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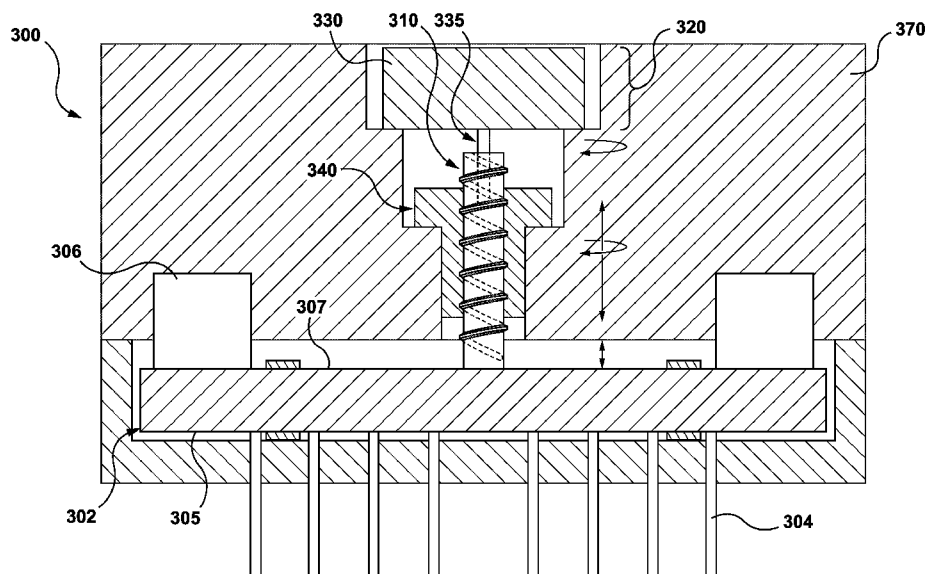
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FIG. 3A



(57) Abstract: An injection molding apparatus including a plurality of hot runner injection nozzles, each injection nozzle having a respective valve gate through which melt is injected into a mold cavity; a first plate disposed substantially perpendicular to the injection nozzles; a plurality of valve stems extending from a first surface of the first plate, each valve stem positioned in vertical alignment with a respective injection nozzle; a first actuator for moving the first plate bi-directionally along a first axis to cause at least one of the plurality of valve stems to move in a respective injection nozzle between an open position permitting flow of melt through a valve gate and a closed position blocking flow of melt; at least one plate position limiter limiting movement of the first plate relative to the injection nozzles; and a first drive controlling the at least one plate position limiter independently of the first actuator.

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SYSTEMS AND METHODS FOR CONTROLLING VALVE STEMS IN A HOT RUNNER-SYSTEM

TECHNICAL FIELD

[0001] The present disclosure relates to injection molding and, in particular, to valve-gated hot runner-systems. More specifically, systems and methods for controlling valve stems for use with valve gate nozzles of a hot runner-system are described herein.

BACKGROUND

[0002] Hot runner-systems are widely used in injection molding machines. A hot runner-system is an assembly of heated components which convey plastic melt from a machine nozzle into the cavities of an injection mold. The flow of plastic melt into a mold cavity can be controlled using gates. Two types of injection molding gates are generally known. In a thermal gate, plastic melt is forced through the hot runner-system under pressure and injected through an injection nozzle into a mold cavity via an opening, or gate. When the mold cavity is filled, the pressure to the hot runner-system is terminated. The plastic melt remaining in the hot runner-system is maintained in a molten or liquid state, while the plastic in the gate area cools and solidifies. This solidification results in formation of a cold, plastic “slug” in the gate area, which acts as an insulating barrier between the plastic in the cavity and the melt in the hot runner nozzle. During the subsequent injection cycle, injection pressure forces the solidified slug into the cavity, opening the gate.

[0003] A part that is molded using a thermal gate retains a vestige (“gate vestige”) at the gate interface. Where thermal gate vestige is undesirable or gate area cooling is difficult to control, mechanical gates, such as valve gates, may be used. In a valve gate arrangement, a valve stem extends into the internal flow channel of an injection nozzle. Through mechanical action, a valve stem cycles between an open position – in which plastic melt is allowed to flow into the mold cavity – and a closed position, in which the gate orifice is sealed and the plastic melt is prevented from flowing into the mold cavity. When the pressure to the hot runner-system is terminated, the

valve stem is moved to the closed position, and the tip of the valve stem blocks the mold opening until the next injection cycle. The valve stem can then be moved to the open position, and pressure applied to the hot runner-system forces plastic melt through the flow channel.

[0004] In certain valve-gated systems, profiling valve stem motion between the open and closed positions can be beneficial for system operation as a means to modulate melt flow. Some systems rely on precise intermediate positioning of valve stems to control material volume. Numerous applications may find improvements in gate vestige and molded part quality when the valve stem speed can be controlled (e.g. reducing stem speed as it approaches a gate) with respect to other injection molding functions, such as hold time, hold pressure, or cooling time.

[0005] Current solutions for controlling valve stem positions typically make use of electric actuators, driving a single valve stem or groups of stems connected through a stem plate, with motion control governed by servo (or other) motors. Such solutions aim to provide precise valve stem positioning control and in-process modification of operation parameters, without requiring a change in hardware.

[0006] This approach to valve stem actuation may pose some challenges to an effective operation of a hot runner-system. Managing the size of actuators and motors is one such challenge. Specifically, the footprint and shut-height of actuators and/or motors may restrict their positioning within an injection molding machine. In some cases, a load transmission assembly may be required to connect actuators to the valve stems, adding to system complexity and size.

[0007] Force transmission and control is another challenge. Due to the size/positioning constraints for motors and actuators in a hot runner-system, the level of available force for actuating valve stems, or stem plates, may be low. Moreover, the force transmitted by the actuators may be non-uniform across the valve stems. The limitations in force transmission may lead to yet another problem – the potential for stem plate deflection resulting from back pressure.

[0008] Thus, it would be advantageous to provide a solution for valve stem actuation that can be suitably integrated into high cavitation injection molding systems.

BRIEF DESCRIPTION OF DRAWINGS

[0009] Reference will now be made, by way of example, to the accompanying drawings which show example embodiments of the present application and in which:

[0010] FIG. 1 is a cross-sectional view of an example valve-gated hot runner-system;

[0011] FIG. 2 is a partial sectional view through a mold cavity with two hot runner injection nozzles, in accordance with an example embodiment of the present disclosure;

[0012] FIGS. 3A and 3B are partial cross-sectional schematic representations of an example hot runner-system in accordance with an embodiment of the present disclosure;

[0013] FIGS. 4A and 4B are partial cross-sectional schematic representations of another example hot runner-system in accordance with an embodiment of the present disclosure;

[0014] FIGS. 5A and 5B are partial cross-sectional schematic representations of another example hot runner-system in accordance with an embodiment of the present disclosure;

[0015] FIG. 6 shows a partial cross-sectional schematic representation of another example hot runner-system in accordance with an embodiment of the present disclosure;

[0016] FIG. 7 is a top view an example arrangement of gears and gear racks of the example hot runner-system of FIG. 6;

[0017] FIGS. 8A and 8B are partial cross-sectional schematic representations of another example hot runner-system in accordance with an embodiment of the present disclosure;

[0018] FIGS. 9A and 9B are partial cross-sectional schematic representations of another example hot runner-system in accordance with an embodiment of the present disclosure;

[0019] FIGS. 10A-10B are partial cross-sectional schematic representations of another example hot runner-system in accordance with an embodiment of the present disclosure;

[0020] Like reference numerals are used in the drawings to denote like elements and features.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0021] The present disclosure provides an injection molding machine which decouples the function of actuating valve stems of a valve-gated system from the function of controlling valve stem position. More specifically, the injection molding machine of the present disclosure provides an actuating mechanism for moving valve stems between open and closed configurations, and a control mechanism for limiting the range of positions of the valve stems relative to the injection nozzles. The valve stem actuating mechanism and the valve stem position control mechanism are independently controllable. The valve stems may be provided on a stem plate. In particular, a plurality of valve stems may be arranged on the same side of a stem plate such that the valve stems are actuated synchronously in their respective injection nozzles when the stem plate is actuated. Accordingly, the valve stem position control mechanism may be configured to restrict movement of the stem plate, rather than individual valve stems, relative to the injection nozzles.

[0022] In one aspect, the present disclosure describes an injection molding apparatus. The injection molding apparatus includes: a plurality of hot runner injection nozzles, each injection nozzle having a respective valve gate through which melt is injected into a mold cavity; a first plate that is disposed substantially perpendicular to the injection nozzles; a plurality of valve stems extending from a first surface of the first plate, each valve stem being positioned in vertical alignment with a respective injection nozzle; a first actuator for moving the first plate bi-directionally along a first axis, the first plate being movable to cause at least one of the plurality of valve stems to move in a respective injection nozzle between an open position permitting flow of melt through a valve gate and a closed position blocking flow of melt through the valve gate; at least one plate position limiter for limiting movement of the first plate relative to the injection nozzles; and a first drive for controlling the at least one plate position limiter independently of the first actuator.

[0023] In some implementations, the first drive may include a motor driving movement of the at least one plate position limiter.

[0024] In some implementations, the at least one plate position limiter may comprise one or more screws that are rotatably coupled to the motor, the one or more screws being disposed over a second surface of the first plate that is opposite to the first surface, and the motor may be configured to drive axial movement of at least one screw shaft along a respective screw shaft axis that is parallel to the first axis.

[0025] In some implementations, the one or more screws may comprise a plurality of screws that are positioned in spaced relation to each other.

[0026] In some implementations, the injection molding apparatus may include one or more nuts held in fixed spaced relation to the motor, wherein the motor may be configured to drive threaded rotation of the at least one screw shaft through a respective nut.

[0027] In some implementations, the injection molding apparatus may include a first gear drivingly coupled to the motor, wherein the first gear may be configured to engage the at least one screw shaft such that rotation of the first gear about a fixed first gear axis causes axial movement of the at least one screw shaft along a respective screw shaft axis.

[0028] In some implementations, the injection molding apparatus may include at least one second gear in threaded engagement with the at least one screw shaft, wherein the first gear may be configured to meshingly engage the at least one second gear such that rotation of the first gear about the first gear axis causes rotation of the at least one second gear about a respective second gear axis.

[0029] In some implementations, the injection molding apparatus may include at least one gear rack having a plurality of rack teeth on a bearing surface, wherein teeth of the first gear and teeth of the at least one second gear may meshingly engage the rack teeth on the bearing surface of the at least one gear rack.

[0030] In some implementations, the at least one plate position limiter may comprise a locking pin that is axially movable along a pin axis between an extended position and a retracted position, the pin axis being substantially perpendicular to the first axis, and the body of the first plate may define at least one opening on a proximal surface for receiving and retaining a first portion of the locking pin when the locking pin is in the extended position.

[0031] In some implementations, the first drive may be configured to apply a constant force to the locking pin in a first direction toward the proximal surface of the first plate.

[0032] In some implementations, the injection molding apparatus may include a cam follower fixedly secured to the body of the first plate, wherein the at least one plate position limiter may

comprise a cam making contact with the cam follower, the cam being axially movable along a cam shaft axis that is substantially perpendicular to the first axis.

[0033] In some implementations, the cam may comprise a ramp defining a sloped surface, the cam follower making contact with the sloped surface.

[0034] In some implementations, the injection molding apparatus may include: one or more rods coupled to the first plate, the rods being configured to move axially parallel to the first axis; and a brake assembly controllably applying a braking force to at least one of the rods.

[0035] In some implementations, the brake assembly may comprise at least one collet forming a collar around a respective one of the rods, wherein the motor may be configured to cause the at least one collet to exert a clamping force on the respective one of the rods.

[0036] In some implementations, the at least one plate position limiter may comprise a cross bar coupled to the motor, and the motor may be configured to drive translational movement of the cross bar to a first position in which the cross bar is positioned between and in pressing engagement against two adjacent collets.

[0037] In some implementations, the first actuator may comprise one or more actuators for causing axial movement of the one or more rods.

[0038] In some implementations, the at least one plate position limiter may comprise a cam that is rotatably coupled to the motor, the cam making contact with a second surface of the first plate that is opposite to the first surface, and the motor may be configured to drive rotation of the cam about a cam shaft axis that is substantially parallel to and offset from the second surface of the first plate.

[0039] In some implementations, the injection molding apparatus may include a cam shaft coupled to the motor at a first end and to the cam at a second opposite end and a cam shaft bearing held in fixed spaced relation to the motor, wherein the motor may be configured to drive rotation of the cam shaft through the cam shaft bearing.

[0040] In some implementations, the valve stems may be positioned in spaced relation to each other on the first surface of the first plate.

[0041] In some implementations, the first actuator may comprise at least one of a pneumatic cylinder and a hydraulic cylinder.

[0042] In some implementations, the at least one plate position limiter may comprise one or more first stop pads and one or more second stop pads, the first stop pads and the second stop pads being positioned on opposite sides of the first plate.

[0043] In some implementations, the one or more first stop pads may be positioned on the first surface and the one or more second stop pads are positioned on a second surface of the first plate that is opposite to the first surface.

[0044] In some implementations, the first plate may be disposed between a first interior wall and a second interior wall opposite to the first interior wall, and the one or more first stop pads may be positioned on the first interior wall and the one or more second stop pads may be positioned on the second interior wall.

[0045] In some implementations, the controller may be configured to move at least one of the first stop pads and the second stop pads axially parallel to the first axis.

[0046] In some implementations, the injection molding apparatus may include one or more proximity sensors for detecting a vertical position of the first plate, wherein the at least one of the first stop pads and the second stop pads may be moved in response to the proximity sensors detecting a change in distance between the first plate and at least one of the first interior wall and the second interior wall.

