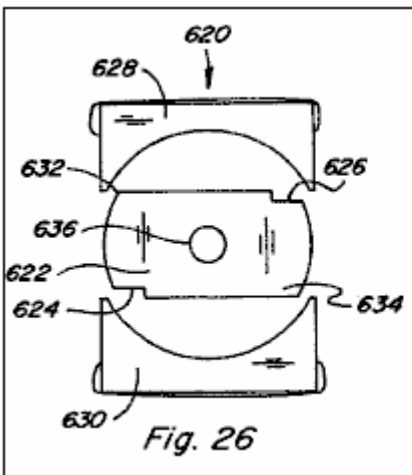


Fig. 26

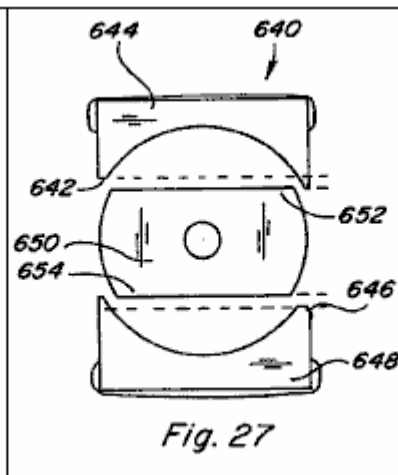


Fig. 27

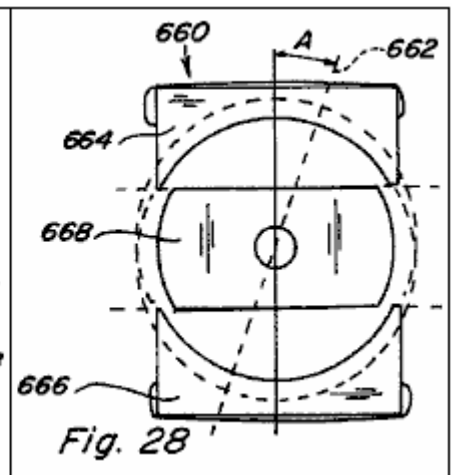


Fig. 28

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

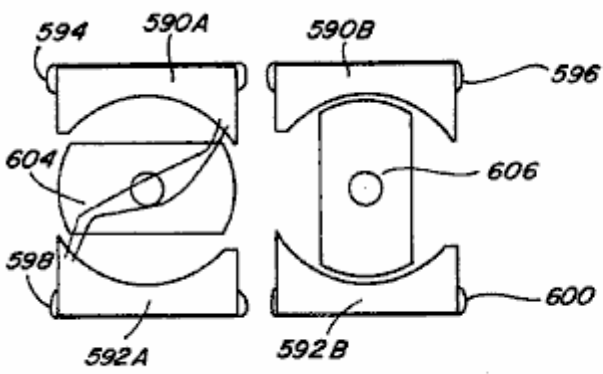


Fig. 29A

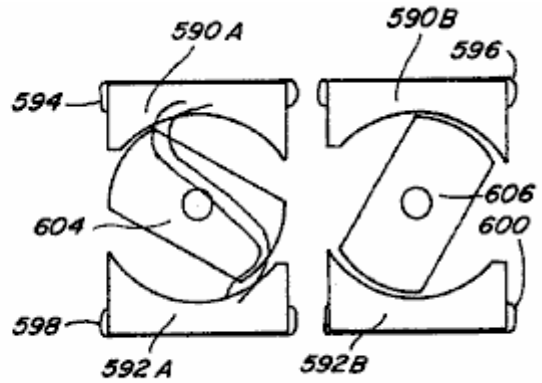


Fig. 29B

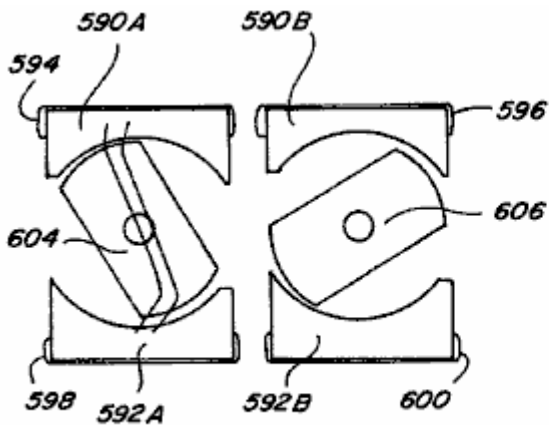


Fig. 29C

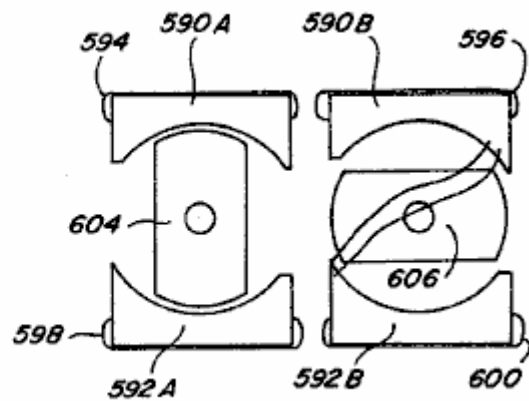


Fig. 29D

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

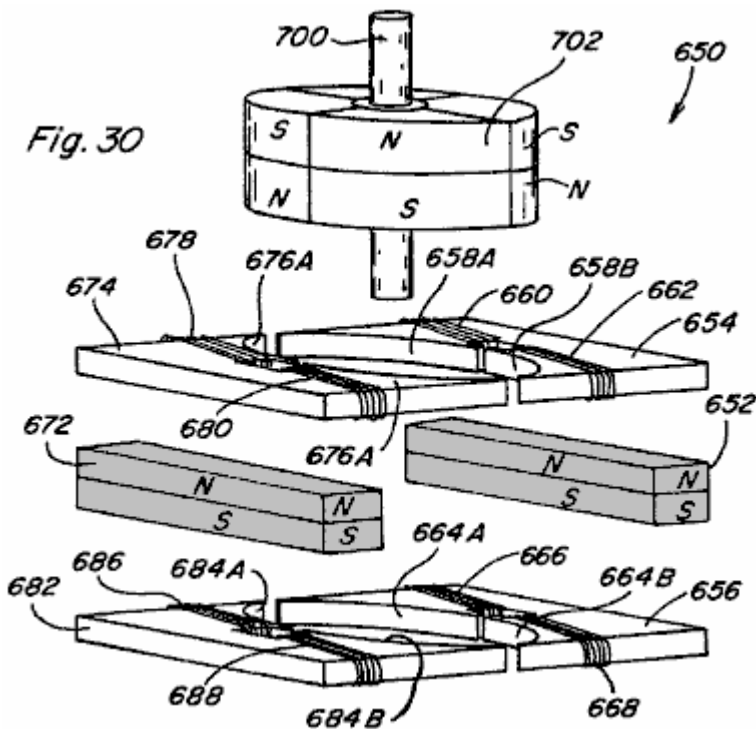


Fig. 30

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

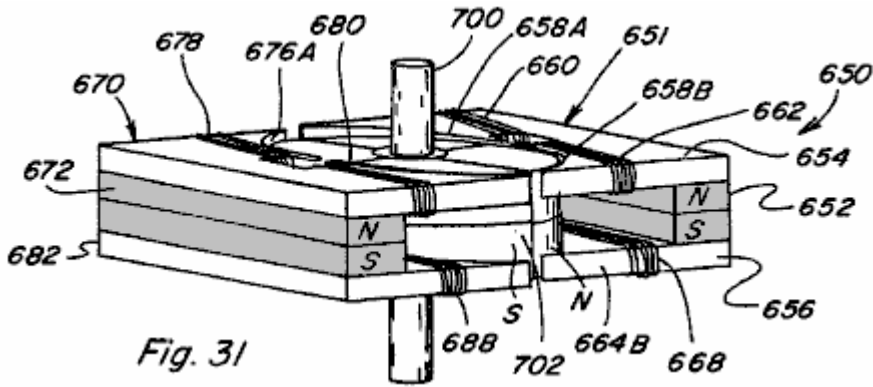


Fig. 31

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

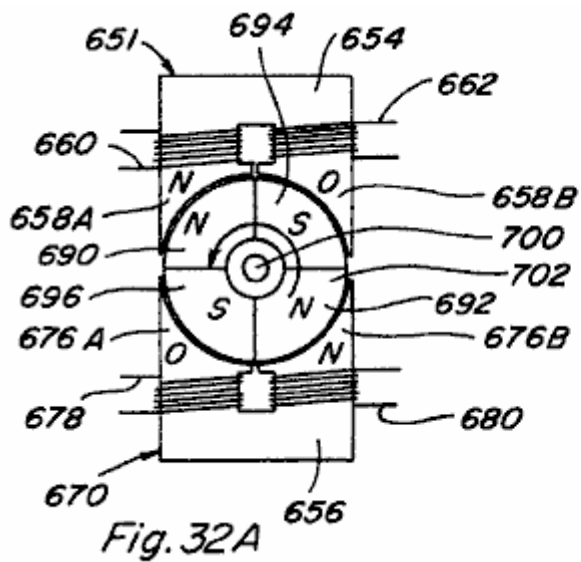


Fig. 32A

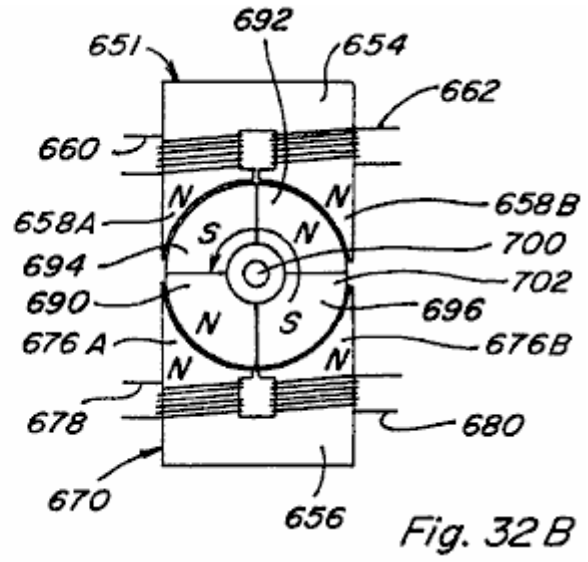


Fig. 32B

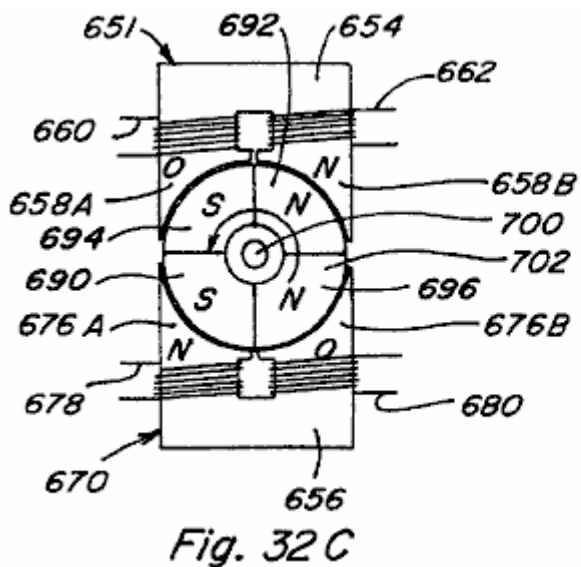


Fig. 32C

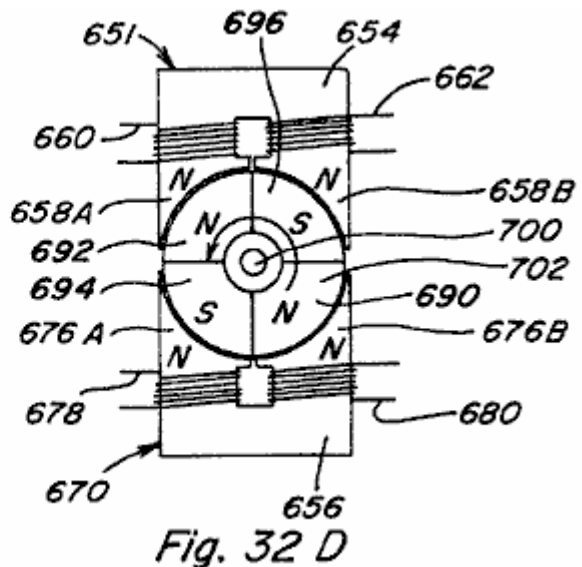


Fig. 32D

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

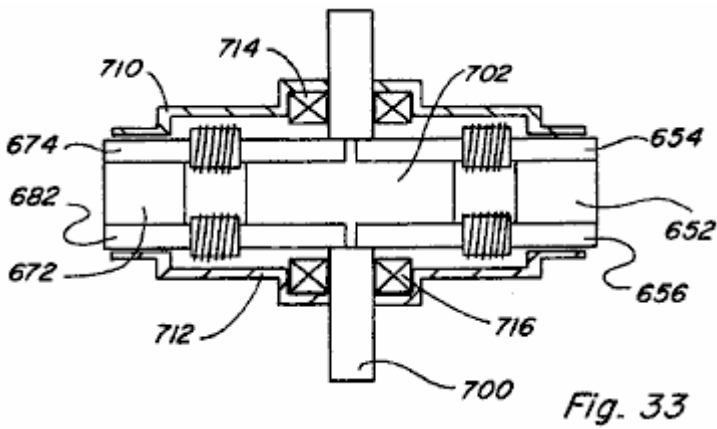


Fig.33 is a side view of the rotary motion device of Fig.31 as assembled and including a housing;

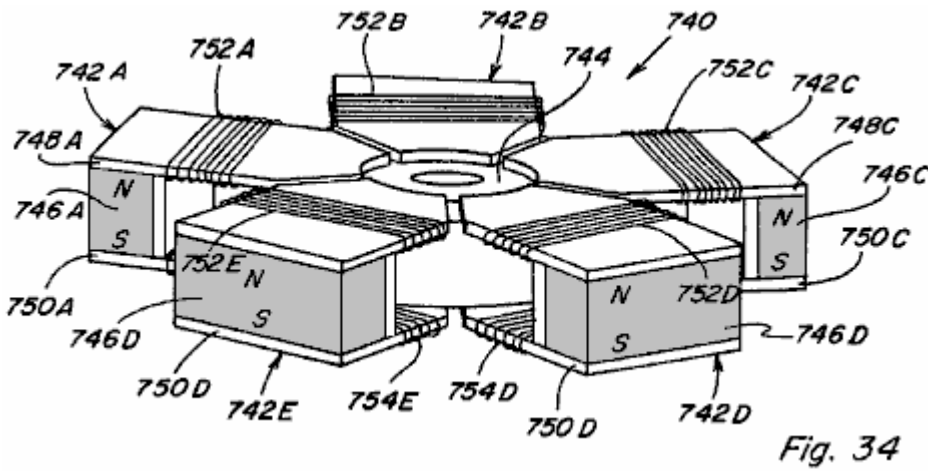


Fig.34 is a perspective view of another embodiment of a rotary motion device;

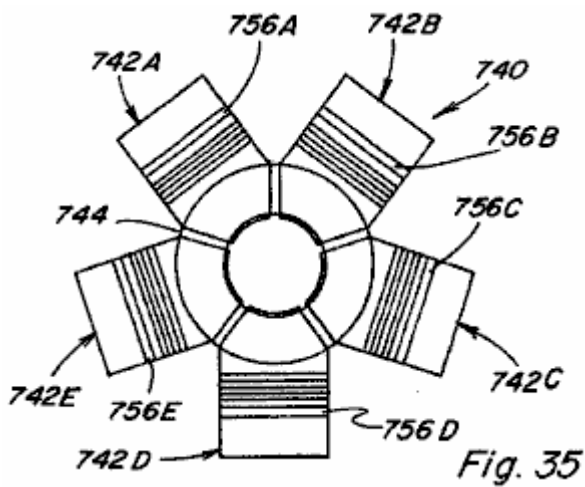


Fig.35 is a top view of the rotary motion device of Fig.34;



