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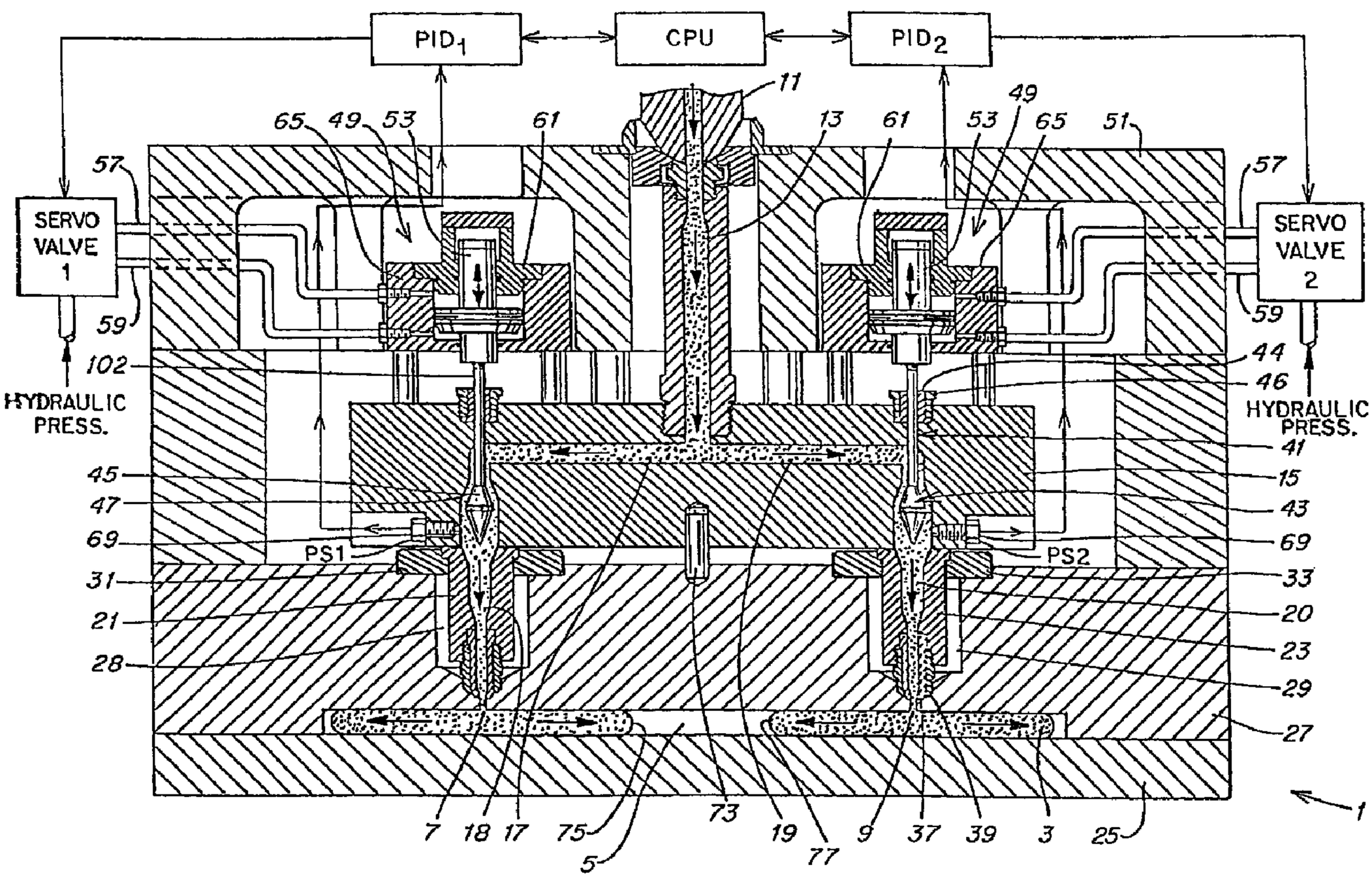

(57) Abrégé/Abstract:
In an injection molding machine having first and second nozzles for delivering melt material from a common manifold to one or more mold cavities, apparatus for controlling delivery of the melt material from the nozzles to the one or more mold cavities, each nozzle having an exit aperture communicating with a gate of a cavity of a mold and being associated with an actuator interconnected to a melt flow controller, the apparatus comprising: a sensor for sensing a selected condition of the melt material

