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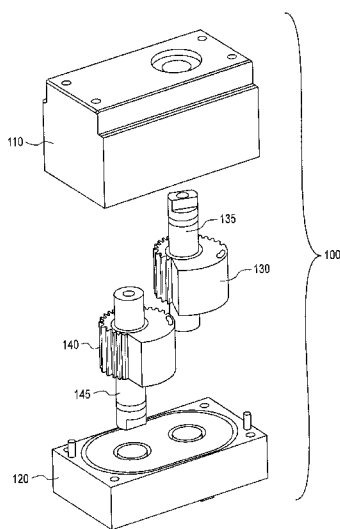


FIG. 1

(57) Abstract: A gear assembly comprises a housing, a first gear shaft in the housing, a first spiral gear coupled to the first gear shaft in the housing, a second gear shaft in the housing, a second spiral gear coupled to the second gear shaft in the housing, and a fluid connection between a first chamber and a second chamber. The first spiral gear and the second spiral gear couple to define the first chamber and the second chamber within the housing.

GEAR ASSEMBLY WITH SPIRAL GEARS

BACKGROUND

- [01]** Door operators and door closers employ mechanical devices to replace the human effort of pushing or pulling a door. Automated doors make entrances accessible to disabled users as well as increase the convenience for all users.
- [02]** Door closers are used to automatically close doors that have been manually opened. Door operators are similar to door closers but are able to both open and close doors automatically. A common door operator design combines a motor with a door closer and uses the motor to open the door and a spring to close the door. A powerful motor is typically required to overcome the force of the spring. An alternative door operator design eliminates the spring and uses a reversible motor to both open and close the door.
- [03]** Door operators and door closers must comply with various local and national building codes and regulations. Local regulations may include state building codes or fire codes and may include more stringent regulations from other states, particularly California. National regulations may include building accessibility regulations required by the Americans with Disabilities Act (ADA). Doors typically must comply with force limits for actions such as opening a door, unlatching a door, setting a door in motion and swinging a door to a fully open position. For instance, a door is considered ADA-compliant when the force for opening the door does not exceed 5 pounds. The same actions may have different standards under different codes and regulations. For example, a state fire code may specify that a door unlatch when subjected to a 15 pound force, the door be set in motion when subjected to a 30 pound force and the door swing to a fully open position when subjected to a 15 pound force. The California fire code may be more stringent and may specify that a door unlatch when subjected to a 15 pound force, the door be set in motion when subjected to a 15 pound force and the door swing to a fully open position when subjected to a 15 pound force. ADA

regulations may be even more stringent and may require that a door unlatch when subjected to a 5 pound force, the door be set in motion when subjected to a 5 pound force and the door swing to a fully open position when subjected to a 5 pound force.

[04] Door operators and door closers typically include a series of gears to provide a mechanical advantage when opening or closing a door and comply with the force limits set by local and national building codes and regulations. A gear assembly may increase the output of a motor or aid in the compression or stretching of a spring to produce a more efficient door operator or door closer. Gear assemblies are often complex and include multiple gears to achieve a desired mechanical output. Including multiple gears in a gear assembly complicates the manufacturing process and increases costs. The presence of multiple gears and other mechanical components within a door operator or closer also increases the possibility of mechanical failure. There is a need for a gear assembly that is compact and uses a minimal number of gears to produce the necessary mechanical advantage required for use in a door operator or door closer.

SUMMARY

[05] In a first aspect, the present invention is a gear assembly comprising a housing, a first gear shaft, a first spiral gear coupled to the first gear shaft, a second gear shaft, a second spiral gear coupled to the second gear shaft and a fluid connection between a first chamber and a second chamber. The first gear shaft, the first spiral gear, the second gear shaft and the second spiral gear are located in the housing. The first spiral gear and the second spiral gear couple to define the first chamber and the second chamber within the housing.

[06] In a second aspect, the present invention is a door operator for opening and closing a door comprising a housing, a first gear shaft, a first spiral gear coupled to the first gear shaft, a second gear shaft, a second spiral gear coupled to the second gear shaft, a fluid connection between a first chamber and a second chamber and a hydraulic

pump. The first gear shaft, the first spiral gear, the second gear shaft and the second spiral gear are located in the housing. The first spiral gear and the second spiral gear couple to define the first chamber and the second chamber within the housing. The hydraulic pump is in fluid connection with the first chamber and the second chamber.

[07]

In a third aspect, the present invention is a door closer for closing a door comprising a housing, a first gear shaft, a first spiral gear coupled to the first gear shaft, a second gear shaft, a second spiral gear coupled to the second gear shaft, a fluid connection between a first chamber and a second chamber and a torsion spring coupled to the second spiral gear shaft. The first gear shaft, the first spiral gear, the second gear shaft and the second spiral gear are located in the housing. The first spiral gear and the second spiral gear couple to define the first chamber and the second chamber within the housing.

[08]

In a fourth aspect, the present invention is a door assembly comprising a door and a door operator. The door operator comprises a housing, a first gear shaft, a first spiral gear coupled to the first gear shaft, a second gear shaft, a second spiral gear coupled to the second gear shaft, a fluid connection between a first chamber and a second chamber and a hydraulic pump. The first gear shaft, the first spiral gear, the second gear shaft and the second spiral gear are located in the housing. The first spiral gear and the second spiral gear couple to define the first chamber and the second chamber within the housing. The hydraulic pump is in fluid connection with the first chamber and the second chamber. The door is coupled to the first spiral gear.

[09]

In a fifth aspect, the present invention is a door assembly comprising a door and a door closer. The door closer comprises a housing, a first gear shaft, a first spiral gear coupled to the first gear shaft, a second gear shaft, a second spiral gear coupled to the second gear shaft, a fluid connection between a first chamber and a second chamber and a torsion spring coupled to the second spiral gear shaft. The first gear shaft, the first spiral gear, the second gear shaft and the second spiral gear are located in the housing. The first spiral gear and the second spiral gear couple to define the first

chamber and the second chamber within the housing. The door is coupled to the first spiral gear.

[10] In a sixth aspect, the present invention is a method of operating a door with a door operator comprising pumping a fluid into a first chamber to rotate a first spiral gear and a second spiral gear in a first direction and move the door open, and pumping the fluid into a second chamber to move the first spiral gear and the second spiral gear in a second direction, opposite the first direction, and move the door closed.

[11] In a seventh aspect, the present invention is a method of operating a door coupled to a gear assembly comprising moving the door from a closed position to an open position such that movement of the door rotates a first spiral gear and a second spiral gear in a first direction and moves a fluid from a first chamber into a second chamber, and moving the door from the open position to the closed position such that movement of the door rotates the first spiral gear and the second spiral gear in a second direction, opposite the first direction, and moves the fluid from the second chamber into the first chamber.

[12] In an eighth aspect, the present invention is a method of operating a door coupled to a door closer comprising moving the door from a closed position to an open position such that movement of the door rotates a first spiral gear and a second spiral gear in a first direction to compress a torsion spring, and moving the door from the open position to the closed position. Relaxation of the torsion spring rotates the first spiral gear and the second spiral gear in a second direction, opposite the first direction, to move the door from the open position to the closed position.

[13] In a ninth aspect, the present invention is a door operator, for opening or closing a door, comprising a first gear shaft, a first spiral gear coupled to the first gear shaft, a second gear shaft, a second spiral gear coupled to the second gear shaft, and an electric motor. The first spiral gear is coupled to the second spiral gear. The electric motor is coupled to the first gear shaft.

[14] In a tenth aspect, the present invention is a door assembly comprising a door and a door operator. The door operator comprises a first gear shaft, a first spiral gear coupled to the first gear shaft, a second gear shaft, a second spiral gear coupled to the second gear shaft, and an electric motor. The first spiral gear is coupled to the second spiral gear. The electric motor is coupled to the first gear shaft. The door is coupled to the first spiral gear.

[15] DEFINITIONS

[16] A “door closer” is a mechanical device that is able to close a door that has been opened. A door closer is not capable of opening a door.

[17] A “door operator” is a mechanical device that is able to open and close a door.

[18] A “spiral gear” is a non-circular gear in which the distance between the gear teeth and the gear axis progressively increases as the teeth are spaced around the gear such that the gear has a profile of an expanding spiral. The gear teeth do not necessarily surround the entire spiral gear. The part of a spiral gear where the teeth are present is known as a “spiral portion.”

[19] A “torsion spring” is a spring that is compressed when it is twisted. A common example of a torsion spring is a watch spring.

[20] A “power source” means a device that supplies energy to a door operator or a door closer. Examples of power sources include electric motors and hydraulic pumps.

[21] Two components are considered to be “substantially identical” if their dimensions vary by no more than ± 0.03 inches.

BRIEF DESCRIPTION OF THE DRAWINGS

- [22] The invention can be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, emphasis instead is placed upon illustrating the principles of the invention.
- [23] Figure 1 shows an exploded view of a gear assembly.
- [24] Figure 2A shows an exploded view of a spiral gear and a gear shaft.
- [25] Figure 2B shows a top view of a spiral gear and a gear shaft when coupled.
- [26] Figure 2C shows a side view of a spiral gear and a gear shaft when coupled.
- [27] Figure 2D shows a bottom view of a spiral gear and a gear shaft when coupled.
- [28] Figure 3A shows a first illustration of two chambers that are defined by two coupled spiral gears within a housing.
- [29] Figure 3B shows a second illustration of two chambers that are defined by two coupled spiral gears within a housing.
- [30] Figure 3C shows a third illustration of two chambers that are defined by two coupled spiral gears within a housing.
- [31] Figure 3D shows a fourth illustration of two chambers that are defined by two coupled spiral gears within a housing.
- [32] Figure 3E shows a fifth illustration of two chambers that are defined by two coupled spiral gears within a housing.
- [33] Figure 3F shows a sixth illustration of two chambers that are defined by two coupled spiral gears within a housing.
- [34] Figure 4 shows a housing upper portion and a valve.

- [35] Figure 5 shows a sectioned view of a gear assembly with needle roller bearings.
- [36] Figure 6 shows a sectioned view of a door operator.
- [37] Figure 7 shows a sectioned view of a door operator fluidly connected to a hydraulic pump.
- [38] Figure 8 shows a sectioned view of a door closer.
- [39] Figure 9 shows an exploded view of a door with a door operator, a controller and an input device.
- [40] Figure 10 shows an exploded view of a door with a door closer.
- [41] Figure 11 shows a top view of a door assembly including a door and door operator with a hydraulic pump within a door frame.
- [42] Figure 12 shows a method of operating a door with a door operator.
- [43] Figure 13 shows a graph illustrating the efficiency of two door closer designs.
- [44] Figure 14 shows a sectioned view of a gear assembly.
- [45] Figure 15A shows a top view of a spiral gear with a seal.
- [46] Figure 15B shows a sectioned view of a spiral gear with a valve.
- [47] Figure 16 shows a sectioned view of a door operator having a gear assembly with spiral gears coupled to an electric motor.