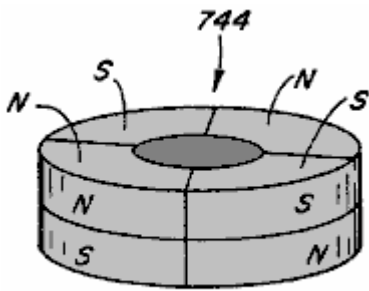


Fig. 36

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

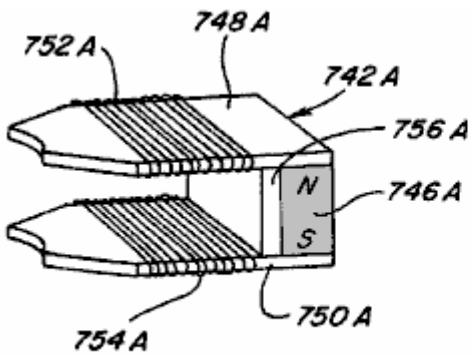


Fig. 37

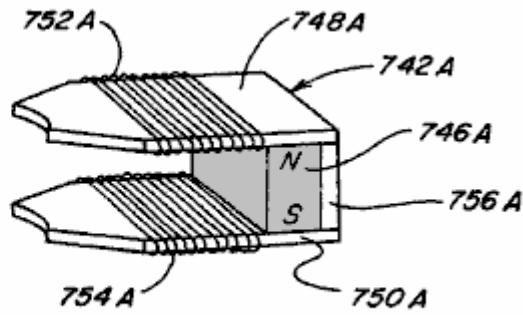


Fig. 38

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

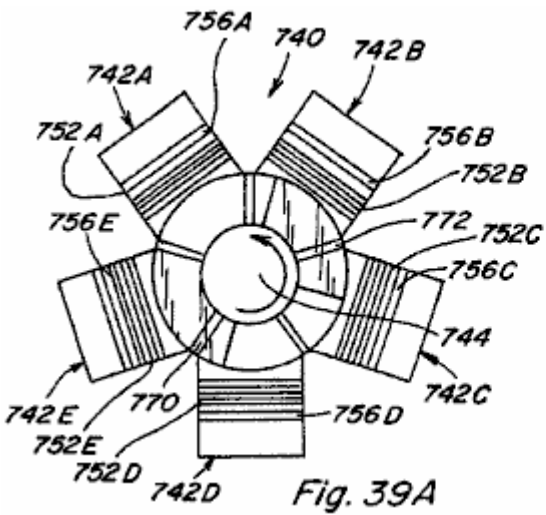


Fig. 39A

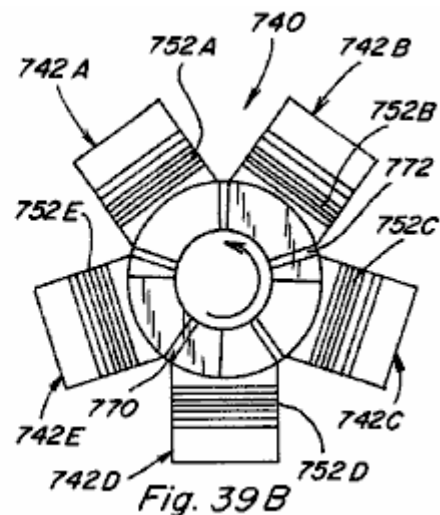
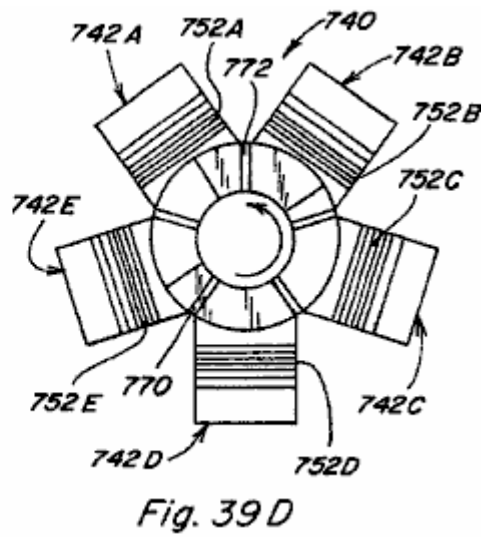
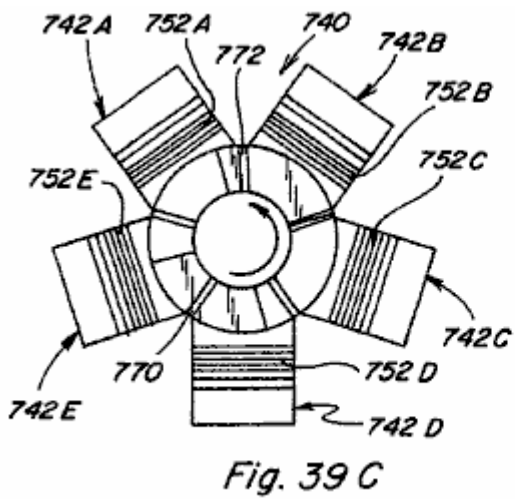
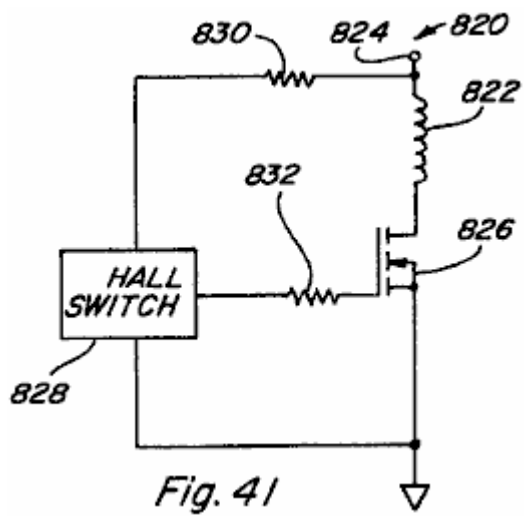
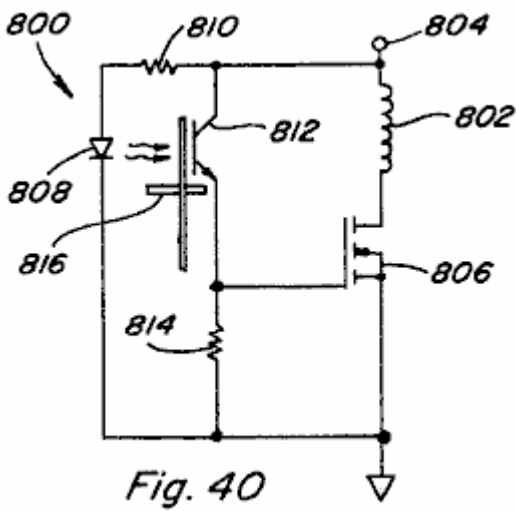