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(57) Abrégé(suite)/Abstract(continued):
through at least one of the nozzles; an actuator controller interconnected to each actuator, each actuator controller comprising a computer interconnected to a sensor for receiving a signal representative of the selected condition sensed by the sensor, the computer including an algorithm utilizing a value corresponding to a signal received from the sensor as a variable for controlling operation of an actuator for the at least one nozzle; wherein at least one of the nozzles has a seal surface disposed on a tip end of the nozzle which is engaged and in compressed contact with a complementary surface surrounding the gate of a cavity of a mold, the engaged surfaces forming a seal against leakage of the melt material around the nozzle.

ABSTRACT

In an injection molding machine having first and second nozzles for delivering melt material from a common manifold to one or more mold cavities, apparatus for controlling delivery of the melt material from the nozzles to the one or more mold cavities, each nozzle having an exit aperture communicating with a gate of a cavity of a mold and being associated with an actuator interconnected to a melt flow controller, the apparatus comprising: a sensor for sensing a selected condition of the melt material through at least one of the nozzles; an actuator controller interconnected to each actuator, each actuator controller comprising a computer interconnected to a sensor for receiving a signal representative of the selected condition sensed by the sensor, the computer including an algorithm utilizing a value corresponding to a signal received from the sensor as a variable for controlling operation of an actuator for the at least one nozzle; wherein at least one of the nozzles has a seal surface disposed on a tip end of the nozzle which is engaged and in compressed contact with a complementary surface surrounding the gate of a cavity of a mold, the engaged surfaces forming a seal against leakage of the melt material around the nozzle.

APPARATUS AND METHOD FOR PROPORTIONALLY CONTROLLING FLUID DELIVERY TO A MOLD

BACKGROUND OF THE INVENTION

The present invention relates to automatic control of plastic flow though injection nozzles in a molding machine. More particularly the invention relates to proportional control of plastic flow via proportional control of the actuator mechanism for a valve for a nozzle particularly where two or more nozzles are mounted on a hotrunner for injection into one or more mold cavities. The proportional control is achieved via the use of one or more sensors which senses a selected condition of the plastic flow through a manifold, nozzle or into a mold and the use of the recorded condition in conjunction with a selected nozzle design, hotrunner/manifold design, actuator design, actuator drive mechanism and /or flow control mechanism. Proportional control of melt flow typically refers to control of the rate of melt flow according to an algorithm utilizing defined by a sensed condition as a variable.

SUMMARY OF THE INVENTION

In accordance with the invention there is provided an apparatus and method for proportionally controlling the rate of melt flow through a melt flow path in an injection molding machine, in particular controlling the melt flow through two nozzles.

More particularly, there is provided in an injection molding machine having first and second nozzles for delivering melt material from a common manifold to one or more mold cavities, an apparatus for controlling delivery of the melt material from the nozzles to the one or more mold cavities, each nozzle having an exit aperture communicating with a gate of a cavity of a mold and being associated with an actuator interconnected to a melt flow controller, the apparatus comprising :

a sensor for sensing a selected condition of the melt material through at least one of the nozzles ; and,

an actuator controller interconnected to each actuator, each actuator controller comprising a computer interconnected to a sensor for receiving a signal representative of the selected condition sensed by the sensor, the computer including an algorithm utilizing a value corresponding to a signal received from the sensor as a variable for controlling operation of an actuator for the at least one nozzle.

At least one of the nozzles has a seal surface disposed on a tip end of the nozzle which is engaged and in compressed contact with a complementary surface surrounding the gate of a cavity of a mold, the engaged surfaces forming a seal against leakage of the melt material around the nozzle and maintaining the pressure of the melt against loss of pressure due to leakage. The at least one nozzle is expandable upon heating to a predetermined operating temperature, the nozzle being mounted relative to the surface surrounding the gate such that the seal surface disposed on the tip end of the nozzle is moved into compressed contact with the complementary

surface surrounding the gate upon heating of the nozzle to the predetermined operating temperature. The complementary mating surfaces of the nozzle and the gate area of the mold are typically radially disposed relative to the axis of the exit aperture of the nozzle, although the mating surfaces may also be disposed longitudinally or axially.