DETAILED DESCRIPTION

- [48] The present invention makes use of the discovery of a gear assembly that includes two spiral gears. The two spiral gears are contained within a housing and the coupling of the two spiral gears defines two chambers within the housing. Fluid may be

contained within the housing and may move between the two chambers defined by the spiral gears. The gear assembly is smaller and less complex than traditional gear assemblies. By using fewer moving parts, the gear assembly is less expensive to produce and less prone to mechanical failure. The gear assembly may be used in a door that moves 90° or 180°.

[49] The gear assembly may be used in a door operator or in a door closer. In a door operator, a power source, such as a hydraulic pump, may cause fluid to move between the chambers, which rotates the spiral gears and moves the door open and closed. Alternatively, a power source, such as an electric motor, may rotate the spiral gears to move the door open and closed without the use of a fluid. In a door closer, the gear assembly may be coupled to a torsion spring such that opening the door rotates the spiral gears and compresses the torsion spring. The relaxation of the torsion spring rotates the spiral gears in the opposite direction and closes the door. The compact size of the gear assembly with spiral gears allows for a single-arm door operator or door closer to be fully concealed in a door assembly. Concealing a door operator or door closer protects the device from abuse and provides an anti-ligation design.

[50] Figure 1 illustrates an exploded view of a gear assembly **100**. A housing has an upper housing portion **110** and a lower housing portion **120**. A first spiral gear **130** and a second spiral gear **140** are located within the housing. The first spiral gear is coupled to a first gear shaft **135** and the second spiral gear is coupled to a second gear shaft **145**. The coupling of the first spiral gear and the second spiral gear to each other within the housing defines a first chamber and a second chamber within the housing. There is a fluid connection between the first chamber and the second chamber.

[51] The housing contains the spiral gears. The housing may be constructed of any durable, rigid material such as metals, plastics, or ceramics. The housing may be composed of multiple components. Preferably, the housing is composed of two monolithic metal components, the upper housing portion and the lower housing portion.

- [52] Figure 2A illustrates an exploded view of a spiral gear **200** and a gear shaft **210**. The spiral gear is coupled to the gear shaft. In one variation, a woodruff key **220** is coupled to the shaft and is configured to fit in the shaft keyway **225**. The woodruff key prevents the spiral gear from rotating axially around the gear shaft. When the spiral gear is coupled to the gear shaft, the spiral gear covers the woodruff key. A seal **230** and a retaining ring **240** may optionally be coupled to the gear shaft.
- [53] Figures 2B, 2C, and 2D illustrate a top view, a side view, and a bottom view, respectively, of the spiral gear **200** and the gear shaft **210** when coupled.
- [54] The first spiral gear and the second spiral gear are sized such that the two gears fit within the housing and the coupling of the gears defines two chambers within the housing. The composition and dimensions of the spiral gears may vary as long as the spiral portions of the spiral gears are substantially identical. For example, the spiral gears may have different sizes, shapes, or weights, or may have differently sized non-spiral portions, as long as they are able to rotate within the housing and define two chambers within the housing when they are coupled. The spiral gears may be constructed of any durable, rigid material such as metals, plastics, or ceramics. The spiral gears may be monolithic or composed of multiple components. Preferably, the spiral gears are monolithic metal components.
- [55] The spiral gears may optionally include a seal. Figure 15A illustrates a top view of a spiral gear **1500** with a seal groove **1510** and a corresponding seal **1520**. The seal prevents any fluid in the housing from leaking around the spiral gear. The seal is preferably a polymer, such as natural or synthetic rubber. The seal is sized to fit in the seal groove. The seal may have any shape that allows it to fit in the seal groove. Preferably, the seal is an X-ring (also known as a QUAD-RING®).
- [56] The spiral gears may optionally include a gear valve to control the opening and closing speeds of the door. The gear valve may be used to increase the opening and closing speeds and control them independently so that the door is easier or more

difficult to move in a particular direction by allowing fluid to pass through the gear, from one chamber to the other chamber during opening or closing of the door. Figure 15B illustrates a sectioned view of a spiral gear **1500** with a valve chamber **1530** and a valve **1540**. The valve chamber passes through the body of the spiral gear and is defined by a first opening **1550** and a second opening **1560**. The first opening is larger than the second opening. Fluid is able to pass through the valve chamber between the first chamber and second chamber within the housing. The valve may be, for example, a ball, or a ball and spring. The valve of Figure 15B includes a ball **1570** and a spring **1580**. The ball is large enough to fully block the second opening. In operation, fluid entering the valve chamber from the first opening will force the ball to seal the second opening, preventing further flow through the valve chamber. When the gear moves in the opposite direction, fluid entering the valve chamber from the second opening will flow around the ball, first compressing the spring, if present. The size of the first opening, the size of the second opening, the size of the ball and the resistance of the spring determine how fast fluid will pass through the valve chamber, and under what pressure. Optionally, a pair of spiral gears may have a ball in both valve chambers but a spring in only one of the valve chambers.

[57] In another variation, the spiral gear and the gear shaft may be a monolithic component. A monolithic spiral gear with an integral gear shaft eliminates movement and leakage between the spiral gear and the gear shaft, obviates the need for fastening devices such as woodruff keys and is less prone to mechanical failure than a spiral gear coupled to a gear shaft. The monolithic spiral gear with an integral gear shaft may be produced, for example, by casting or by machining. The monolithic spiral gear with an integral gear shaft may be constructed of any durable, rigid material such as metals, plastics, or ceramics. Preferably, the monolithic spiral gear with an integral gear shaft is a metal component formed by casting.

[58] Figure 14 illustrates a sectioned view of a gear assembly **1400**. A housing has an upper housing portion **1410** and a lower housing portion **1420**. A first spiral gear

1430 and a first gear shaft **1435** form a first monolithic spiral gear with an integral gear shaft in the housing. A second spiral gear **1440** and a second gear shaft **1445** form a second monolithic spiral gear with an integral gear shaft in the housing. The coupling of the first and second monolithic spiral gears with integral gear shafts to each other within the housing defines a first chamber and a second chamber within the housing. There is a fluid connection **1450** between the first chamber and the second chamber.

[59] Figures 3A-3F illustrate two chambers that are defined by two coupled spiral gears within a housing **300**. A first spiral gear **310** and a second spiral gear **320** couple to define a first chamber **330** and a second chamber **340**. The progression of figures from Figure 3A to Figure 3F shows how the rotation of the spiral gears results in a change in the volumes of the first chamber and the second chamber. In Figures 3A to 3F, the first spiral gear rotates counterclockwise and the second spiral gear rotates clockwise within the housing. As the spiral gears rotate, the first chamber grows progressively larger in volume while the second chamber grows progressively smaller in volume.

[60] The gear assembly may include a fluid connection between the first chamber and the second chamber. The fluid connection may be any passage between the chambers that allows fluid to travel through it, such as a pipe, channel, or conduit.

[61] A fluid may be contained within the housing. The fluid may move between the first and second chambers that are defined by the spiral gears as the spiral gears rotate. The rotation of the spiral gears forces the fluid to move from the chamber that is reducing in volume to the chamber that is increasing in volume. The fluid may also be used to drive the spiral gears if a power source, such as a pump, is in fluid connection with the chambers. For example, pumping fluid into the smaller chamber may exert a pressure on the spiral gears and cause the gears to rotate. The fluid may be any hydraulic fluid, such as oil, synthetic oil, automobile transmission fluid, or automobile break fluid. Preferably, the fluid is oil. The fluid may optionally contain additives, for example, extreme pressure additives (also known as EP additives).

[62] The gear assembly may include a fluid connection valve. Figure 4 illustrates a housing upper portion **410** and a valve **420**. There is a fluid connection **430** within the housing. In a fully-assembled gear assembly, the fluid connection fluidly connects a first chamber and a second chamber which are defined by the coupling of a first spiral gear and a second spiral gear within the housing. The valve is located along the fluid connection between the first chamber and the second chamber. The valve may be used to control the flow of fluid within the housing. Any valve design may be used, such as a ball valve, globe valve, or needle valve. The valve may be constructed of any durable, rigid material such as metals, plastics, or ceramics. The valve may be monolithic or composed of multiple components. Preferably, the valve is a monolithic metal component.

[63] The gear assembly may optionally include bearings coupled to the gear shafts to reduce friction. Any suitable type of bearing may be used, such as a plain bearing or a rolling-element bearing. A preferred plain bearing is a bushing. A preferred rolling-element bearing is a needle roller bearing. The bearings may be coupled to one gear shaft or to both gear shafts. The bearings may be located on one side, or on both sides, of the spiral gears. The gear assembly may have multiple bearings, including, for example, 1, 2, 3, or 4 bearings. Alternatively, bearings may be eliminated by machining the gear assembly components and housing to have extremely close tolerances.

[64] Figure 5 illustrates a sectioned view of a gear assembly **500** with four needle roller bearings. A first spiral gear **510** is coupled to a first gear shaft **520**. A second spiral gear **530** is coupled to a second gear shaft **540**. A first needle roller bearing **550** is coupled to the first gear shaft above the first spiral gear. A second needle roller bearing **560** is coupled to the first gear shaft below the first spiral gear. A third needle roller bearing **570** is coupled to the second gear shaft above the second spiral gear. A fourth needle roller bearing **580** is coupled to the second gear shaft below the second spiral gear.

[65] Figure 14 shows a gear assembly with four bushings. A first bushing **1460** and a second bushing **1470** are coupled to the first gear shaft of the first monolithic spiral gear with an integrated gear shaft. A third bushing **1480** and a fourth bushing **1490** are coupled to the second gear shaft of the second monolithic spiral gear with an integrated gear shaft.

[66] Figure 6 illustrates a sectioned view of a door operator **600** for opening and closing a door. The door operator includes a housing **610**. A first spiral gear **620** and a second spiral gear **630** are located within the housing. The first spiral gear is coupled to a first gear shaft **625** and the second spiral gear is coupled to a second gear shaft **635**. The coupling of the first spiral gear and the second spiral gear defines a first chamber and a second chamber within the housing. There is a fluid connection between the first chamber and the second chamber. A hydraulic pump **640** is fluidly connected to a first fluid channel **650** and to a second fluid channel **660**. The first fluid channel is in fluid connection with the first chamber and the second fluid channel is in fluid connection with the second chamber. The door operator may be coupled to a door and may be used to move the door from a closed position to an open position, and from an open position to a closed position. The hydraulic pump may cause fluid to move between the chambers through the fluid connection, which rotates the spiral gears and moves the door.

[67] The door operator may include an output shaft. Figure 6 shows an output shaft **670** coupled to the second gear shaft **635**. The output shaft may be coupled to either gear shaft and is also coupled to the door. The movement of the output shaft results in movement of the door. The output shaft may have any design or configuration that allows it to be coupled to the door and the gear shaft. Preferably, the output shaft is a monolithic metal component.

[68] Figure 7 illustrates a sectioned view of a door operator **710** fluidly connected to a pump **720**. A first fluid channel **730** is fluidly connected to a first chamber within the door operator. A second fluid channel **740** is fluidly connected to a second chamber within the door operator. The first fluid channel and the second fluid channel are both

fluidly connected to a pumping channel **750** located within a pump housing **760**. A pumping member **770** is also located within the pump housing and is coupled to the pumping channel such that the pumping member is capable of moving fluid in either direction along the pumping channel. A motor **780** is coupled to the pump and is used to drive the pump.