Fig. 39B



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



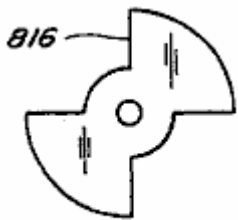


Fig. 42

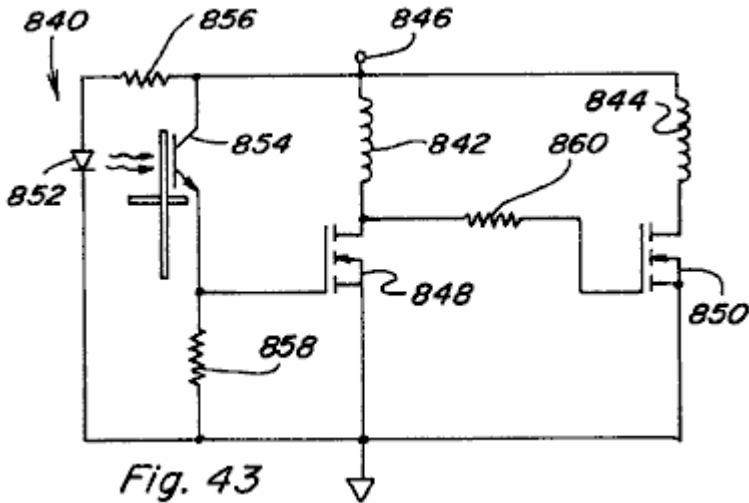


Fig. 43

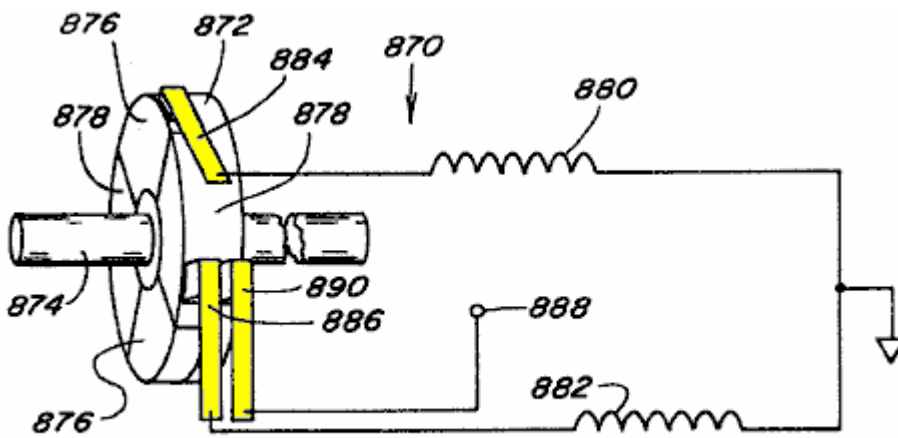


Fig. 44

**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;

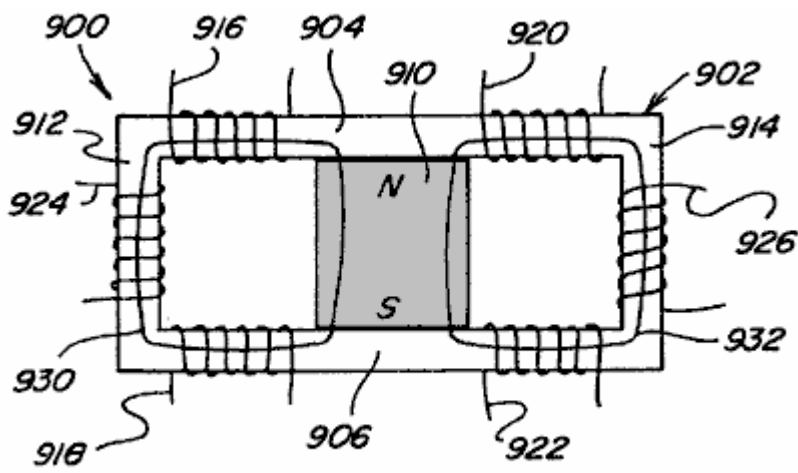


Fig. 45A

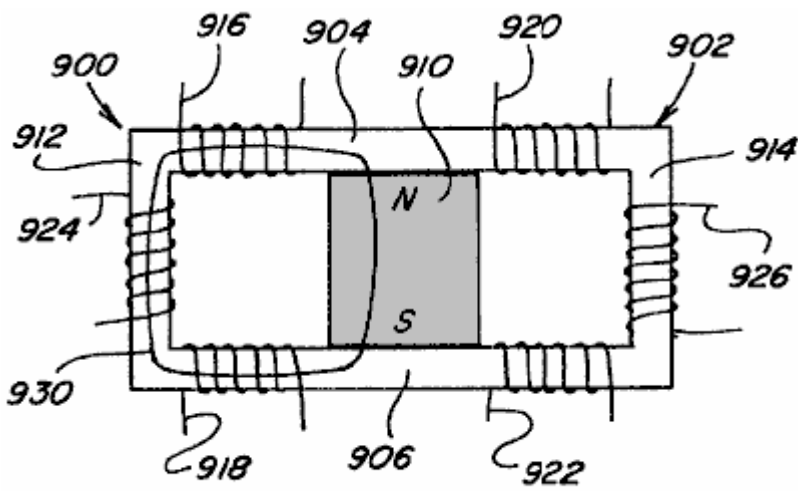


Fig. 45B

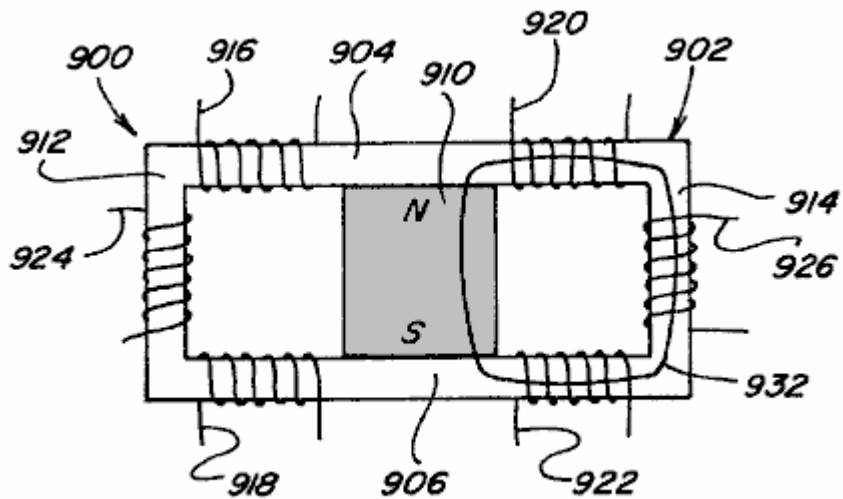


Fig. 45C

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

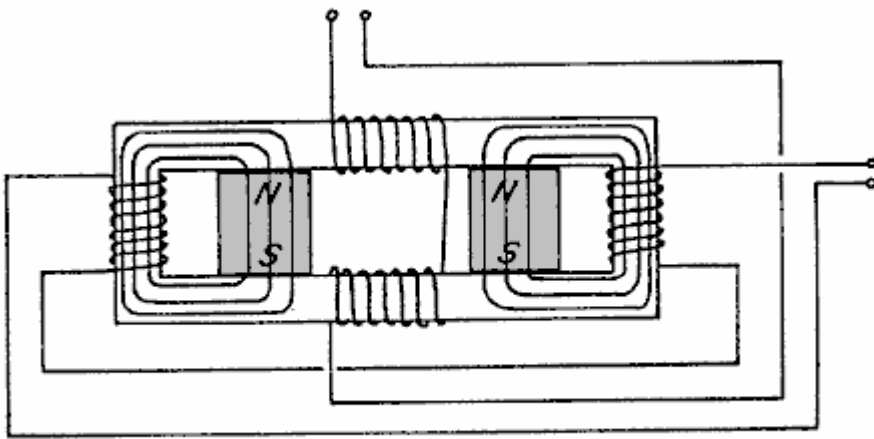


Fig. 45 X

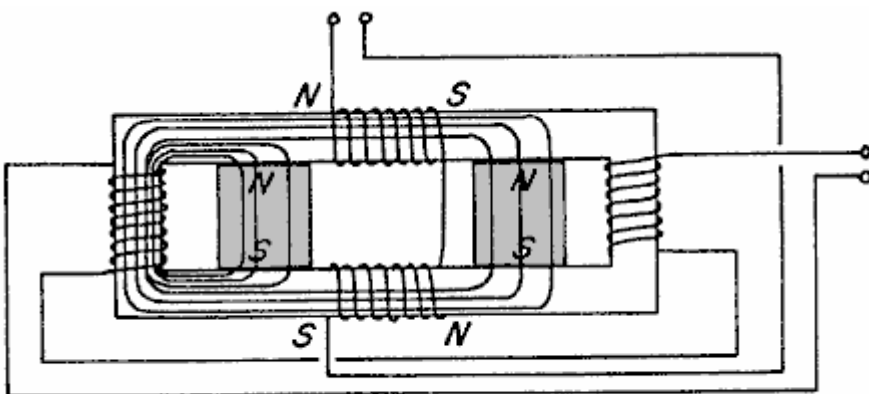


Fig. 45 Y

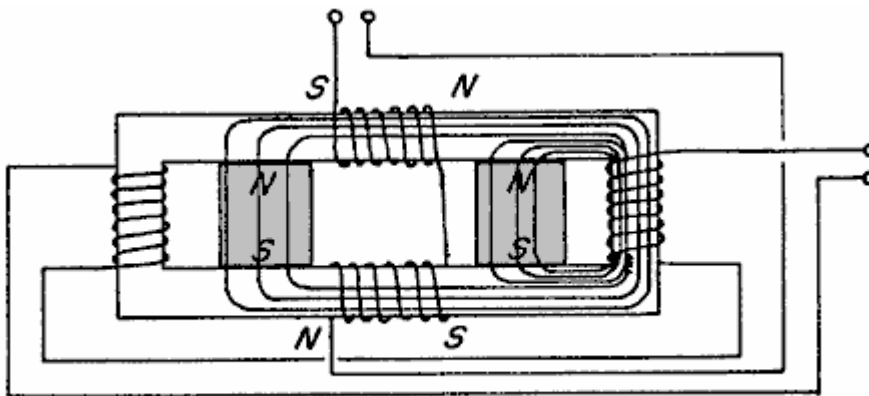


Fig. 45 Z

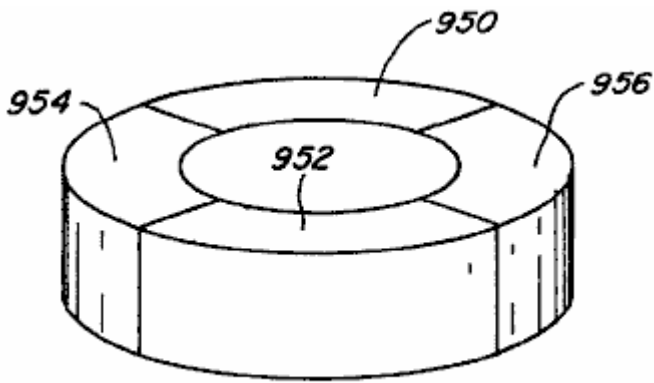


Fig. 46

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

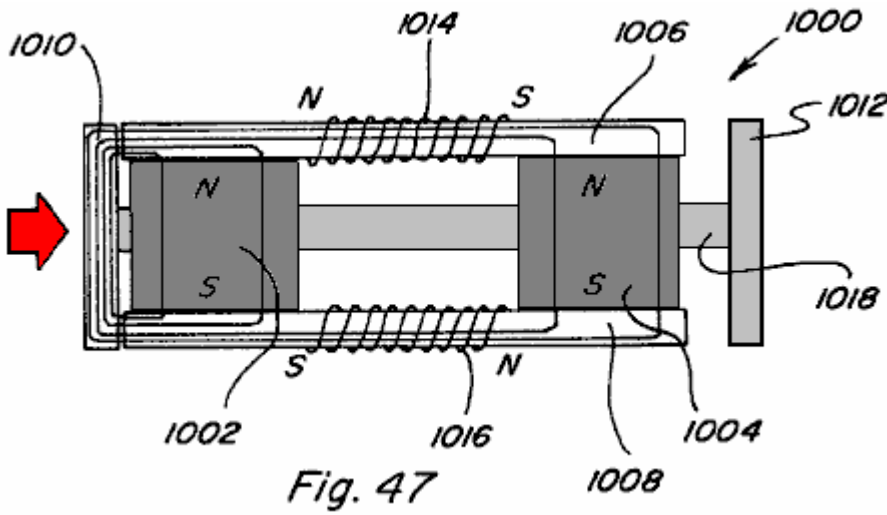


Fig. 47

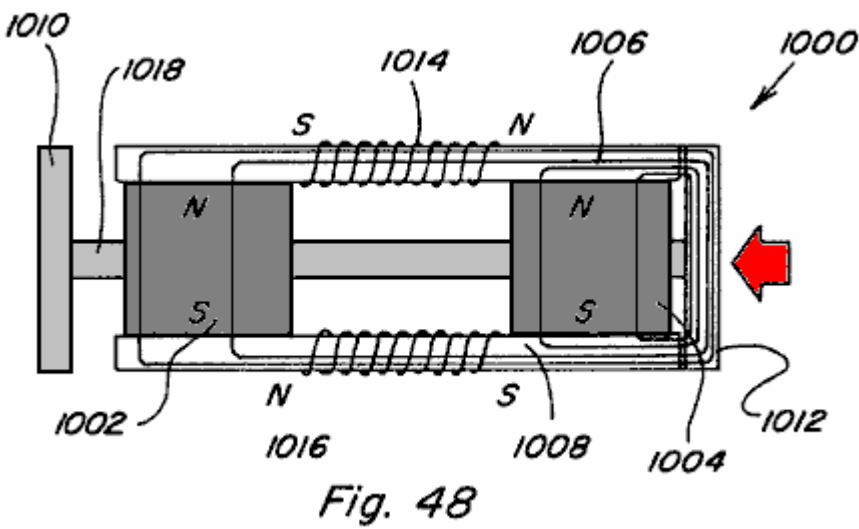


Fig. 48

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

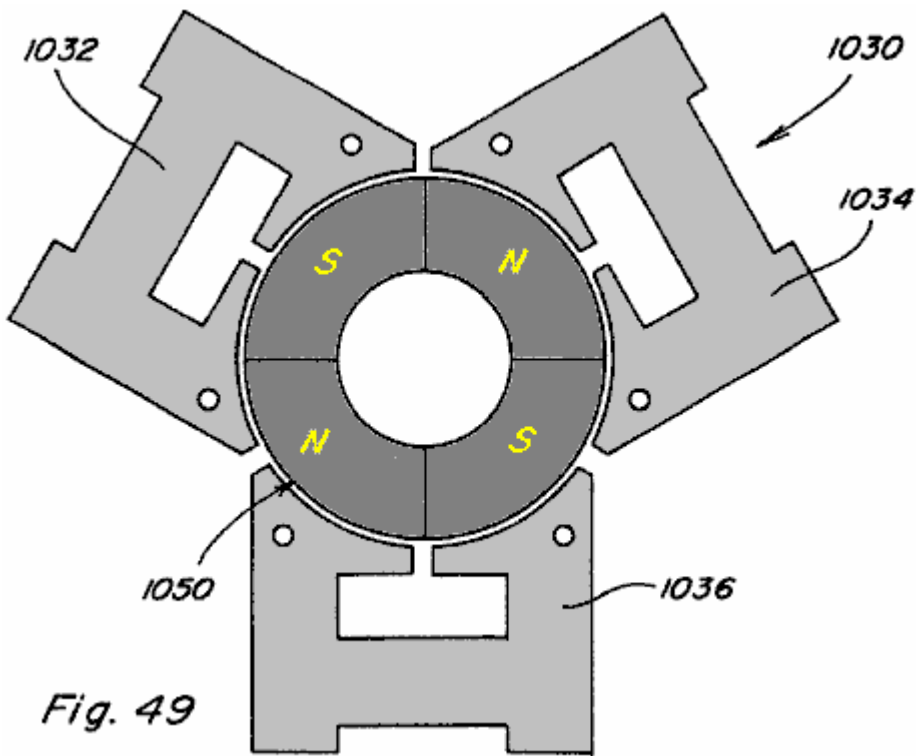


Fig. 49

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

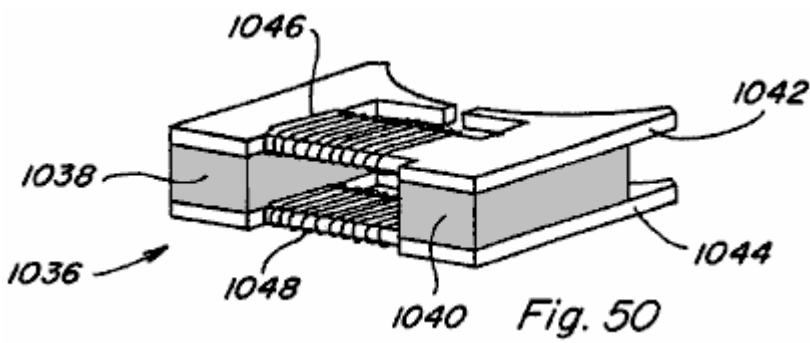


Fig. 50

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**

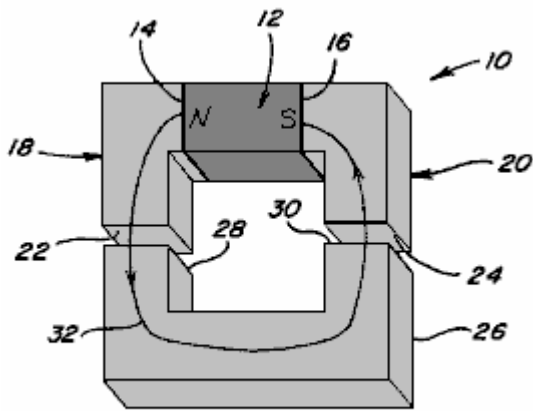


Fig. 1

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 hysteresis, 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 **20**, 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  $F_{T26}$  of armature **26** against pole pieces **18** and **20** will be:

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



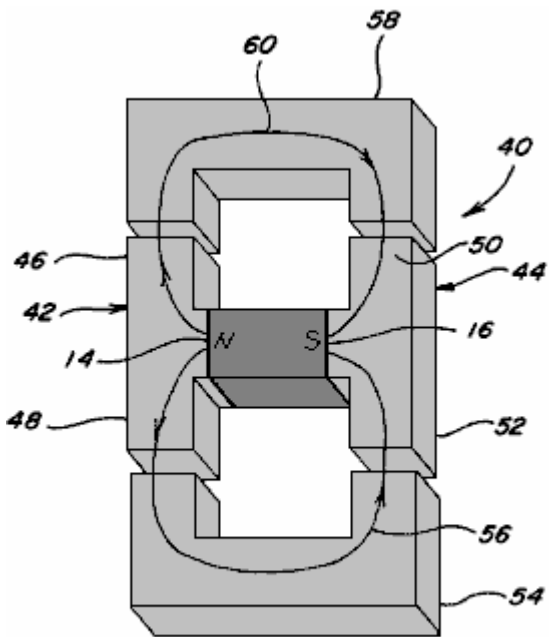


Fig. 2

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.

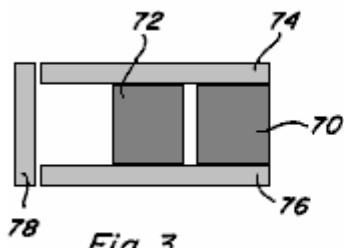


Fig. 3

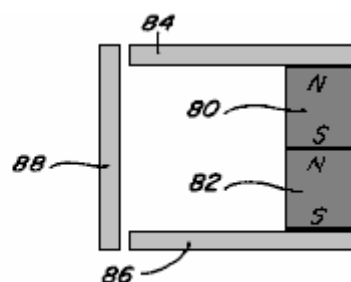


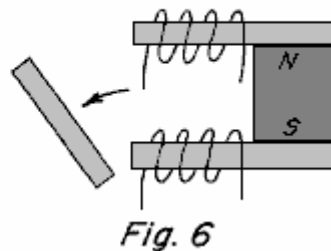
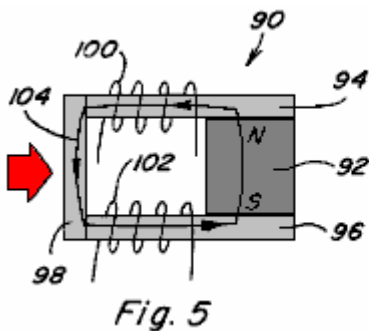
Fig. 4

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**.

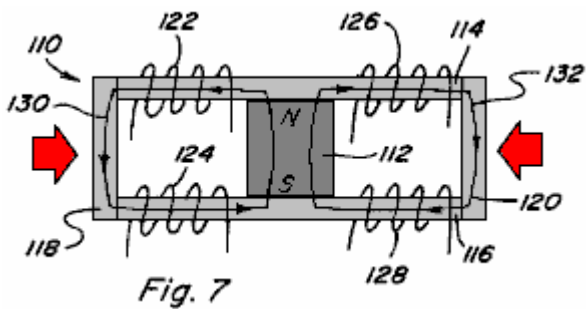
In a first case, if both members **80** and **82** are permanent magnets, the magnetic field intensity  $H$  resulting from the two permanent magnets will be double that of one permanent magnet and the flux density  $B$  through armature **88** will be the same as what the flux density would be if only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

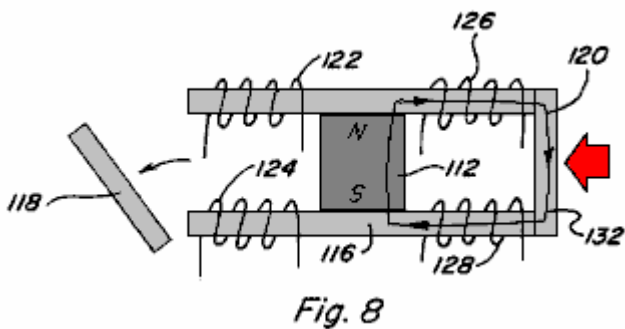
In a third case, if member **80** is a permanent magnet and member **82** is an electromagnet, the field intensity  $H$  again doubles, but, since the permanent magnet is near flux density saturation  $B_r$  the flux density can only be increased from  $B_r$  to  $B_{max}$  of the permanent magnet. At 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 **80** 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.



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 its 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.



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**.



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.

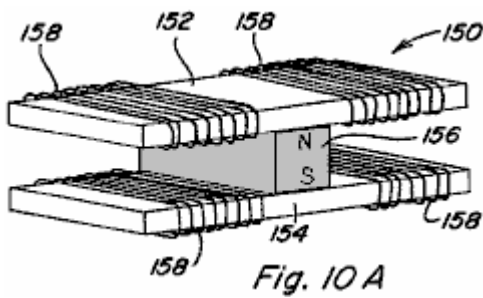


Fig. 10 A

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.

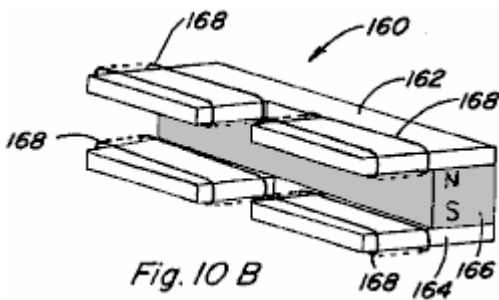


Fig. 10 B

**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.

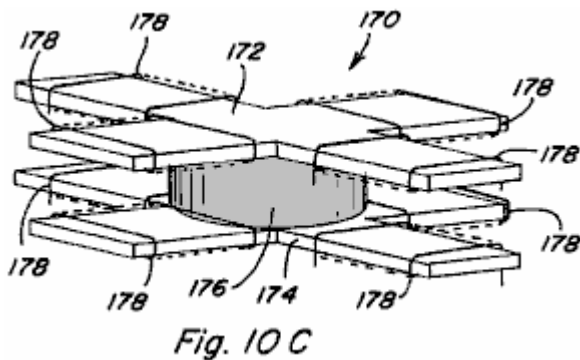


Fig. 10 C

**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.

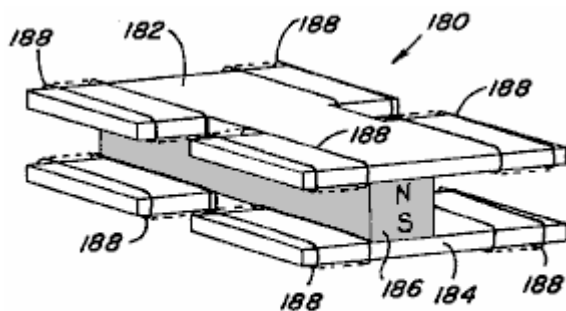
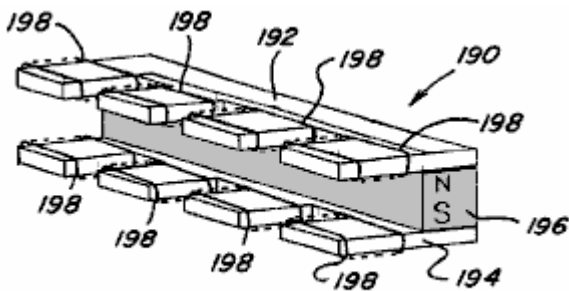


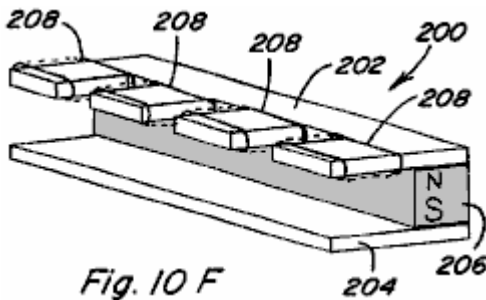
Fig. 10 D

**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.

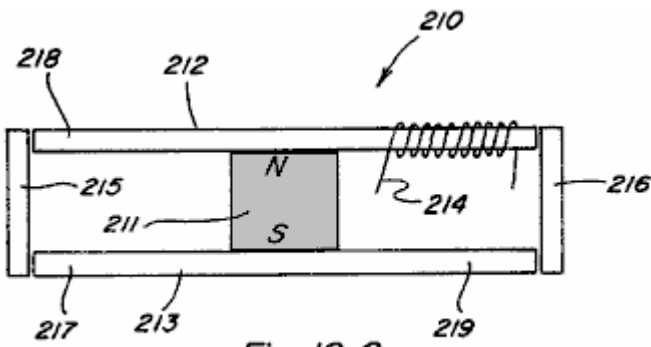


Fig. 10 G

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.

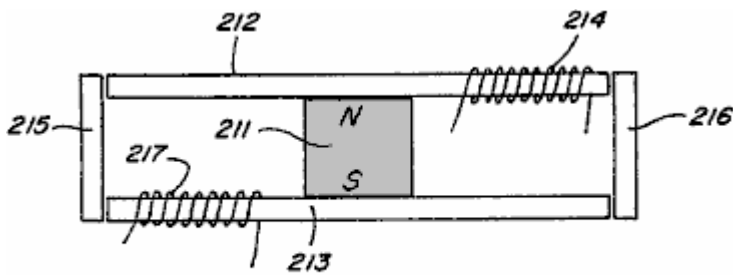


Fig. 10 H

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**.

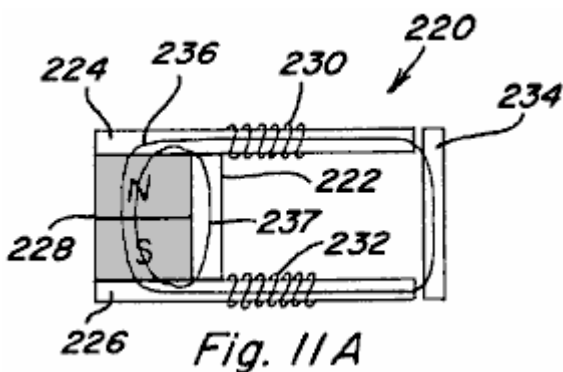
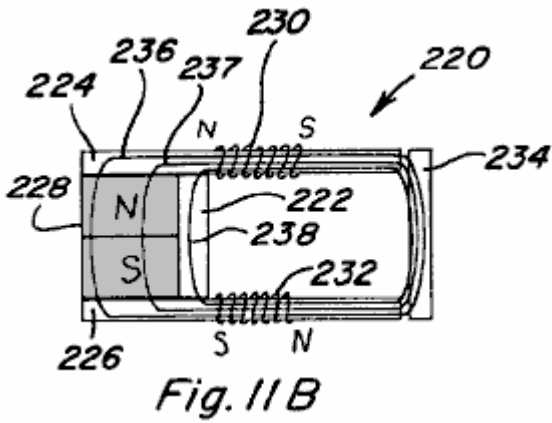
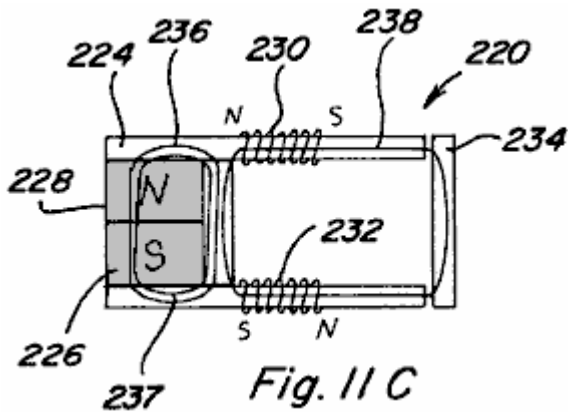


Fig. 11 A

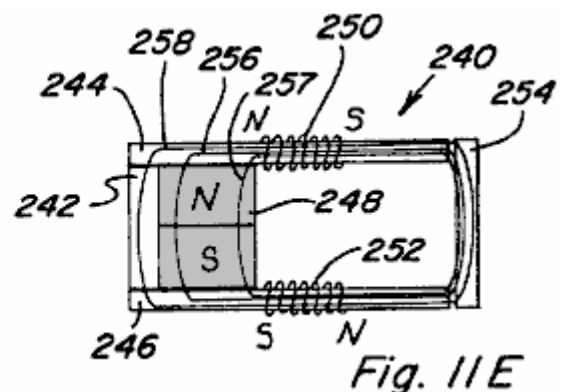
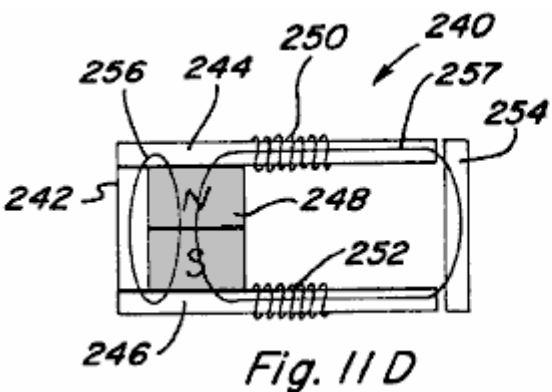
Reference is made to **Figs.11A-11F** which depict devices similar to that of **Figs.5-6** except that a bypass, formed of magnetic material, is provided in each case. In device **220** of **Figs.11A-11C** a bypass **222** is provided from pole piece **224** to pole piece **226** and is located between 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.