The tip end of the nozzle may comprise a single unitary piece or, in another embodiment, an outer unitary piece formed of a first material and an inner unitary piece formed of a second material, the first material being substantially less heat conductive than the second material. The complementary mating surfaces of the nozzle and the gate area of the mold are typically radially disposed relative to the axis of the exit aperture of the nozzle, although the mating surfaces may also be disposed longitudinally or axially.

At least one of the nozzles may have a tip end having a central portion having a central bore in alignment with a gate and an outer circumferential flange portion surrounding the gate and the central portion of the tip end of the at least one nozzle.

The melt flow controller of the apparatus typically comprises a pin which is controllably slidable via interconnection to an actuator along a reciprocal path of movement within the bore of a nozzle, or the controller typically comprises a rotary valve having a rotatable flow channel connecting an input flow channel to the exit aperture of at least one of the nozzles, the rotatable channel being interconnected to the actuator and controllably rotatable via the actuator to selectively vary the rate of flow of plastic melt through the rotatable flow channel to the exit aperture according to the degree of rotation of the rotary valve. The rotary valve typically comprises a cylinder rotatably mounted within a housing the cylinder having a bore rotatably communicable with a pair of bores in the housing.

One or more actuators may comprise a piston mounted within a fluid sealed housing, the piston having a stem extending outside the fluid sealed housing, the valve

pin having a head wherein the stem is readily detachably interconnected to the head of the valve pin outside the fluid sealed housing.

One or more actuators may comprise an electrically driven motor, the motor being mechanically interconnected to either a valve pin disposed in a bore of one of the nozzles such that the valve pin is reciprocally drivable within the bore of the nozzle by the motor, or a rotary valve for rotatable drive of a rotatable component having a fluid flow bore, the motor being electrically interconnected to the algorithm, the algorithm controlling the drive of the motor.

Each actuator for each of the first and second nozzles may be fluid driven wherein each actuator is commonly supplied with an actuator drive fluid flowing through a manifold which commonly delivers fluid to each of the nozzles.

The actuator controller for a fluid driven actuator typically comprises a solenoid having a piston controllably movable between selected positions for selectively delivering a pressurized actuator drive fluid to one or the other of at least two chambers of the actuator.

The actuator controller for a fluid driven actuator may include a drive fluid valve which receives pressurized drive fluid from a source, the drive fluid valve having one or more fluid ports sealably communicating with one or more complementary fluid drive chambers disposed within the fluid driven actuator, the drive fluid valve being controllably driven to selectively distribute received pressurized fluid through the one or more fluid ports to the one or more complementary fluid drive chambers of the actuator. The drive fluid valve typically comprises a sealed housing and a plunger movable within the sealed housing to positions along a path wherein the one or more fluid ports are open to communication, partially open to communication, or closed from communication with the one or complementary fluid drive chambers by the plunger, the plunger being

controllably movable to any position along the path between the open and closed positions such that flow of the drive fluid to a drive fluid chamber is controllably variable to a selected rate. The plunger typically comprises a slidably movable rod having interference projections which are selectively slidable by movement of the rod over the fluid ports to open, partially open to any desired degree, or close the fluid ports.

In another embodiment, at least one gate of a mold may be an edge gate extending radially outward through a mold cavity plate, at least one of the nozzles having a bore having a first portion having an inlet for the plastic melt which is not in alignment with the edge gate and a second portion extending radially outward from the first portion terminating in the exit aperture being in alignment with the edge gate. In such an embodiment the nozzle may have an exit end comprising a center nozzle member and a circumferential nozzle member surrounding the center nozzle member, the exit aperture extending through the center nozzle member in alignment with one of the gates, the circumferential nozzle member surrounding the one gate, wherein a groove is formed between the circumferential nozzle member and the center portion.

The apparatus typically includes a plurality of enclosed heat conductive tubes containing a fluid which vaporizes and condenses within each tube and a wick disposed within and along the length of each tube, at least one of the manifold and one of the nozzles having the tubes embedded within the manifold or the nozzle making heat conductive contact with the manifold or the nozzle.

