US 20090191073A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2009/0191073 A1**

Kopecek et al.

(43) **Pub. Date: Jul. 30, 2009**

(54) **MAGNETIC PUMPING MACHINES**

(75) Inventors: **Herbert Kopecek**, Hallbergmoos (DE); **Michael Bernhard Schmitz**, Freising (DE); **Johannes Eckstein**, Ismaning (DE); **Nicola Marcucci**, Florence (IT); **Stefano Meucci**, Florence (IT); **Carlos Jimenez Haertel**, Muenchen (DE)

Correspondence Address:
GENERAL ELECTRIC COMPANY
GLOBAL RESEARCH
PATENT DOCKET RM. BLDG. K1-4A59
NISKAYUNA, NY 12309 (US)

(73) Assignee: **GENERAL ELECTRIC COMPANY**, Schenectady, NY (US)

(21) Appl. No.: **12/019,697**

(22) Filed: **Jan. 25, 2008**

Publication Classification

(51) **Int. Cl.**
F04B 17/00 (2006.01)
F04B 35/04 (2006.01)

(52) **U.S. Cl.** **417/415**

(57) **ABSTRACT**

Magnetic pumping systems and methods of pumping using such systems are disclosed. In one embodiment, a system for pumping fluid comprises: a substantially cylinder-shaped pump housing (**200**); a magnetic piston (**210**) residing within the pump housing (**200**) for displacing the fluid; a magnetic actuator (**220**) surrounding the pump housing (**200**), wherein the magnetic actuator (**220**) is configured to move the piston (**210**) by a magnetic force between the magnetic piston (**210**) and the magnetic actuator (**220**); and a magnetic ring (**230**) surrounding and attached to the magnetic actuator (**220**) for increasing a magnitude of the magnetic force. In another embodiment, a system for pumping fluid comprises: a pump housing (**10**); a magnetic piston (**20**) residing within the pump housing (**10**) for displacing the fluid; an electromagnetic actuator (**150**) outside the pump housing (**10**) comprising a movable conductive coil (**160**), wherein the electromagnetic actuator (**150**) is configured to move the piston (**20**) by an electromagnetic force; and an external driver for moving the conductive coil (**160**).