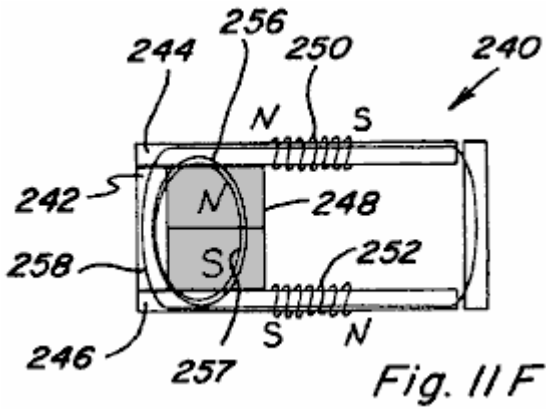
When coils 230 and 232 are energised in an aiding or adding manner as in **Fig.11B**, the result is permanent magnet magnetic flux components 236 and 237 travelling as shown, and with the added magnetic flux component 238 from coils 230 and 232 also travelling as shown. Thus, in device 220 energising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



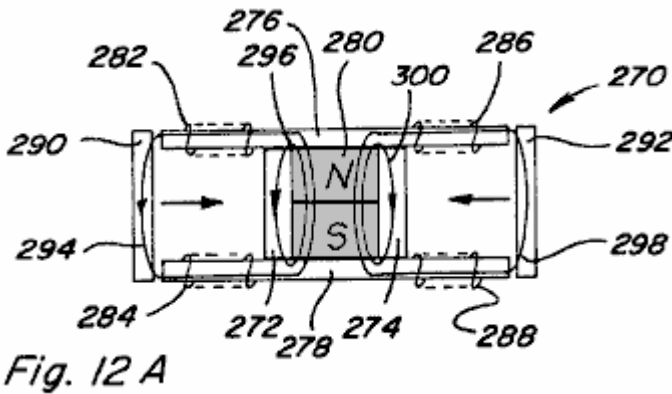
In **Fig.11C** coils 230, 232 are energised in an opposing exceeding manner which results in permanent magnetic flux components 236 and 237 travelling as shown and excess magnetic flux component 238 travelling as shown. Thus, in device 220 energising the coils in an opposing exceeding manner results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



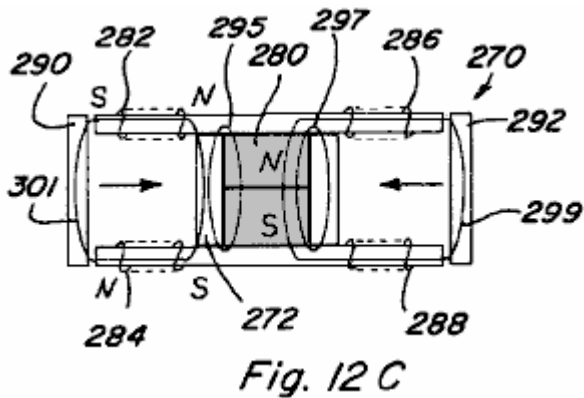
In device 240 of **Figs.11D-11F** a bypass 242 is provided between pole piece 244 and pole piece 246 but is located on an opposite side of permanent magnet 248 as compared to control coils 250, 252 and armature 254. Permanent magnet flux components 256 and 257 are shown for no coil energisation in **Fig.11D**.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



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.

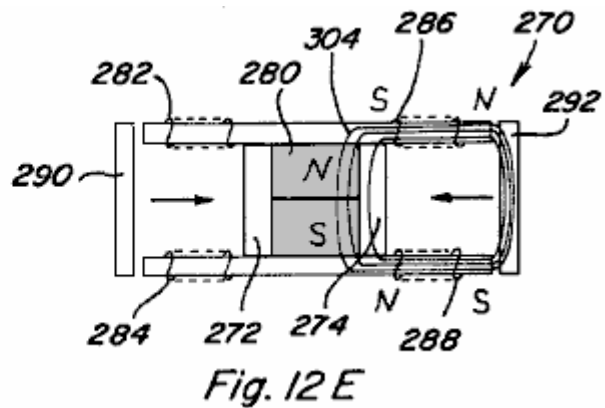
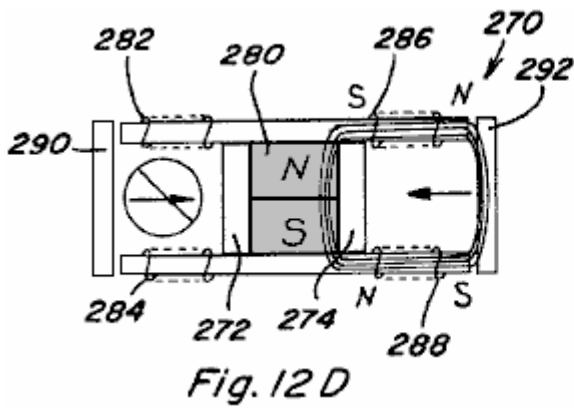


Figs.12A-12E depict a device 270 similar to that shown in Figs.7-9 except that bypasses 272 and 274 are provided from pole piece 276 to pole piece 278. Bypass 272 is located between permanent magnet 280 and control coils 282, 284 and bypass 274 is located between permanent magnet 280 and control coils 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.



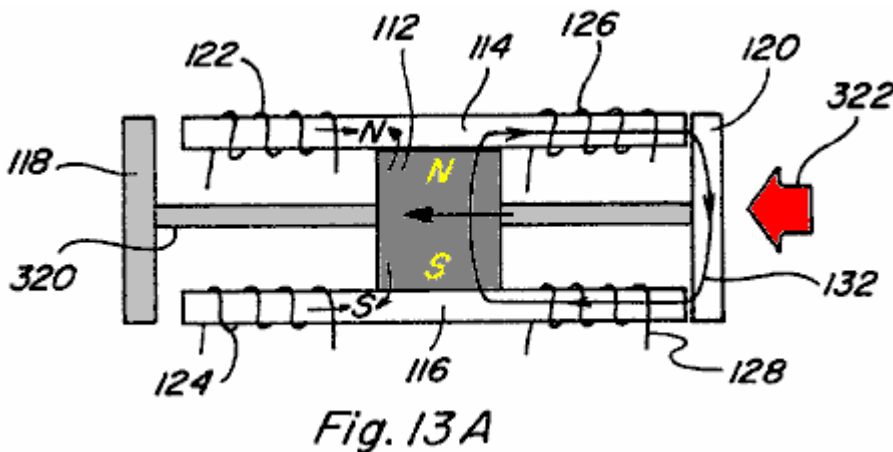
If coils 282, 284 are energised in an opposing manner permanent magnet flux components 295, 297, and 299 travel as shown, with no flux component traversing the path which includes armature 290 and therefore no magnetic coupling force acting thereon. This would be the case when coils 282, 284 are energised 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.



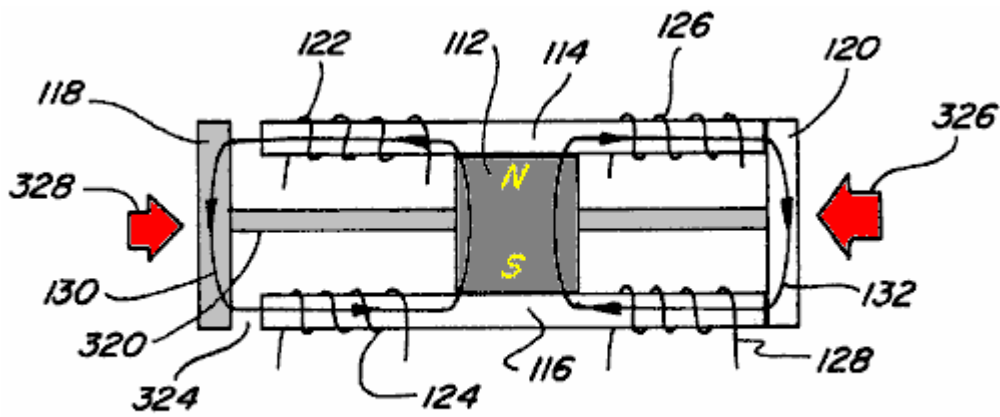


Coils 286, 288 may be energised in an aiding manner such that all permanent magnet magnetic flux travels along the path which includes armature 292 as shown in Fig.12D. If coils 286, 288 are energised in excess of the level of Fig.12D then the excess magnetic flux component 304 traverses the path which 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

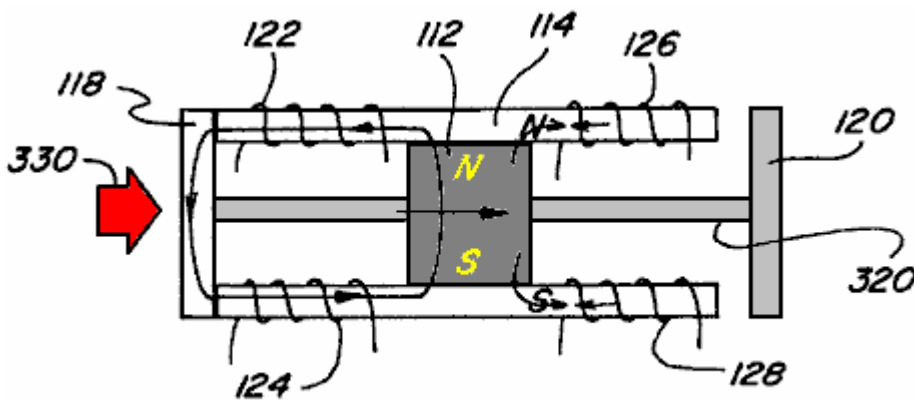


As mentioned above, controlling the path of magnetic flux from a permanent magnet can be useful in a variety of applications such as achieving reciprocating motion. In this regard, if the device 110 of Figs.7-9 is modified such that armatures 118 and 120 are fixed to a sliding shaft 320 as shown in Figs.13A-13C, 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. 13 B*

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.

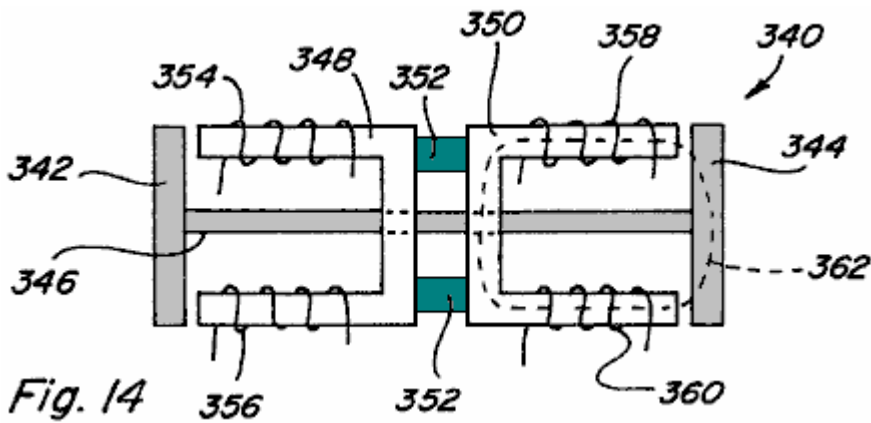


*Fig. 13 C*

**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.

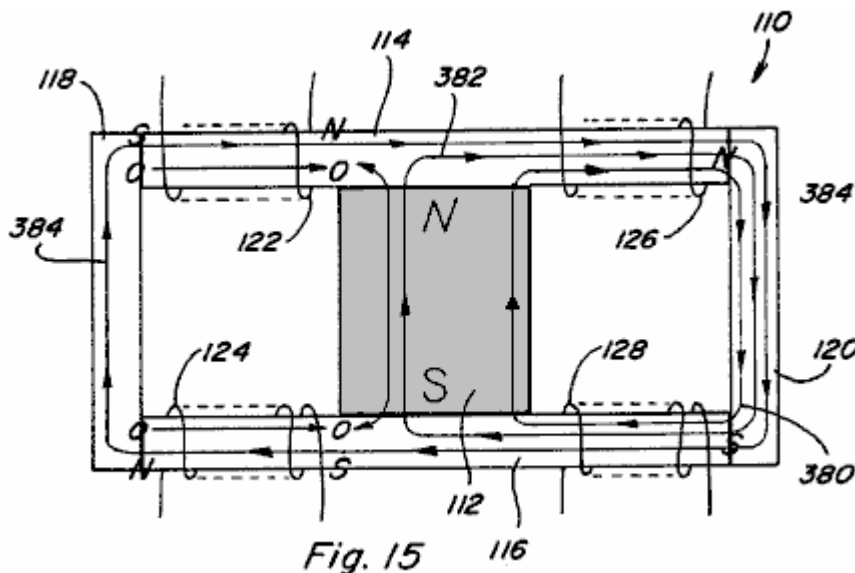
Control coils 122, 124 and 126, 128 could also be energised in a flux aiding manner to achieve the same result. In such a device, **Fig.13A** would represent coils 126, 128 energised to aid magnetic flux along path 132, **Fig.13B** would again represent no coils energised, and **Fig.13C** would represent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

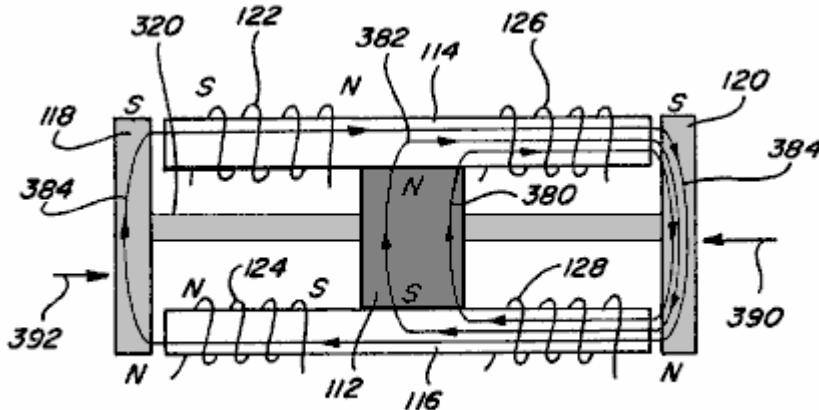


Fig. 16 A

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.

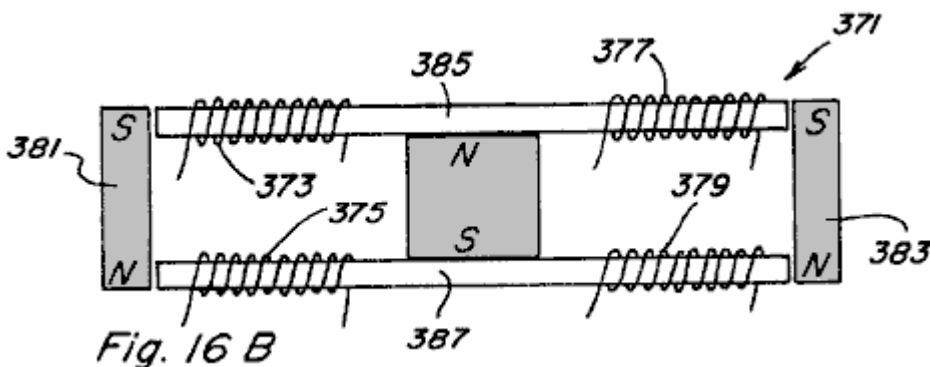


Fig. 16 B

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.

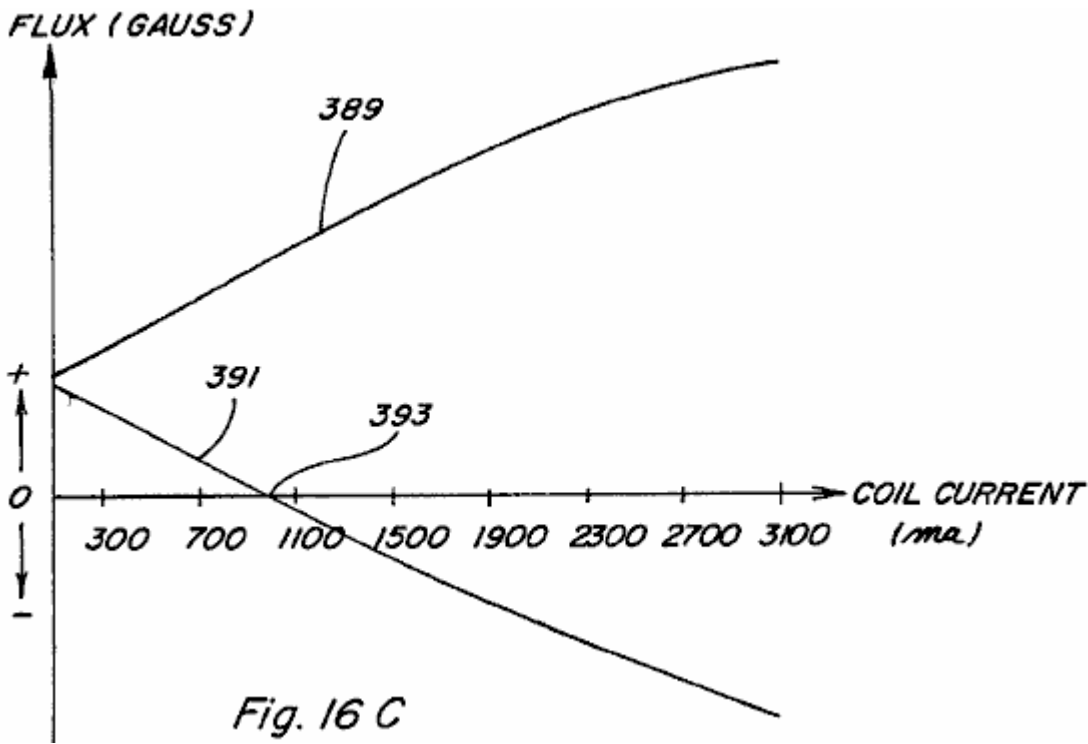


Fig. 16 C

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 versus 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.