[69] The hydraulic pump may be any type of pump, such as, for example, a gear pump, a rotary vane pump, or a peristaltic pump. The specific type of pump will depend on the desired pump output and the fluid within the door operator. Preferably the pump is compact. The pump must be able to move fluid from the first chamber into the second chamber and from the second chamber into the first chamber.

[70] In an alternative variation, the power source of a door operator may be an electric motor. The electric motor may rotate the spiral gears in a first direction to open the door, and may rotate the spiral gears in a second direction, opposite the first direction, to close the door. The electric motor may optionally be coupled to a gear train. One advantage to using an electric motor for the power source is that the spiral gears may be driven directly by the motor without the use of a fluid. Eliminating the fluid also eliminates the need for a fluid connection, fluid connection valve, and/or a housing, which greatly simplifies the design. Another advantage to using an electric motor as the power source is that the motor can be very precisely controlled.

[71] Figure 16 illustrates a sectioned view of a door operator **1600** having a gear assembly with spiral gears **1610** coupled to an electric motor **1620**. The gear assembly is contained within an optional housing **1630**. The gear assembly includes a first spiral gear **1640** coupled to a first gear shaft **1645** and a second spiral gear **1650** coupled to a second gear shaft **1655**. The first spiral gear and the second spiral gear are coupled to each other. The electric motor is coupled to the first gear shaft. The second gear shaft is coupled to an output shaft **1660**. The output shaft may be coupled to a door (not shown).

[72] Figure 8 illustrates a sectioned view of a door closer **800** for closing a door. The door closer includes a housing **810**. A first spiral gear **820** and a second spiral gear **830** are located within the housing. The first spiral gear is coupled to a first gear shaft **825** and the second spiral gear is coupled to a second gear shaft **835**. The coupling of the first spiral gear and the second spiral gear defines a first chamber and a second chamber within the housing. There is a fluid connection between the first chamber and the second chamber. A torsion spring **840** is located within a spring housing **850**. The torsion spring is coupled to the first gear shaft. The door closer may be coupled to a door such that opening the door causes the spiral gears to rotate. The rotation of the gears causes a corresponding rotation of the gear shaft, which provides the twisting motion to compress the torsion spring. The relaxation of the torsion spring rotates the gear shaft and the spiral gears in the opposite direction, closing the door.

[73] The specific characteristics of the torsion spring such as material, length, winding direction, number of coils, coil diameter, and pitch are selected based on the desired spring compression and relaxation properties. For example, the spring may be a steel wire with a 3/16 inch diameter and a 1.4 inch diameter coil. The torsion spring may be coupled to either gear shaft. Preferably, the torsion spring is a monolithic metal component.

[74] The door closer may include an output shaft. Figure 8 shows an output shaft **860** coupled to the second gear shaft **835**. The output shaft may be coupled to either gear shaft and is also coupled to the door. Preferably, the output shaft is coupled to the gear shaft that is not also coupled to the torsion spring. The movement of the output shaft results in movement of the door. The output shaft may have any design or configuration that allows it to be coupled to the door and the gear shaft. Preferably, the output shaft is a monolithic metal component.

[75] The door closer may include fluid within the housing and the spring housing. As the spiral gears rotate, the fluid is moved from the chamber that is decreasing in volume to the chamber that is increasing in volume by passing through the fluid connection.

The fluid may be used to affect the speed at which the door closes based on the movement of the fluid through the fluid connection. For example, a high viscosity fluid may move slowly through the fluid connection and may be chosen to increase the time it takes for the door to close.

[76] Incorporating the gear assembly with spiral gears in a door closer produces a door closer that is more efficient than existing door closers. The efficiency of a door closer is determined by comparing the force needed to open a door with the force needed to close the door. The efficiency may be calculated graphically by measuring the area under the curve for the door opening force and subtracting the area under the curve for the door closing force. A large difference between the opening force and closing force corresponds to a low efficiency. Figure 13 shows a graph of force versus degrees of movement (0 degrees indicates a closed door and 180 degrees indicates an open door) for a standard door closer with a spring (upper curves) and a door closer that includes a gear assembly with spiral gears (lower curves). The standard door closer has an efficiency of approximately 55% while the door closer including a gear assembly with spiral gears has a significantly higher efficiency.

[77] A door closer that includes a gear assembly with spiral gears has a more desirable force profile than a standard door closer with a spring. In a standard door closer with a spring, the forces increase as the door is opened and have a minimum when the door is shut. The graph illustrates this behavior in the upward slope of the upper curves. This force profile reflects the forces experienced when compressing a spring and allowing it to relax. By contrast, a door closer that includes a gear assembly with spiral gears exhibits a decrease in force as the door is opened and has a maximum force when the door is closed. This force profile is shown in the downward slope of the lower curves in the graph. A door closer that experiences the greatest force when the door is closed ensures that the door closer provides reliable latching pressure. In addition, a decreasing force curve indicates that a door becomes easier to move as it is opened while an increasing force curve indicates that a door becomes more difficult to

move as it is opened. This is significant since door closers are manually opened by users. A door closer that includes a gear assembly with spiral gears is thus more efficient, provides better latching pressure and is easier to move than standard door closers.

[78] Figure 9 illustrates an exploded view of a door **900** with a door operator **910**, a controller **920**, and an input device **930**. The door may be constructed, for example, of metal, wood, or composite materials and may be solid or hollow. The door may be monolithic or composed of multiple pieces, such as multiple outer faces known as “door skins.” The door of Figure 9 is composed of a first outer face **940** and a second outer face **950**. The interior space between the door skins may be filled with various materials, such as spacers or fire resistant materials. The door operator may be attached to the outside of the door or may be located inside the door between first and second door skins.

[79] The door operator may include a controller to control various actions or outputs based upon various inputs. The controller may be a microprocessor in electrical communication with the power source that generates appropriate signals to open or close the door. The controller receives information from an input device to determine when to open the door. The input device may be a manually operated input device such as a button, push pad, or wall switch. The input device may also be automatically operated by the physical proximity of the user. Automatic input devices include devices such as motion sensors, floor mats with integrated pressure sensors, infrared sensors, radio frequency sensors, or photoelectric cells. A signal from the input device causes the controller to signal the power source to rotate the spiral gears in a first direction and open the door. The controller then directs a signal to the power source to rotate the spiral gears in a second direction, opposite the first direction, and close the door.

[80] The controller provides a safety mechanism to prevent the door from continuing to move when it encounters resistance. The controller may be programmed to determine when the door has encountered an obstruction. An obstruction may be

detected based on the position of the door, the time it takes for the door to open or close, or data supplied by the input device. For example, the controller may detect when the door remains open longer than a specified period of time. If the door normally returns to a closed position in 3 seconds, the controller may be programmed to interpret that when the door does not close within 3 seconds, the door has encountered an obstruction. When the controller detects an obstruction, it signals the power source to stop moving the door. The controller may then direct the power source to move the door in the opposite direction to prevent further contact with the obstruction.

[81] Figure 10 illustrates an exploded view of a door **1000** with a door closer **1010**. The door may be constructed, for example, of metal, wood, or composite materials and may be solid or hollow. The door may be monolithic or composed of multiple pieces, such as multiple outer faces known as “door skins.” The door of Figure 10 is composed of a first outer face **1020** and a second outer face **1030**. The interior space between the door skins may be filled with various materials, such as spacers or fire resistant materials. The door closer may be attached to the outside of the door or may be located inside the door between first and second door skins.

[82] In a door closer, the door may be opened manually and closed automatically. A door closer is significantly less complex than a door operator because the door does not need to be opened automatically. A comparison of Figure 9 and Figure 10 shows that the combination of a door and door closer in Figure 10 does not include a controller or an input device. Door closers also do not require any electrical components such as pumps or motors, which greatly reduces operating costs.

[83] Figure 11 illustrates a top view of a door assembly including a door and door operator with a power source within a door frame. The door operator may be the door operator shown in Figure 6. The frame **1110** is attached to a wall (not shown). The frame includes a track **1120** that allows a first end **1130** of an output arm **1150** to slide along the track in the direction of the arrows. A second end **1140** of the output arm is coupled to an output shaft (not shown), which is coupled to the door operator **1160**. The

door operator is coupled to the door **1170**. When the door operator is activated, the power source delivers motion to move fluid from the first chamber through the fluid connection and into the second chamber. Movement of the fluid causes the spiral gears to rotate. The output shaft is coupled to the first gear shaft and rotation of the spiral gear causes the output shaft to rotate. The output shaft rotates the second end of the output arm in the direction indicated by the curved arrow which causes the first end of the output arm to slide along the track, moving the door open. When the power source moves fluid from the second chamber into the first chamber, the gears are rotated in the opposite direction. Rotation of the second end of the output arm in the opposite direction causes the first end of the output arm to slide in the opposite direction along the track, moving the door closed.

[84] A door assembly may include a door and a door closer with a torsion spring. The door assembly shown in Figure 11 would be suitable for a door assembly including a door closer within the door frame. If the door assembly shown in Figure 11 were modified to include a door closer instead of a door operator, the door closer would take the place of the door operator **1160** but the other components would remain the same. The door closer may be the door closer shown in Figure 8. When a door assembly includes a door closer, the door is opened manually by a user. Moving the door open causes a corresponding movement of the output arm along the track. The output arm is coupled to the output shaft, which is coupled to the first gear shaft of the door closer. As the door is opened, the first gear shaft is rotated, which causes the first spiral gear to rotate. Rotation of the first spiral gear forces fluid to move from the first chamber through the fluid connection and into the second chamber, and causes a corresponding rotation of the second spiral gear. The rotation of the second spiral gear causes the second gear shaft to rotate. The second gear shaft is coupled to the torsion spring and rotation of the second gear shaft compresses the torsion spring. When the user releases the door, the torsion spring relaxes and returns to its original state. The relaxation of the torsion spring causes the second gear shaft to rotate in a direction opposite the direction it rotated when the door was opened. Rotation of the second

gear shaft causes the second gear to also rotate, which moves the fluid from the second chamber through the fluid connection and into the first chamber. Movement of the fluid rotates the first gear, which rotates the first gear shaft. The rotation of the first gear shaft causes the output shaft to move the output arm along the track to its initial location and close the door.

[85]

Figure 12 illustrates a method of operating a door with a door operator **1200**. First, fluid is moved from a first chamber into a second chamber, to rotate a first spiral gear and a second spiral gear in a first direction and move the door open at **1210**. Next, fluid is moved from the second chamber into the first chamber, to move the first spiral gear and the second spiral gear in a second direction, opposite the first direction, and move the door closed at **1220**.