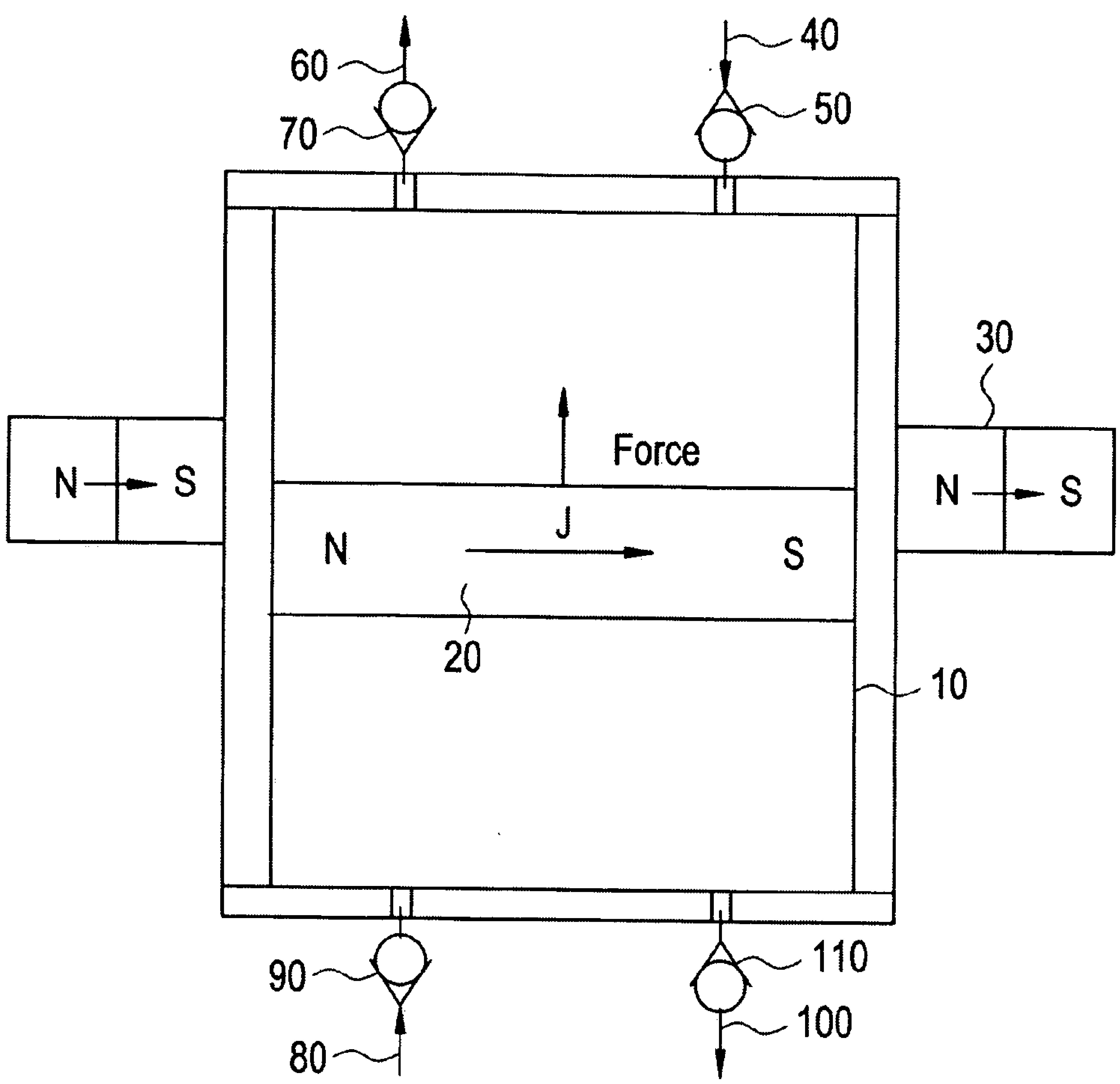


FIG. 1

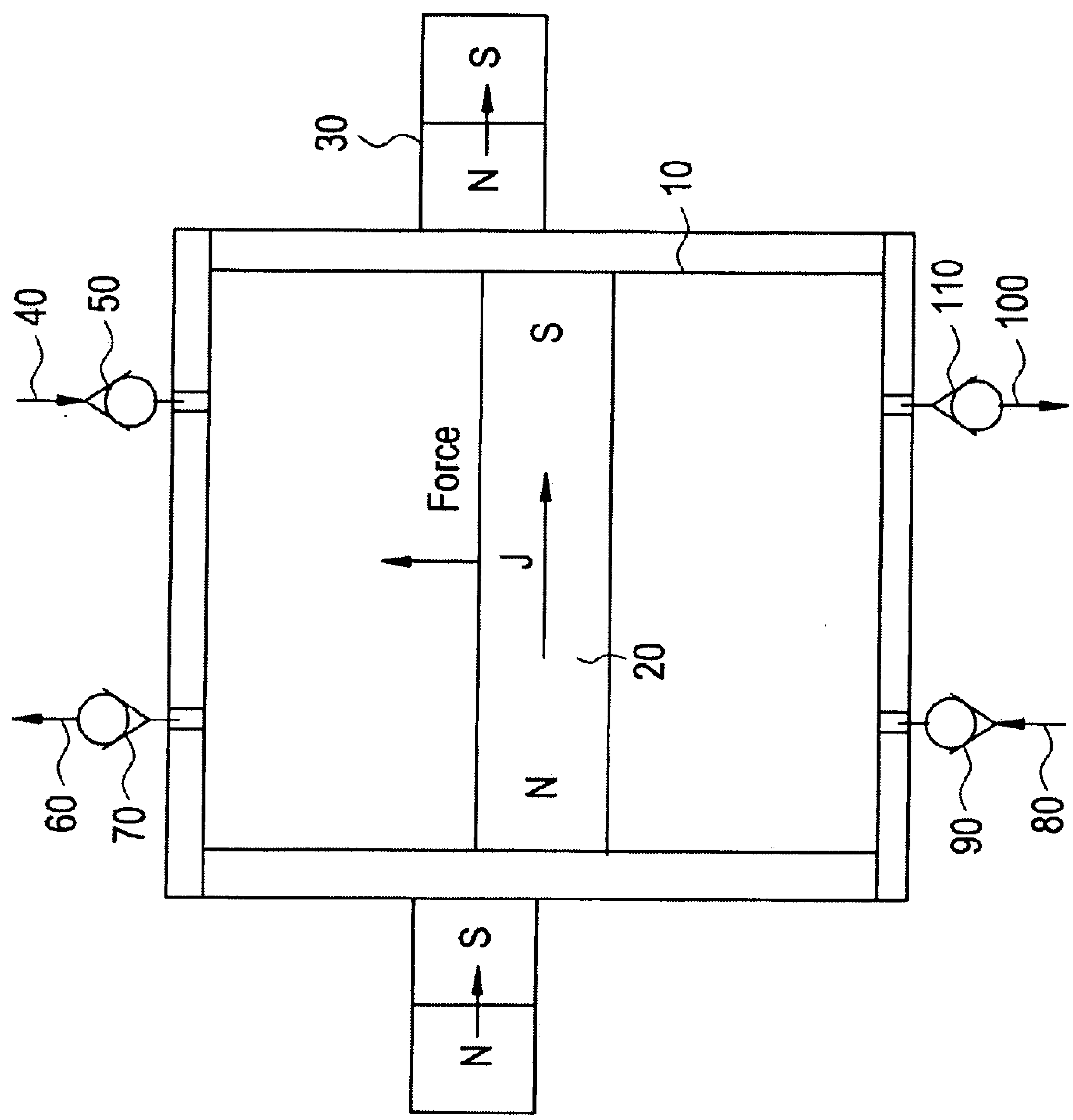


FIG. 2

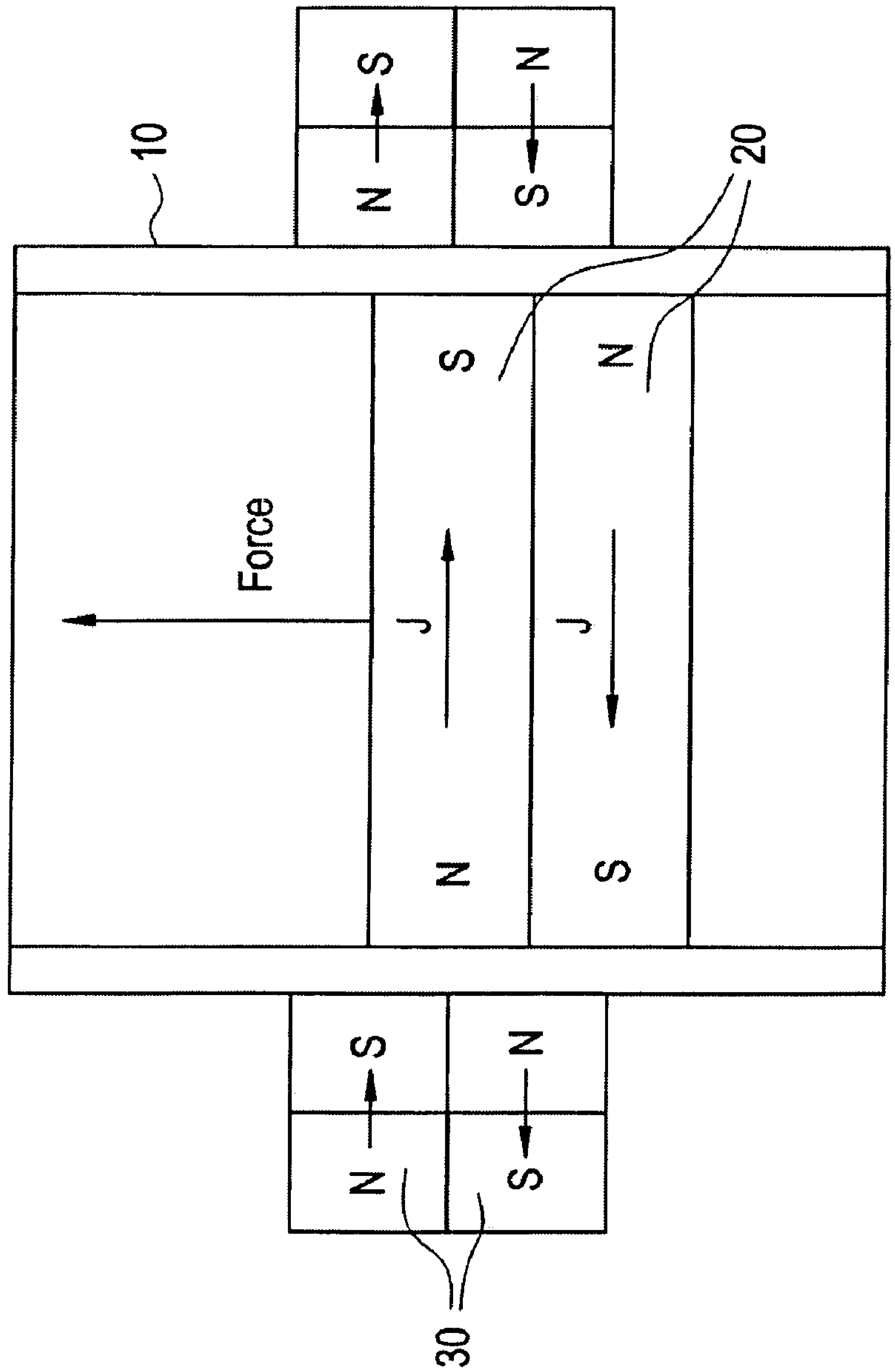


FIG. 3