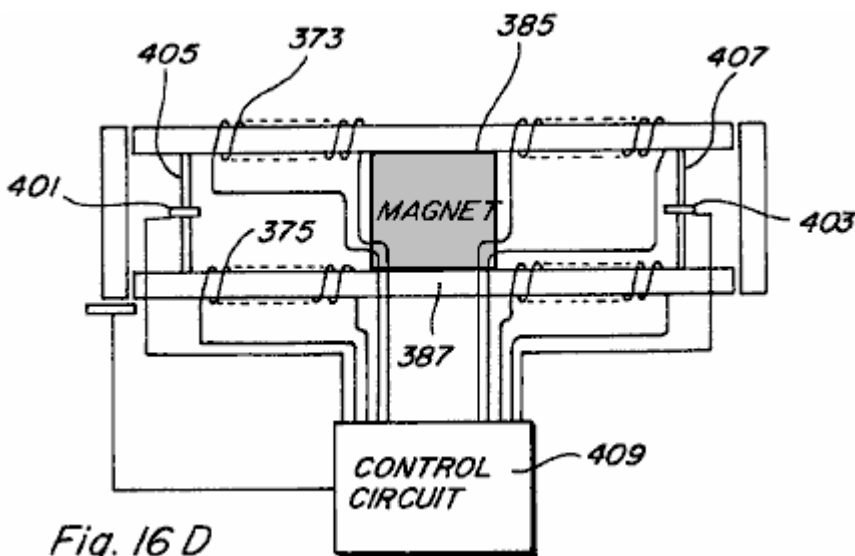


Fig. 16 D

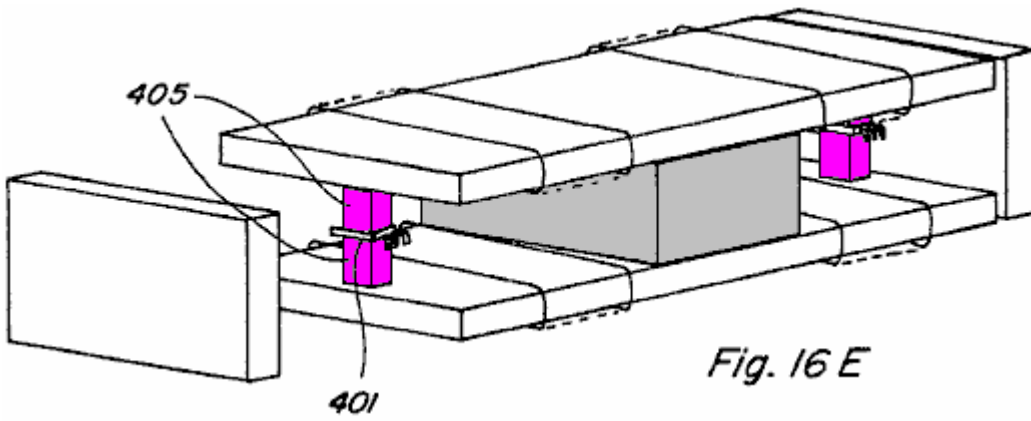


Fig. 16 E

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.

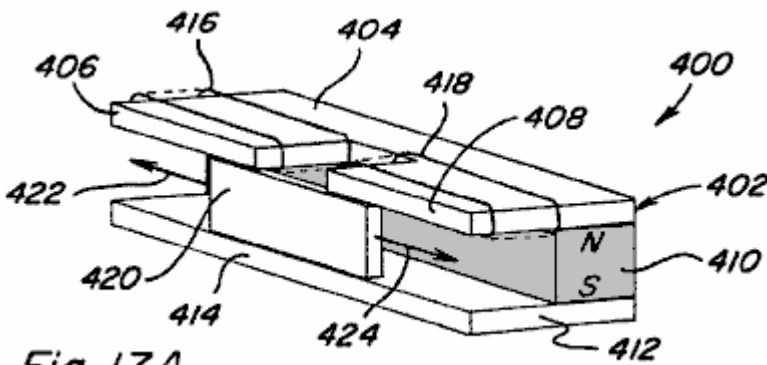


Fig. 17 A

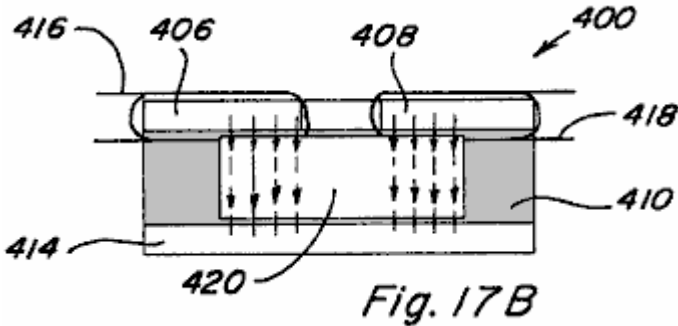


Fig. 17 B

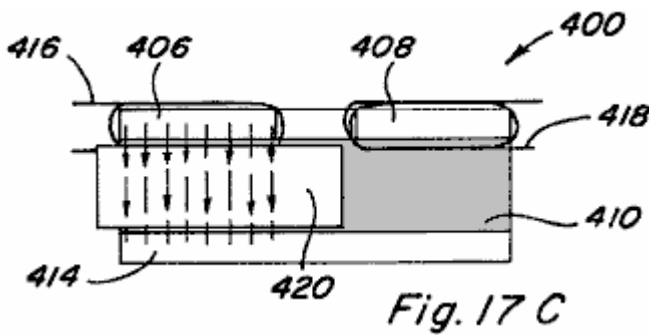
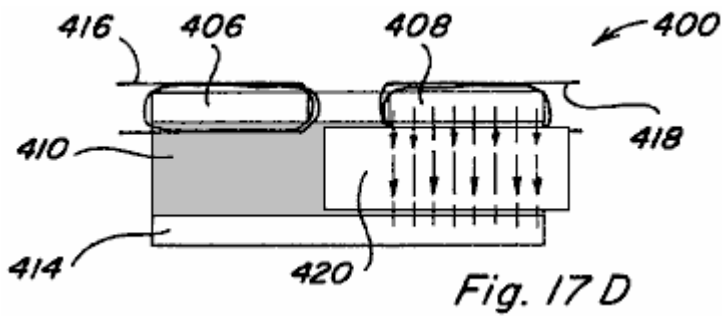


Fig. 17 C

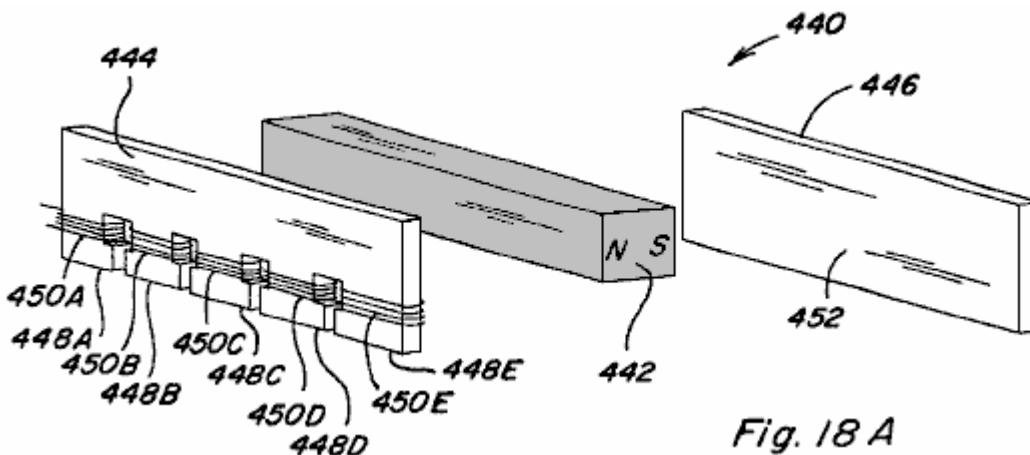


Another embodiment of a device **400** which would provide reciprocating motion is shown in **Figs.17A-17D** in which a permanent magnet control component **402** having two flux paths may be provided. A first pole piece **404**, has two spaced, adjacent path portions **406** and **408** extending beyond 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



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 its north pole face and a pole piece **446** positioned against its south pole face is shown in an exploded view in **Fig.18A** and assembled in **Fig.18B**.

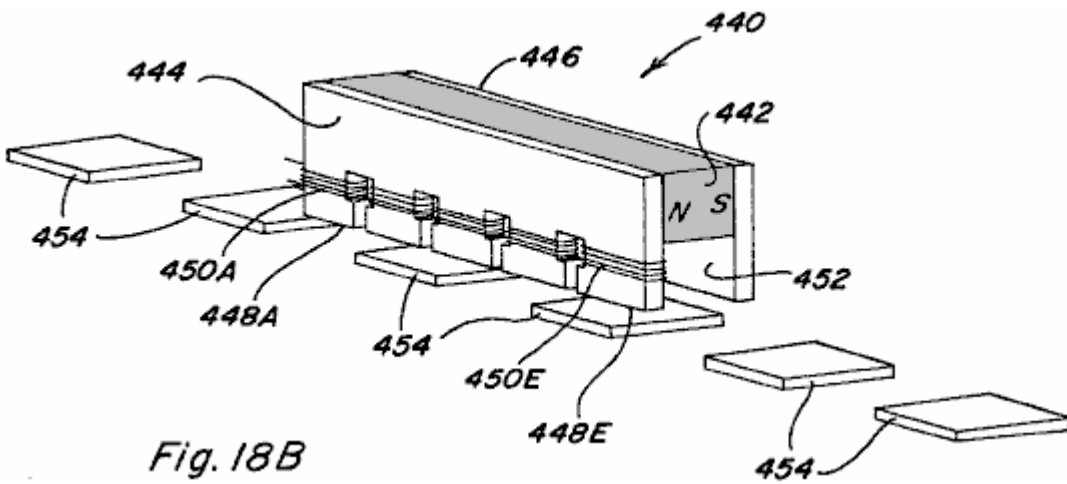


Fig. 18B

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 its 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

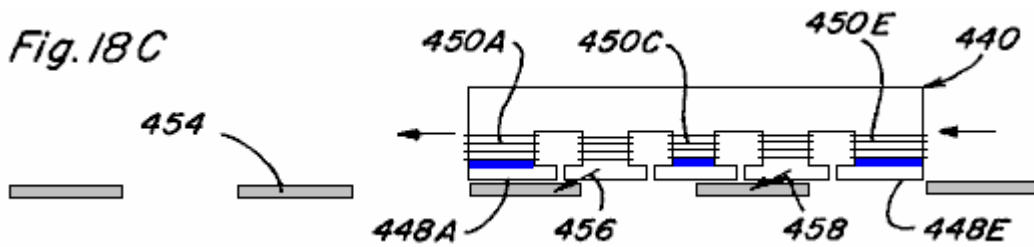


Fig. 18D

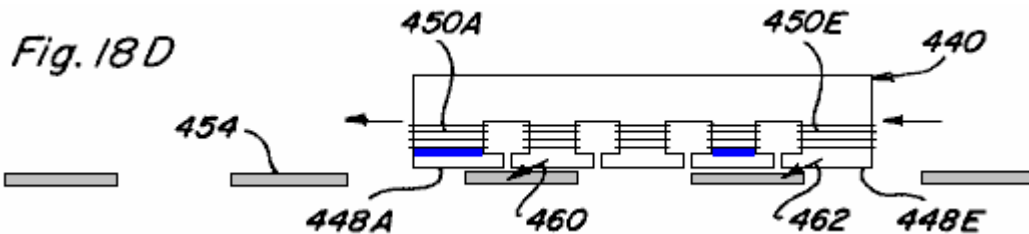
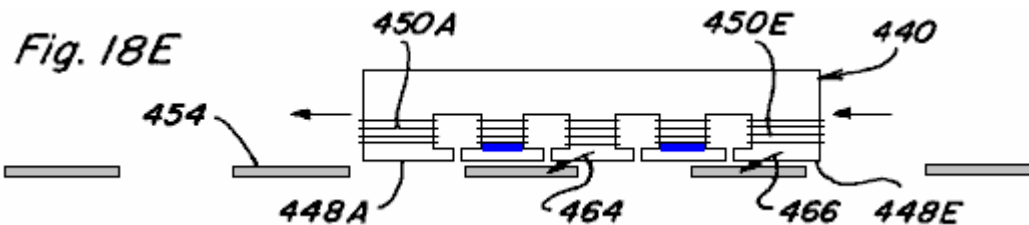


Fig. 18E



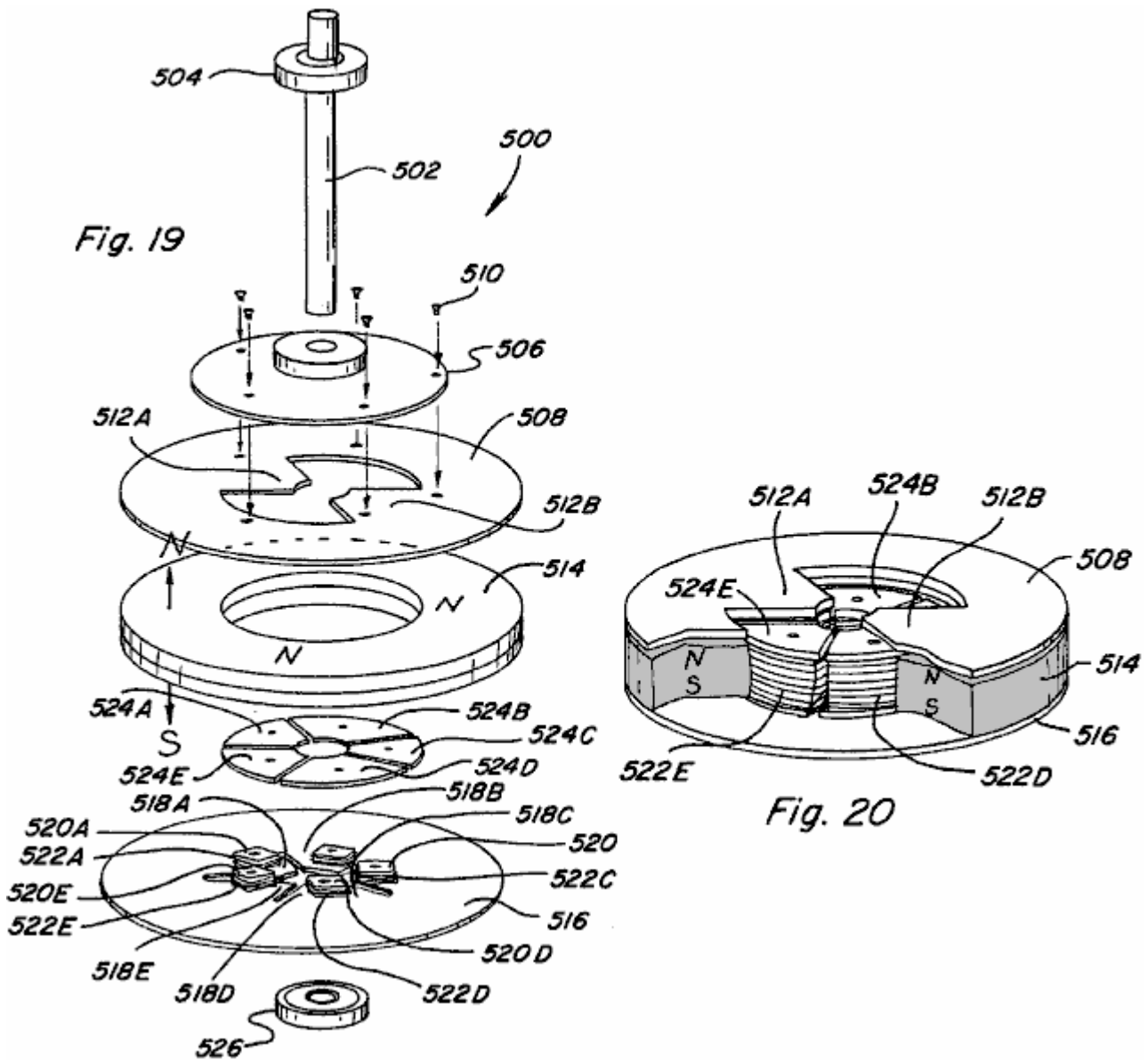
The sequence of side views depicted in **Figs.18C-18E** illustrate such relative movement, with coils **450A**, **450C** and **450E** being **energised** in an opposing manner simultaneously in **Fig.18C**, with coils **450A** and **450D** being **energised** simultaneously in an opposing manner in **Fig.18D**,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



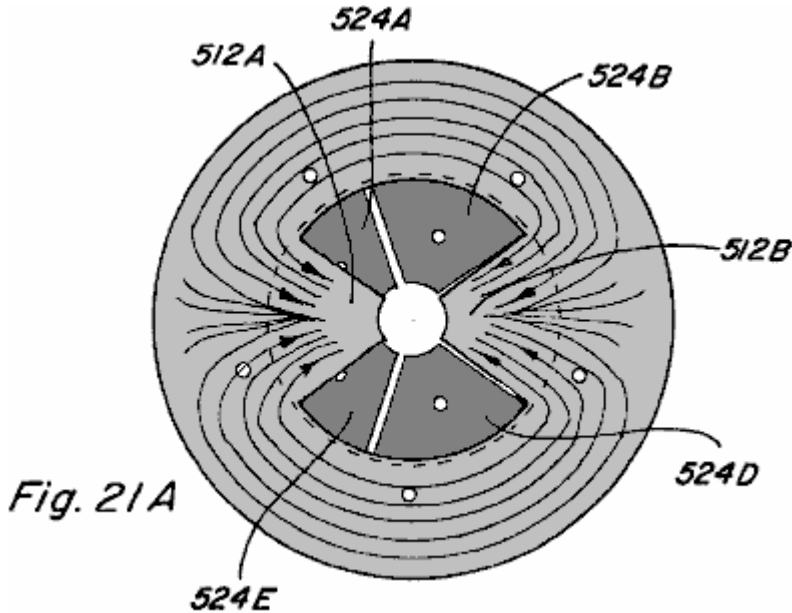
Thus, if permanent magnet control component **440** were fixed to a device or structure, controlled movement of the device or structure along the path defined by armatures **454** could be achieved. Conversely, if permanent magnet control component **440** were fixed and armatures **454** were located 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