WHAT IS CLAIMED IS:

1. A gear assembly, comprising:
a housing,
a first gear shaft, in the housing,
a first spiral gear coupled to the first gear shaft, in the housing,
a second gear shaft, in the housing,
a second spiral gear coupled to the second gear shaft, in the housing, and
a fluid connection between a first chamber and a second chamber,
wherein the first spiral gear and the second spiral gear couple to define the first chamber and the second chamber within the housing.
2. A door operator, for opening and closing a door, comprising:
a housing,
a first gear shaft, in the housing,
a first spiral gear coupled to the first gear shaft, in the housing,
a second gear shaft, in the housing,
a second spiral gear coupled to the second gear shaft, in the housing,
a fluid connection between a first chamber and a second chamber, and
a hydraulic pump, in fluid connection with the first chamber and the second chamber,
wherein the first spiral gear and the second spiral gear couple to define the first chamber and the second chamber within the housing.
3. A door closer, for closing a door, comprising:
a housing,
a first gear shaft, in the housing,
a first spiral gear coupled to the first gear shaft, in the housing,
a second gear shaft, in the housing,

a second spiral gear coupled to the second gear shaft, in the housing,
a fluid connection between a first chamber and a second chamber, and
a torsion spring, coupled to the second spiral gear shaft,
wherein the first spiral gear and the second spiral gear couple to define the first chamber and the second chamber within the housing.

4. A door operator, for opening or closing a door, comprising:
a first gear shaft,
a first spiral gear, coupled to the first gear shaft,
a second gear shaft,
a second spiral gear, coupled to the second gear shaft,
an electric motor, coupled to the first gear shaft,
wherein the first spiral gear is coupled to the second spiral gear.

5. The gear assembly, the door operator, or the door closer of any of the previous claims, wherein the first and second spiral gears are substantially identical.

6. The gear assembly, the door operator, or the door closer of any of the previous claims, further comprising a fluid in the first and second chambers.

7. The gear assembly, the door operator, or the door closer of any of the previous claims, wherein the fluid is oil.

8. The gear assembly, the door operator, or the door closer of any of the previous claims, further comprising a fluid connection valve along the fluid connection.

9. The gear assembly, the door operator, or the door closer of any of the previous claims, further comprising a first bearing, coupled to the first gear shaft, and a second bearing, coupled to the second gear shaft.

10. The gear assembly, the door operator, or the door closer of any of the previous claims, wherein the first and second bearings are bushings.

11. The gear assembly, the door operator, or the door closer of any of the previous claims, wherein the first and second bearings are needle roller bearings.

12. The gear assembly, the door operator, or the door closer of any of the previous claims, wherein the first spiral gear includes a first gear valve, and the second spiral gear includes a second gear valve.

13. The gear assembly, the door operator, or the door closer of any of the previous claims, wherein the first gear valve comprises a ball, and the second gear valve comprises a ball and a spring.

14. The gear assembly, the door operator, or the door closer of any of the previous claims, wherein the first spiral gear and the first gear shaft comprise a first monolithic component, and the second spiral gear and the second gear shaft comprise a second monolithic component.

15. The gear assembly, the door operator, or the door closer of any of the previous claims, further comprising a first bearing, coupled to the first gear shaft, and a second bearing, coupled to the second gear shaft, wherein the first and second spiral gears are substantially identical, the first spiral gear includes a first gear valve, the second spiral gear includes a second gear valve, the first spiral gear and the first gear shaft comprise a first monolithic component, and the second spiral gear and the second gear shaft comprise a second monolithic component.

16. The door operator or the door closer of any of the previous claims, further comprising an output shaft, coupled to the door and either the first gear shaft or the second gear shaft.

17. A door assembly, comprising:
a door, and
the door operator or the door closer of any of the previous claims,
wherein the door is coupled to the first spiral gear.

18. The door assembly of any of the previous claims, wherein the door operator or the door closer is located within the door.

19. A method of operating a door with the door operator of any of the previous claims, comprising:

pumping a fluid into the first chamber, to rotate the first spiral gear and the second spiral gear in a first direction and move the door open; and

pumping the fluid into the second chamber, to move the first spiral gear and the second spiral gear in a second direction, opposite the first direction, and move the door closed.

20. A method of operating a door coupled to the gear assembly of any of the previous claims, comprising:

moving the door from a closed position to an open position, such that movement of the door rotates the first spiral gear and the second spiral gear in a first direction and moves a fluid from the first chamber into the second chamber; and

moving the door from the open position to the closed position, such that movement of the door rotates the first spiral gear and the second spiral gear in a second direction, opposite the first direction, and moves the fluid from the second chamber into the first chamber.

21. A method of operating a door coupled to the door closer of any of the previous claims, comprising:

moving the door from a closed position to an open position, such that movement of the door rotates the first spiral gear and the second spiral gear in a first direction to compress the torsion spring; and

moving the door from the open position to the closed position;

wherein relaxation of the torsion spring rotates the first spiral gear and the second spiral gear in a second direction, opposite the first direction, to move the door from the open position to the closed position.

22. The method of any of the previous claims, further comprising adjusting a fluid connection valve along the fluid connection to increase or decrease the speed at which the door moves.