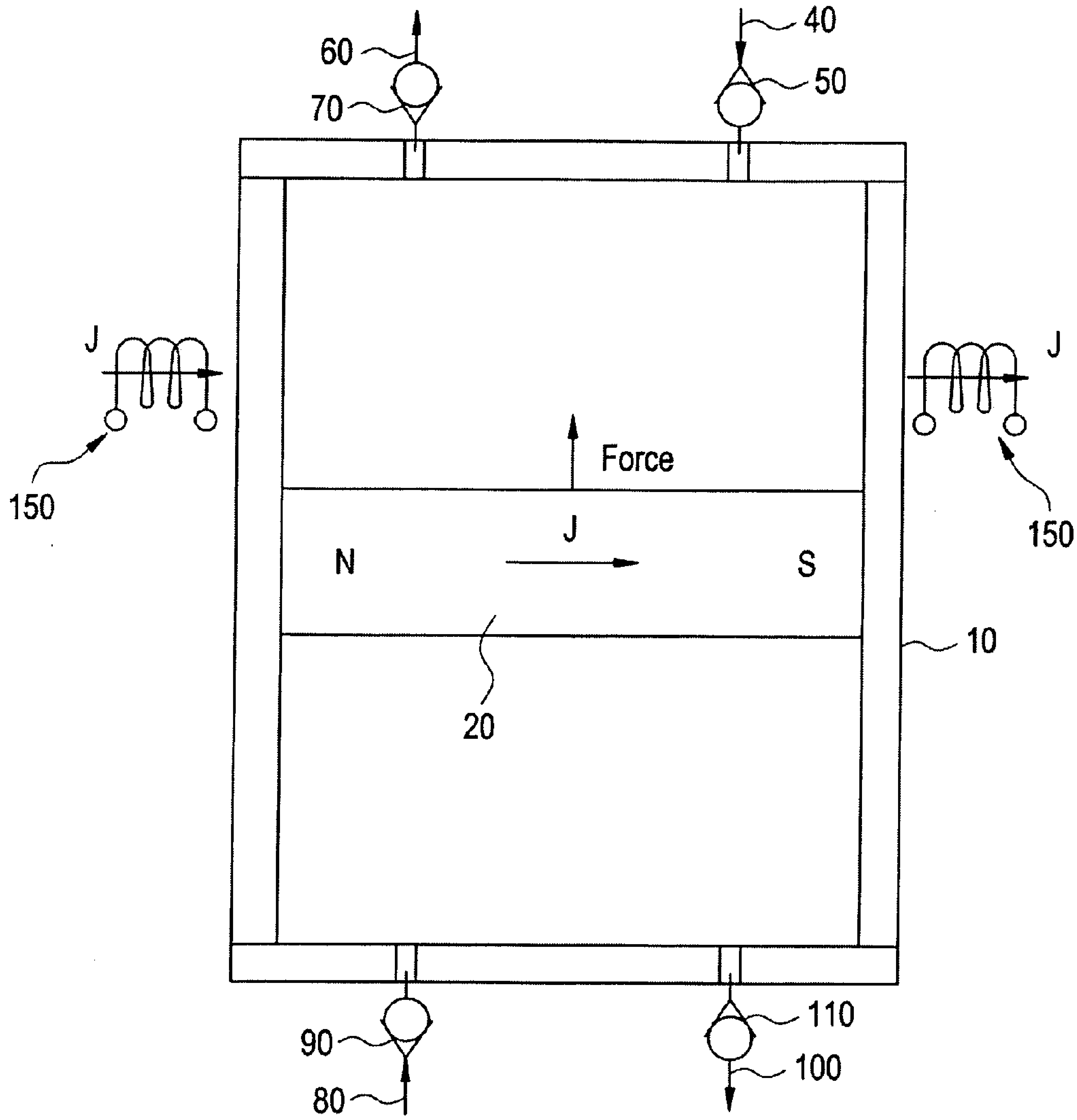


FIG. 4

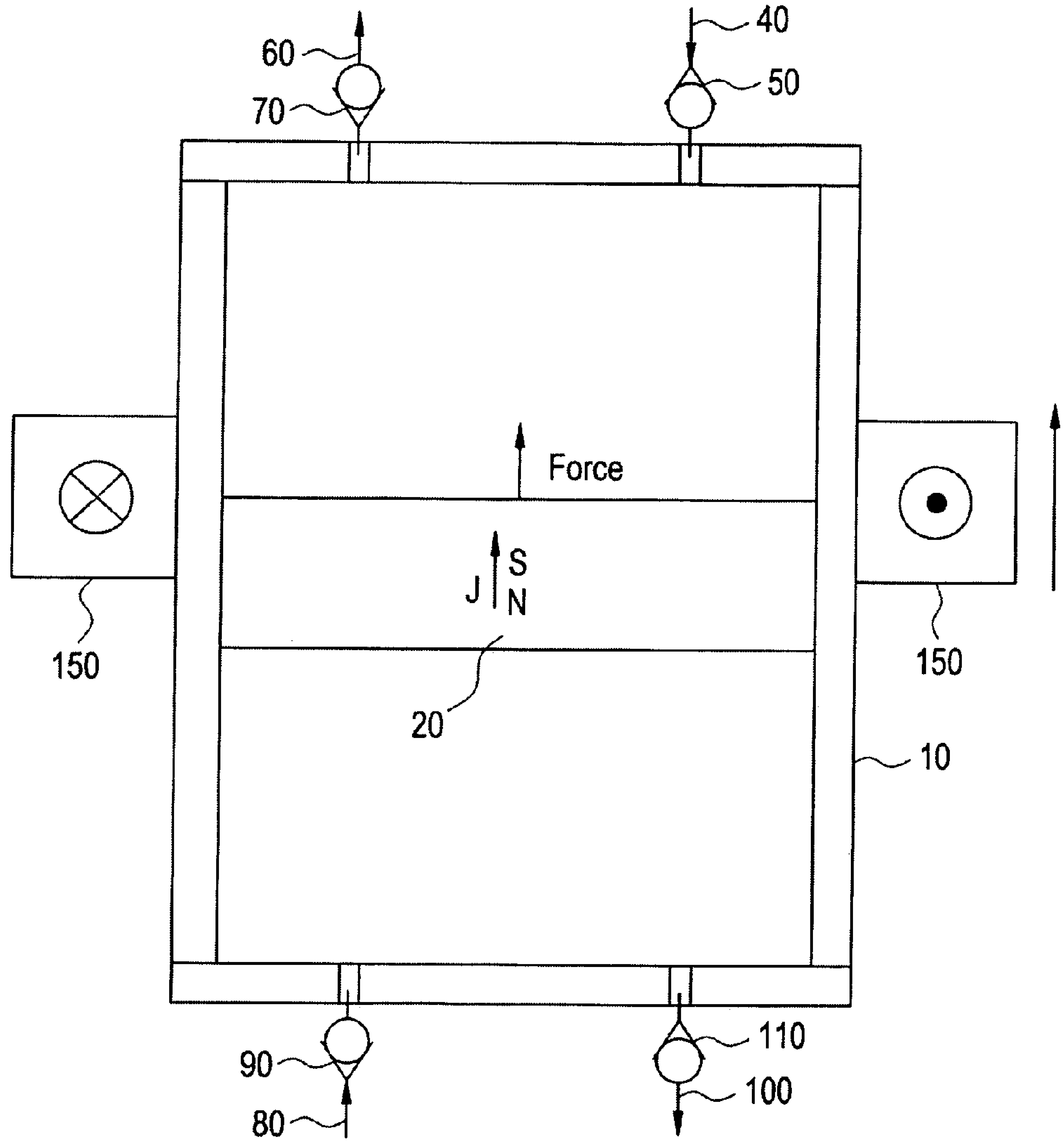


FIG. 5

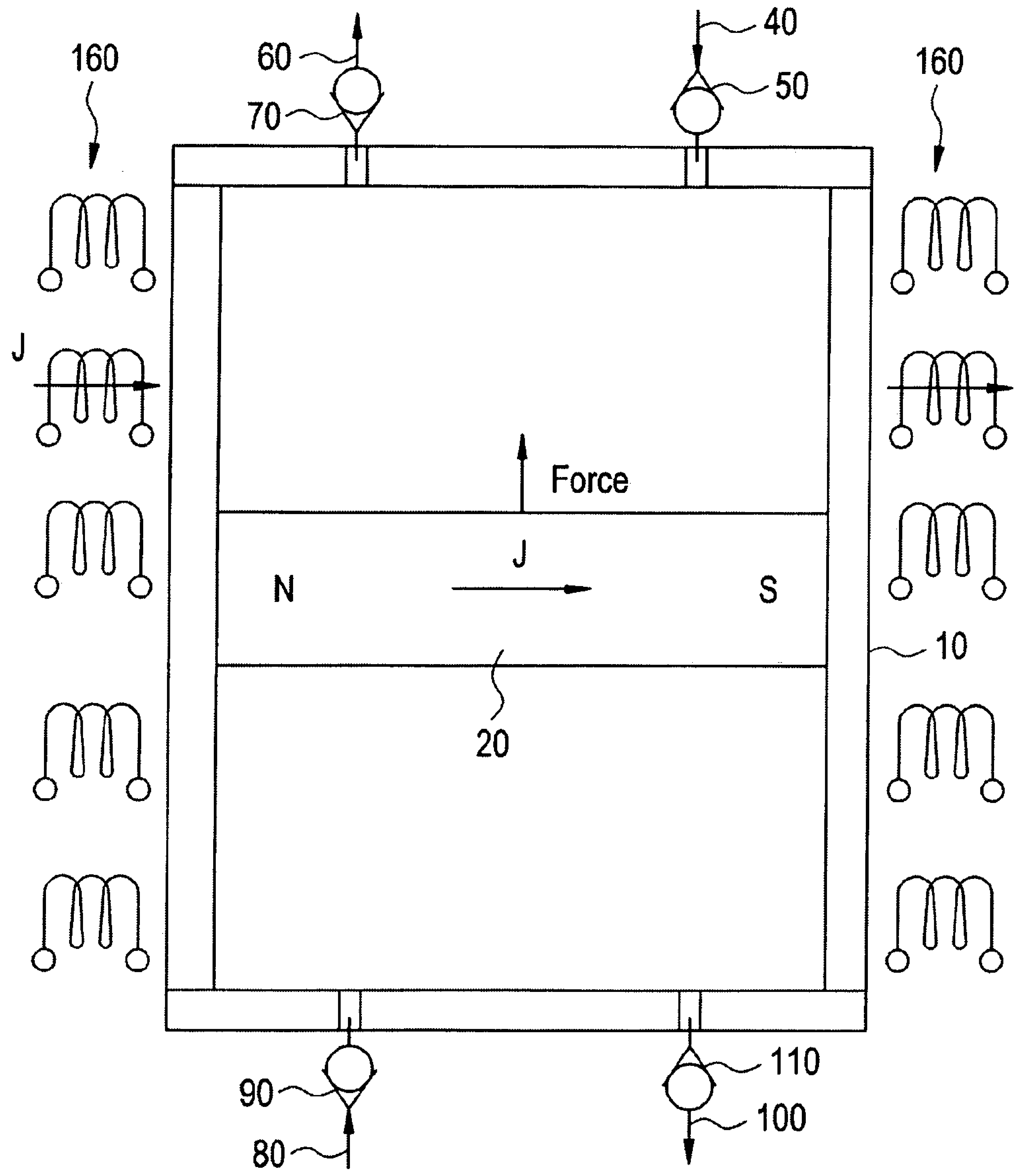


FIG. 6

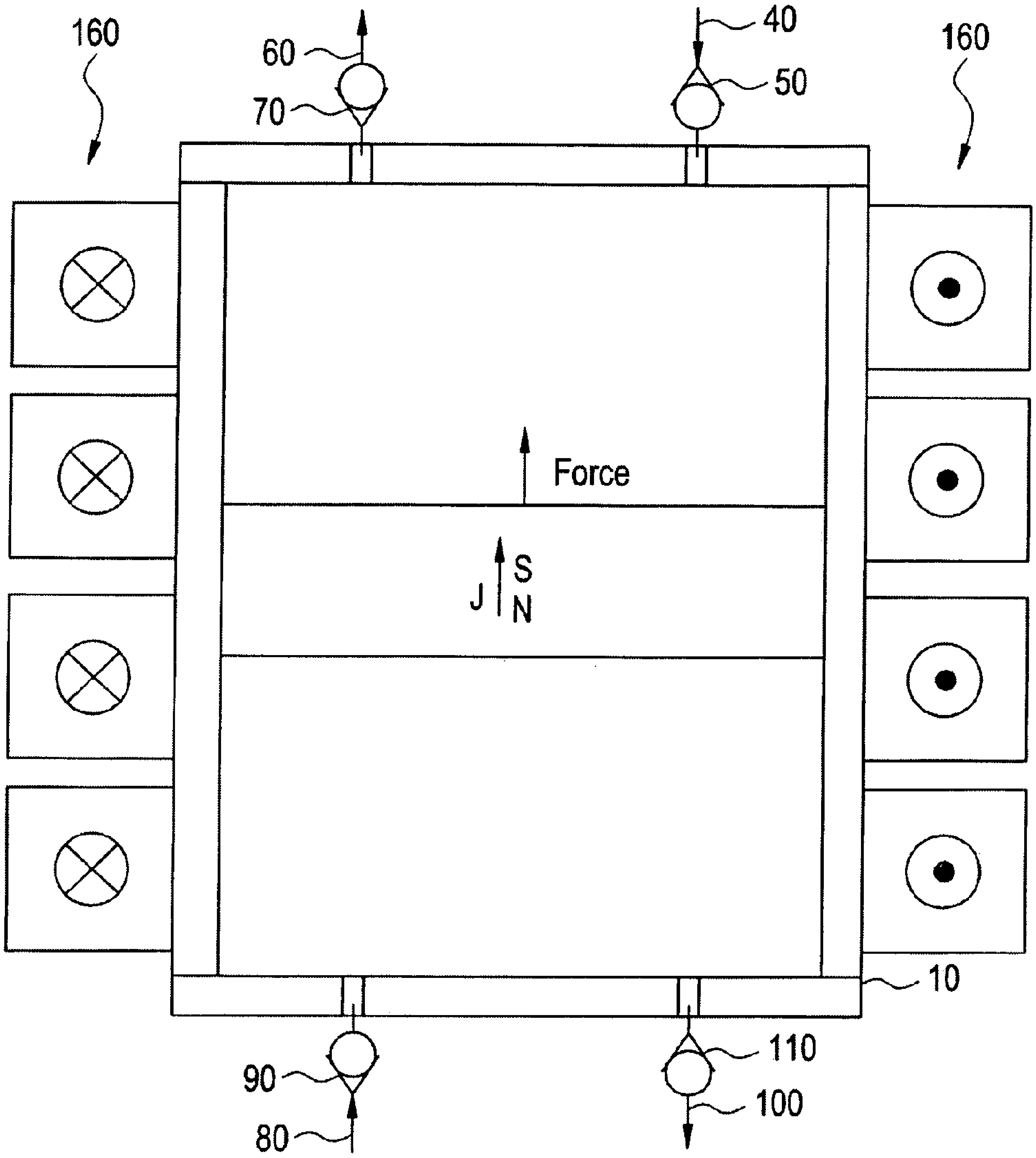