[0047] In another aspect, the present disclosure describes a method of operating an injection molding apparatus. The injection molding apparatus includes: a plurality of hot runner injection nozzles, each injection nozzle having a respective valve gate through which melt is injected into a mold cavity; a first plate having a plurality of valve stems extending therefrom, the first plate being disposed substantially perpendicular to the injection nozzles; and at least one plate position limiter for limiting movement of the first plate relative to the injection nozzles. The method includes: coupling a first actuator to the first plate for moving the first plate along a first axis; coupling a first drive to the at least one position limiter; and controlling the first drive independently of the first actuator.

[0048] Other example embodiments of the present disclosure will be apparent to those of ordinary skill in the art from a review of the following detailed descriptions in conjunction with the drawings.

[0049] The solutions for valve stem actuation that are described herein may allow for efficiency gains in force transmission and system size, while providing effective valve stem position control. In particular, space efficient actuators may be used for the main stem plate drive and the valve stem position controller. For example, the valve stem position controller may include an actuator for driving one or more shafts or actuating a cam that interferes with the movement of a stem plate. The force from the main stem plate drive would be accepted by the cam or other load accepting feature, transferring load away from the actuator. As a result of the load isolation, the actuator may only need to be sized to accommodate the cam movement, allowing for smaller actuator/motor selection for the injection molding system.

[0050] Reference is first made to FIG. 1, which is a partial cross-sectional view of an example hot runner-system 10. The hot runner-system 10 includes a plurality of valve stems 12. The hot runner-system 10 is used to transfer plastic melt from a machine nozzle to mold cavities 46 defined by cooperating mold plates 48 and 49. The hot runner-system 10 includes a manifold 16 for distributing heated plastic resin to internal flow channels 24 of nozzles 22. The manifold 16 is mounted between a manifold plate 28 and a backing plate 30.

[0051] In order to maintain the plastic resin in liquid form in the internal flow channels 24 of the nozzles 22, a nozzle heater 32 is operatively mounted to the nozzle 22. The nozzle 22 has internal flow channels 24 that are in fluid communication with the internal flow channels 18 of the manifold 16, and/or manifold bushing or valve bushing (“valve bushing 54”). The nozzle 22 injects plastic melt through a nozzle tip 34 into the mold cavities 46, thereby producing plastic parts when the plastic solidifies. In some embodiments, rather than a valve bushing 54, a bore may be defined through the manifold 16 and the nozzle 22 has internal flow channels 24 in fluid communication with the bore or internal flow channels 18 of the manifold 16.

[0052] In FIG. 1, cylinders (e.g. pneumatic, hydraulic) are used to actuate the valve stems 12 between an open position 42 and a closed position 40. The transition to the closed position 40 includes termination of the injection pressure to the hot runner-system 10 and downward movement of the valve stem 12 such that a valve stem tip 38 blocks an opening 44 in the gate. This

prevents plastic melt from flowing from the internal flow channels 24 of the nozzle 22 in the hot runner-system 10 to the mold cavities 46. In the open position 42, injection pressure to the hot runner-system 10 is initiated and the valve stem 12 is moved upward so that the valve stem tip 38 is removed from the opening 44 in the gate. This allows plastic melt to flow from the internal flow channels 24 of the nozzle 22 to the mold cavity 46.

[0053] FIG. 2 is a schematic partial section view through large mold cavity 100 with two hot runner injection nozzles 120. Each nozzle 120 includes a valve gate 140 and a valve stem 160 that is movable in the nozzle 120. The valve stem 160 is movable axially between an open position, which permits flow of melt through the valve gate 140 into the mold cavity 100, and a closed position, which blocks flow of melt through the valve gate 140.

[0054] Reference is now made to FIGS. 3A-3B, which are partial cross-sectional schematic representations of an example hot runner-system 300. The hot runner-system 300 may be integrated in a runner-system of an injection molding apparatus. In particular, the hot runner-system 300 may be incorporated into a valve-gated hot runner injection molding apparatus. The injection molding apparatus may include, for example, a plurality of vertically oriented hot runner injection nozzles (not shown) and a mold defining a mold cavity. Each injection nozzle may have a respective valve gate through which plastic resin/melt is injected into the mold cavity.

[0055] The hot runner-system 300 includes a first plate 302. The first plate 302 is disposed substantially perpendicular to the injection nozzles of the injection molding apparatus. In particular, where the injection nozzles are vertically oriented, the first plate 302 may be disposed substantially horizontally.

[0056] The hot runner-system 300 also includes a plurality of valve stems 304. The valve stems 304 extend from a first surface 305 of the first plate 302. In particular, as in the example of FIG. 3A, the valve stems 304 may be positioned in spaced relation to each other on the first surface 305. Each valve stem 304 is positioned in axial alignment with a respective injection nozzle of the injection molding apparatus. More specifically, each valve stem 304 may be disposed over a respective injection nozzle such that it is generally aligned with an internal flow channel of the injection nozzle. An internal flow channel of an injection nozzle may, for example, be a vertically oriented cavity defined by the inner walls of the injection nozzle.

[0057] A first actuator 306 is configured to move the first plate 302 along a first axis. In particular, the first actuator 306 may move the first plate 302 along a vertical axis. The first actuator may, for example, be a pneumatic cylinder, a hydraulic cylinder, a pneumatic bladder, or any other suitable actuator type. The movement of the first plate 302 causes at least one of the plurality of valve stems 304 to move in a respective injection nozzle. As the valve stems 304 are axially aligned with the injection nozzles, moving the first plate 302 up or down causes at least one of the valve stems 304 to traverse the internal flow channel of a respective injection nozzle. Specifically, a valve stem 304 may move axially in an injection nozzle between an open position that permits flow of melt through a valve gate of the injection nozzle and a closed position that blocks flow of melt through the valve gate. In particular, a valve stem 304 may be moved from a position in which it does not seal (i.e. close off) a gate orifice to another position in which it does seal the gate orifice.

[0058] Accordingly, the first actuator 306 may be controlled to move the first plate 302 a sufficient distance in order for the at least one valve stem 304 to reach a closed position. The control parameters for moving the first plate 302 may include, for example, a length of the at least one valve stem, a height of the internal cavity of an injection nozzle, and a relative distance between a tip of the at least one valve stem and the injection nozzle.

[0059] The hot runner-system 300 includes at least one plate position limiter 310. The plate position limiter 310 serves to interfere with or limit the movement of the first plate 302. Specifically, the plate position limiter 310 acts on the first plate 302 to constrain its movement relative to the injection nozzles. A first drive 320 is provided for controlling the at least one plate position limiter 310. The first drive 320 is controlled independently of the first actuator 306. That is, the first plate 302 is actuated by a mechanism that is different from and operated independently of a control mechanism for controlling the plate position limiter 310.

[0060] The hot runner-system 300 of FIGS. 3A-3B is an example system for valve stem actuation and position control. The hot runner-system 300 includes a motor 330. The first drive 320 includes the motor 330 which drives movement of the at least one plate position limiter 310. In the example of FIGS. 3A-3B, the plate position limiter is a screw. The screw is disposed over a second surface 307 of the first plate 302 that is opposite to the first surface 305. The screw is rotatably coupled to the motor 330, and the motor 330 is configured to drive axial movement of the screw along a

vertical screw shaft axis. That is, the screw is caused to move axially either away from or toward the first plate 302.

[0061] In at least some embodiments, the hot runner-system 300 may include a (screw) nut 340 which is held in fixed spaced relation to the motor 330. In FIG. 3A, the nut 340 is seated on a shoulder defined by the inner walls of a cavity in the back plate 370. The vertical location of the shoulder within the cavity allows the nut 340 to be fixedly position in spaced relation to the motor 330.

[0062] The motor 330 is configured to drive threaded rotation of the screw shaft of screw through the nut 340. As the motor 330 rotates a motor shaft 335 about a motor shaft axis, the motor shaft 335 engages the screw shaft and rotates it. A hex-shaped interface between the motor shaft and screw shaft allows axial translation of the screw shaft during its rotation. The screw shaft rotates within the nut 340, which advances the screw shaft axially along a (vertical) screw shaft axis.

[0063] When the screw shaft has advanced sufficiently far vertically, a first end of the screw interfaces with the first plate 302 and acts as a linear position control. In particular, the screw may be configured to push against the second surface 307 to provide a holding force for the first plate 302. That is, after the actuator 306 moves the first plate 302 to a first position, thereby moving the valve stems relative to the injection nozzles, the at least one plate position limiter 310 is configured to maintain that first position of the first plate 302. The screw (or more generally, the plate position limiter) may retract after an intermediate vertical position of the first plate 302 is reached. The vertical limit of movement for the first plate 302 is set at different levels in the examples of FIGS. 3A and 3B. Specifically, the upper limit of vertical movement of the first plate 302 is set at a lower level in FIG. 3A due to the further (downward) advancement of the plate position limiting screw.

[0064] The presence and positioning of the nut 340 allows any back pressure exerted by the first plate 302 to be absorbed by the nut. As the nut 340 is maintained away from the motor 330, load is transferred to a component other than the actuator/motor 330, which may allow for selection of a suitably small or lightweight motor for the hot runner-system 300.

[0065] In at least some embodiments, the hot runner-system 300 may include one or more processors that are coupled to at least one of the first drive 320 and the first actuator 306. The one or more processors may be configured to control operations of the first drive 320 and the first

actuator 306. A single processor may control operations for both the first drive 320 and the first actuator 306, or the first drive 320 and the first actuator 306 may each be controlled by a respective processor. The processors may obtain operating instructions for the first drive 320 and the first actuator 306, either as input or by accessing a storage medium (e.g. memory) that is coupled to the processors. A processor that is coupled to the actuator 306 may be configured to control a translational movement (e.g. speed, distance, direction) of the first plate 302 by the actuator 306. A processor that is coupled to the drive 320 may be configured to control the motor 330 of drive 320.

[0066] Another hot runner-system 400 is illustrated in FIGS. 4A-4B. The hot runner-system 400 may be integrated in a runner-system of an injection molding apparatus. In particular, the hot runner-system 400 may be incorporated into a valve-gated hot runner injection molding system. In particular, the hot runner-system 400 may be incorporated into a valve-gated hot runner injection molding apparatus. The injection molding apparatus may include, for example, a plurality of vertically oriented hot runner injection nozzles (not shown) and a mold defining a mold cavity. Each injection nozzle may have a respective valve gate through which plastic resin/melt is injected into the mold cavity. The hot runner-system 400 provides a stem position control mechanism for limiting movement of valve stems relative to injection nozzles of the injection molding apparatus.

[0067] The hot runner-system 400 includes a first plate 402, a first actuator 406 for moving the first plate 402 axially, a plurality of valve stems 404 extending vertically from the first plate 402, at least one plate position limiter for limiting movement of the first plate 402 relative to the injection nozzles, and a first drive 420 which controls the at least one plate position limiter. The first drive 420 includes a motor 430 and a first gear 434 that is drivingly coupled to the motor 430. The first gear 434 is configured to engage a screw shaft of at least one screw 410 such that rotation of the first gear 434 about a fixed first gear axis causes axial movement of the at least one screw shaft along a respective screw shaft axis. As the motor 430 rotates a motor shaft 432 and gear about a motor shaft axis, the gear may engage the screw shaft to rotate it. The screw shaft, in turn, rotates within a nut 440 which advances the screw shaft axially along a screw shaft axis. A first end of the screw 410 interfaces with the first plate 402 and acts as a linear position control.

[0068] In some embodiments, the hot runner-system 400 may include a second gear 412 in threaded engagement with the shaft of screw 410. The first gear 434 may be configured to engage

(e.g. meshingly engage) the second gear 412, such that rotation of the first gear 434 about its own vertical axis causes rotation of the second gear 412. Due to the threaded interface between the screw 410 and second gear 412, the shaft of screw 410 may advance axially along its own screw shaft axis. For example, the rotation of second gear 412 may cause the screw shaft to rotate within both the second gear 412 and nut 440, allowing the screw 410 to move axially. In the example of FIGS. 4A and 4B, the vertical limit of movement for the first plate 402 is set at different levels by virtue of the vertical position of the screw shaft end. Specifically, the upper limit of vertical movement of the first plate 402 is set at a lower level in FIG. 4A due to the further (downward) advancement of the plate position limiting screw 410.

[0069] More generally, the gear arrangement of FIGS. 4A-4B can be extended to include a plurality of gears that are in threaded engagement with multiple screws. That is, a plurality of screw shafts may be grouped together by use of mating gear arrangements that are in threaded engagement with the screws so that the screw shafts can be actuated together.

[0070] One such example of the use of an arrangement of multiple gears for plate position limiter control is illustrated in FIGS. 5 and 6. The hot runner 500 includes a first plate 502, a plurality of valve stems 504 extending vertically from the first plate 502, and a first actuator 506 for moving the first plate 502 vertically. The hot runner 500 also includes a first gear 534, two second gears 512, and at least one gear rack 550. The gear rack 550 has a plurality of rack teeth 536 defined on a bearing surface 538. The teeth of the first gear 534 and teeth of the second gears 512 meshingly engage the rack teeth 536 on the bearing surface 538 of the gear rack 550. As the motor 530 rotates the motor shaft 532 and the first gear 534 about the motor shaft axis, the first gear 534 engages the rack teeth 536 and causes translation of the gear rack 550. In particular, the gear rack 550 is slidably engaged with the first gear 534, such that rotation of the first gear 534 in a clockwise direction causes translation of the gear rack 550 in a first direction and rotation of the first gear 534 in a counter-clockwise direction causes translation of the gear rack 550 in a second direction opposite to the first direction. The rack teeth 536 engage the second gears 512 to cause them to rotate and advance the screw shafts in an axial direction along their respective screw shaft axis. The threaded rotation of the screw shafts through the second gears 512 and nuts 540 is similar to that described with reference to FIGS. 4A-4B. Specifically, the rotation of one of the second gears 512 causes a corresponding screw shaft to rotate within said second gear 512 and nut 540, allowing the screw

to move axially. The direction of rotation (i.e. clockwise or counter-clockwise) of the second gear 512 determines the direction of movement of the screw (either vertically up or down).