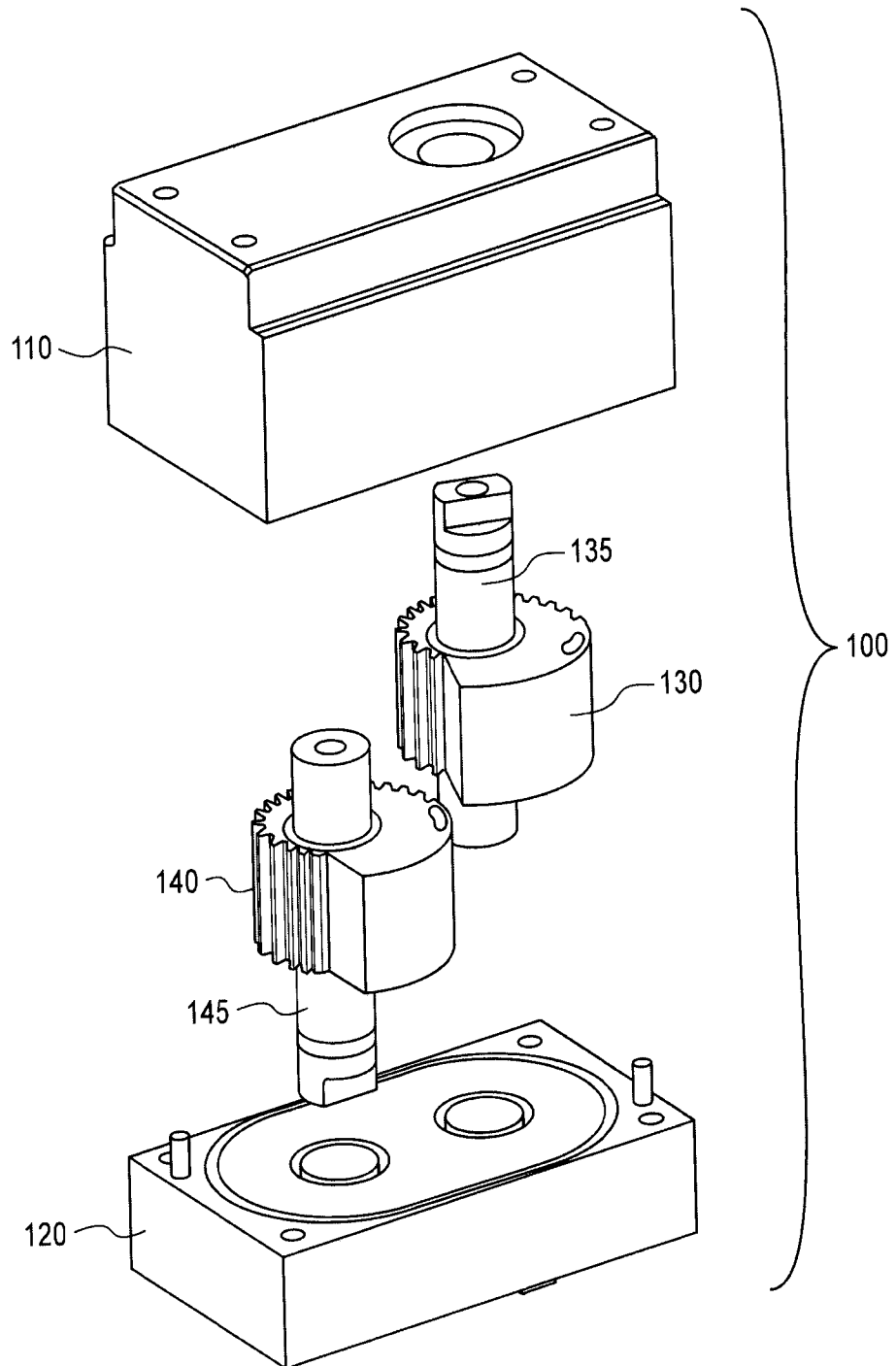


FIG. 1

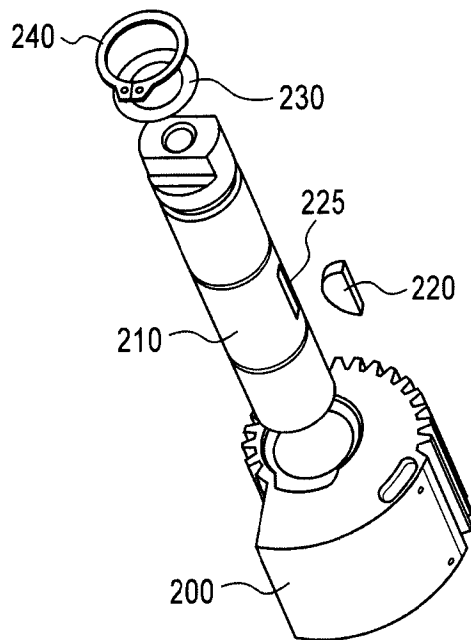


FIG. 2A

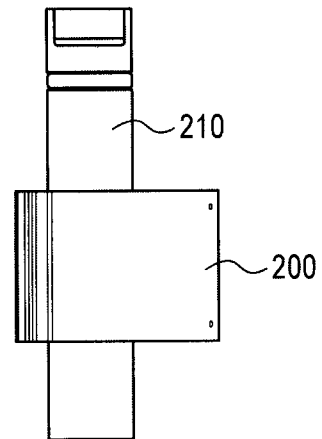


FIG. 2C

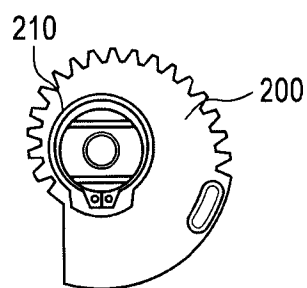


FIG. 2B

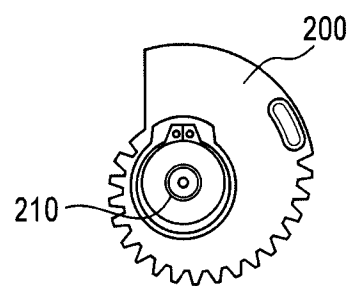


FIG. 2D

FIG. 3A

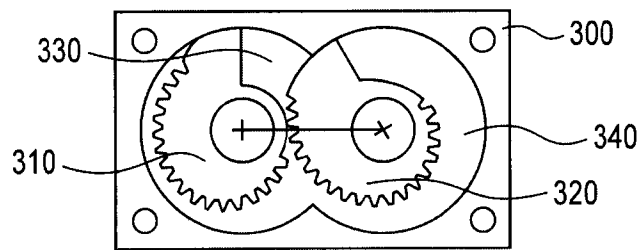


FIG. 3B

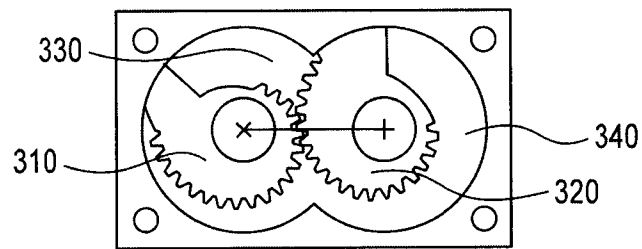


FIG. 3C

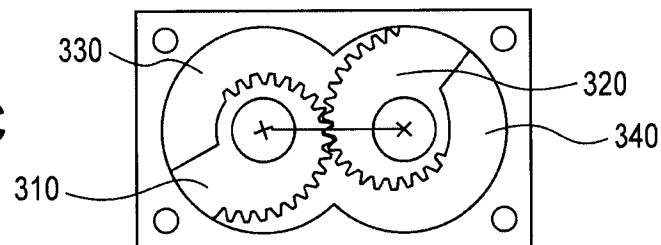


FIG. 3D

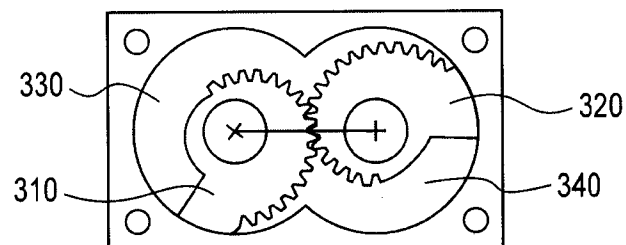


FIG. 3E

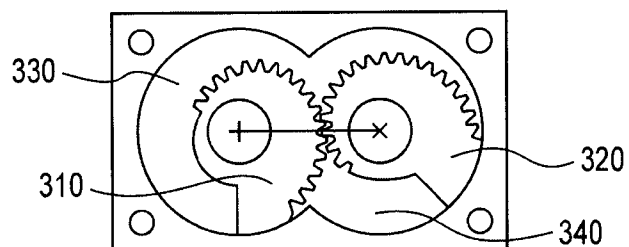
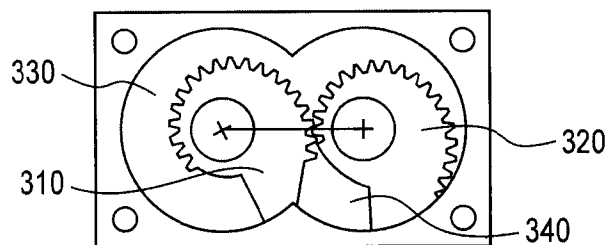