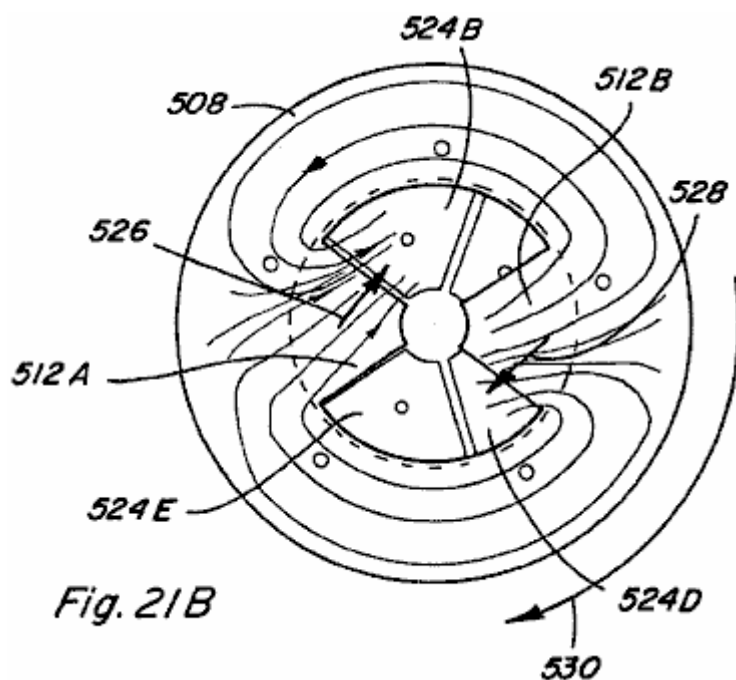


One embodiment of a rotary motion device or motor **500** which incorporates various permanent magnet flux control aspects of the present invention is shown in the exploded view of **Fig.19** and in the partial assembled view of **Fig.20**. Motor **500** includes a rotor assembly which includes a shaft **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

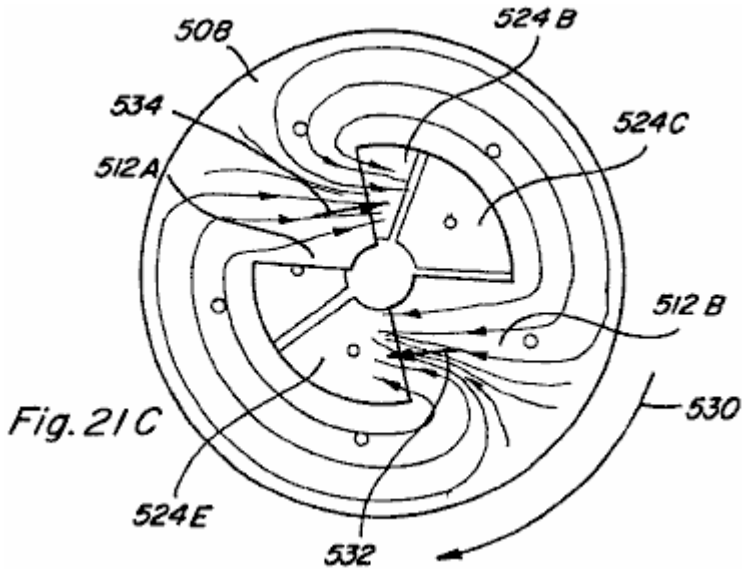
control coil **522A-522E** wound on it. Stator pole piece faces **524A-524E** are which can be positioned on respective winding posts **518A-518B** and, as shown in the partial assembly of **Fig.20**, are substantially aligned with the top surface of permanent magnet **514** so as to be which can be 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.



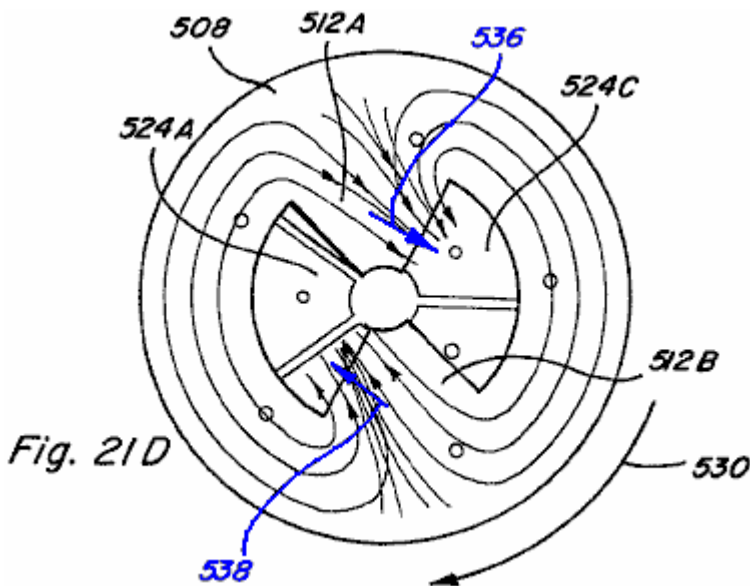
**Figs.21A-21E** illustrate top views of the partial assembly of **Fig.20** with magnetic flux shown. In **Fig.21A** magnetic flux travel when none of coils **522A-522E** are energised is depicted. Disregarding leakage flux, due to the low-reluctance path provided by rotor pole piece path portions **512A** 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.



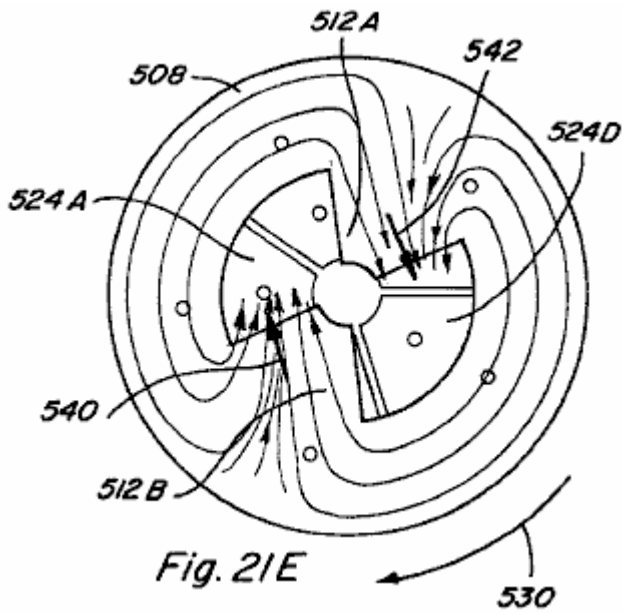
In particular, referring to **Figs.21B-21D**, an energising sequence which results in such rotary motion is described. In **Fig.21B**, control coils **522A** and **522C** are energised in a permanent magnet flux opposing manner. Permanent magnet magnetic flux travelling along rotor pole piece path portion **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**.



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.

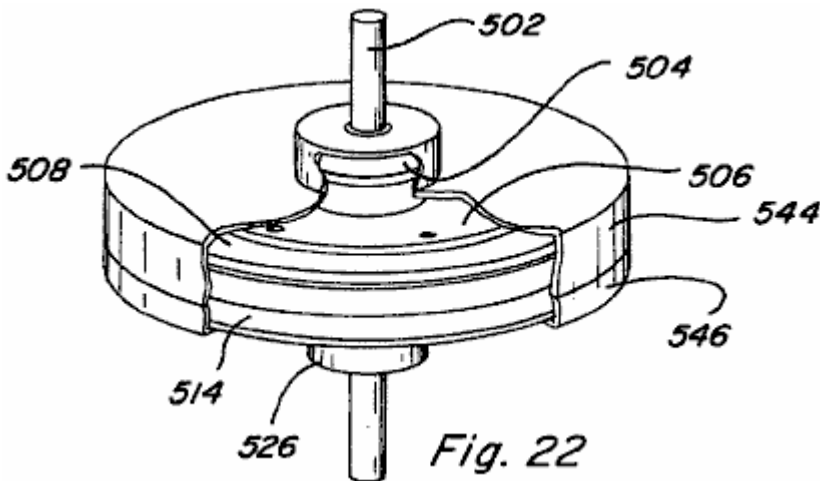


In **Fig.21D**, just after rotor pole piece path portion **512A** is no longer aligned with stator pole piece face **524B**, control coil **522A** is de-energised and control coil **522B** is energised in a permanent magnet magnetic flux opposing manner such that the permanent magnet magnetic flux travelling 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.



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.



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.

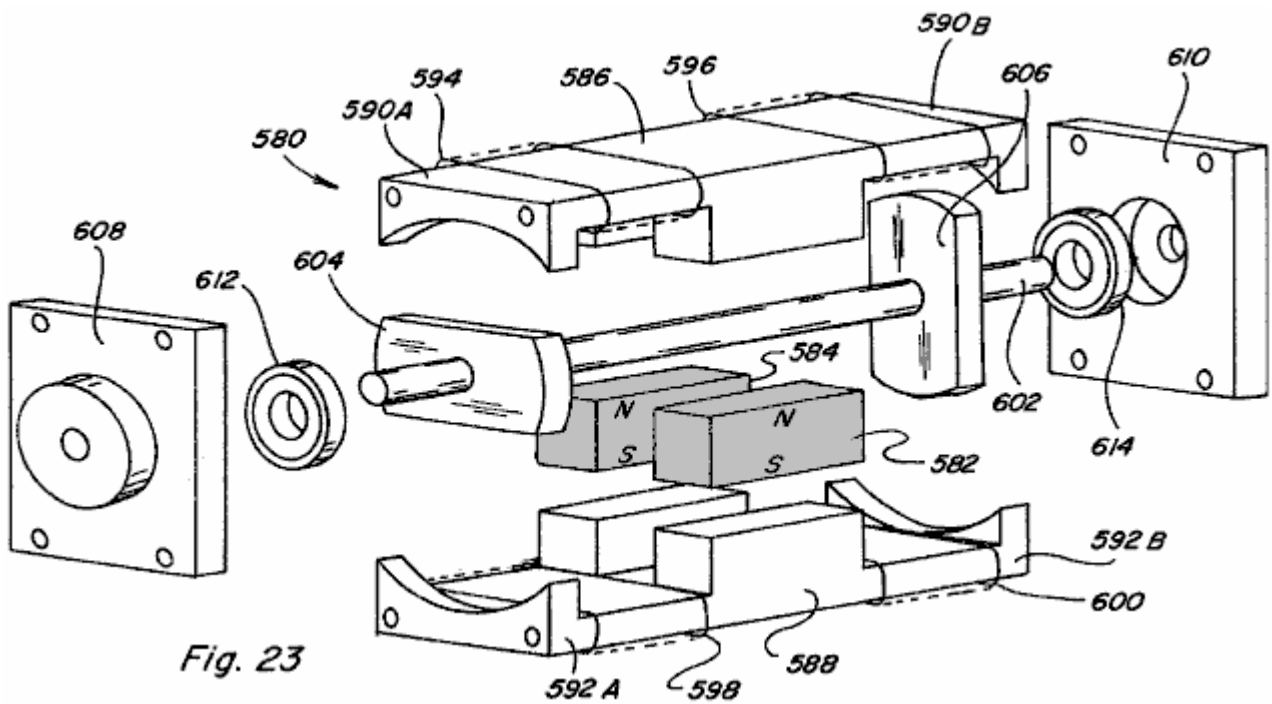


Fig. 23

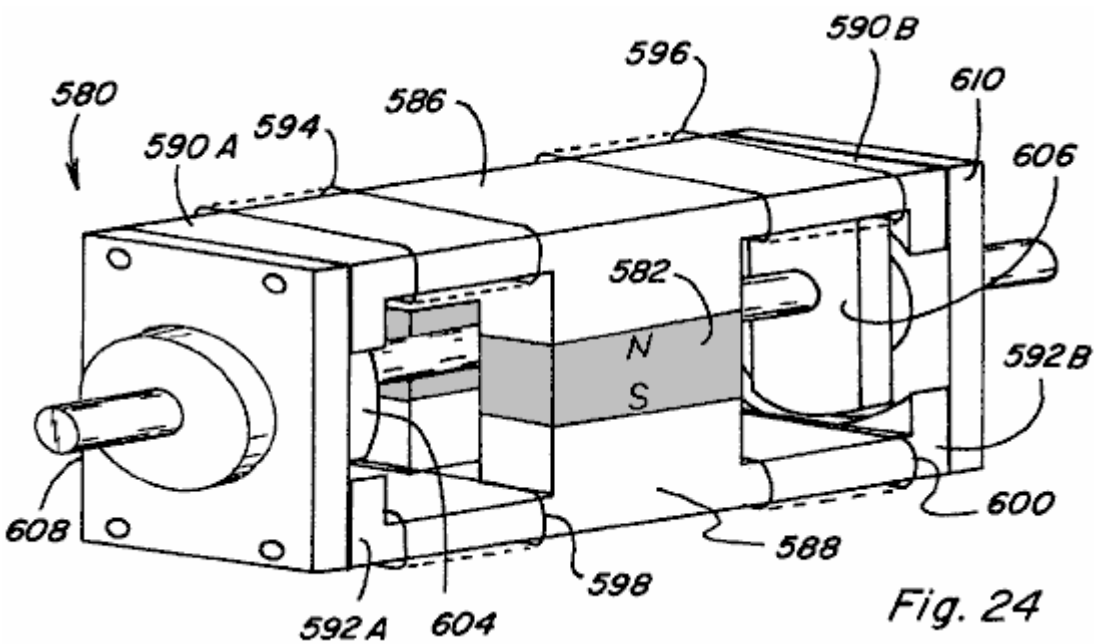
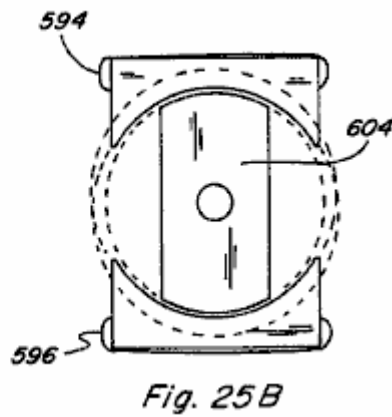
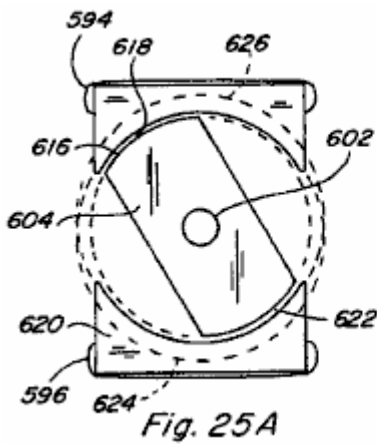


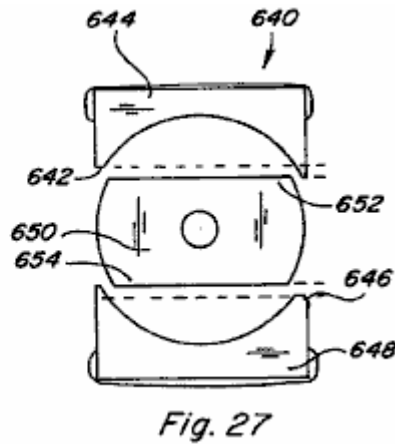
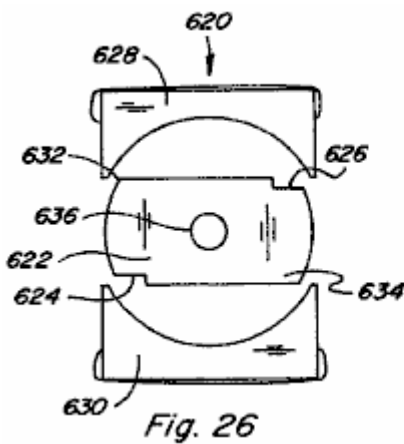
Fig. 24

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.



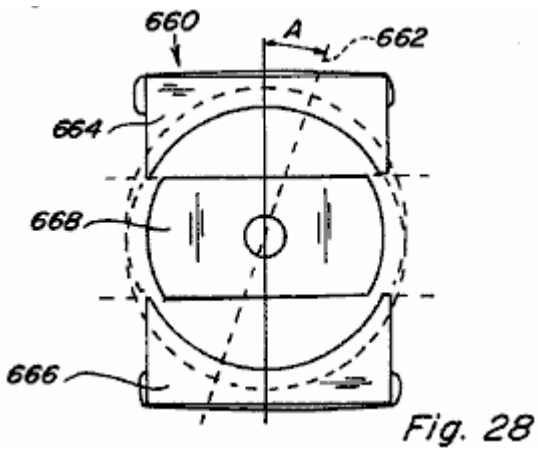
The ends of the stator pole pieces **506** and **508** are configured for a given desired coupling relationship with rotor members **604** and **606**. For example, as shown in the exemplary end views of **Fig.25A** and **Fig.25B**, with end cap **608** removed, the end of stator pole piece **586** may 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.