[0071] Reference is now made to FIGS. 7A-7B, which are partial cross-sectional schematic representations of an example hot runner-system 700. The hot runner-system 700 may be integrated in a runner-system of an injection molding apparatus. In particular, the hot runner-system 700 may be incorporated into a valve-gated hot runner injection molding system, having a plurality of vertically oriented hot runner injection nozzles and a mold defining a mold cavity.

[0072] The hot runner-system 700 includes a stem plate 702, a plurality of valve stems 704 extending vertically from the stem plate 702, and a first actuator 706 for moving the stem plate 702 vertically. In the hot runner-system 700, a brake system is implemented for controlling the movement of the stem plate 702. More specifically, brakes are provided in the hot runner-system 700 for engaging shafts (e.g. rods) that are affixed to the body of the stem plate 702. The brakes may be engaged, for example, to prevent the stem plate 702 from moving vertically (or beyond a threshold upper and/or lower level). That is, the brakes may facilitate maintaining the stem plate 702 at one or more predetermined vertical positions.

[0073] In the example illustrated in FIG. 7A, the hot runner-system 700 includes two rods 710 that are coupled to the stem plate 702. The rods 710 are configured to move vertically. For example, the rods 710 may move axially along a vertical rod shaft axis, and through a nut. The hot runner-system 700 also includes a brake assembly 720 for controllably applying a braking force to at least one of the rods 710.

[0074] In at least some embodiments, the brake assembly 720 may include at least one collet 722, at least one taper collar 724 surrounding each of the at least one collet 722, and one or more shaft guides 740 surrounding rods 710. A collet 722 forms a collar around one of the rods 710. In FIG. 7A, two collets 722 are provided, each collet 722 forming a collar around a respective one of the rods 710. That is, each rod 710 moves through a bore defined a collet 722. A controller, and in particular the motor 730, may be configured to cause the at least one collet 722 to exert a clamping force on the respective one of the rods 710.

[0075] In the hot runner-system 700, the plate position limiter is a cross bar 750 that is drivingly coupled to the motor 730. The motor translates the cross bar 750 to engage with adjacent collets

722. More specifically, the motor 730 is configured to drive translational (i.e. vertical) movement of the cross bar 750 to a first position in which the cross bar 750 is positioned between and in pressing engagement against two adjacent collets 722. When the cross bar 750 is moved to the first position, it may slide in the space between the two adjacent collets 722 and form a friction fit with both collets. In particular, the cross bar 750 may exert a pressing force against exterior surfaces of both collets. This may cause the collets to clamp against the rods 710, preventing their movement and, consequently, the vertical movement of the stem plate 702.

[0076] FIG. 7C shows a variant of hot runner-system 700 in which the rods 710 themselves are actuated by the first actuators 706. That is, the actuators for moving the stem plate 702 vertically actuate the rods 710 along their respective rod shaft axes. In the hot runner-system 700, the rods are fixedly secured to the stem plate 702 and, consequently, vertical movement of the rods 710 results in corresponding movement of the stem plate 702. As seen in FIG. 7C, the actuators 706 are positioned atop the rods 710, and drive the vertical movement of the rods 710.

[0077] Reference is now made to FIGS. 8A-8B, which are partial cross-sectional schematic representations of an example hot runner-system 800. The hot runner-system 800 may be integrated in a runner-system of an injection molding apparatus. In particular, the hot runner-system 800 may be incorporated into a valve-gated hot runner injection molding system, having vertically oriented injection nozzles.

[0078] The hot runner-system 800 includes a stem plate 802, a plurality of valve stems 804 extending vertically from the stem plate 802, and a first actuator 806 for moving the stem plate 802 vertically. In the hot runner-system 800, a cam 810 acts as a plate position limiter. The cam 810 is rotatably coupled to the motor 830, and makes contact with a second surface 807 of the stem plate 802 that is opposite to the first surface 808 from which extend the plurality of vertically oriented valve stems. The motor 830 is configured to drive rotation of the cam 810 about a cam shaft axis 801 that is substantially parallel to and offset from the second surface 807 of the stem plate 802.

[0079] The hot runner-system 800 may also include a cam shaft 812 that is coupled to the motor 830, via a motor shaft 832, at a first end and to the cam 810 at a second opposite end, as well as a cam shaft bearing 840 which may be held in fixed spaced relation to the motor 830. The cam shaft

bearing 840 may, in some embodiments, serve to transfer load away from the motor 830 in the hot runner-system 800.

[0080] The motor 830 is configured to drive rotation of the cam shaft 812 through the cam shaft bearing 840. As the cam 810 is rotated about the cam shaft axis 801, the body of stem plate 802 acts as a cam follower. In particular, the rotational motion of the cam 810 results in translational (i.e. vertical) movement of the stem plate 802. The motor 830, which drives the rotation of cam 810, can be controlled such that a rotational position of the cam 810 can be maintained to hold the stem plate 802 at a desired vertical position. FIGS. 8A and 8B show two different rotational positions of the cam 810 during its rotation, and the resulting vertical positioning of the stem plate 802. In particular, two different front views of the cam 810 along the cam shaft axis 801 are illustrated in FIGS. 8A and 8B (labelled as “View 1” and “View 2”).

[0081] Reference is now made to FIGS. 9A-9B, which are partial cross-sectional schematic representations of an example hot runner-system 900. The hot runner-system 900 may be integrated in a runner-system of an injection molding apparatus. In particular, the hot runner-system 900 may be incorporated into a valve-gated hot runner injection molding system, having a plurality of vertically oriented injection nozzles interfacing with one or more mold cavities.

[0082] The hot runner-system 900 includes a first plate 902, a plurality of valve stems 904 extending vertically from the first plate 902, and a first actuator 906 for moving the first plate 902 vertically. In the hot runner-system 900, the plate position limiter is in the form of a locking pin 910. The locking pin 910 may, for example, be a rod, a screw, or any object having an elongate body. The locking pin 910 is axially movable along a pin axis 901, between an extended position (shown in FIG. 9B) and a retracted position (shown in FIG. 9A). In particular, the locking pin 910 may be coupled to the motor 930 via a motor shaft 932. The pin axis 901 is substantially horizontal, i.e. perpendicular to the axis of translation of the first plate 902. That is, the pin axis 901 is actuated perpendicularly relative to the first plate movement. The hot runner-system 900 may additionally include a pin guide 940 that guides axial movement of the locking pin 910.

[0083] The body of the first plate 902 defines at least one opening 950 on a proximal surface 960. The at least one opening 950 is sized to receive and retain at least a portion of the locking pin 910 when the locking pin 910 is in the extended position. FIG. 9A illustrates a single opening 950 on

the surface 960 of first plate 902 which is sized to receive a first end, or tip, of the locking pin 910 when the locking pin 910 has been moved to the extended position. For example, the motor 930 may be configured to drive the axial movement of the locking pin 910.

[0084] In some embodiments, the first drive for controlling the locking pin 910, which may include the motor 930, is configured to apply a constant force, at least at predetermined times or periods of time, to the locking pin 910 in a first direction toward the surface 960 of the first plate 902. In particular, the motor 930 may cause the locking pin 910 to exert a pressing force against the surface 960 of the first plate 902. When the opening 950 aligns with the locking pin 910 as a result of vertical movement of the first plate 902, the tip of the locking pin 910 may slide into the opening 950.

[0085] Once a locking pin 910 is received and retained in an opening 950, a perpendicular force is exerted against the first plate 902 to prevent the first plate 902 from moving vertically. That is, the locking pin 910 defines a vertical stop position for the first plate 902. The first plate 902 may only move if the locking pin 910 is withdrawn from the opening 950. For example, the motor 930 may cause the locking pin 910 to be retracted along the pin axis 901, and allow the first plate 902 to freely move vertically once the locking pin 910 has been completely withdrawn from the opening 950.

[0086] Reference is now made to FIGS. 10A-10B, which are partial cross-sectional schematic representations of an example hot runner-system 1000. The hot runner-system 1000 may be integrated in a runner-system of an injection molding apparatus. In particular, the hot runner-system 1000 may be incorporated into a valve-gated hot runner injection molding system, having a plurality of vertically oriented hot runner injection nozzles and a mold defining a mold cavity.

[0087] The hot runner-system 1000 includes a stem plate 1002, a plurality of valve stems 1004 extending vertically from the stem plate 1002, and a first actuator 1006 for moving the stem plate 1002 vertically. In the hot runner-system 1000, a cam mechanism is used to limit the movement of the stem plate 1002 with respect to the injection nozzles of the injection molding apparatus. As shown in FIG. 10A, the hot runner-system 1000 includes a cam follower 1012 that is fixedly secured to the body of the stem plate 1002. The cam follower 1012 may, for example, have a generally cylindrical shape. The cam follower 1012 may be affixed near or at one end of the stem

plate 1002. For example, the cam follower 1012 may be located at a first end of the stem plate 1002 while the first actuator 1006 for actuating the stem plate 1002 is located at an opposite second end.

[0088] A cam 1010 may act as a plate position limiter. In particular, a cam that makes contact with the cam follower 1012 may be used for limiting the positions of the stem plate 1002. In at least some embodiments, the cam 1010 may be axially movable along a cam shaft axis 1001 that is substantially perpendicular to an axis of movement of the stem plate 1002. The cam 1010 may be actuated by a motor 1030 to along the axis 1001, substantially perpendicular to the stem plate 1002 motion. In particular, the cam 1010 may be positioned on cam shaft 1013 which is coupled to the motor 1030 via a motor shaft 1032.

[0089] In some embodiments, the cam 1010 may be a ramp defining a sloped surface 1016. Alternatively, the cam 1010 may be in the form of a wedge, defining an inclined plane. The cam follower 1012 may make contact with and move along the sloped (or inclined) surface 1016 when the cam 1010 is moved along the cam shaft axis 1001. As the cam follower is fixedly coupled to the body of the stem plate 1002, the stem plate 1002 undergoes linear/vertical motion as the cam follower 1012 traverses the sloped surface 1016 of the cam 1010. FIG. 10A shows the cam follower 1012 when it is located near the bottom of the sloped surface 1016, and FIG. 10B shows the cam follower 1012 when it is near the top of the sloped surface 1016. The traversal of the sloped surface 1016 by the cam follower 1012 results from the axial movement of the cam 1010 along axis 1001, driven by the motor 1030. In particular, the cam follower 1012 rises further up the sloped surface 1016 as the cam 1010 extends further away from the motor 1030.

[0090] In at least some of the above described examples of stem plate position control systems, additional components may be included to facilitate limiting the motion of the stem plate. For example, as shown by pads 850 in FIG. 8A, one or more stop pads may be attached to surfaces of the stem plate for limiting the range of vertical movement of the stem plate.

[0091] In some embodiments of hot runner-systems, stop pads may act as plate position limiters. By way of example, one or more first stop pads and one or more second stop pads may be positioned on opposite sides of a stem plate. For example, the first stop pads may be attached on a first surface of the stem plate and the second stop pads may be attached on a second opposite

surface of the stem plate. Alternatively, the stem plate may be disposed between a pair of interior walls and the first stop pads and second stop pads may be positioned on the interior walls, to prevent movement of the stem plate beyond limits defined by the first and second stop pads.

[0092] The stop pads may, in some cases, be movable. For example, a controller may be configured to move at least one of the first stop pads and the second stop pads vertically. This may have the effect of increasing or decreasing the limits of vertical movement for the stem plate. In some embodiments, one or more sensors (e.g. proximity sensors) may be employed in the hot runner-system to detect a vertical position of the stem plate. When the sensors detect a change in distance between the stem plate and one of the interior walls surrounding (i.e. above or below) the stem plate, the stop pads may be actuated by the controller. For example, if the stem plate is detected to be moving vertically away from an interior wall that is below the stem plate, stop pads located above the stem plate may be actuated to limit or counter the upward movement of the stem plate.

[0093] The various embodiments presented above are merely examples and are in no way meant to limit the scope of this application. Variations of the innovations described herein will be apparent to persons of ordinary skill in the art, such variations being within the intended scope of the present application. In particular, features from one or more of the above-described example embodiments may be selected to create alternative example embodiments including a sub-combination of features which may not be explicitly described above. In addition, features from one or more of the above-described example embodiments may be selected and combined to create alternative example embodiments including a combination of features which may not be explicitly described above. Features suitable for such combinations and sub-combinations would be readily apparent to persons skilled in the art upon review of the present application as a whole. The subject matter described herein and in the recited claims intends to cover and embrace all suitable changes in technology.

CLAIMS

1. An injection molding apparatus, comprising:
 - a plurality of hot runner injection nozzles, each injection nozzle having a respective valve gate through which melt is injected into a mold cavity;
 - a first plate that is disposed substantially perpendicular to the injection nozzles;
 - a plurality of valve stems extending from a first surface of the first plate, each valve stem being positioned in axial alignment with a respective injection nozzle;
 - a first actuator for moving the first plate bi-directionally along a first axis, the first plate being movable to cause at least one of the plurality of valve stems to move in a respective injection nozzle between an open position permitting flow of melt through a valve gate and a closed position blocking flow of melt through the valve gate;
 - at least one plate position limiter for limiting movement of the first plate relative to the injection nozzles; and
 - a first drive for controlling the at least one plate position limiter independently of the first actuator.
2. The injection molding apparatus of claim 1, wherein the first drive includes a motor driving movement of the at least one plate position limiter.
3. The injection molding apparatus of claim 2, wherein the at least one plate position limiter comprises one or more screws that are rotatably coupled to the motor, the one or more screws being disposed over a second surface of the first plate that is opposite to the first surface, and wherein the motor is configured to drive axial movement of at least one screw shaft along a respective screw shaft axis that is parallel to the first axis.
4. The injection molding apparatus of claim 3, wherein the one or more screws comprise a plurality of screws that are positioned in spaced relation to each other.