FIG. 3F



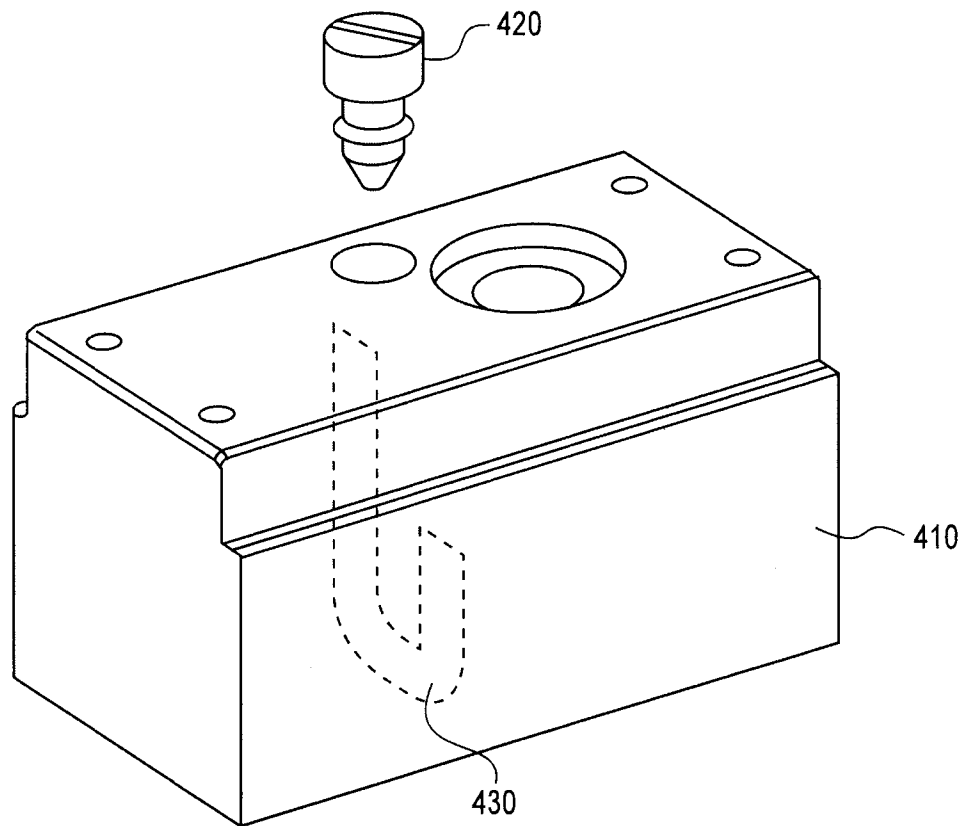


FIG. 4

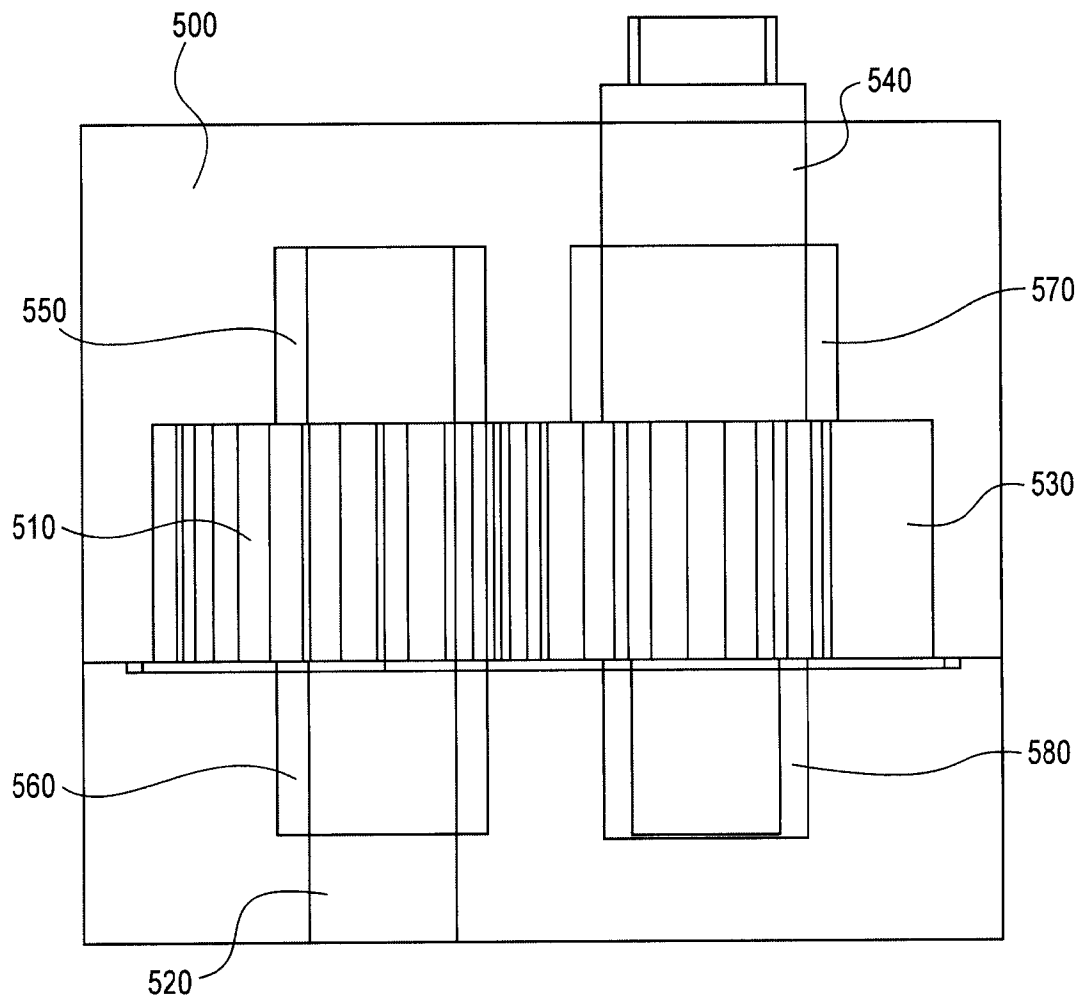


FIG. 5

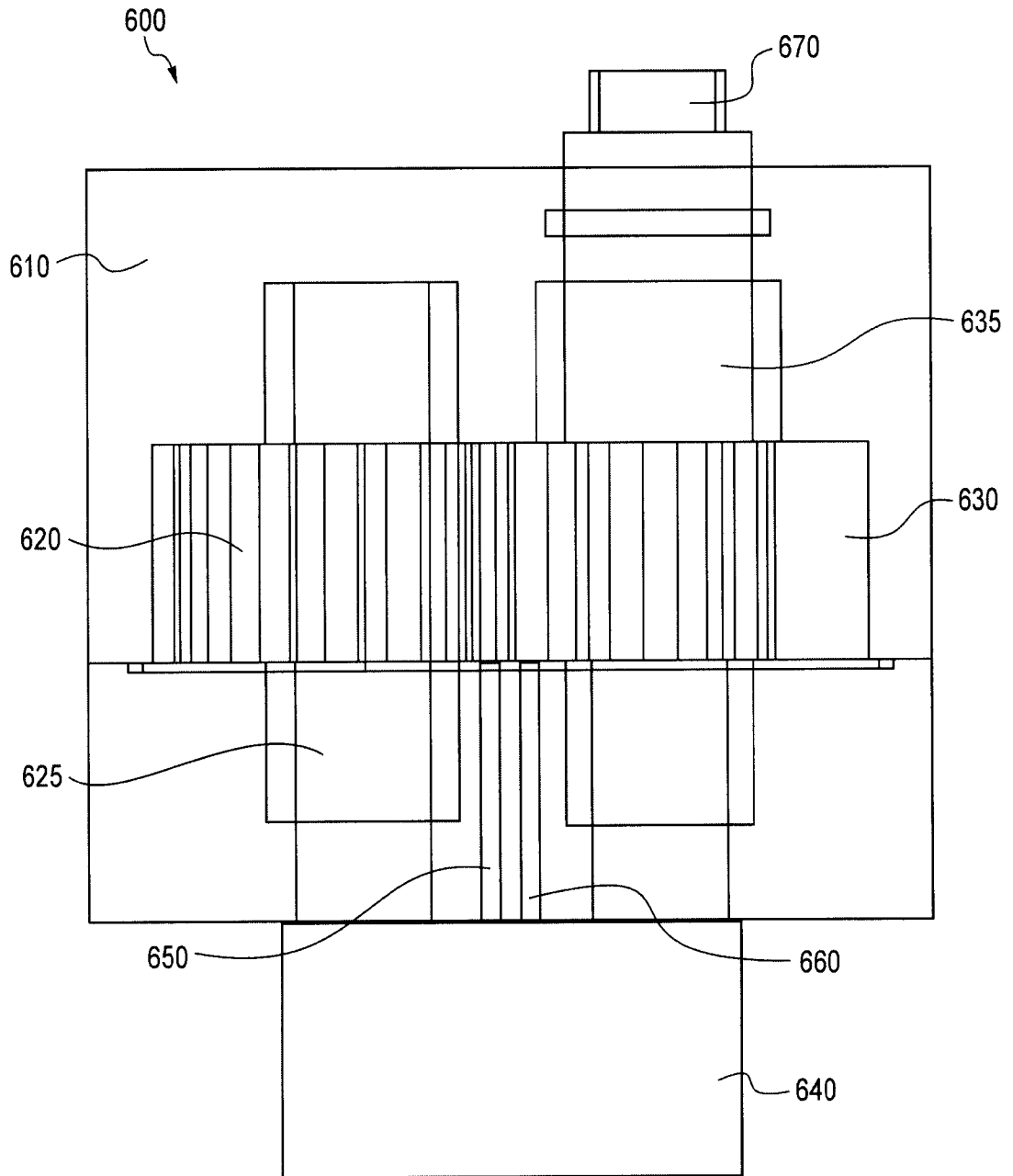


FIG. 6

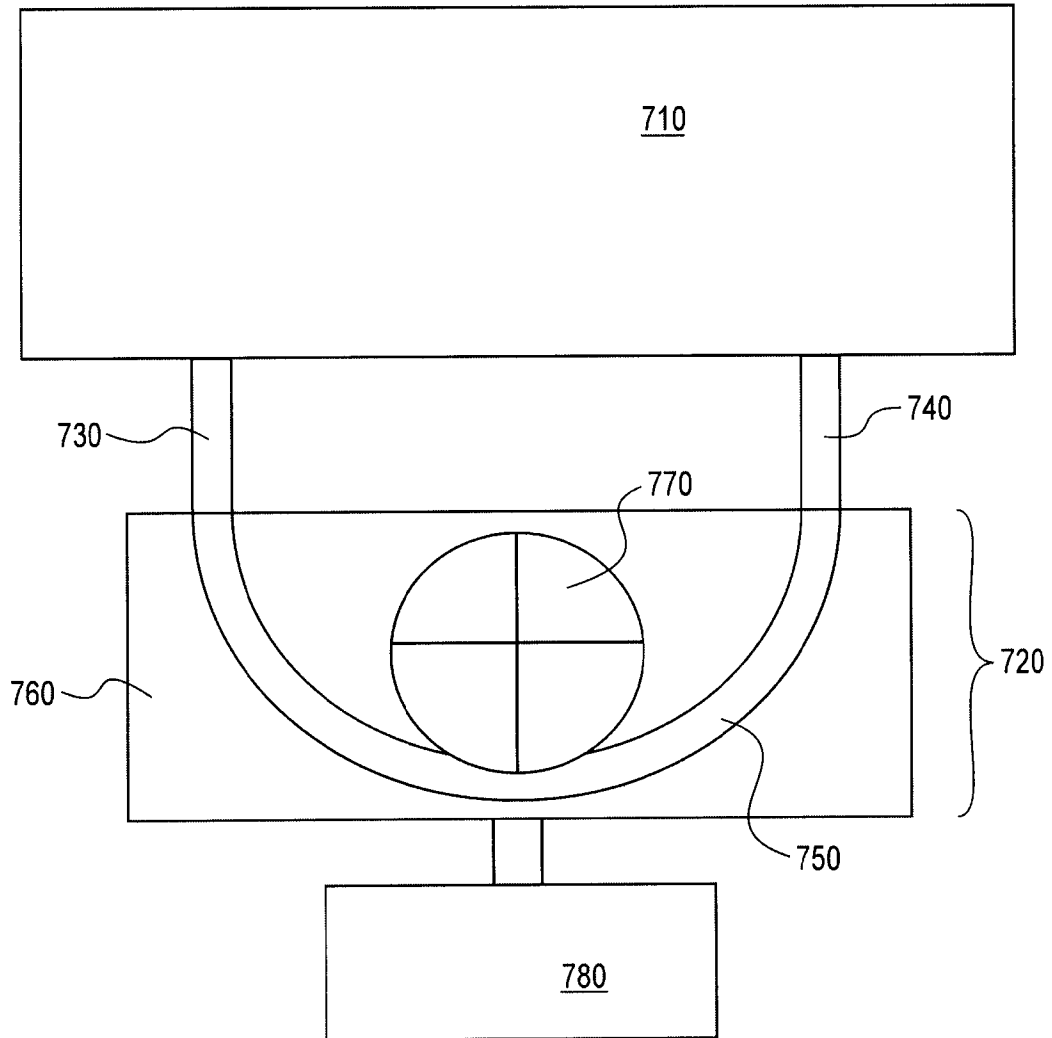


FIG. 7

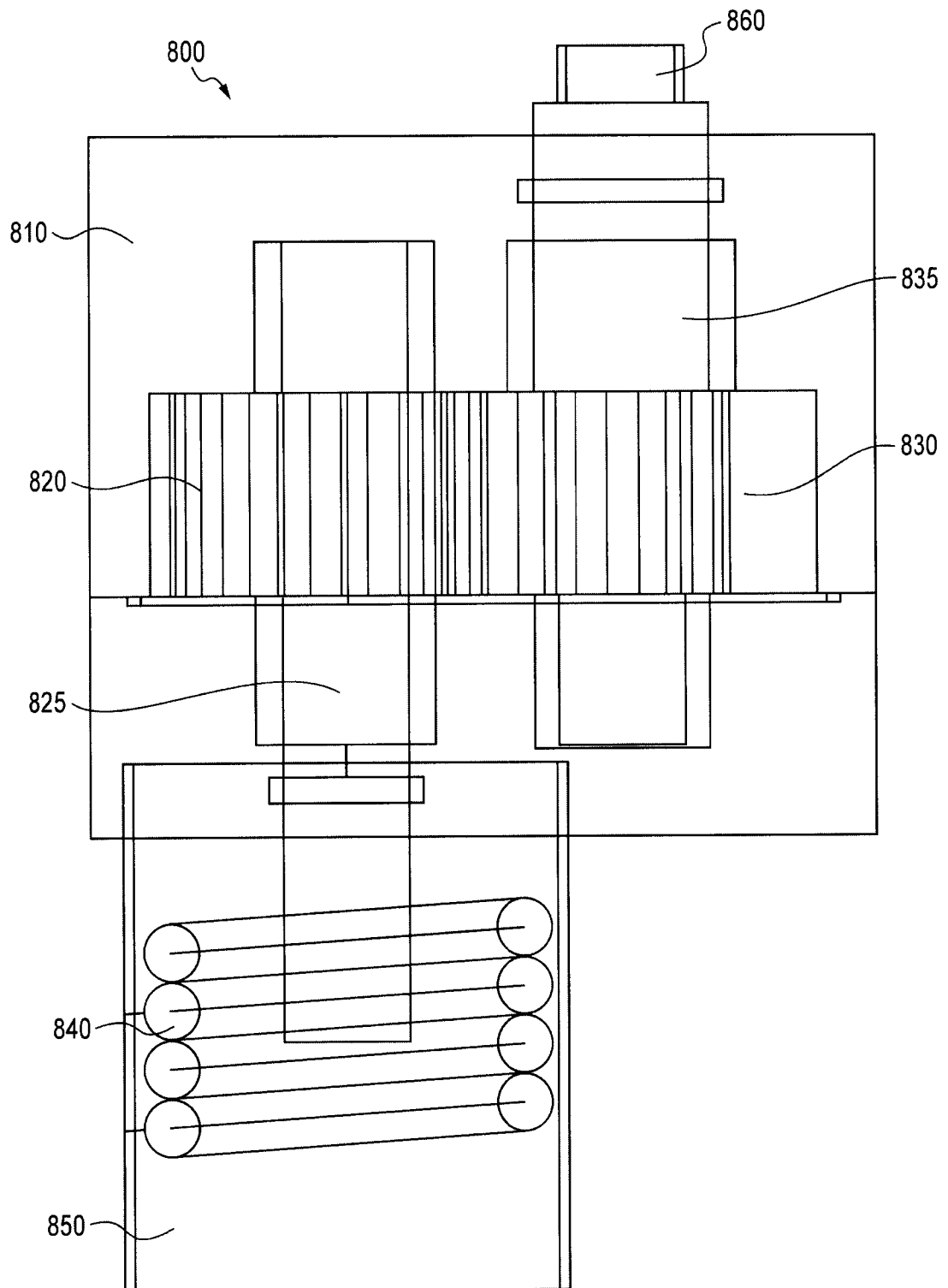