FIG. 7

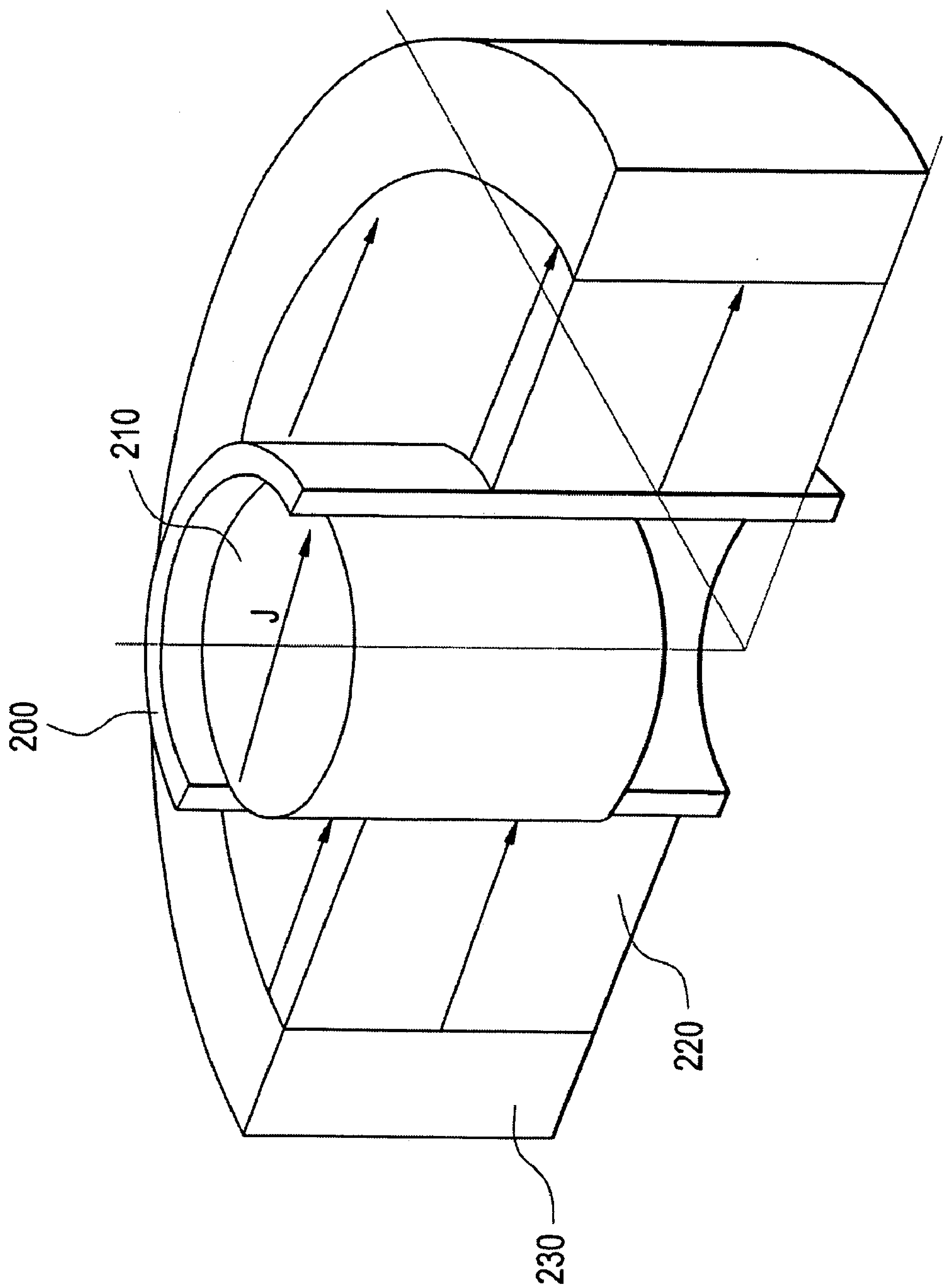


FIG. 8B

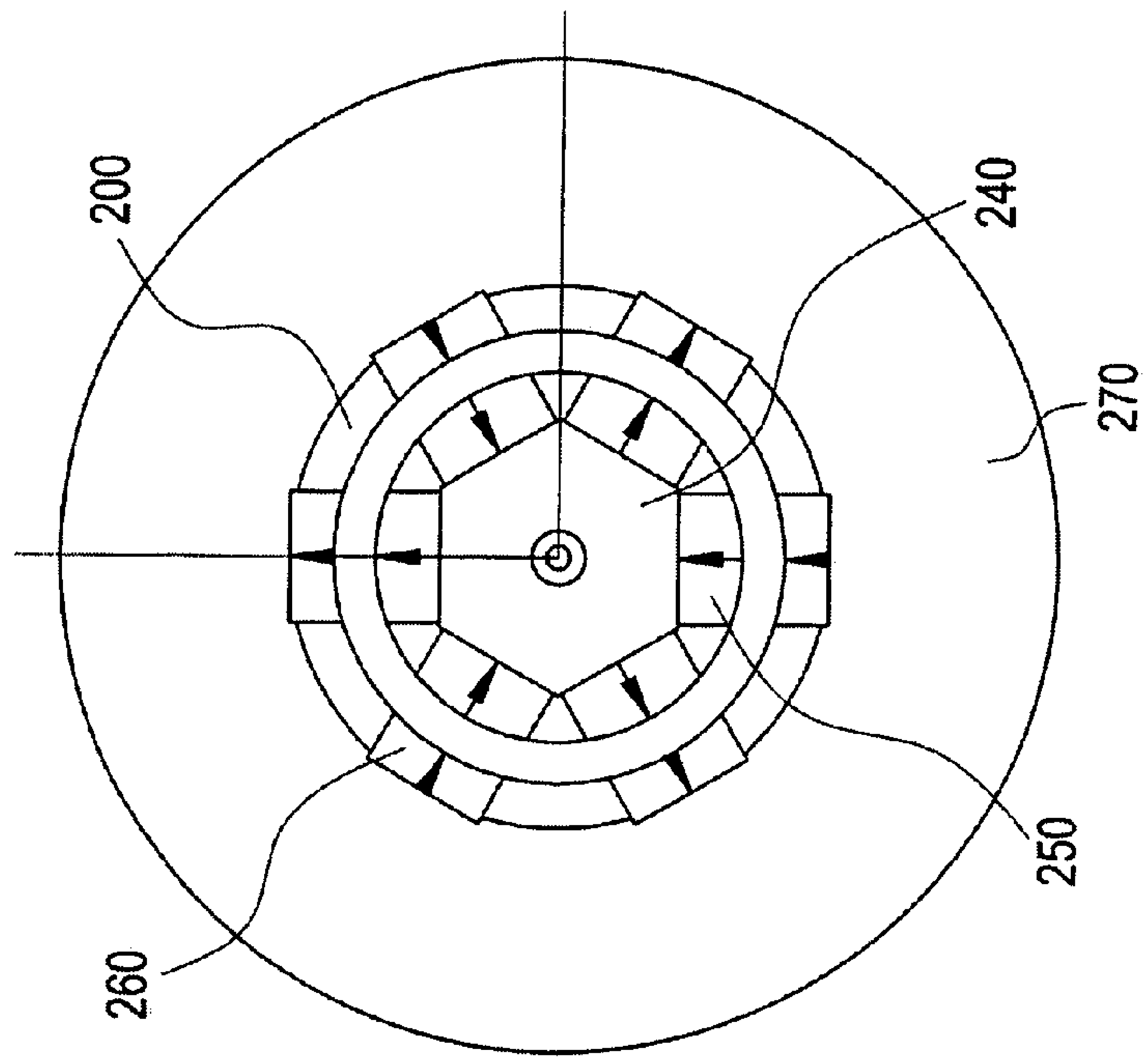
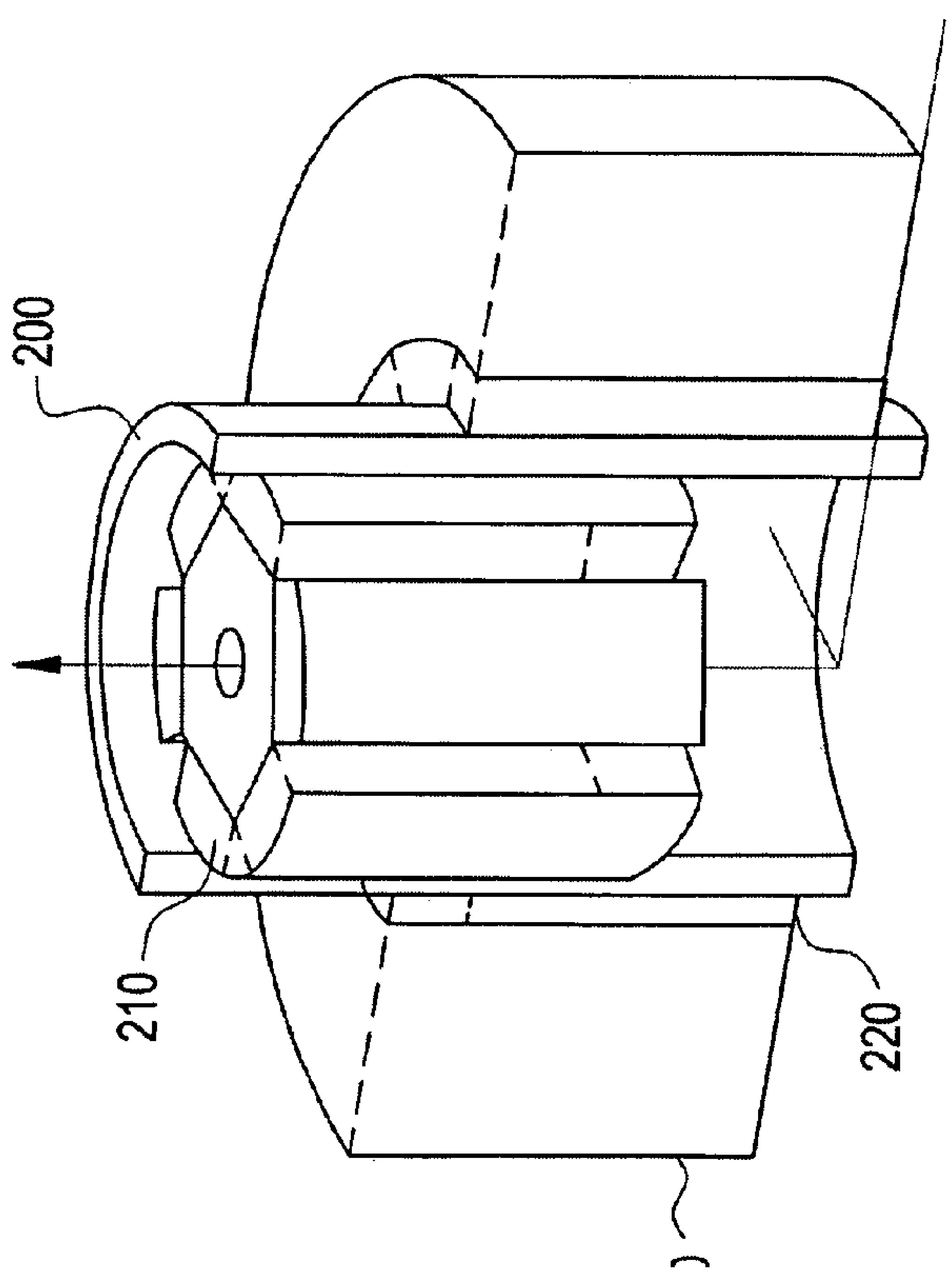