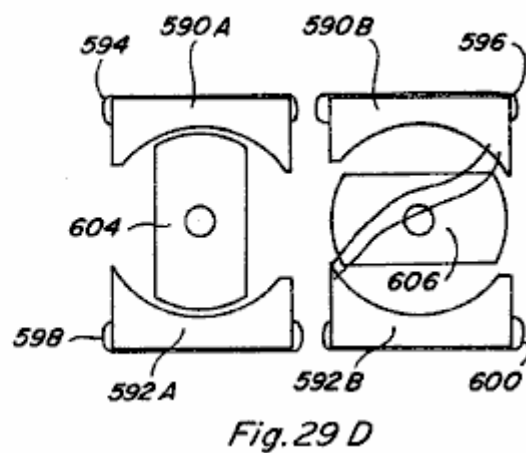
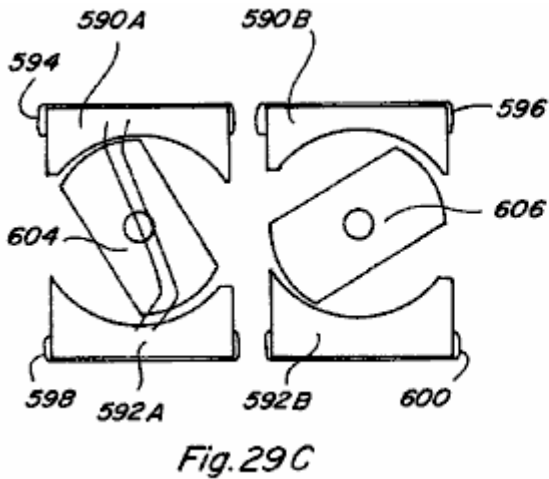
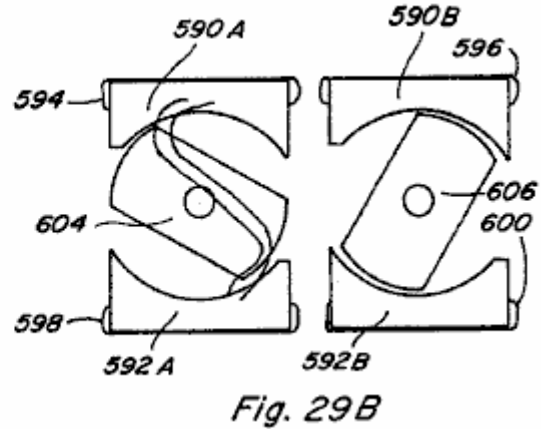
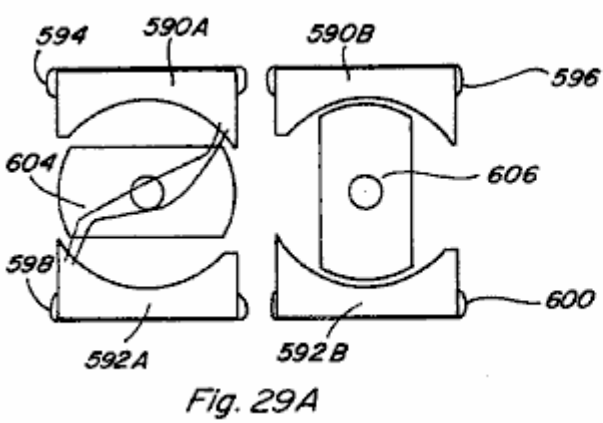


In this regard, various configurations for the rotor and ends of the stator pole pieces are shown in the end views of **Figs.26-28**, which configurations provide skewing the direction of rotation. In particular, in device **620** of **Fig.26** a rotor member **622** having notches **624** and **626**, 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** 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.

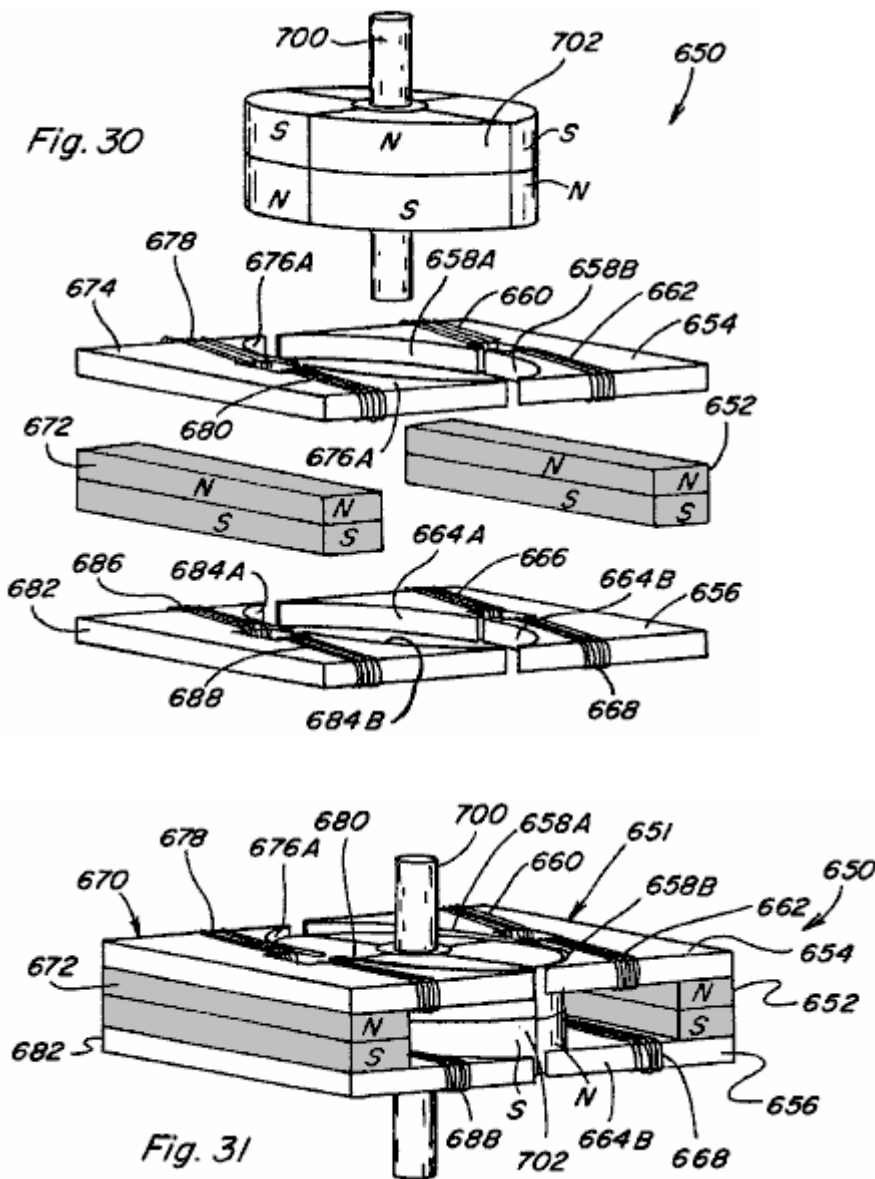


Referring again to motor **580** of **Figs.23-25**, rotary motion of such device is depicted in the end views of **Figs.29A-29D**. In each end view the end cap has been removed to show rotation of the rotor members and in each of **Figs.29A-29D** an end view depicting rotor member **604** and an end 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.



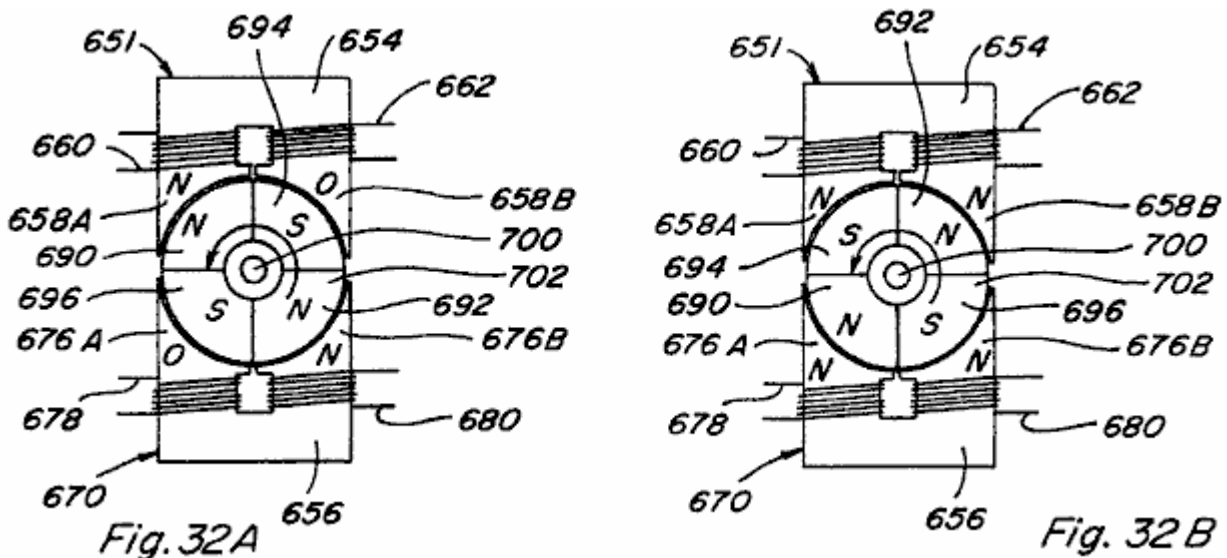
A third embodiment of a rotary motion device or motor **650** is shown in the exploded partial perspective view of **Fig.30** and in the assembled partial perspective view of **Fig.31**. In motor **650** the stator assembly includes a control component **651** including a permanent magnet **652** having 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.



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.

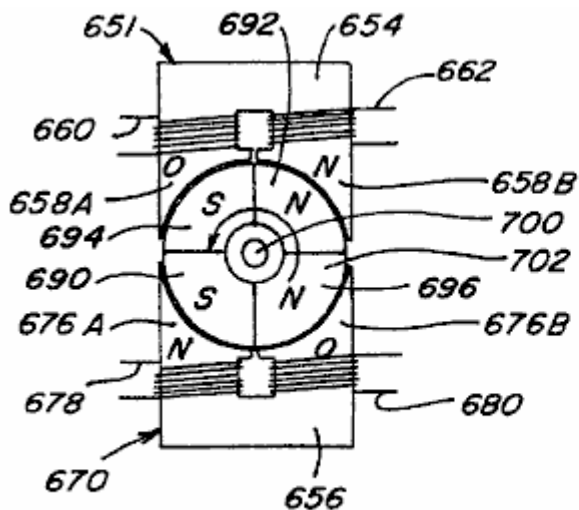


Fig. 32 C

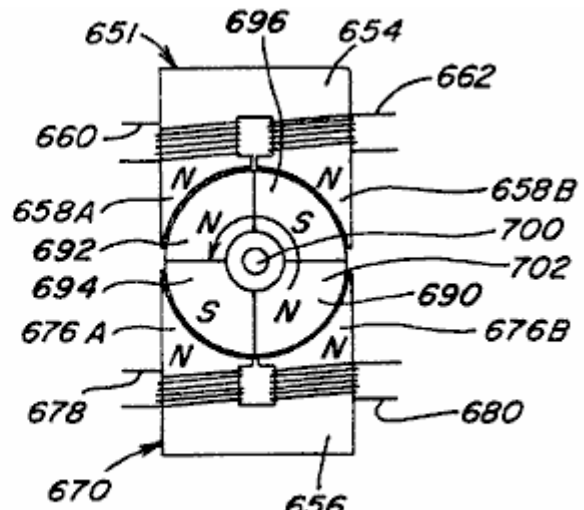


Fig. 32 D

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.

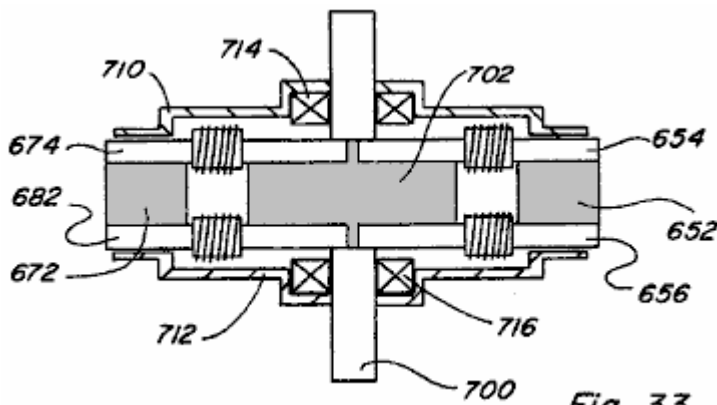


Fig. 33

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.

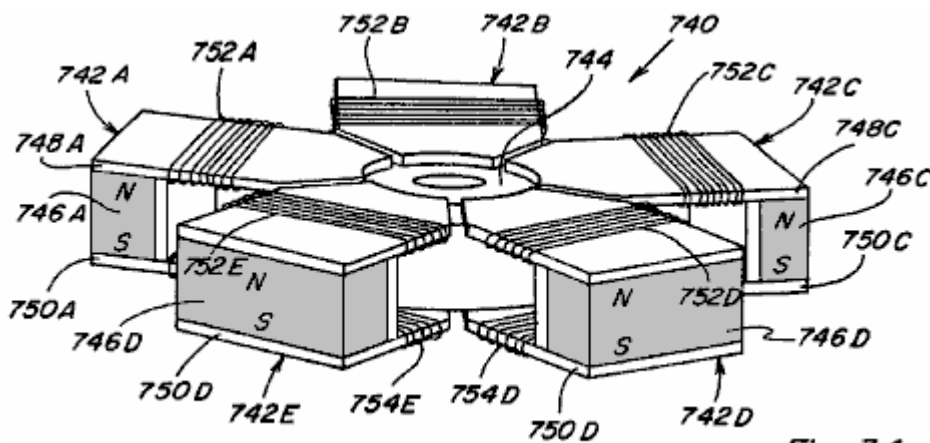


Fig. 34

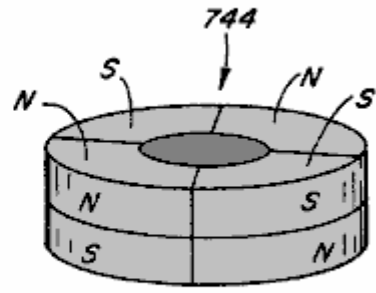
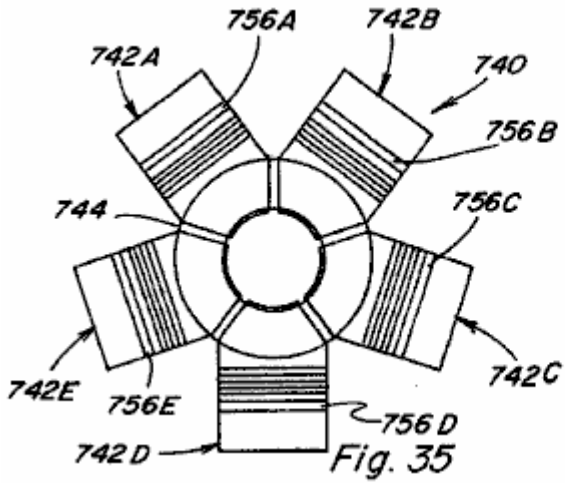


Fig. 36

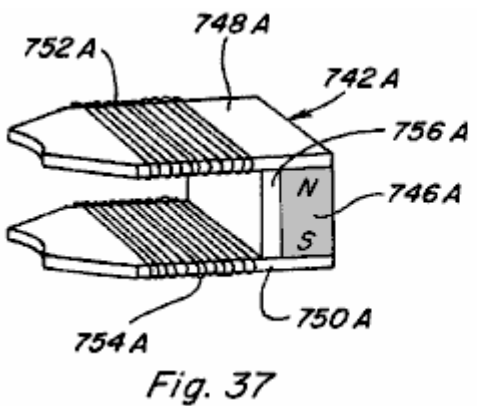


Fig. 37

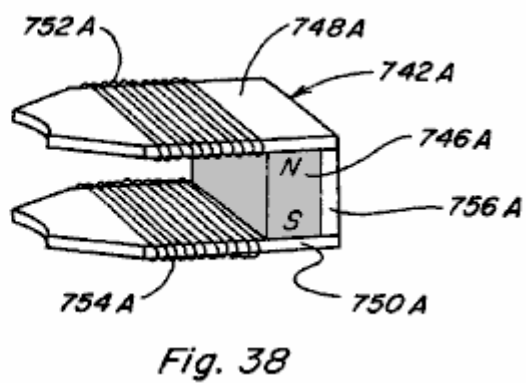


Fig. 38

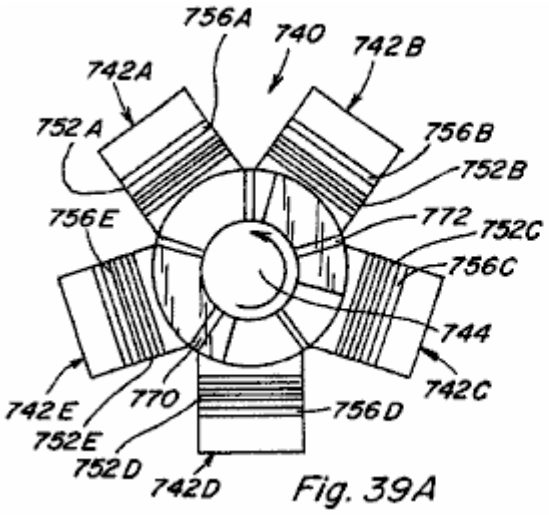


Fig. 39A

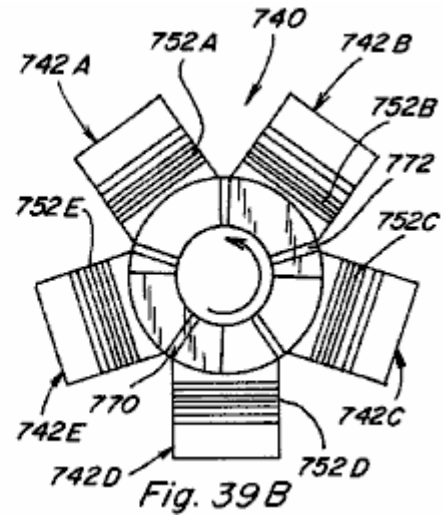
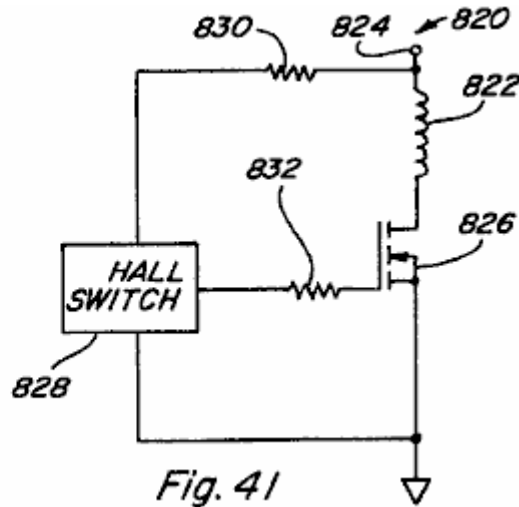
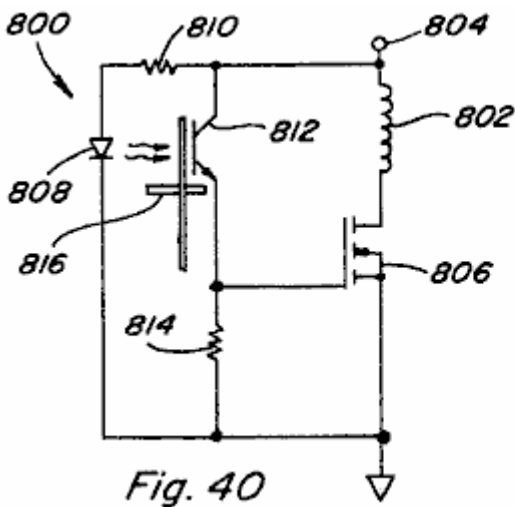


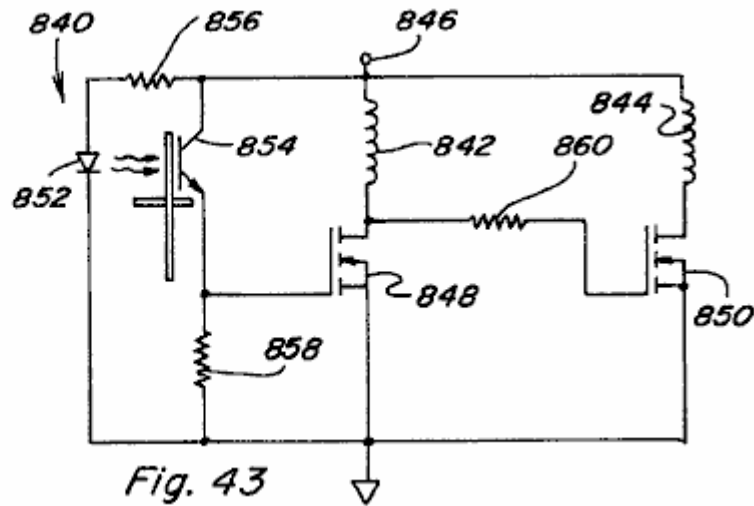
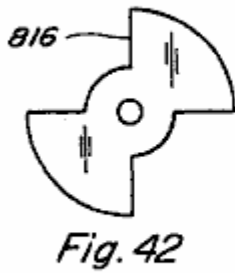
Fig. 39B

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.