FIG. 8

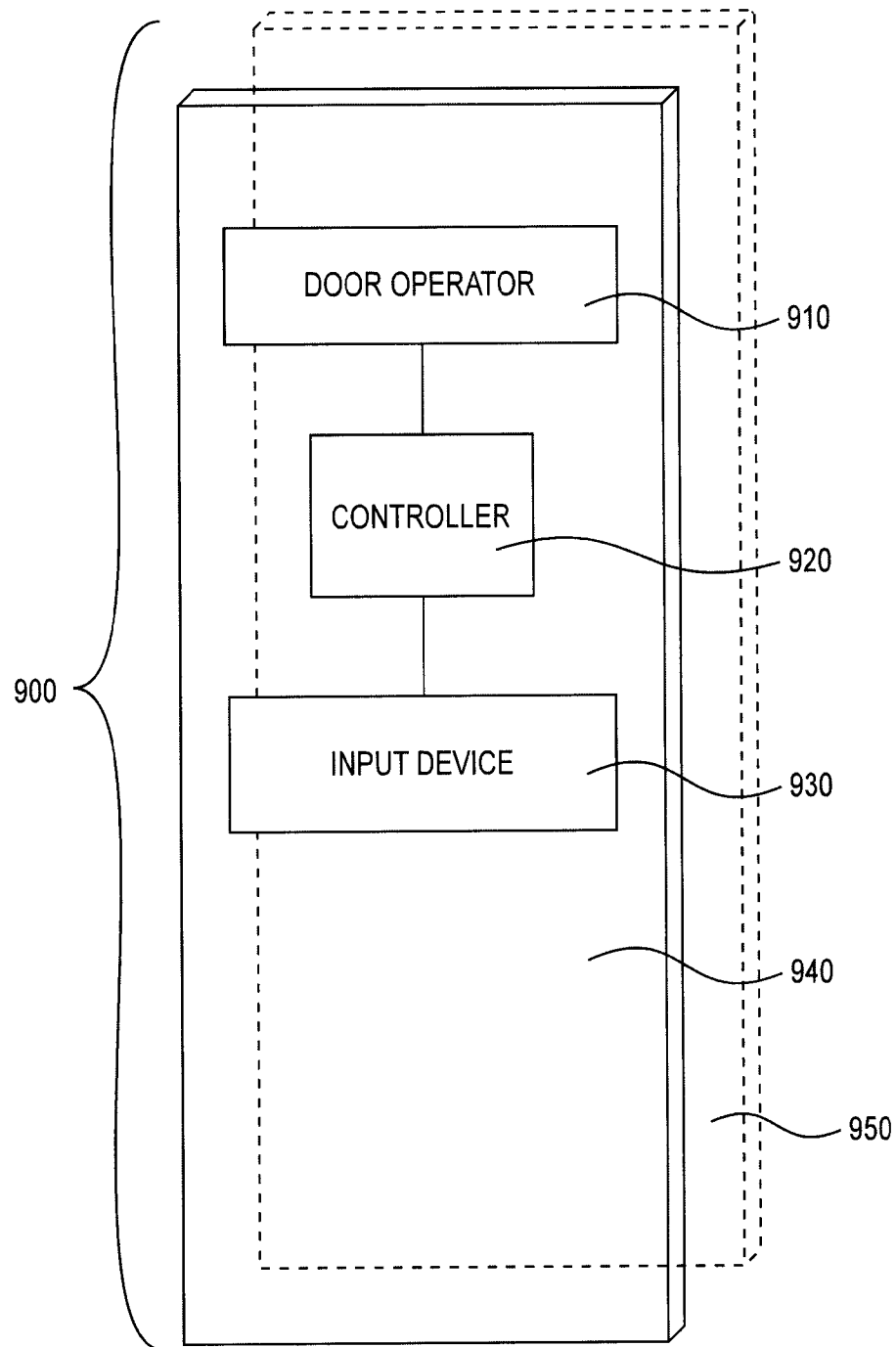


FIG. 9

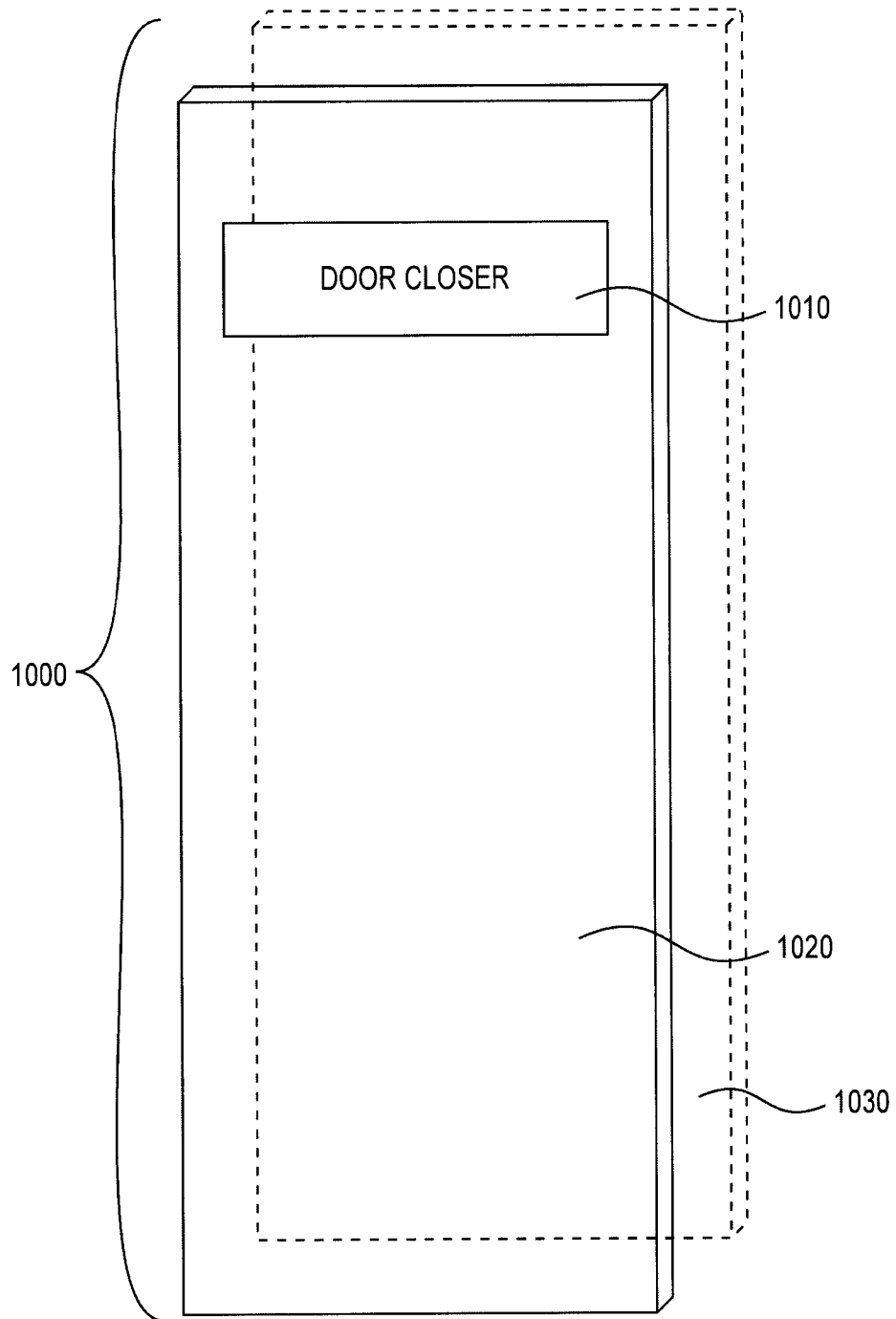


FIG. 10

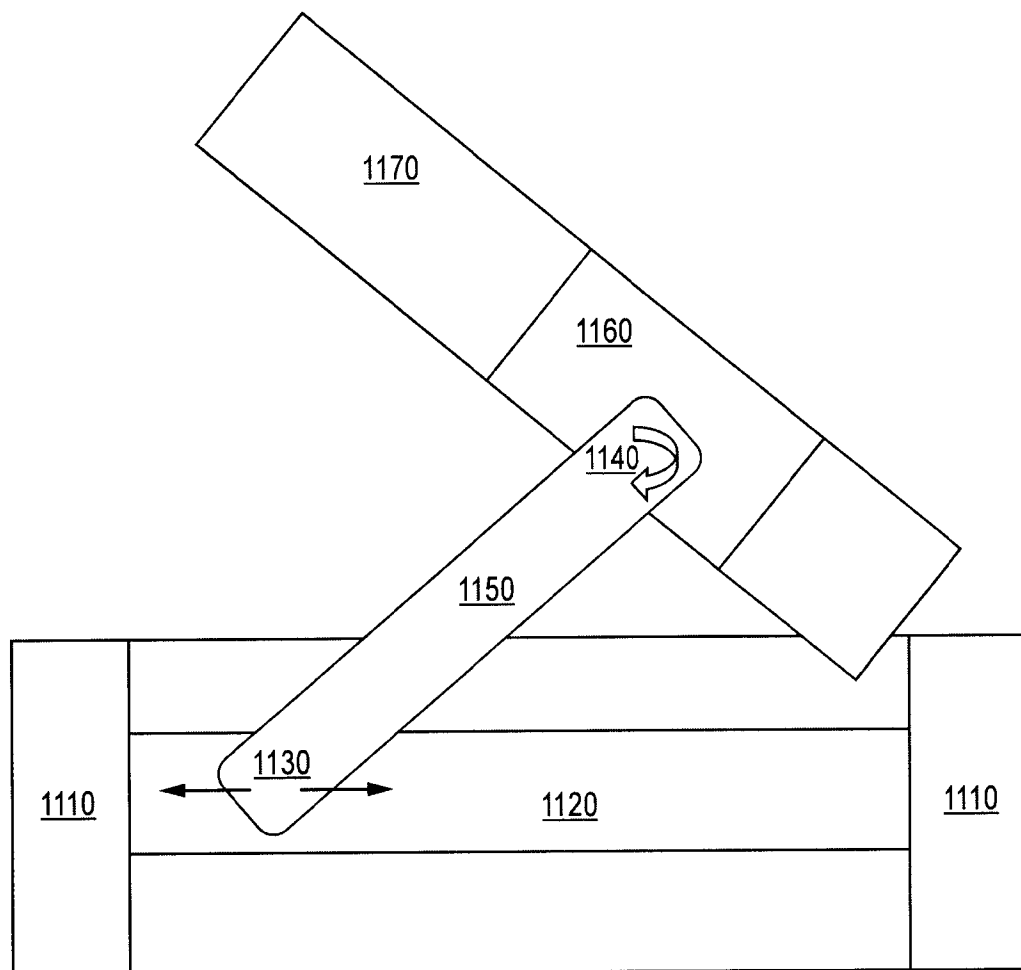


FIG. 11

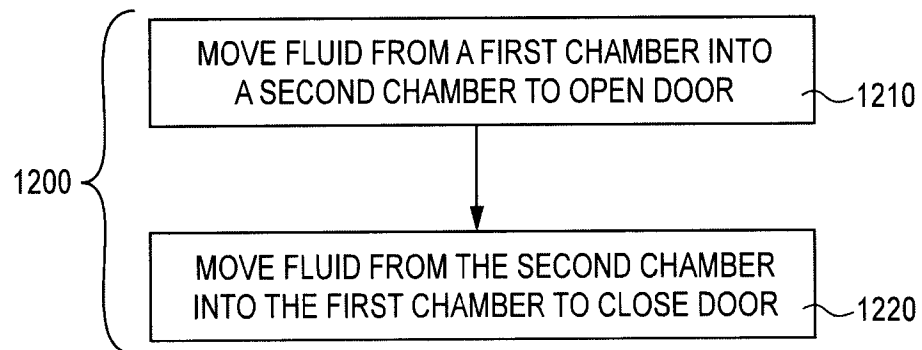


FIG. 12