FIG. 8A



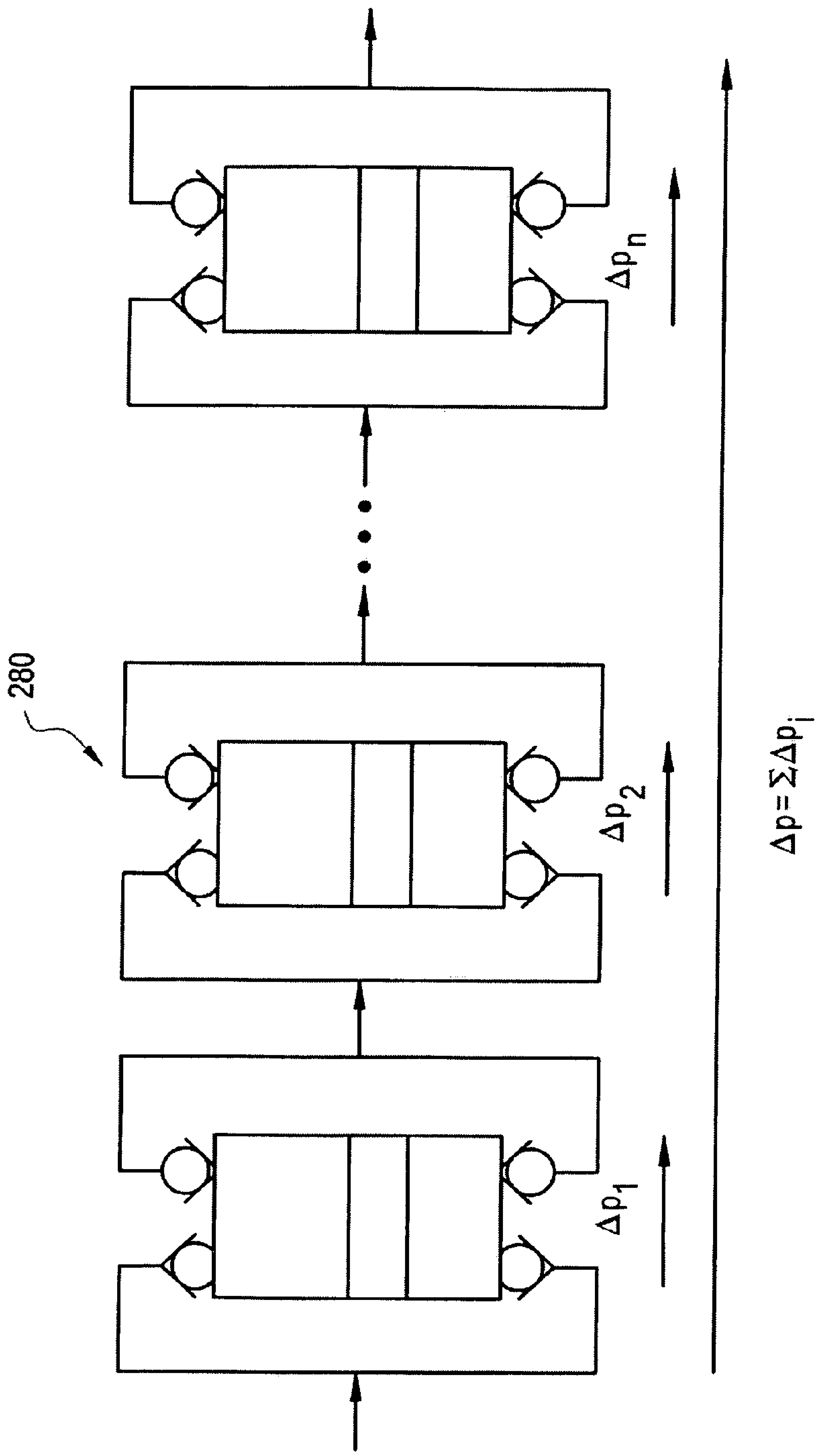


FIG. 9

FIG. 10

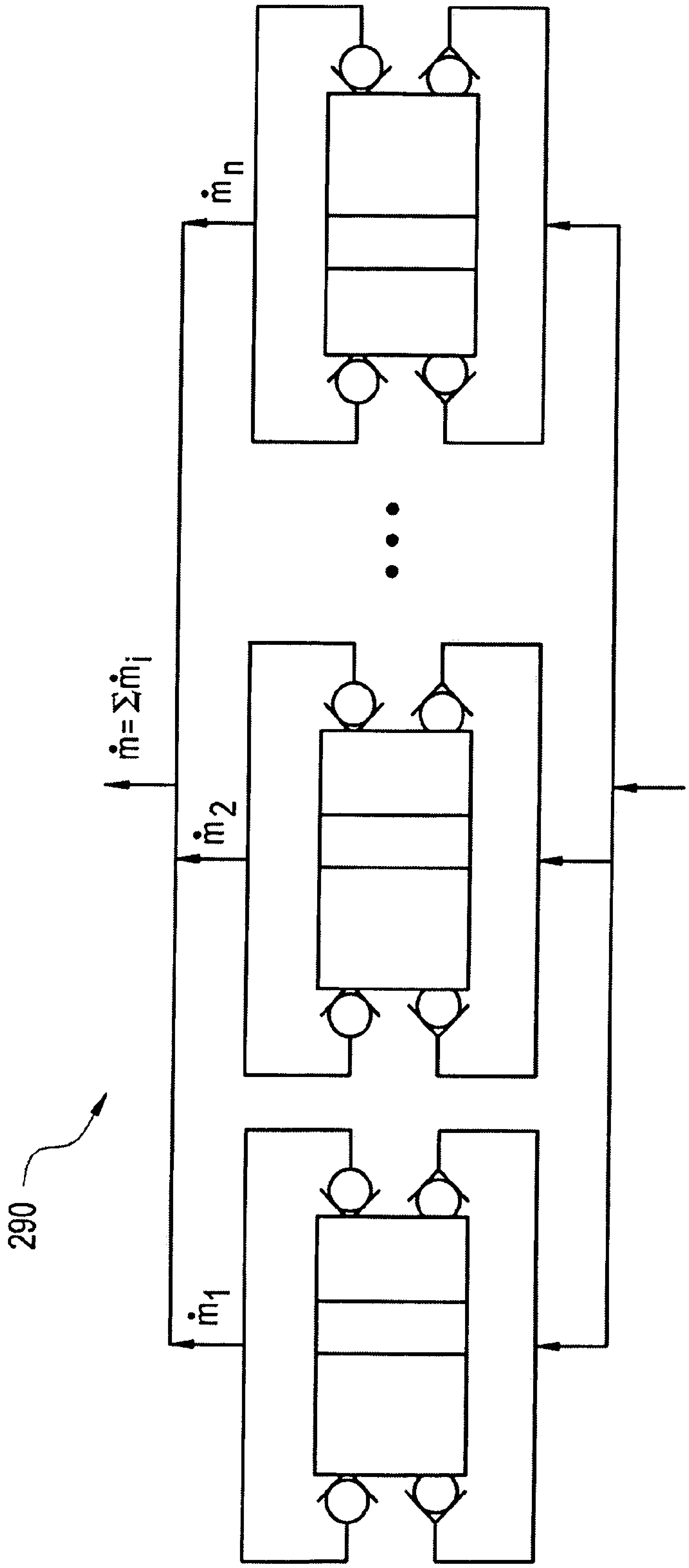


FIG. 11

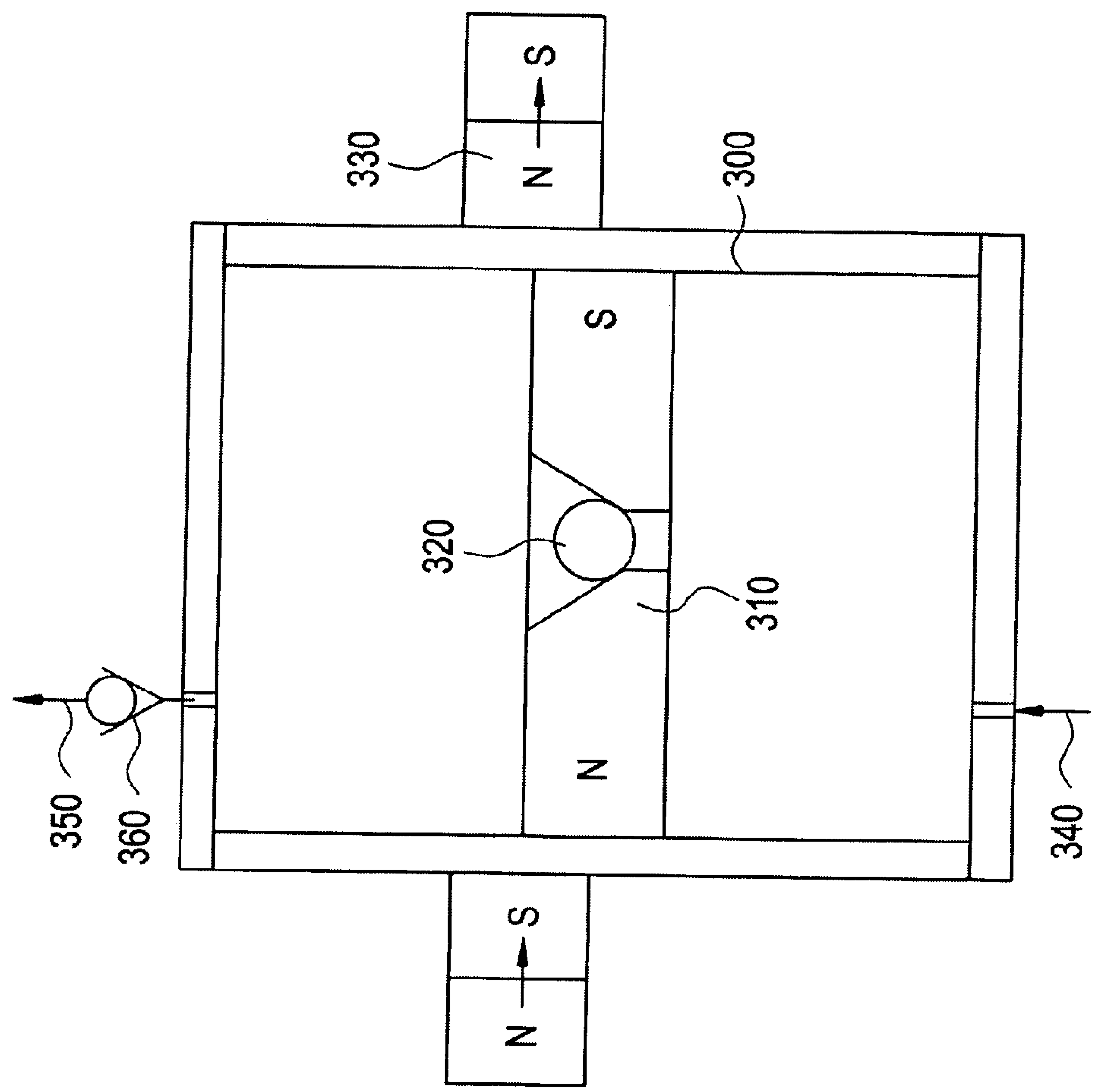


FIG. 12

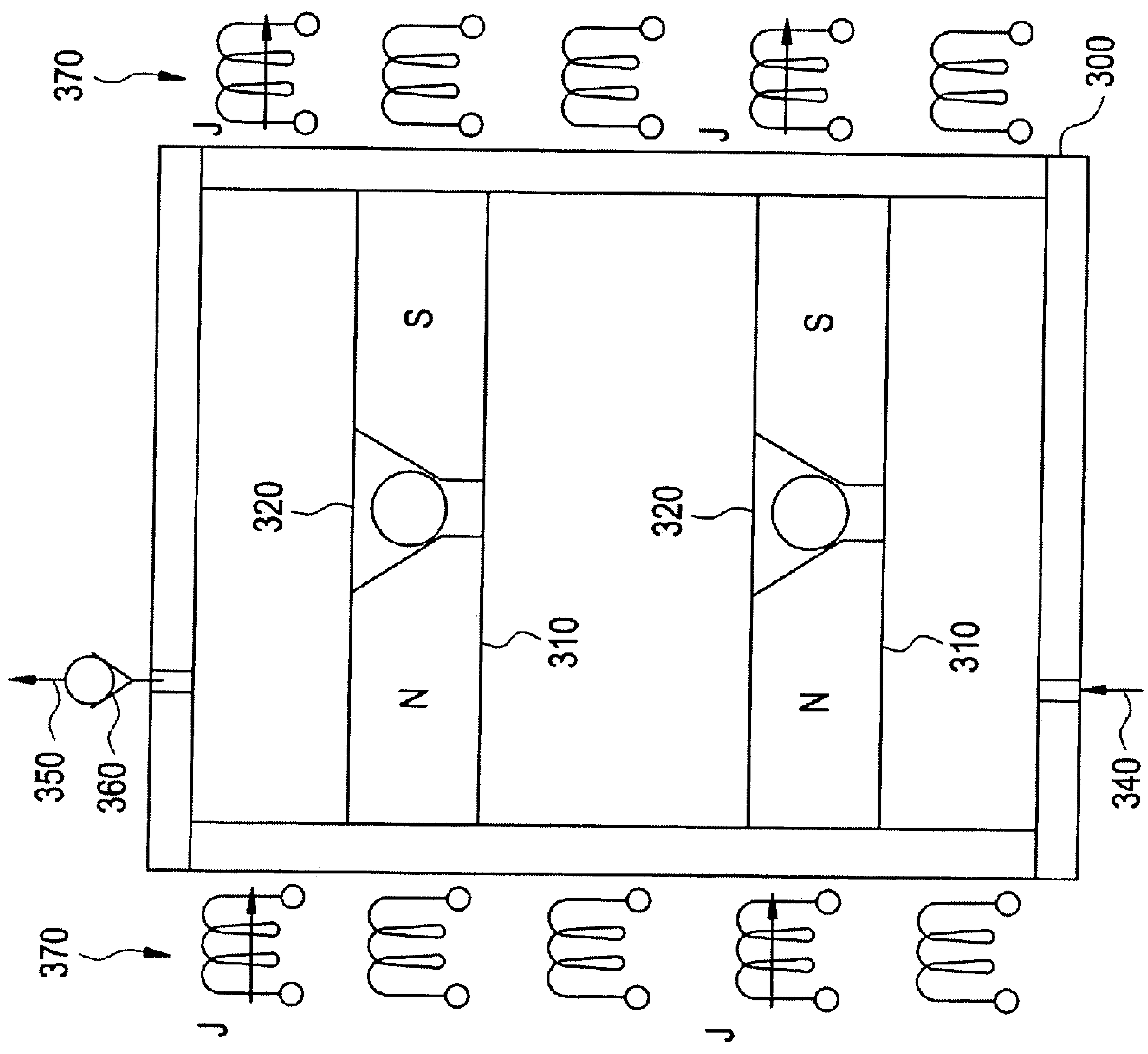
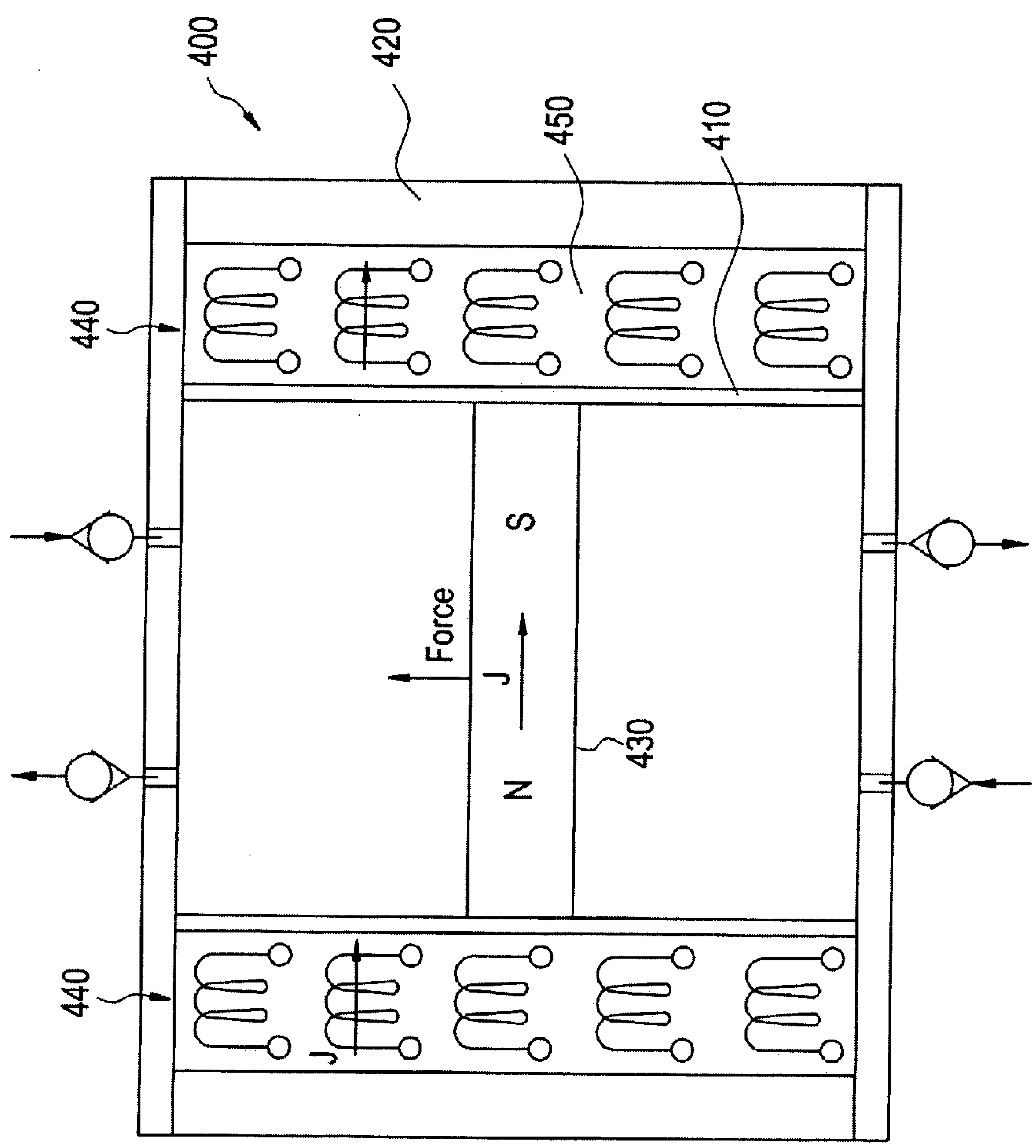


FIG. 13



MAGNETIC PUMPING MACHINES

BACKGROUND

[0001] This disclosure relates generally to fluid movement and, more specifically, to magnetic pumping systems for displacing fluid.

[0002] Gas pumps or compressors are widely used for a variety of purposes. For example, they are used in pipeline transport to move natural gas from the production site to the consumer and in refrigeration and air conditioner equipment to move heat from one place to another. They are also used in industrial plants, such as petroleum refineries and chemical plants, to compress intermediate and end product gases. Further, they are used to deliver pressurized auxiliary gas (e.g., inert gas such as nitrogen or process gas such as natural gas) to the gas seals of a larger turbo compressor in order to maintain the sealing functionality of the seals.

[0003] Unfortunately, currently used gas pumps are susceptible to leaking, which can be very dangerous when the gas being compressed is highly corrosive or explosive. Gas pumps can be redesigned to fulfill the safety and reliability requirements of such challenging applications. However, this redesign can be costly and time consuming.

[0004] One type of gas pump is the reciprocating compressor, which employs a piston driven by a crankshaft to exert force on a fluid within a cylinder, thereby compressing it. Reciprocating compressors have several drawbacks. For example, they are usually powered by a near-by electric supply, which poses a safety hazard in those cases where combustible gases are being compressed. Also, reciprocating compressors have moving parts, e.g., the crankshaft, that compromise their reliability. Further, the flow output and the output pressure of reciprocating compressors are difficult to control.