5. The injection molding apparatus of claim 3, further comprising one or more nuts held in fixed spaced relation to the motor, wherein the motor is configured to drive threaded rotation of the at least one screw shaft through a respective nut.
6. The injection molding apparatus of claim 3, further comprising a first gear drivingly coupled to the motor, wherein the first gear is configured to engage the at least one screw shaft such that rotation of the first gear about a fixed first gear axis causes axial movement of the at least one screw shaft along a respective screw shaft axis.
7. The injection molding apparatus of claim 6, further comprising at least one second gear in threaded engagement with the at least one screw shaft, wherein the first gear is configured to meshingly engage the at least one second gear such that rotation of the first gear about the first gear axis causes rotation of the at least one second gear about a respective second gear axis.
8. The injection molding apparatus of claim 7, further comprising at least one gear rack having a plurality of rack teeth on a bearing surface, wherein teeth of the first gear and teeth of the at least one second gear meshingly engage the rack teeth on the bearing surface of the at least one gear rack.
9. The injection molding apparatus of claim 1, wherein the at least one plate position limiter comprises a locking pin that is axially movable along a pin axis between an extended position and a retracted position, the pin axis being substantially perpendicular to the first axis, and wherein a body of the first plate defines at least one opening on a proximal surface for receiving and retaining a first portion of the locking pin when the locking pin is in the extended position.
10. The injection molding apparatus of claim 9, wherein the first drive is configured to apply a constant force to the locking pin in a first direction toward the proximal surface of the first plate.

11. The injection molding apparatus of claim 1, further comprising a cam follower fixedly secured to a body of the first plate, wherein the at least one plate position limiter comprises a cam making contact with the cam follower, the cam being axially movable along a cam shaft axis that is substantially perpendicular to the first axis.
12. The injection molding apparatus of claim 11, wherein the cam comprises a ramp defining a sloped surface, the cam follower making contact with and moving along the sloped surface when the cam is moved along the cam shaft axis.
13. The injection molding apparatus of claim 2, further comprising:
 - one or more rods coupled to the first plate, the rods being configured to move axially parallel to the first axis; and
 - a brake assembly for controllably applying a braking force to at least one of the rods.
14. The injection molding apparatus of claim 13, wherein the brake assembly comprises at least one collet forming a collar around a respective one of the rods, wherein the motor is configured to cause the at least one collet to exert a clamping force on the respective one of the rods.
15. The injection molding apparatus of claim 14, wherein the at least one plate position limiter comprises a cross bar coupled to the motor, and wherein the motor is configured to drive translational movement of the cross bar to a first position in which the cross bar is positioned between and in pressing engagement against two adjacent collets.
16. The injection molding apparatus of claim 13, wherein the first actuator comprises one or more actuators for causing axial movement of the one or more rods.
17. The injection molding apparatus of claim 1, wherein the at least one plate position limiter comprises a cam that is rotatably coupled to a motor, the cam making contact with a second surface of the first plate that is opposite to the first surface, and wherein the motor

is configured to drive rotation of the cam about a cam shaft axis that is substantially parallel to and offset from the second surface of the first plate.

18. The injection molding apparatus of claim 17, further comprising:

a cam shaft coupled to the motor at a first end and to the cam at a second opposite end; and

a cam shaft bearing held in fixed spaced relation to the motor, wherein the motor is configured to drive rotation of the cam shaft through the cam shaft bearing.

19. The injection molding apparatus of claim 1, wherein the valve stems are positioned in spaced relation to each other on the first surface of the first plate.

20. The injection molding apparatus of claim 1, wherein the first actuator comprises at least one of a pneumatic cylinder, a hydraulic cylinder, or a pneumatic bladder.

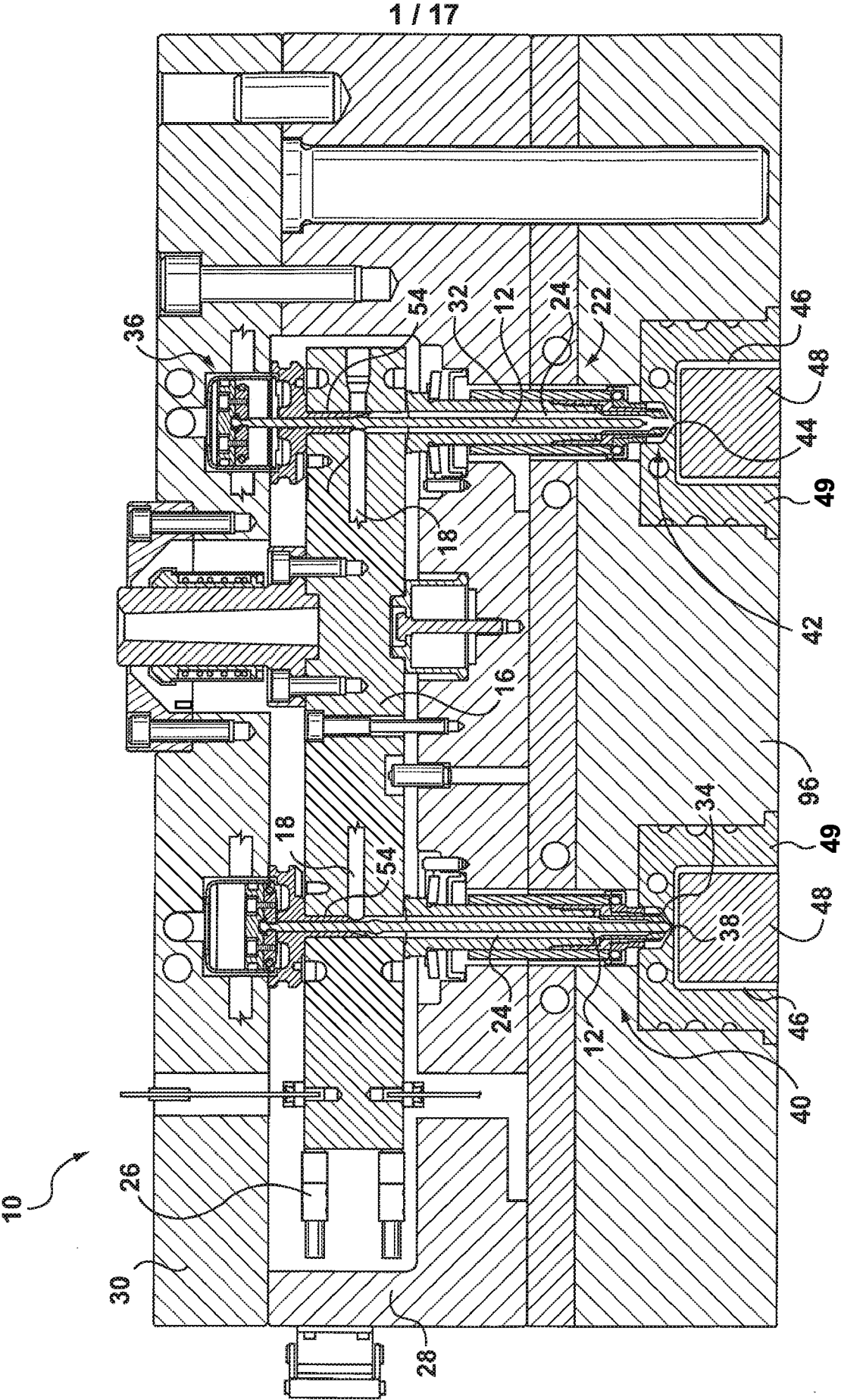
21. The injection molding apparatus of claim 1, wherein the at least one plate position limiter comprises one or more first stop pads and one or more second stop pads, the first stop pads and the second stop pads being positioned on opposite sides of the first plate.

22. The injection molding apparatus of claim 21, wherein the one or more first stop pads are positioned on the first surface and the one or more second stop pads are positioned on a second surface of the first plate that is opposite to the first surface.

23. The injection molding apparatus of claim 21, wherein the first plate is disposed between a first interior wall and a second interior wall opposite to the first interior wall, and wherein the one or more first stop pads are positioned on the first interior wall and the one or more second stop pads are positioned on the second interior wall.

24. The injection molding apparatus of claim 23, wherein a controller is configured to move at least one of the first stop pads and the second stop pads axially parallel to the first axis.

25. The injection molding apparatus of claim 24, further comprising one or more sensors for detecting a vertical position of the first plate, wherein the at least one of the first stop pads and the second stop pads is moved in response to the sensors detecting a change in distance between the first plate and at least one of the first interior wall and the second interior wall.