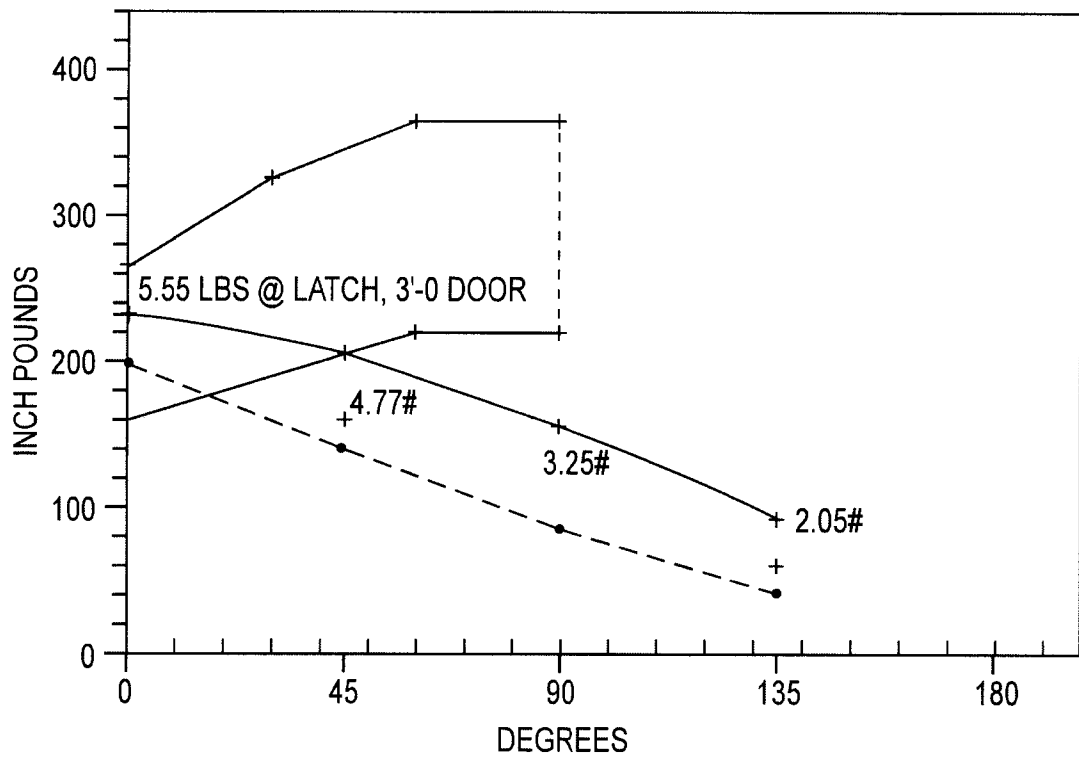


FIG. 13

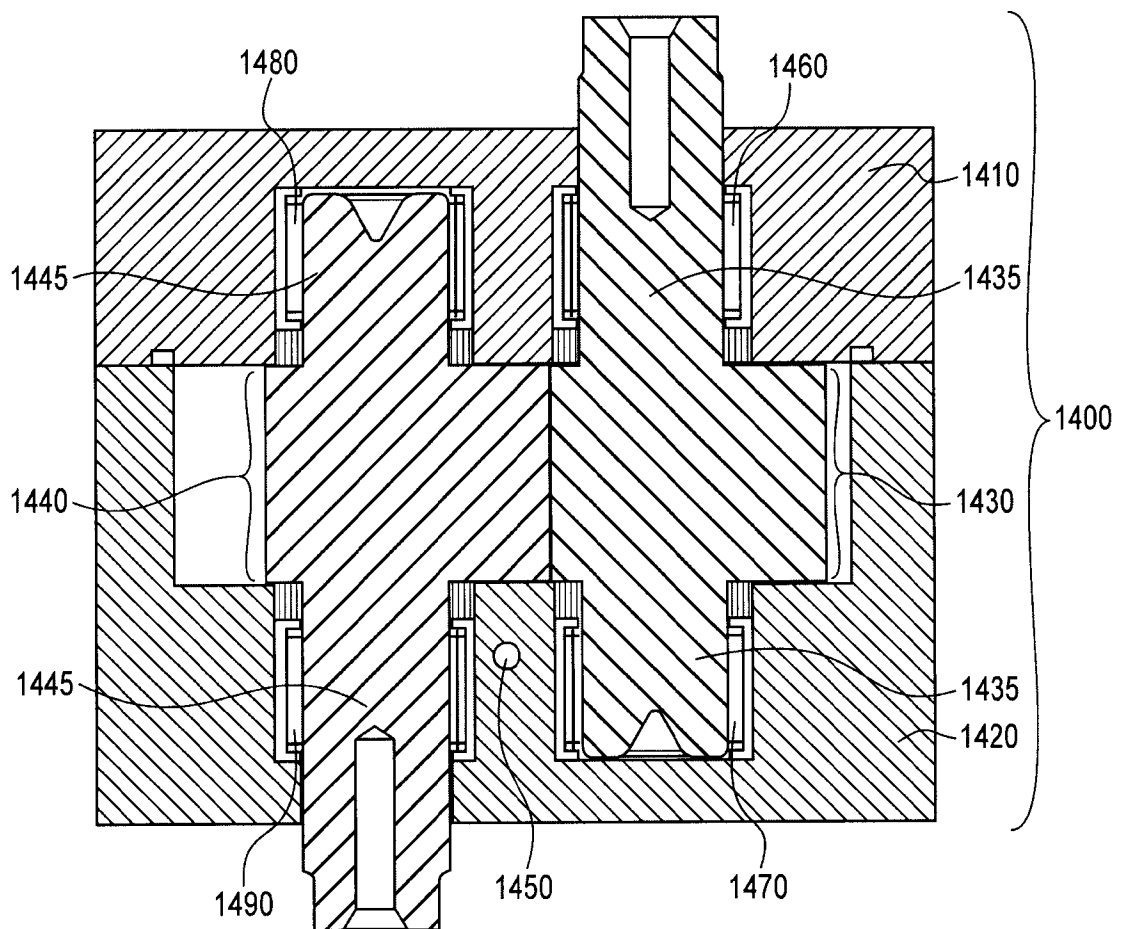


FIG. 14

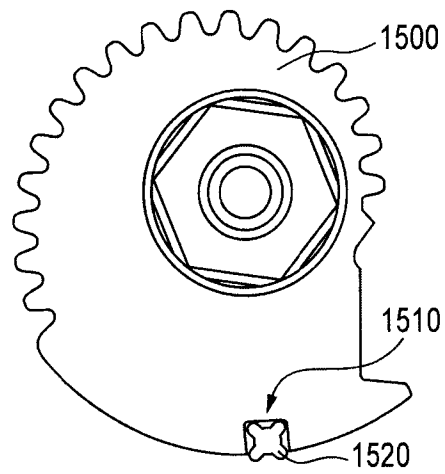


FIG. 15A

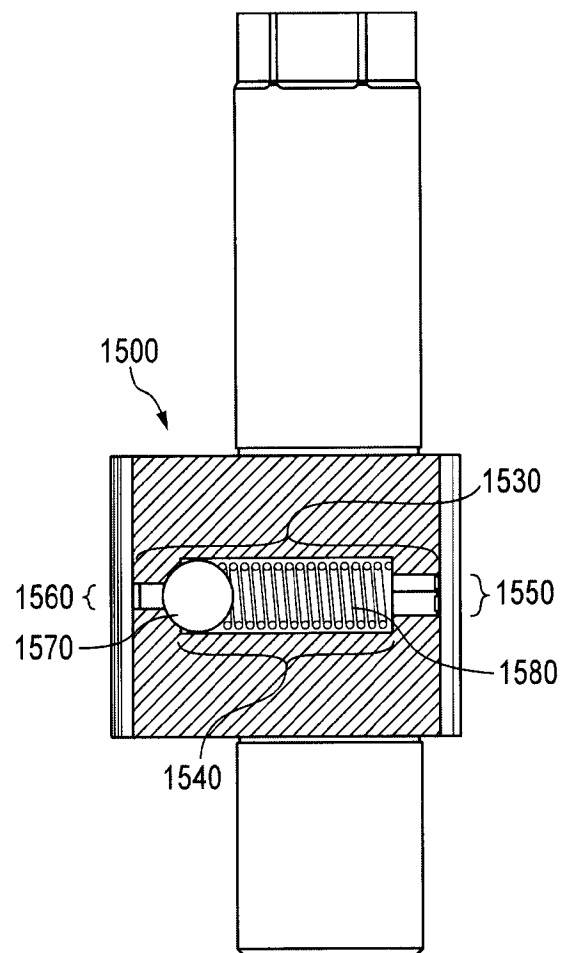


FIG. 15B

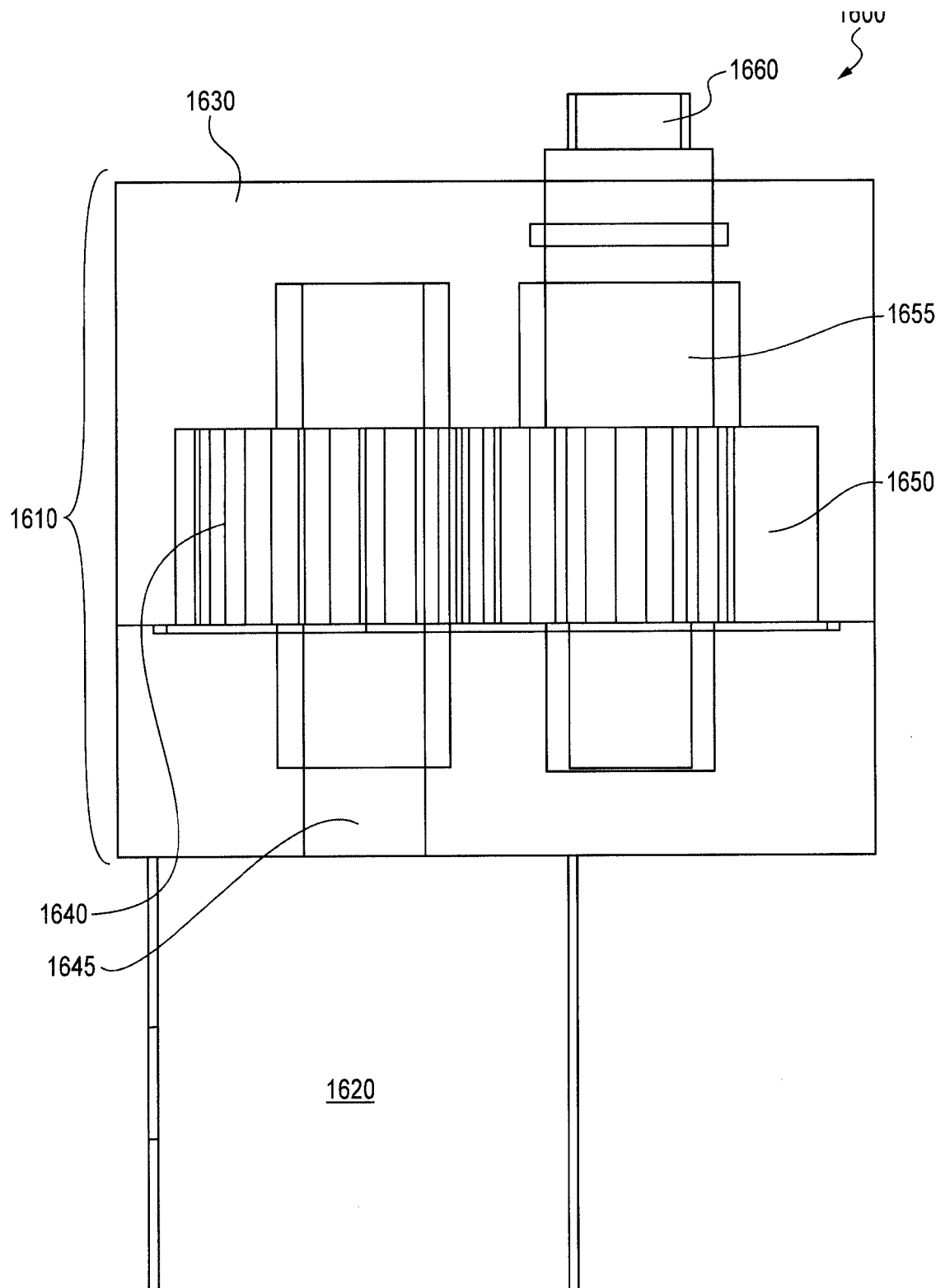


FIG. 16