[0005] A need therefore exists for improved pumps for conveying fluids such as gas.

SUMMARY

[0006] Disclosed herein are magnetic pumping systems. In one embodiment, a system for pumping fluid comprises: a substantially cylinder-shaped pump housing; a magnetic piston residing within the pump housing for displacing the fluid; a magnetic actuator surrounding the pump housing, wherein the magnetic actuator is configured to move the piston by a magnetic force between the magnetic piston and the magnetic actuator; and a ring comprising a magnetic element surrounding and attached to the magnetic actuator for increasing a magnitude of the magnetic force.

[0007] In an additional embodiment, a system for pumping fluid comprises: a pump housing; a magnetic piston residing within the pump housing for displacing the fluid; and an electromagnetic actuator outside the pump housing, wherein the electromagnetic actuator is configured to move the piston by an electromagnetic force.

[0008] In another embodiment, a system for pumping fluid comprises: a pump housing; a stack of at least two magnetic pistons residing within the pump housing for displacing the fluid; and a stack of at least two magnetic actuators outside the pump housing, wherein the magnetic actuators are configured to move the pistons by a magnetic force between the magnetic pistons and the magnetic actuators.

[0009] In yet another embodiment, a system for pumping fluid comprises: at least two magnetic pumps arranged in series or in parallel, wherein each magnetic pump comprises: a pump housing; a magnetic piston residing within the pump housing for displacing the fluid; and an actuator outside the pump housing, wherein the actuator is configured to move the piston by a magnetic or electromagnetic force.