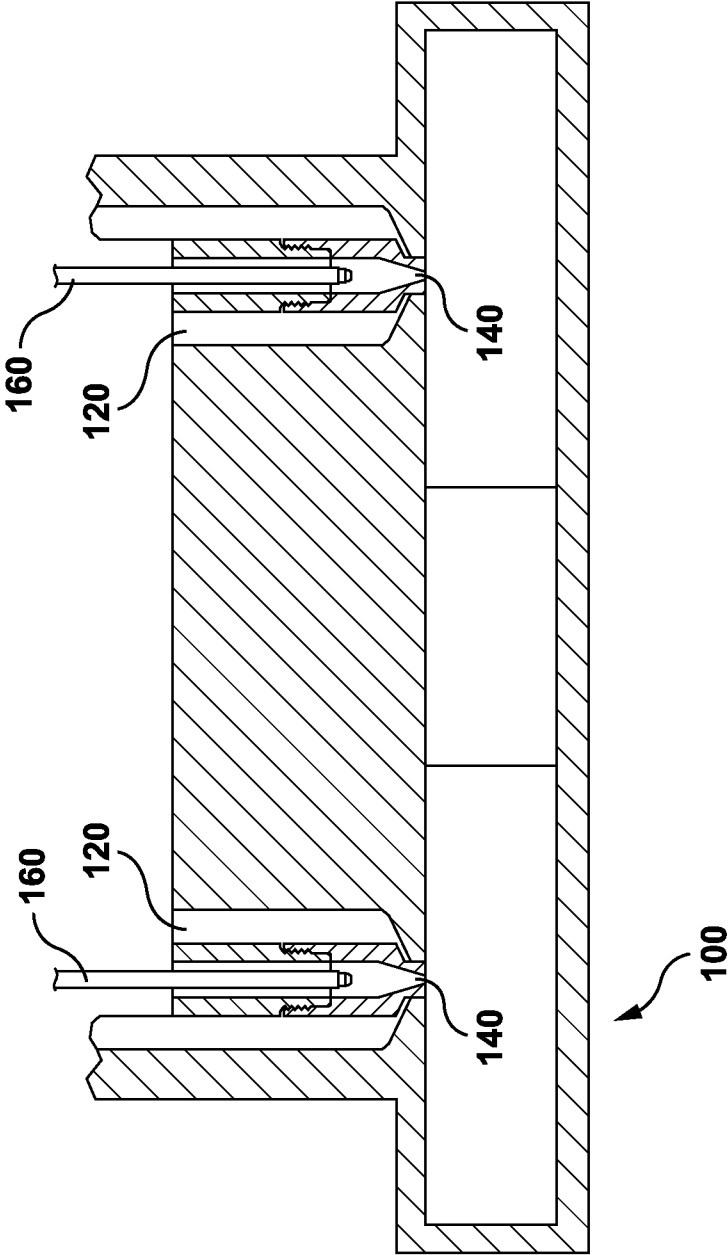


FIG. 2

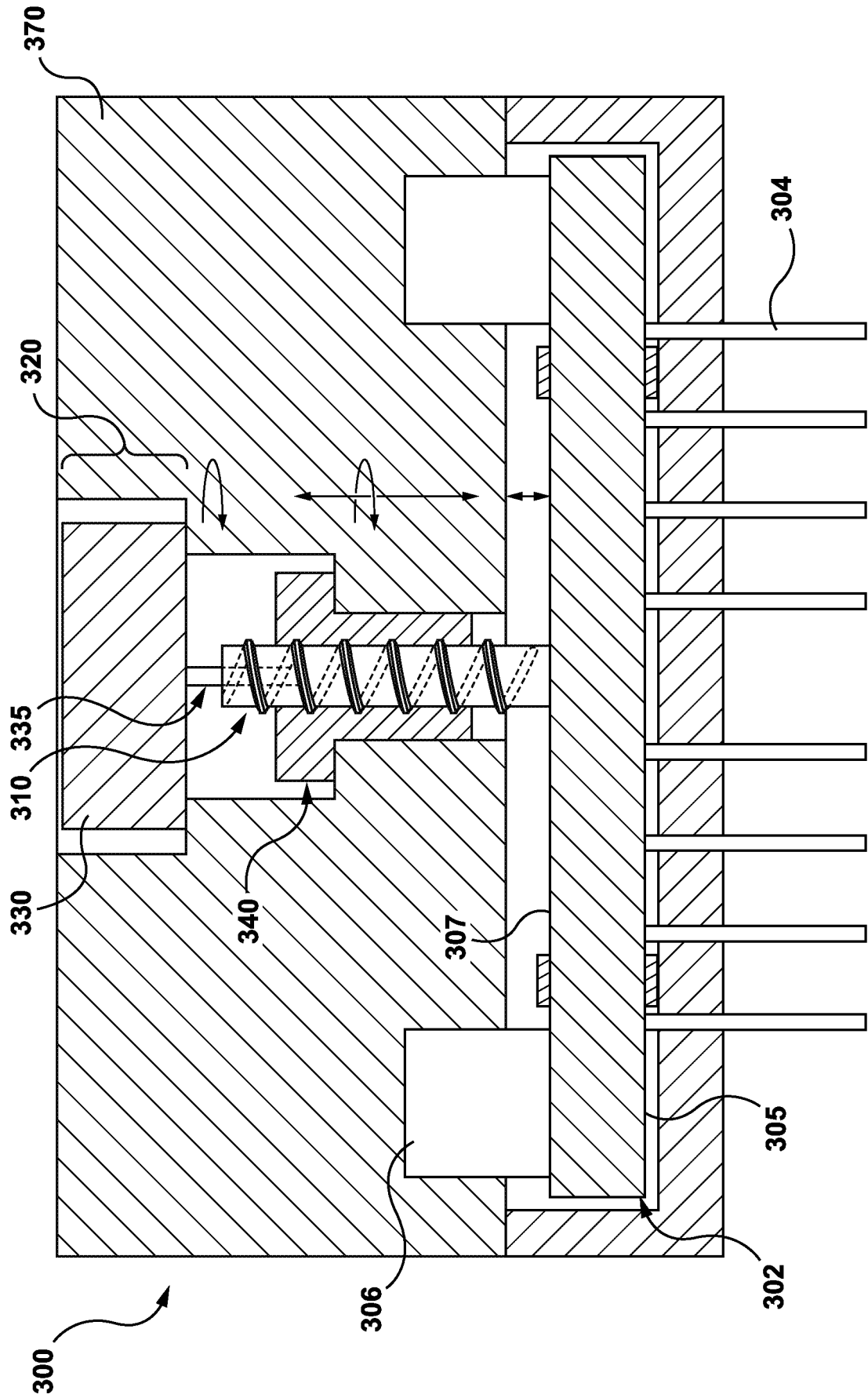


FIG. 3A

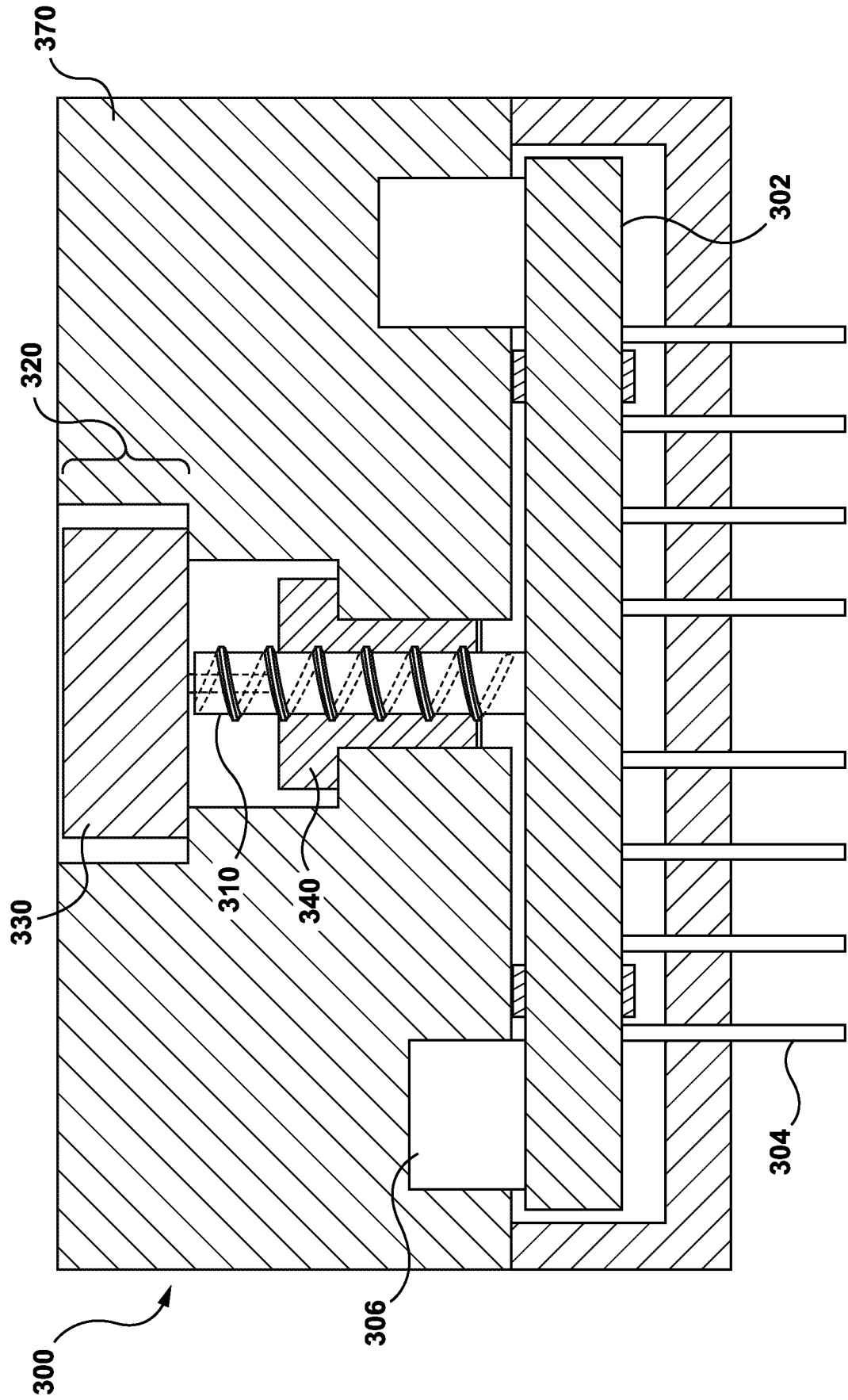


FIG. 3B

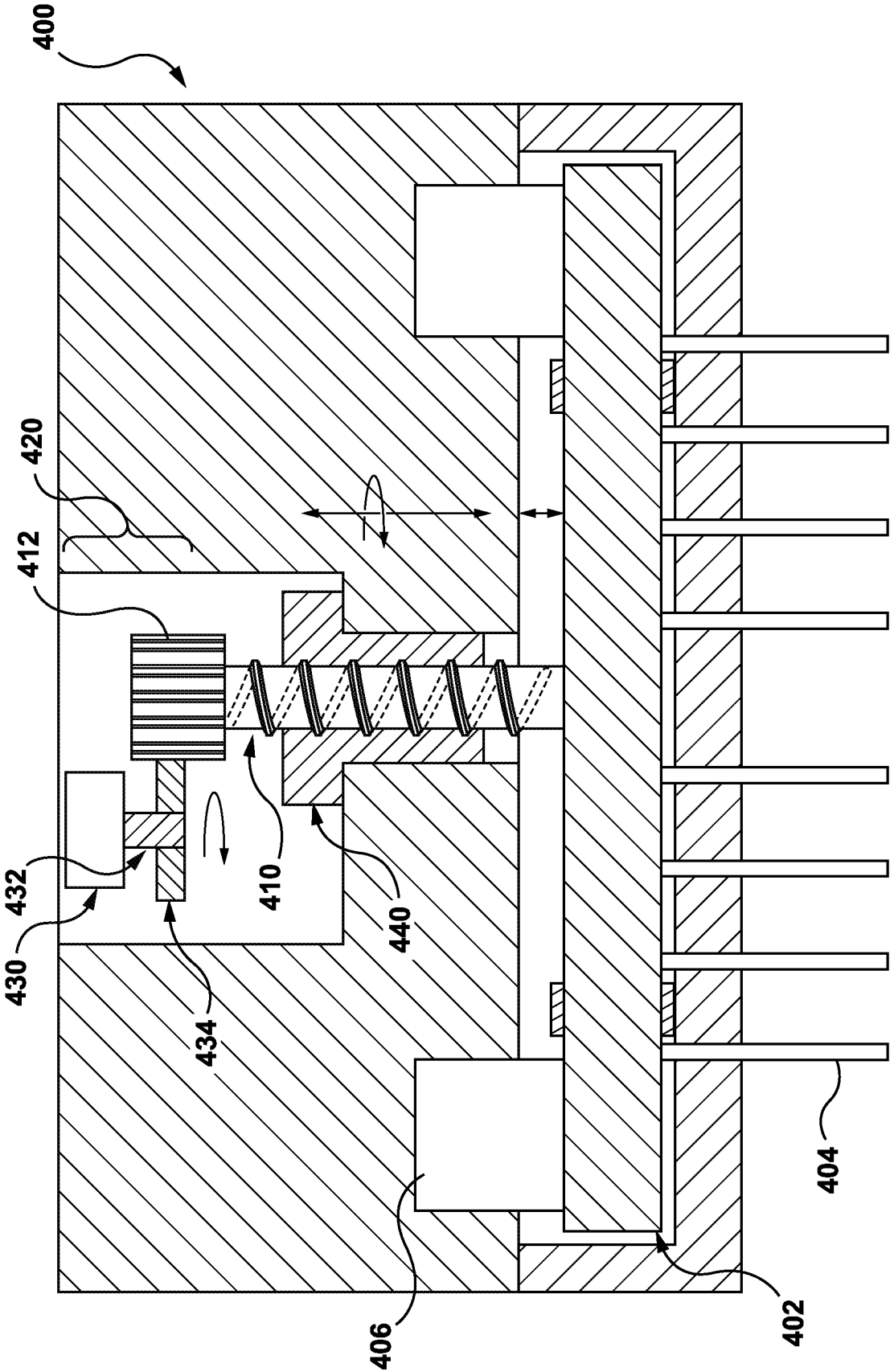


FIG. 4A

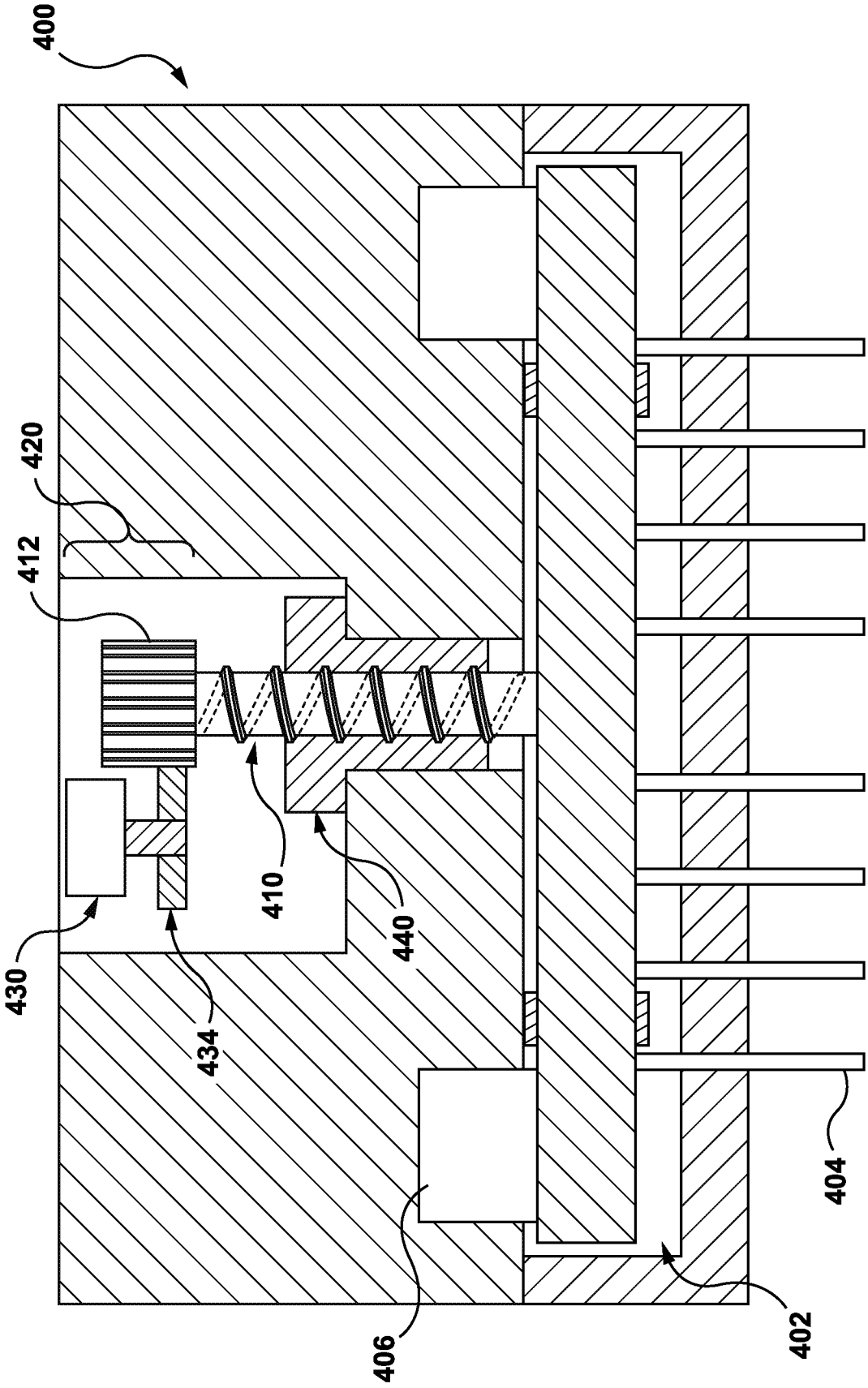


FIG. 4B

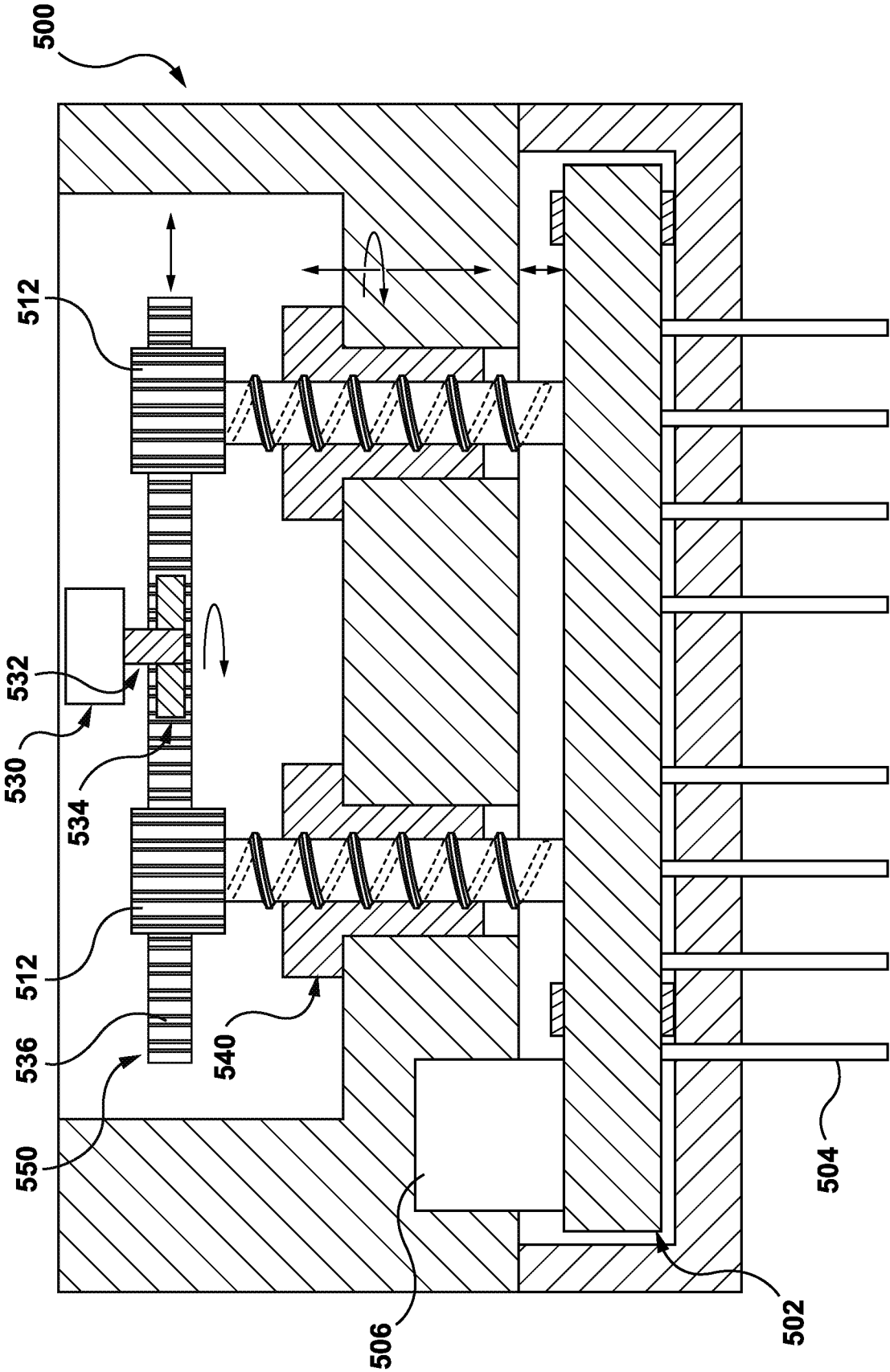


FIG. 5

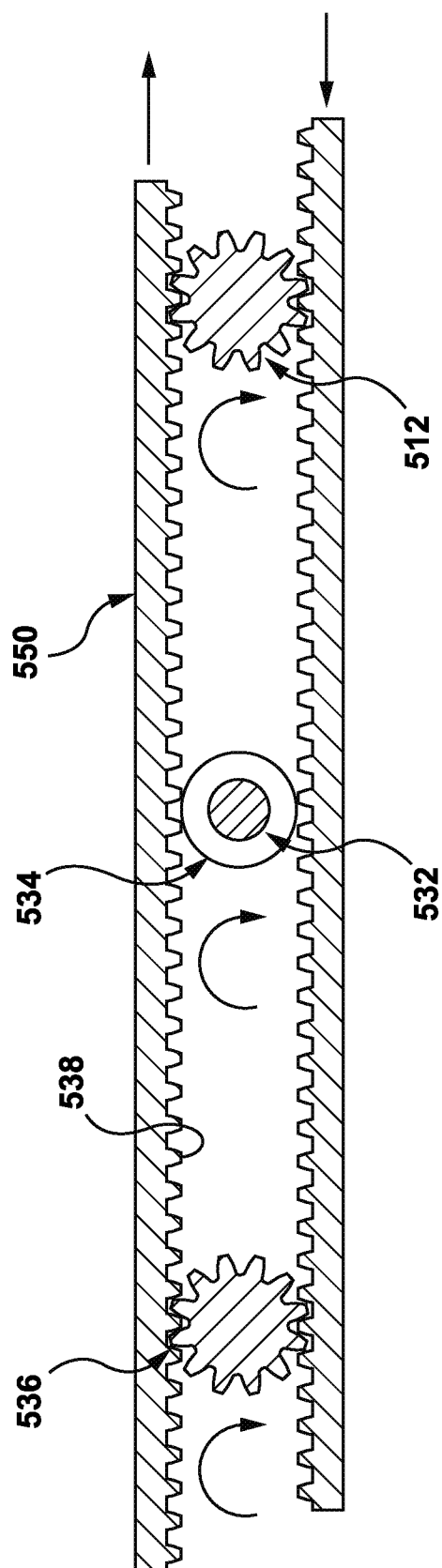


FIG. 6

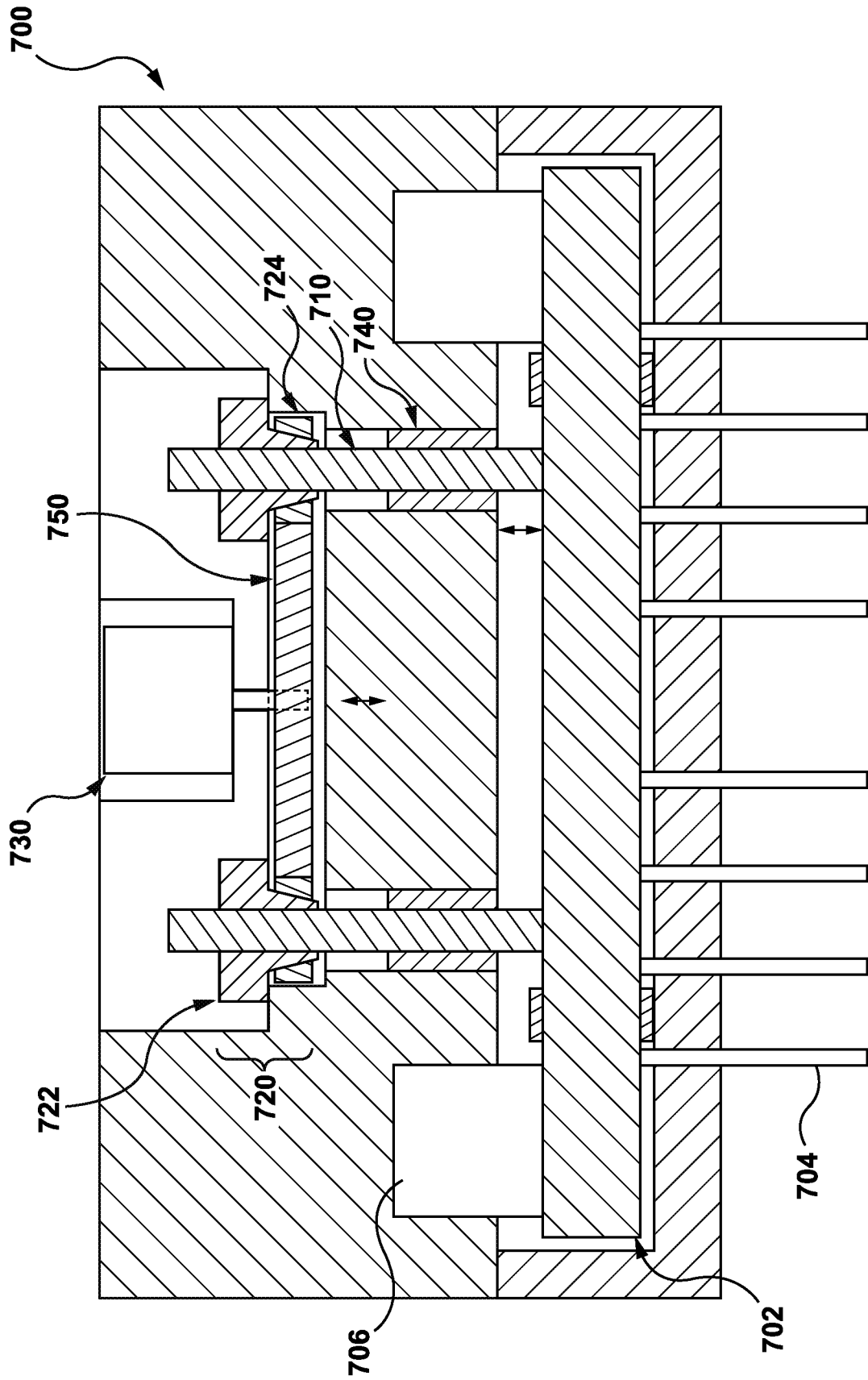


FIG. 7A

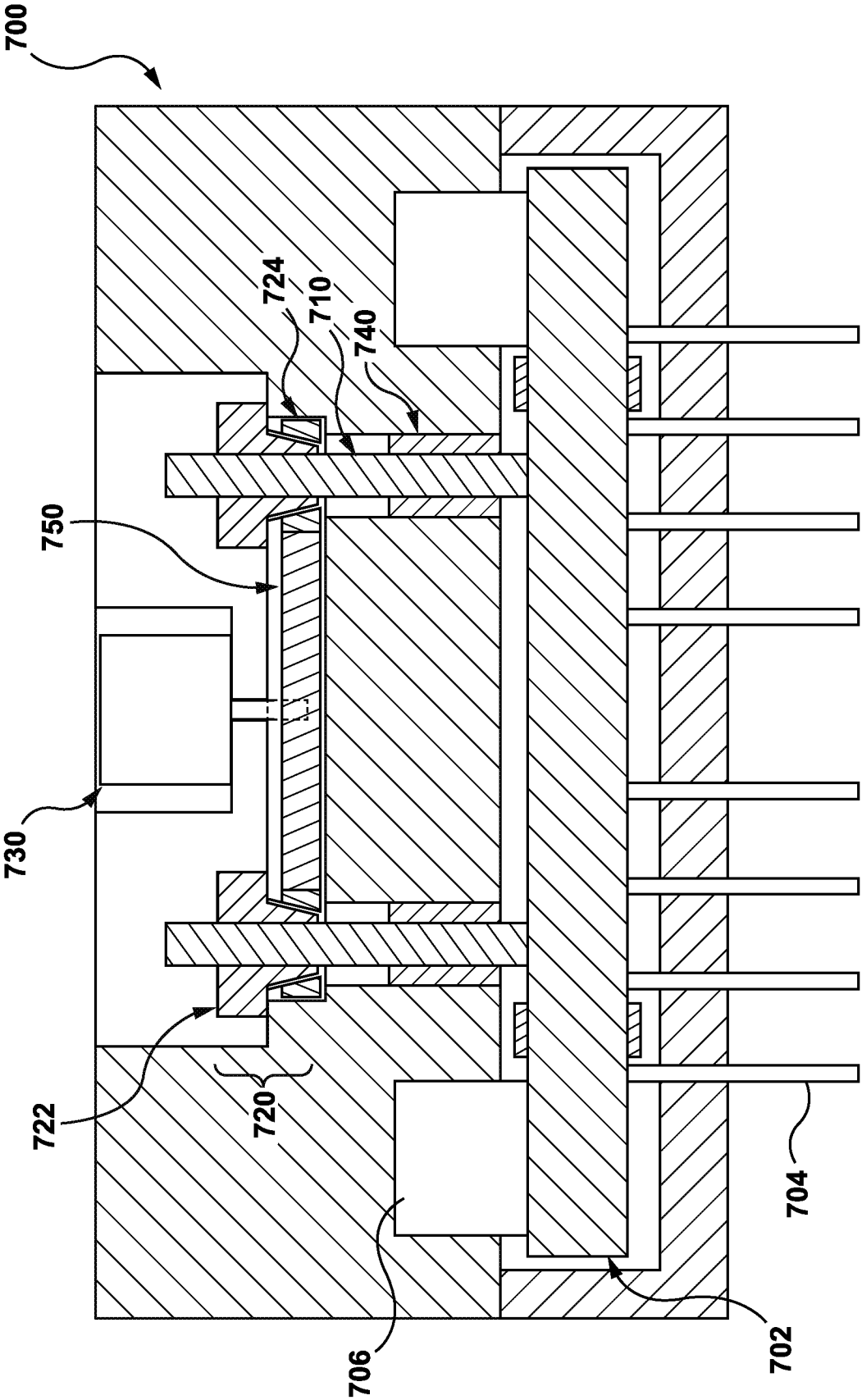


FIG. 7B

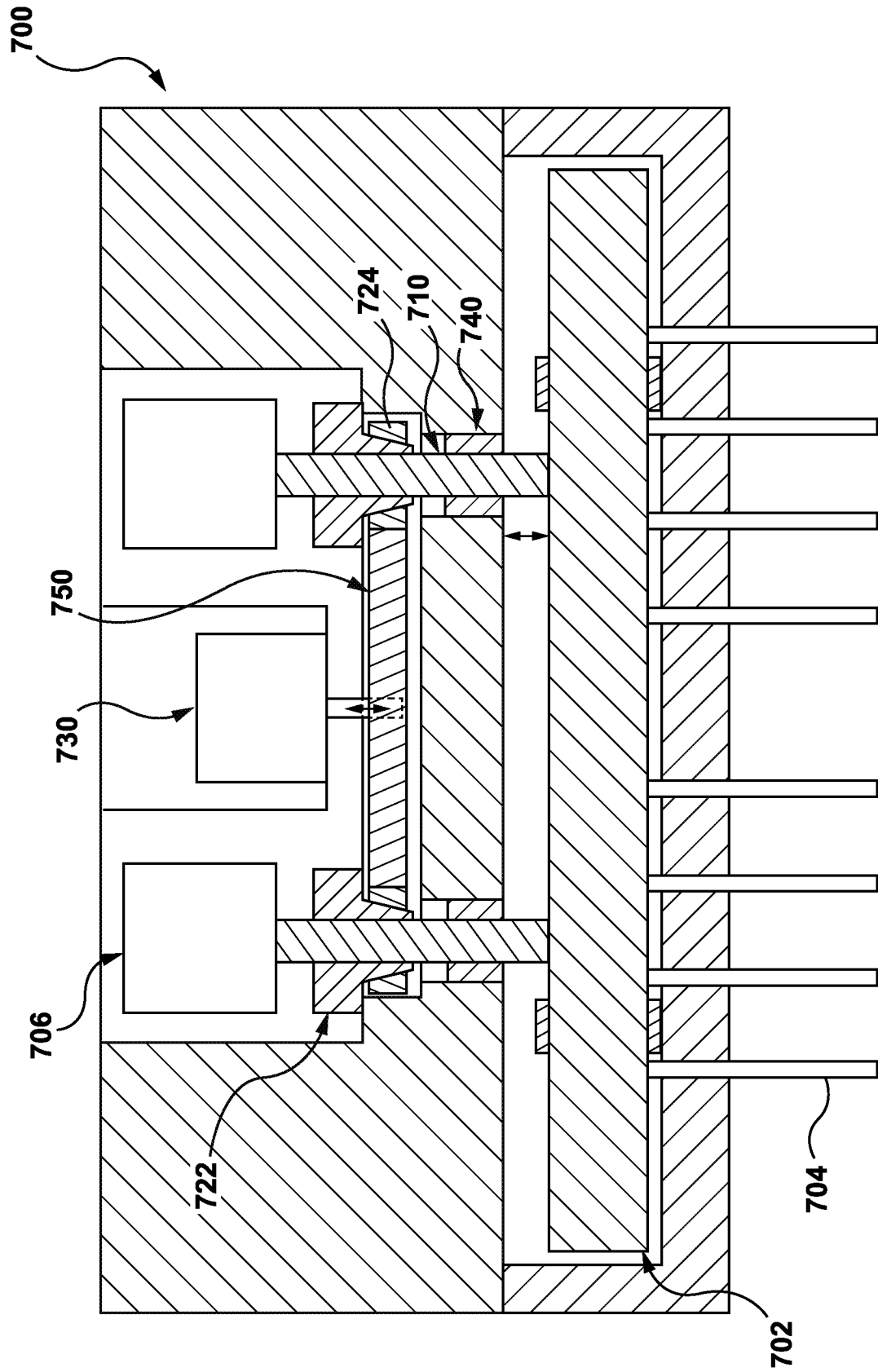