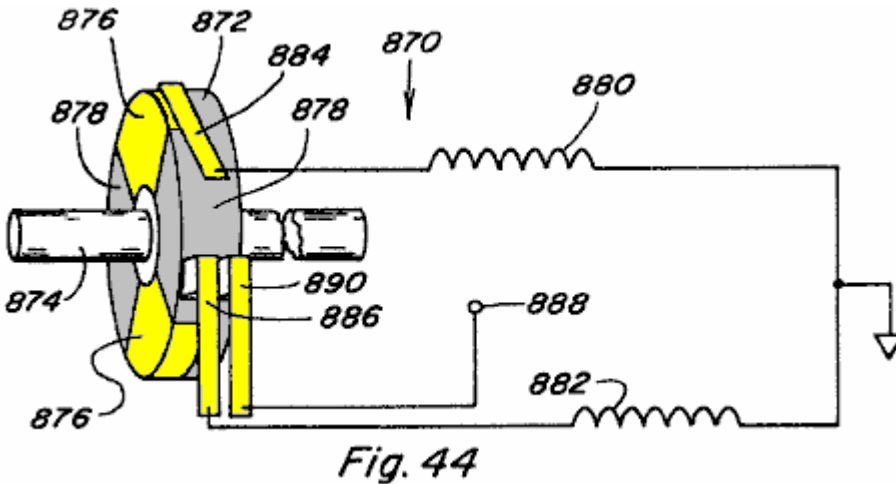


In terms of controlling the energisation of coils in the devices described above, various electronic control circuit/switching means and electromechanical control circuit/switching machines are depicted in **Figs.40-44**. In circuit **800** of **Fig.40** a given coil **802** is placed in series between 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/photoreistor pairs may be provided.



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.



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**.

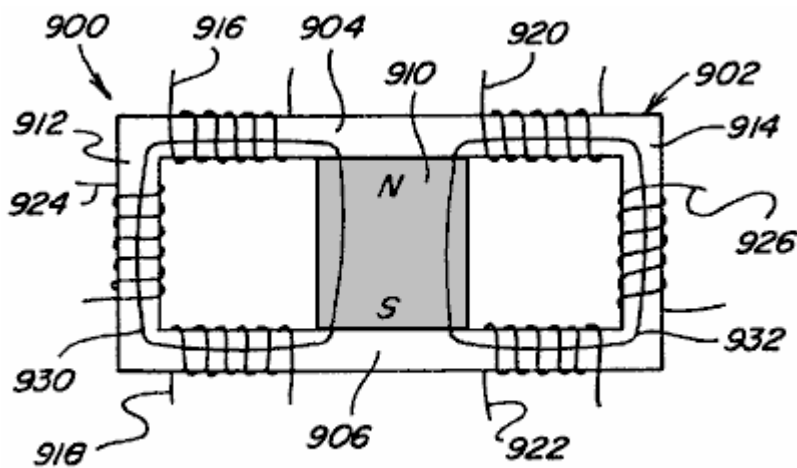


Fig. 45A

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**.

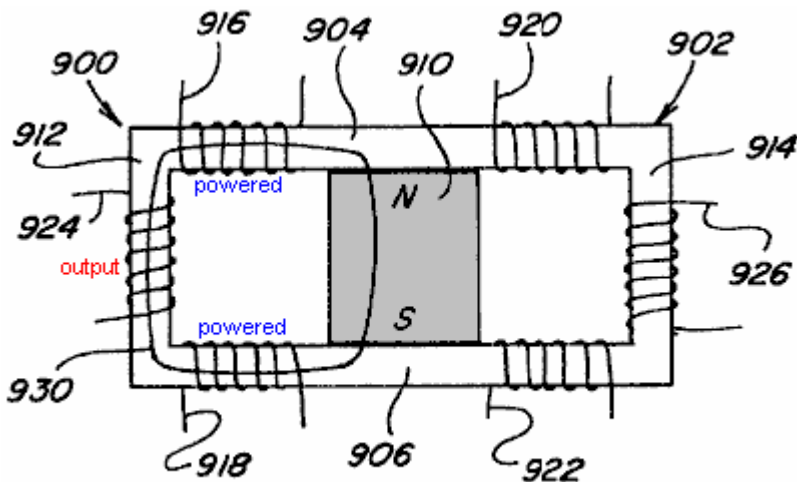
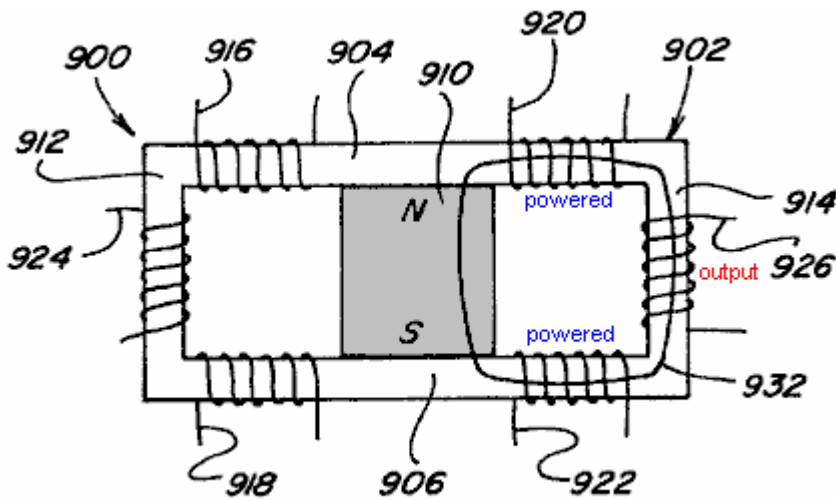


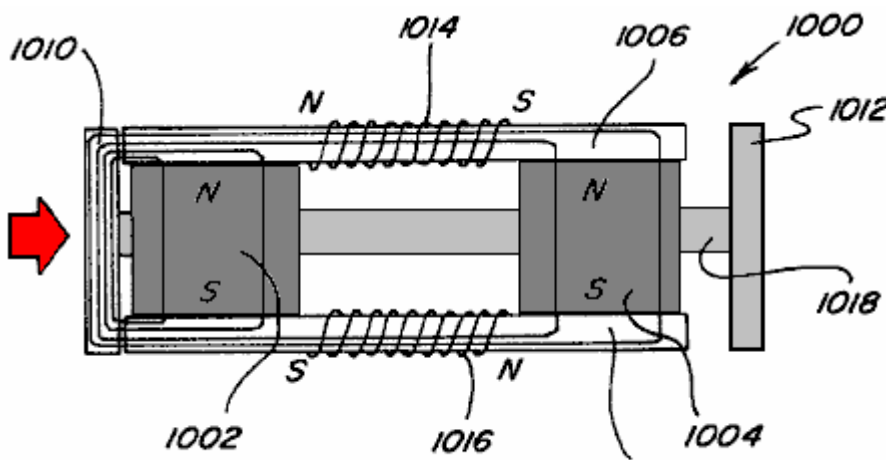
Fig. 45B

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**.



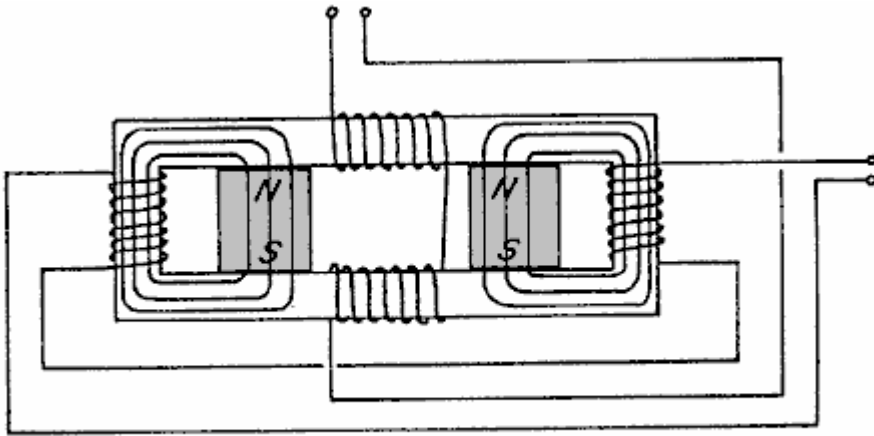
*Fig. 45 C*

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.

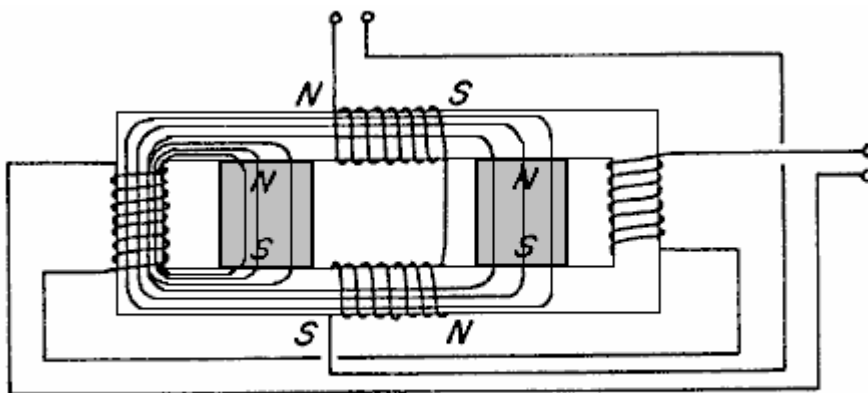


*Fig. 45 X*

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.

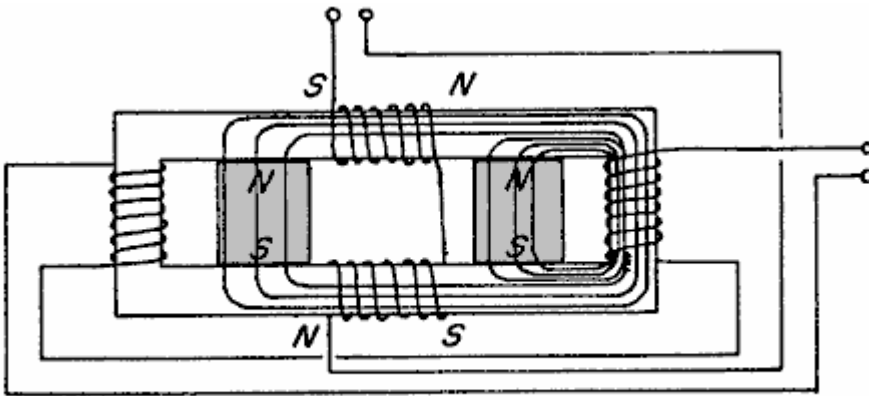


*Fig. 45 Y*

**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



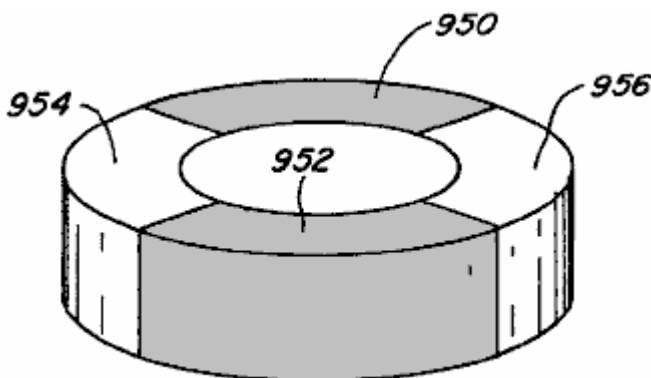
side of the coil blocks the passage of flux from the permanent magnet on the opposing side of the coil and the aiding side of the coil couples with the flux of the other permanent magnet and therefore all of the flux of both the permanent magnets passes through the working region as shown.



*Fig. 45 Z*

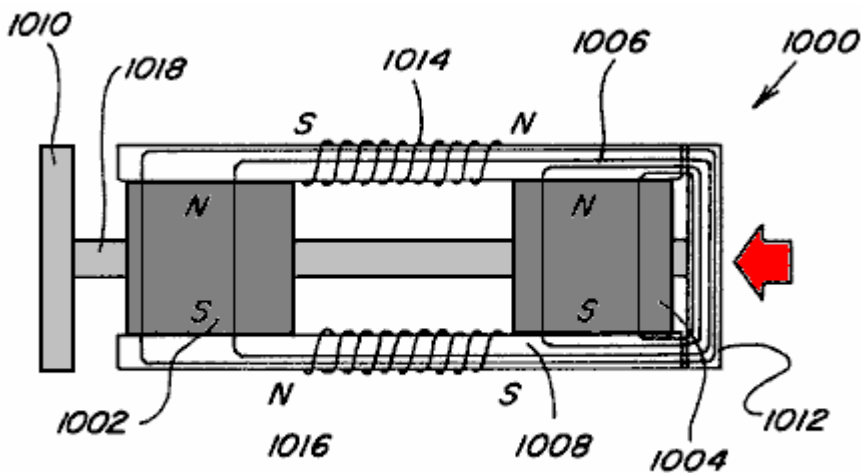
**Fig.45Z** and **Fig.45C** show the control coils energised with a polarity opposite of that shown in **Fig.45Y** and **Fig.45B**. The same action occurs and results in all of the permanent magnet or magnets path flux passing through the opposite working regions.

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.

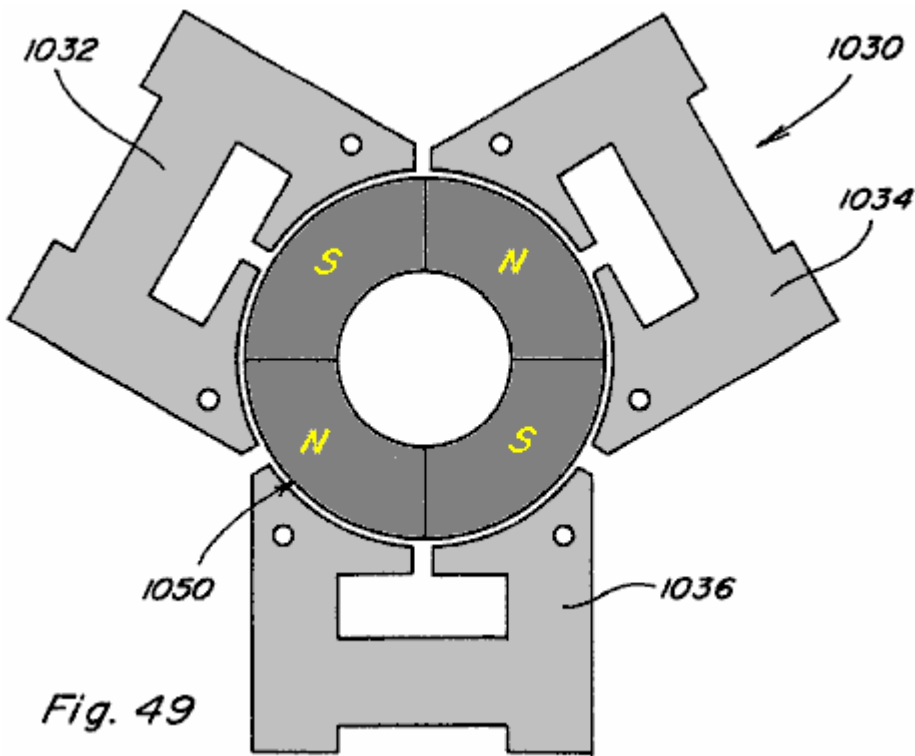


*Fig. 48*

**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**.

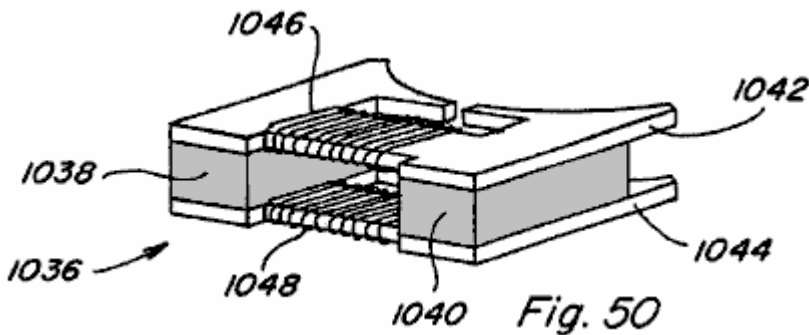
The members **1006** and **1008** extend slightly beyond the opposite sides of the respective permanent magnets **1002** and **1004** and a pair of spaced armature members **1010** and **1012** are positioned to move into and out of engagement with the ends of the members **1006** and **1008**. Coils **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 (f) 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.