[0010] In still another embodiment, a system for pumping a fluid comprises: a pump housing comprising an inner wall laterally spaced from an outer wall; a magnetic piston residing within the inner wall for displacing the fluid; and a plurality of conductive coils arranged inside the outer wall along a periphery of the inner wall, wherein the piston is configured to move upon application of a current in a sequential pattern to the different conductive coils.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Referring now to the Figures, which are exemplary embodiments, and wherein the like elements are numbered alike:

[0012] FIGS. **1-6** are cross-sectional views of magnetic pumping systems in accordance with various embodiments;

[0013] FIG. **7** is a perspective view of a portion of a magnetic pumping system having two poles in accordance with an embodiment;

[0014] FIGS. **8***a* and **8***b* are perspective and cross-section views, respectively of a magnetic pumping system having multiple poles in accordance with an embodiment;

[0015] FIG. **9** is a flow diagram of magnetic pumps arranged in series;

[0016] FIG. **10** is a flow diagram of magnetic pumps arranged in parallel; and

[0017] FIGS. **11-13** are cross-sectional views of magnetic pumping systems in accordance with different embodiments.

DETAILED DESCRIPTION

[0018] Systems for pumping fluid that comprise magnetic pistons and permanent-magnetic or electromagnetic actuators for moving the pistons are described. In an embodiment, these pumping systems are suitable for use in high-pressure applications, e.g., greater than about 400 psi which, could be required in oil and gas production units. As used herein, the term "magnetic" refers to an ability to exhibit an attractive or repulsing force on other materials (i.e., magnetism) resulting from the quantum-mechanical spin and orbital motion of electrons, wherein magnetic objects/materials are considered to be "permanent" magnetic objects/materials since the magnetism occurs even when no electrical current is applied. As used herein, the term "electromagnetic" refers to an ability to exhibit an attractive force on other materials resulting from electric currents, wherein electromagnetic objects/materials are considered to be "temporary" magnetic objects/materials since a magnetic field is generated only when an electric current flows through the objects/materials. The pumping systems described herein are referred to as "magnetic pumping systems", meaning that they operate by means of a magnetic or electromagnetic force.

[0019] Tuning to FIG. **1**, an embodiment of a magnetic pumping system is shown. The magnetic pumping system comprises a pump housing **10** for holding fluid, a magnetic piston **20** disposed inside the pump housing **10**, and a permanent-magnetic actuator **30** disposed outside the pump housing **10**. The pump housing **10** can be substantially cylinder-shaped, and the magnetic piston **20** can be sized to fit inside the pump housing **10**. The magnetic piston **20** is capable of sliding in a direction parallel to a central axis (not shown) of the pump housing **10**. The magnetic actuator **30** can be in the form of a ring sized to fit around the pump housing **10**. The piston **20** and the actuator **30** can comprise a permanent magnetic material. Examples of suitable permanent magnetic materials include but are not limited to metals such as steel, iron, iron ore (e.g., magnetite and lodestone), cobalt, zinc, nickel, and rare earth metals (e.g., gadolinium and dysprosium), alloys such as NdFeB, SmCo, and AlNiCo, composite materials such as AlNiCo in a plastic, and combinations comprising at least one of the foregoing materials. A suction line **40** and a discharge line **60** in fluid communication with the pump housing **10** are located on one end of the pumping system for allowing fluid to flow into and out of the pump housing **10**. Check valves **50** and **70** are disposed in the suction line **40** and the discharge line **60**, respectively. Another suction line **80** and another discharge line **100** having check valves **90** and **110**, respectively, are located on the opposite end Of the pumping system from the suction and discharge lines **40** and **60**.

[0020] The operation of the magnetic pumping system shown in FIG. **1** entails moving the magnetic actuator **30** by an external driver (not shown). The external driver can be, for example, an electric, hydraulic, pneumatic, or piezoelectric driver. The use of an electrical driver is less desired in cases where the fluid being displaced is explosive. Due to a magnetic force between the magnetic actuator **30** and the magnetic piston **20**, the movement of the piston **20** can follow the movement of the actuator **30** such that it compresses the fluid in the forward chamber. The magnetic force between the piston **20** and the actuator **30** is the highest if the piston **20** is deflected at half of its length against the actuator **30**. The magnetic polarization J of the piston **20** and the actuator **30** have the same orientation. In FIG. **1**, J is oriented in the radial direction (i.e., parallel to the radius of the pump housing **10**) with the south pole S and the north pole N of the magnetic field being oriented as shown.

[0021] The movement of the magnetic piston **20** can be controlled such that it repeatable slides forward in a first stroke that is parallel to an axis of the pump housing **10** and backward in a second stroke that is counter/opposite to the first stroke. When the piston **20** slides forward, the check valve **70** to the discharge line **60** can open as a result of the pressure inside the adjacent chamber rising above the pressure of the discharge line **60**, allowing fluid to flow out of that chamber. At the same time, the pressure in the opposite chamber can drop, causing the check valve **90** to the suction line **80** to open such that fluid flows back into that chamber. When the piston **20** slides backward, the check valve **110** to the discharge line **100** can open to allow fluid to be forced out of the adjacent chamber. At the same time, the check valve **50** to the suction line **40** can open to allow fluid to flow back into the opposite chamber. Hence, both chambers can be used for fluid delivery.

[0022] Another embodiment of a magnetic pumping system is shown in FIG. **2**. The magnetic pumping system of FIG. **2** is similar to the one depicted in FIG. **1** except that it contains multiple magnetic pistons **20** stacked together and multiple magnetic actuators **30** stacked together. Configuring the pistons **20** and the actuators **30** in this manner can achieve a greater magnetic force between the two. J of one of the magnetic pistons **20** and J of another of the magnetic pistons **20** are oriented in opposite directions.

[0023] FIGS. **3** and **4** illustrate additional embodiments of the magnetic pumping system with the same components as the pumping system depicted in FIG. **1**. However, instead of a permanent-magnetic actuator, an electromagnetic actuator **150** is employed to move the magnetic piston **20** as a result of an electromagnetic force between the two. As shown, the electromagnetic actuator **150** can be a conductive coil **150** outside the pump housing **10** that is coupled to an electrical supply. The conductive coil **150** can comprise any conductive material such as a metal, e.g., copper or aluminum, or alloys of metals. The current in the conductive coil **150** can be switched on to operate the magnetic pumping system. Current flowing through the coil **150** can produce an electromagnetic field of sufficient strength to drag the magnetic piston **20** along as the coil **150** moves parallel to the axis of the pump housing **10**. An external driver, e.g., an electric, hydraulic, pneumatic, or piezoelectric driver, can be used to cause the conductive coil to move in the desired direction.

[0024] The conductive coil **150** can be oriented as shown in FIG. **3** (i.e., with the axis of the coil in a radial direction) such that J is oriented in the radial direction. The coil **150** in FIG. **3** is wound around a permanent-magnetic core, e.g., a ferromagnetic core (not shown). The smaller the distance between the poles of the permanent-magnetic core and the magnetic piston, the higher the magnetic force between the two. Alternatively, the conductive coil **150** can be oriented as shown in FIG. **4** such that J is oriented in the axial direction (i.e., parallel to an axis of the pump housing **10**). No permanent-magnetic core is needed in the design of FIG. **4**.

[0025] Two magnetic pumping system designs/embodiments that overcome the problems associated with moving parts are depicted in FIGS. **5** and **6**. In particular, moving parts are no longer present outside the pump housing **10**. This elimination of moving parts can improve the robustness and reduce the costs (e.g., maintenance cost) of the magnetic pumping system. As shown in FIG. **5**, several conductive coils **160** (also called stator coils) can be arranged at different fixed positions along the lateral periphery of the pump housing **10**. The coils **160** can comprise any conductive material such as a metal, e.g., copper or aluminum, or alloys of different metals. The coils **160** can be coupled to an electric supply. By switching the current through the coils **160** on and off in a defined sequential pattern, a moving electromagnetic field can be produced that attracts and thus moves the magnetic piston **20**. Thus, the coils **160** do not have to be moved by an external driver to place the piston **20** in motion. Accordingly, the pumping system is absent of moving parts outside of the pump housing **10**.

[0026] The conductive coils **160** can be oriented as shown in FIG. **5** to allow J to be oriented in a radial direction when current is flowing through the coils **160**. The coils **160** in FIG. **5** are wound around a permanent-magnetic core, e.g., a ferromagnetic core (not shown). The smaller the distance between the poles of the permanent-magnetic core and the magnetic piston, the higher the magnetic force between the two. Alternatively, the coils **160** can be oriented as shown in FIG. **6** to allow J to be oriented in an axial direction when current is flowing through the coils **160**. No permanent-magnetic core is needed in the design of FIG. **6**.

[0027] Turning to FIG. **7**, an embodiment of a magnetic pumping system having a two-pole design is depicted. The pump housing **200** can be substantially cylinder-shaped. The magnetic piston **210** can be a single cylinder-shaped permanent magnet, and the magnetic actuator **220** can be a single permanent magnet that surrounds the pump housing **200**. Also, an additional permanent-magnetic ring **230** made of a ferromagnetic material, e.g., iron or steel, can surround and be attached to the magnetic actuator **220**. The aforementioned examples of magnetic materials are appropriate for use in the piston **210** and the actuator **220**. The magnetic pumping system shown in FIG. **7** operates in the same way as the previously described pumping systems with the exception that the additional magnetic ring **230** and the magnetic actuator **220** can be moved together using an external driver (e.g., a pneumatic driver, a hydraulic driver, a piezoelectric driver, or an electric driver) such that two magnetic fields are produced. The magnetic polarization J of each field is oriented in the same radial direction. The ring **230** encloses the actuator **220** to provide a return path for the magnetic flux, thus increasing the magnitude of the magnetic force between the piston **200** and the actuator **2200**/ring **230** assembly. This increased magnetic force and the compact design of this pumping system provide for excellent performance.