FIG. 7C

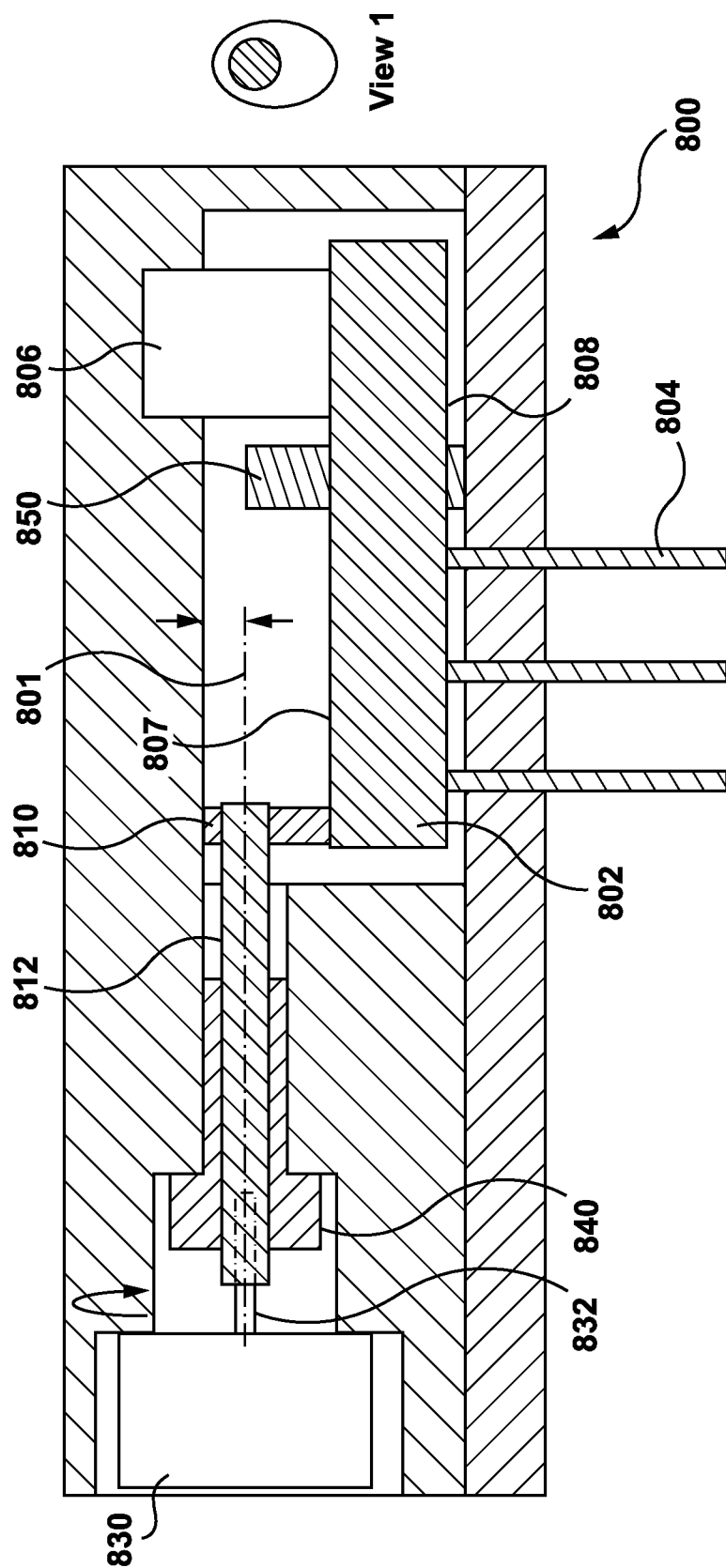


FIG. 8A

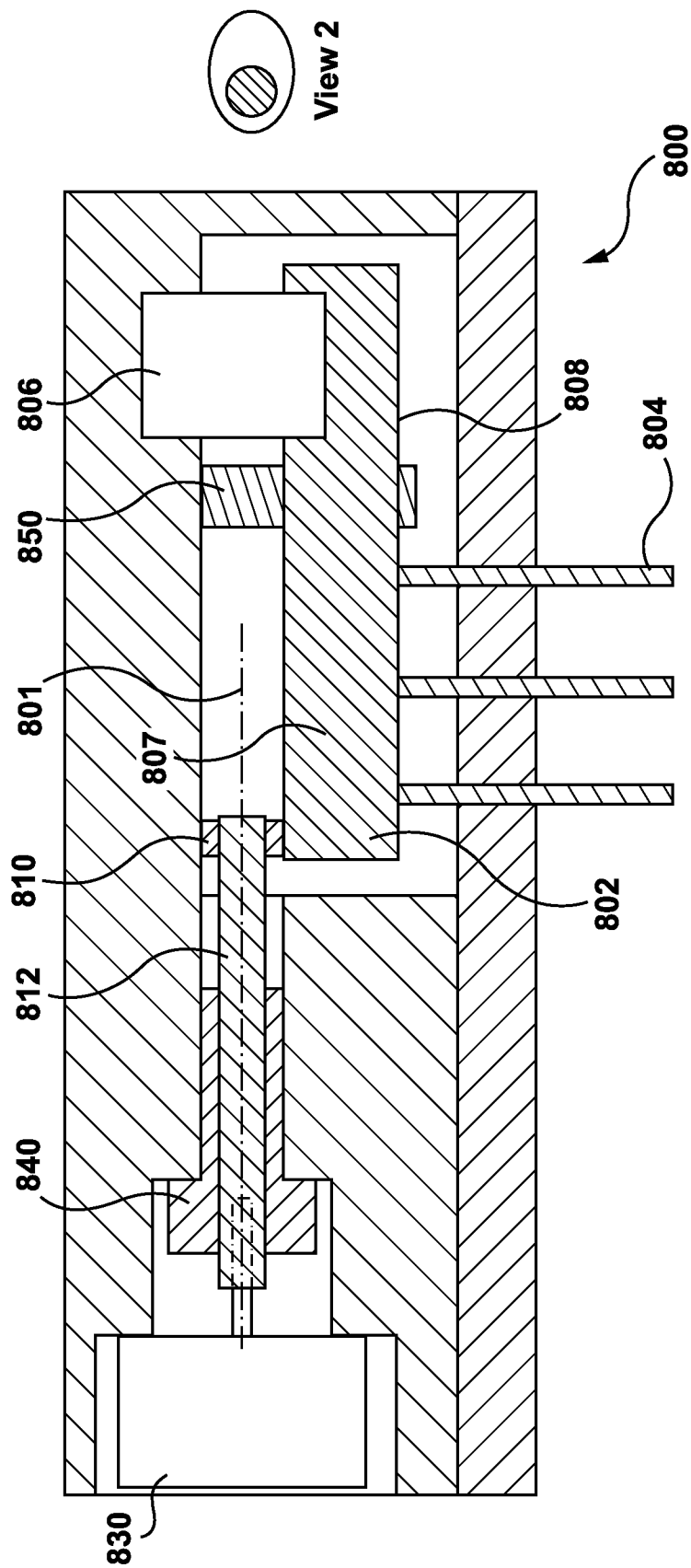


FIG. 8B

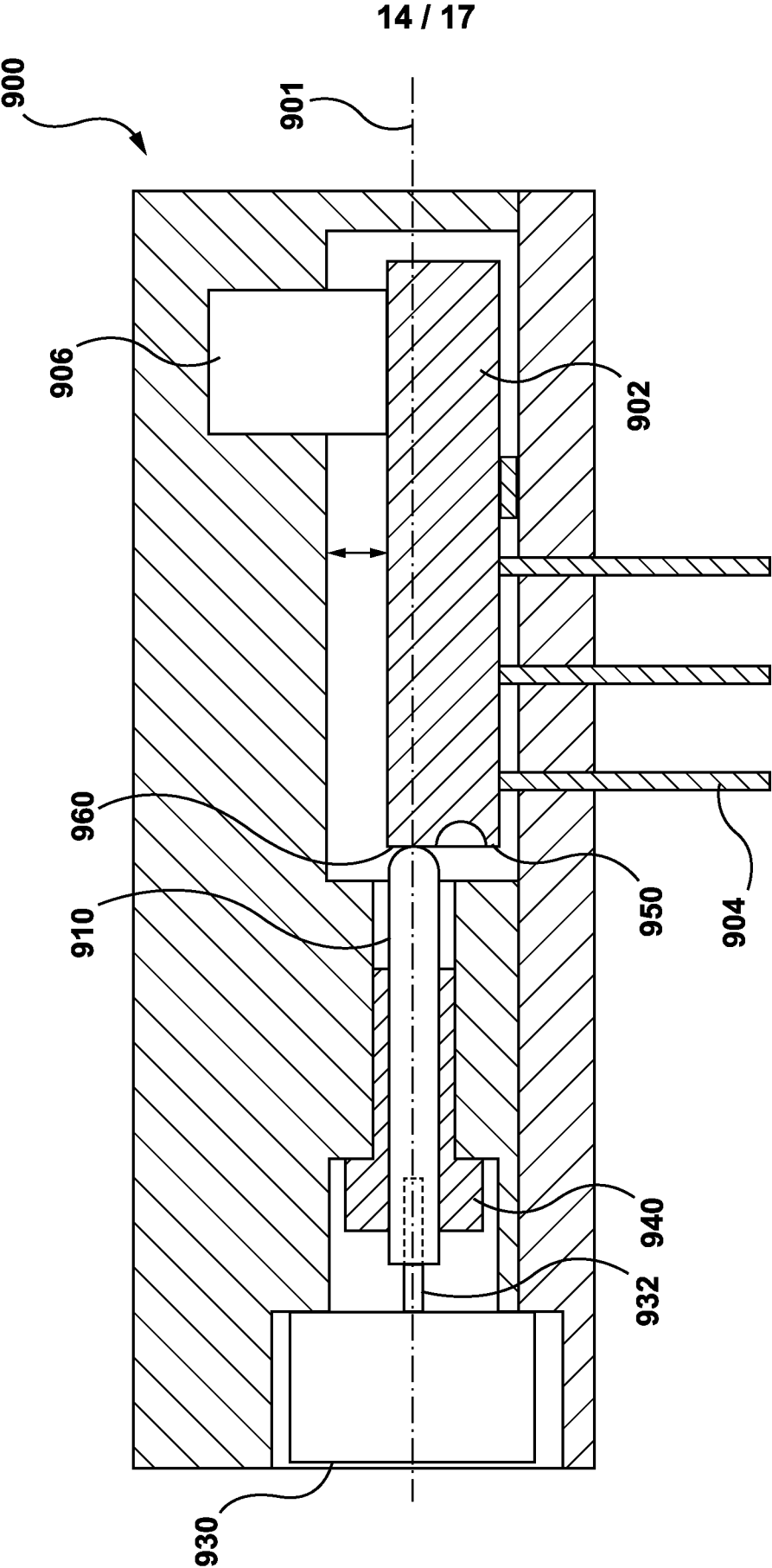


FIG. 9A

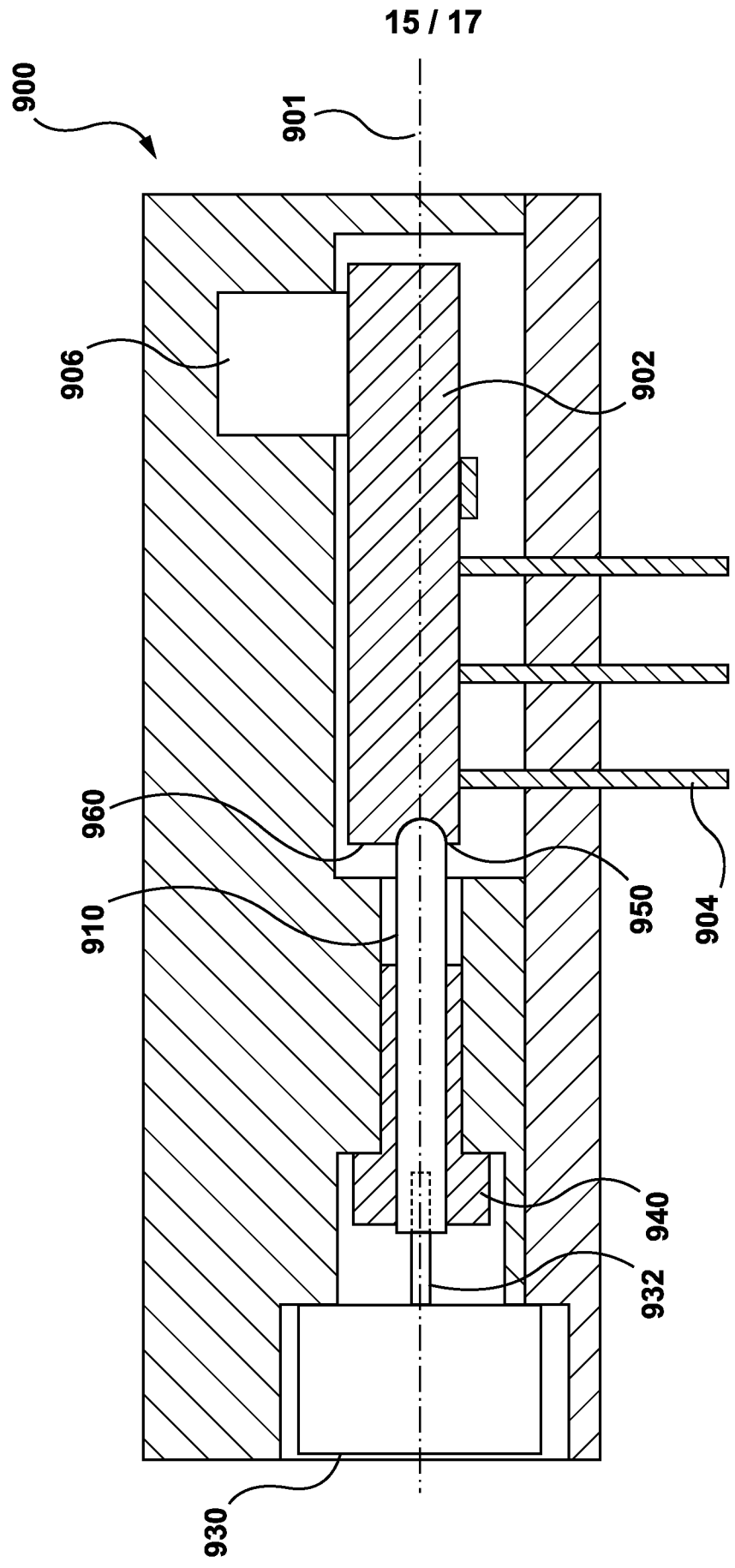


FIG. 9B

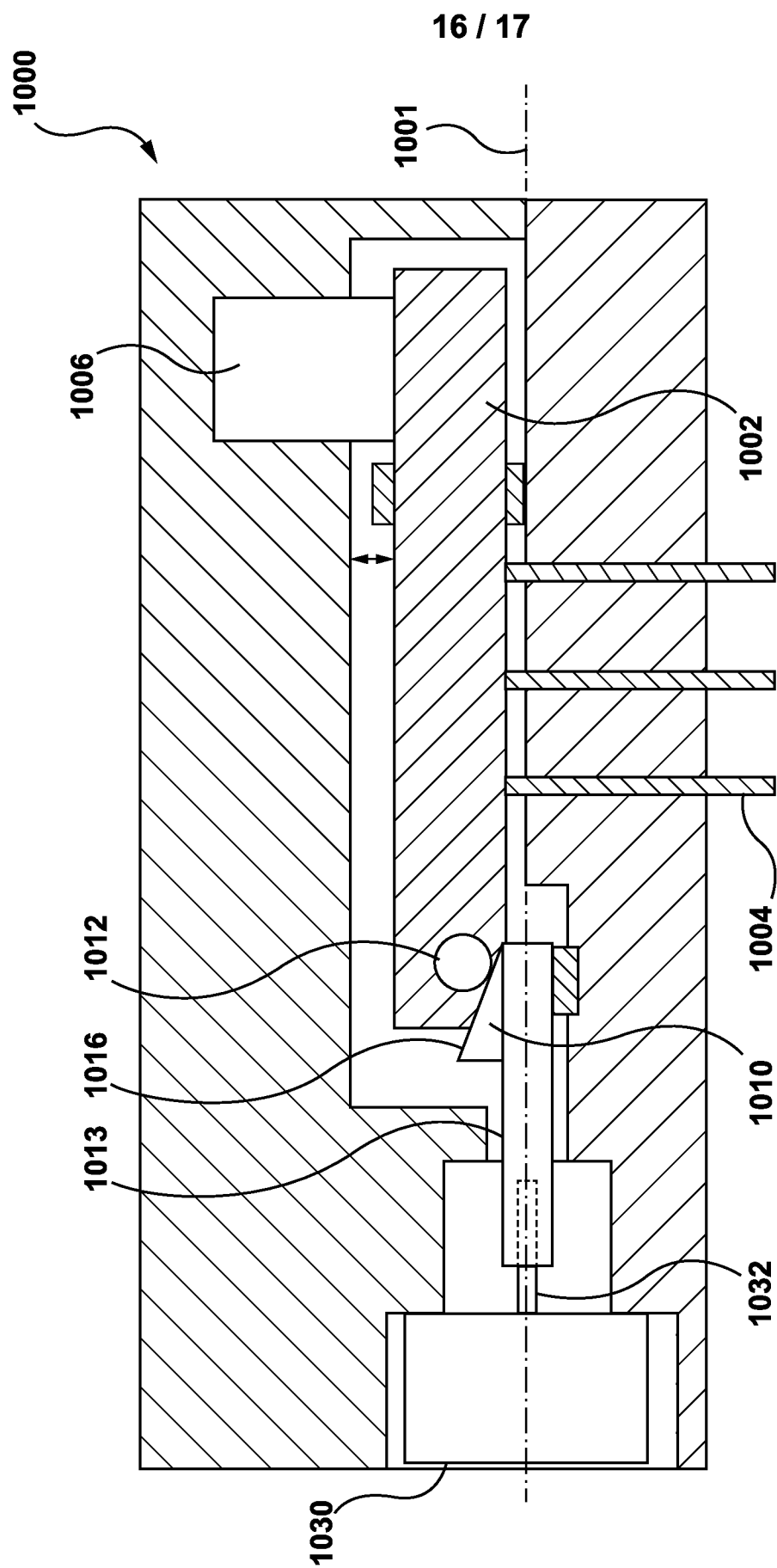


FIG. 10A

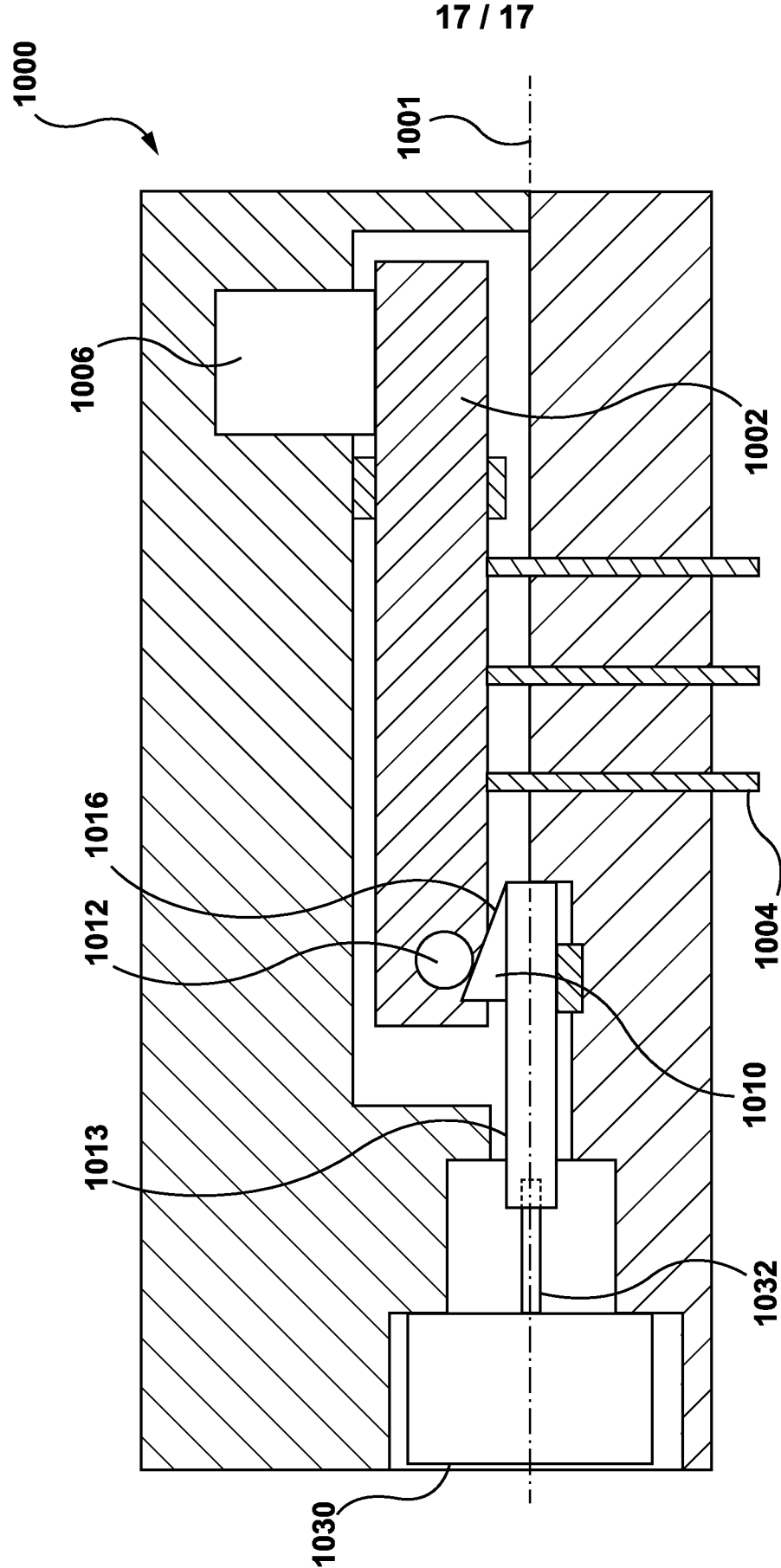


FIG. 10B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 20/20022

A. CLASSIFICATION OF SUBJECT MATTER

IPC - B29C 45/28 (2020.01)

CPC - B29C 45/281

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2006/080807 A1 (KIM) 03 August 2006 (03.08.2006), entire document, especially Fig 10-15; para [68]-[71], [78], [80]-[84], [88], [90], [92]-[93]	1-25
A	US 9,358,713 B2 (OTTO MANNER INNOVATION GMBH) 07 June 2016 (07.06.2016), entire document, especially Fig 1, 2A-2B; col 2, ln 50-56, 59-61; col 3, ln 4-17, 25-28, 63-65	1-25
A	US 5,078,589 A (OSUNA-DIAZ) 07 January 1992 (07.01.1992), entire document, especially Fig 1-2; col 2, ln 44-58; col 3, ln 10-19	1-25
A	US 2018/0345553 A1 (OTTO MANNER GMBH) 06 December 2018 (06.12.2018), entire document	1-25
A	US 8,393,889 B2 (HONTHEIM et al.) 12 March 2013 (12.03.2013), entire document	1-25
A	US 7,722,351 B2 (FEICK et al.) 25 May 2010 (25.05.2010), entire document	1-25
A	US 5,599,568 A (DONNELL, JR.) 04 February 1997 (04.02.1997), entire document	1-25

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

22 April 2020

Date of mailing of the international search report

22 MAY 2020

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