[0028] A multi-pole design of a magnetic pumping system in accordance with an embodiment is shown in FIGS. **8***a* and **8***b*. The magnetic piston **210** can include a permanent-magnetic core **240** made of a ferromagnetic material, e.g., iron or steel, and multiple permanent magnets **250** arranged around a periphery of the core **240**. The core **240** is shown as being hexagonal in shape with six magnets **250** encircling the core **240**. It is understood that the core **240** can take the form of other shapes as long as the magnets **250** can be positioned snug against the outside of the core **240**. The magnetic actuator **220** also can include multiple permanent magnets **260** aligned to the piston magnets **250**. A permanent-magnetic ring **270** made of a ferromagnetic material, e.g. iron or steel, can surround and be attached to the actuator magnets **260**. This magnetic pumping system operates in a manner similar to the pumping system shown in FIG. **7**. However, six magnetic fields rather than two can be produced to aid the movement of the piston **210**. The magnetic flux thus can be guided from any actuator magnet **260** through the pump housing **200** to the opposite piston magnet **250** via the permanent-magnetic core **240** to the next piston magnet **250**, back through the pump housing **200** again, past the opposite actuator magnet **260** and the permanent-magnetic ring **270**, and back to the same actuator magnet **260** where it started. The magnetic polarization J of each piston magnet **250** and each actuator magnet **260** is depicted in FIG. **8***b*.

[0029] FIGS. **9** and **10** illustrate that a series of magnetic pumps can be cascaded in sequential or parallel order, respectively. The pumping system **280** shown in FIG. **9** includes magnetic pumps **280** arranged in series to increase the differential pressure ΔP across the entire pumping system. The pumping system shown in FIG. **10** includes magnetic pumps **290** arranged in parallel to increase the mass flow rate, m, through the entire pumping system. Any of the previously described pumping systems or any combinations thereof can be cascaded as shown in FIGS. **9** and **10**.

[0030] Yet another embodiment of a magnetic pumping system is shown in FIG. **11**. This system can include a pump housing **300** for holding the fluid being compressed, a magnetic piston **310** for displacing the fluid, and a magnetic actuator **330** that can cause the motion of the magnetic piston **310** via a magnetic force between the piston **310** and the actuator **330**. An external driver (not shown) such as a hydraulic, pneumatic, piezoelectric, or electric driver can be utilized to move the actuator **330**. The magnetic components can comprise any of the previously mentioned magnetic materials. A suction line **340** and a discharge line **350** in fluid communication with the pump housing **300** can be located at opposite ends of the pump system. Due to a lack of space on the pump housing **300**, a suction check valve **320** can be located on piston **310** instead of in the suction line **340**. The check valve **320** can open and close due to the differential pressure along the valve **320** without any additional actuation. Hence, more space is available on the pump housing **300** for a discharge valve **360**. Therefore, the flow cross-section of the suction and discharge valves **320** and **360** can be increased to reduce valve losses. The previously described embodiments could also incorporate a check valve in the magnetic piston to provide for more space along the pump housing.

[0031] In an additional embodiment, a pumping system can include two or more magnetic pistons **310** cascaded in a spaced apart orientation as shown in FIG. **12**. Optionally, the pistons **310** can include check valves **320** to permit the flow of fluid through the pistons **310**. Multiple conductive coils **370** coupled to an electric supply can be arranged at the periphery of the pump housing **300**. Each of the conductive coils **370** can be wound around a permanent-magnetic core comprising a ferromagnetic material such as iron (not shown). An electric current can be applied to two of the coils **370** at a time in a defined sequential pattern to move both of the magnetic pistons **310**. A specific phase shift can be applied between the movements of the pistons **310** to boost differential pressure and to reduce pressure pulsations. The distance between the poles of the magnetic pistons **310** and the poles of the coils **370** (i.e., the actuator poles) determines the magnetic force there between and thus dictates the maximum differential pressure delivered by the pumping system. However, the amount by which this distance can be reduced is limited because the wall thickness of the pump housing **300** needs to be sufficient to withstand a specific amount of pressure.

[0032] A solution to this limitation on the reduction of the distance between the magnetic piston and the conductive coils is illustrated by the magnetic pumping system shown in FIG. **13**. The magnetic pumping system can include a pump housing **400** comprising an inner wall **410** laterally spaced from an outer wall **420**, wherein the outer wall **420** is thicker than the inner wall **410**. A magnetic piston **430** can be disposed within the inner wall **410** for displacing fluid within the pump housing **400**. Further, a plurality of conductive coils **440** can be arranged inside the outer wall **420** along a periphery of the inner wall **410** (i.e., between the outer wall **420** and the inner wall **410**). Each of the conductive coils **440** can be wound around a permanent-magnetic core comprising a ferromagnetic material such as iron (not shown). As in previous embodiments, a current can be applied in a defined sequential pattern to the different coils **440** to cause the piston **430** to move. The relatively thin inner wall **410** can separate the fluid from the coils **440**, and the thicker outer wall **420** can serve to withstand the pressure forces. The intermediate space unoccupied by the coils **440** can be filled with a suitable solid or liquid, such as mineral oil, to transfer the pressure forces from the inner wall **410** to the outer wall **420**. Examples of suitable filler materials include, but are not limited to, epoxy, mineral oil, a thermoplastic, and combinations comprising at least one of the foregoing filler materials. Additionally, this filling improves heat removal from the coils **440** and thus enables the increase of power density.

[0033] The magnetic pumping systems described above have several advantages over currently used pumping systems. For example, the magnetic actuator and the magnetic piston are not physically connected, thus allowing the pump housing to be "hermetically sealed". As used herein, "hermetically sealed" refers to the ability of the pump housing to prevent any material from moving into or out of the pump housing except through a line or conduit connected to the pump housing. As such, the fluid passing through the pump housing cannot escape into the atmosphere. This benefit is especially useful when the fluid being delivered is corrosive or explosive. Further, the pumping systems can be actuated without utilizing a high power electrical supply that could pose a danger if placed near a combustible and explosive fluid. In addition, the pumping systems can be volumetric acting devices that deliver the fluid in an unsteady pulsating mode. Thus, in contrast to other volumetric acting machines, the flow output and the output pressure can be controlled easily by a suitable actuating mechanism, e.g., by the aforementioned electrically driven actuator. Another advantage is that moving parts outside the pump housing can be avoided by employing conductive coils to actuate the magnetic piston, thereby improving reliability and reducing cost. Keeping the actuator and the piston separated also makes the system modular, meaning that several pumps can be easily stacked together in series or in parallel to increase differential pressure and/or mass flow.

[0034] As used herein, the terms "a" and "an" do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items. Reference throughout the specification to "one embodiment", "another embodiment", "an embodiment", and so forth means that a particular element (e.g., feature, structure, and/or characteristic) described in connection with the embodiment is included in at least one embodiment described herein, and may or may not be present in other embodiments. In addition, it is to be understood that the described elements may be combined in any suitable manner in the various embodiments. Unless defined otherwise, technical and scientific terms used herein have the same meaning as is commonly understood by one of skill in the art to which this invention belongs.

[0035] While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A system for pumping fluid, comprising:

a substantially cylinder-shaped pump housing;

a magnetic piston residing within the pump housing for displacing the fluid;

a magnetic actuator surrounding the pump housing, wherein the magnetic actuator is configured to move the piston by a magnetic force between the magnetic piston and the magnetic actuator; and

a magnetic ring surrounding and attached to the magnetic actuator for increasing a magnitude of the magnetic force.

2. The system of claim **1**, further comprising an external driver for moving the magnetic actuator and the magnetic ring, wherein the external driver is capable of moving the magnetic actuator and the ring repeatedly in a first direction parallel to an axis of the pump housing followed by a second direction opposite the first direction.

3. The system of claim **2**, wherein the external driver is selected from the group consisting of a pneumatic driver, a hydraulic driver, a piezoelectric driver, and an electric driver.

4. The system of claim **1**, wherein the fluid is hermetically sealed within the pump housing when the fluid passes through the pump housing.

5. The system of claim **1**, wherein the magnetic piston is substantially cylinder-shaped, and wherein the magnetic ring comprises iron.

6. The system of claim **1**, wherein the magnetic piston comprises a magnetic core surrounded by piston magnets arranged around a periphery of the magnetic core, and wherein the magnetic actuator comprises a plurality of actuator magnets aligned to the piston magnets.

7. The system of claim **1**, comprising two or more pumps arranged in series or in parallel, wherein each pump comprises the pump housing, the magnetic piston, the magnetic actuator, and the ring.

8. A system for pumping fluid, comprising:

a pump housing;

a stack of at least two magnetic piston residing within the pump housing for displacing the fluid; and

a stack of at least two magnetic actuators outside the pump housing, wherein the magnetic actuators are configured to move the pistons by a magnetic force between the magnetic pistons and the magnetic actuators.

9. The system of claim **8**, further comprising an external driver for moving the at least two magnetic actuators, wherein the external driver is configured to move the at least two magnetic actuators repeatedly in a first direction parallel to an axis of the pump housing followed by a second direction opposite the first direction.

10. The system of claim **8**, wherein the fluid is hermetically sealed within the pump housing when the fluid passes through the pump housing.

11. A system for pumping fluid, comprising:

at least two magnetic pumps arranged in series or in parallel, wherein each magnetic pump comprises:

a pump housing;

a magnetic piston residing within the pump housing for displacing the fluid; and

an actuator outside the pump housing, wherein the actuator is configured to move the piston by a magnetic or electromagnetic force.

12. A system for pumping a fluid, comprising:

a pump housing comprising an inner wall laterally spaced from an outer wall,

a magnetic piston residing within the inner wall for displacing the fluid; and

a plurality of conductive coils arranged inside the outer wall along a periphery of the inner wall, wherein the piston is configured to move upon application of a current in a sequential pattern to the different conductive coils.

13. The system of claim **12**, wherein the outer wall is thicker than the inner wall.

14. The system of claim **12**, wherein a solid or liquid material fills unoccupied space provided between the inner wall and the outer wall.

15. The system of claim **12**, wherein the fluid is hermetically sealed within the pump housing when the fluid passes through the pump housing.

16. A system for pumping fluid, comprising:

a pump housing;

a magnetic piston residing within the pump housing for displacing the fluid;

an electromagnetic actuator outside the pump housing comprising a movable conductive coil, wherein the electromagnetic actuator is configured to move the piston by an electromagnetic force; and

an external driver for moving the conductive coil.

17. The system of claim **16**, wherein the external driver is configured to move the conductive coil repeatedly in a first direction parallel to an axis of the pump housing followed by a second direction opposite the first direction.

18. The system of claim **16**, wherein the fluid is hermetically sealed within the pump housing when the fluid passes through the pump housing.

19. The system of claim **16**, further comprising one or more additional magnetic pistons spaced from and in parallel to the magnetic piston within the pump housing.

20. The system of claim **16**, comprising two or more pumps arranged in series or in parallel, wherein each pump comprises the pump housing, the magnetic piston, and the electromagnetic actuator.

* * * * *