The apparatus may include a melt flow reservoir sealably communicating with and disposed between a common feed channel of the manifold and an exit aperture of a nozzle, the reservoir having a defined volume sealably fillable and closed off from communication with the common feed channel, the reservoir including an injection mechanism operable on melt material residing in the reservoir to force the melt material

through the exit aperture of the nozzle under pressure. In such an embodiment, the melt flow controller preferably comprises a valve disposed in the melt flow between the reservoir and the exit aperture of the nozzle. The melt flow controller may also alternatively comprise the injection mechanism.

The sensor typically comprises a pressure transducer interconnected to at least one of the bore of a nozzle or a mold cavity for detecting the pressure of the melt material. The sensor may comprise a mechanism selected from the group consisting of a pressure transducer, a load cell, a valve pin position sensor, a temperature sensor and a barrel screw position sensor.

In a typical embodiment, at least one of the nozzles has a bore, a valve pin as the flow controller and a surface for forming a gap with a surface of the bore away from the gate, wherein the size of the gap is increased when the valve pin is retracted away from the gate and decreased when the valve pin is displaced toward the gate. Alternatively the valve pin and the bore may be configured such that valve pin has a surface for forming a gap with a surface of the bore away from the gate, wherein the size of the gap is decreased when the valve pin is retracted away from the gate and increased when the valve pin is displaced toward the gate. In such embodiments the apparatus typically includes a plug mounted in a recess of the manifold opposite a side of the manifold where the at least one nozzle is coupled, the plug having a bore through which a stem of the valve pin of the nozzle passes, the valve pin having a head which has the surface which forms the gap with the complementary surface of the bore, the bore of the plug through which the stem passes having a smaller diameter than the valve pin head at the valve pin head's largest cross-sectional point and the recess of the manifold having a larger diameter than the diameter of the valve pin head at the valve pin head's largest

point, so that the valve pin can be removed from the manifold from a side of the manifold. in which the recess is formed when the plug is removed from the manifold.

The apparatus most preferably includes a second-sensor for sensing a second selected condition of the melt material through the second nozzle, the computer being interconnected to the second sensor for receiving a signal representative of the selected condition sensed by the second sensor, the computer including an algorithm utilizing a value corresponding to a signal received from the second sensor as a variable for controlling operation of an actuator for the second nozzle.

The present invention also provides an injection molding machine having first and second nozzles for delivering melt material from a common manifold to one or more mold cavities, apparatus for controlling delivery of the melt material from the nozzles to the one or more mold cavities, each nozzle having an exit aperture communicating with a gate of a cavity of a mold and being associated with an actuator interconnected to a melt flow controller, the apparatus comprising:

a sensor for sensing a selected condition of the melt material through at least one of the nozzles;

an actuator controller interconnected to each actuator, each actuator controller comprising a computer interconnected to a sensor for receiving a signal representative of the selected condition sensed by the sensor, the computer including an algorithm utilizing a value corresponding to a signal received from the sensor as a variable for controlling operation of an actuator for the at least one nozzle;

wherein at least one of the nozzles has a tip end having a central portion having a central bore in alignment with the gate and an outer circumferential flange portion surrounding the gate and the central portion of the tip end of the at least one nozzle.

Brief Description of the Drawings

Figure 1 is a partially schematic cross-sectional view of an injection molding system according to one embodiment of the present invention ;

Figure 2 is an enlarged fragmentary cross-sectional view of one side of the injection molding system of Figure 1;

Figure 3 is an enlarged fragmentary cross-sectional view of an alternative embodiment of a system similar to Figure 1, in which a plug is used for easy removal of the valve pin ;

Figure 4 is an enlarged fragmentary cross-sectional view of an alternative embodiment of a system similar to Figure 1, in which a threaded nozzle is used;

Figure 5 is a view similar to Figure 4, showing an alternative embodiment in which a plug is used for easy removal of the valve pin ;

Figure 5a is a generic view of the end of the nozzles shown in Figs 1-5;

Figure 5b is a close-up more detailed view of a portion of the nozzle end encircled by arrows 5b-5b shown in Fig. 5a;

Figure 5c is cross sectional view of an alternative nozzle end configuration similar to the Figs. 5a and 5b configuration;

Figure 6 shows a fragmentary cross-sectional view of a system similar to Figure 1, showing an alternative embodiment in which a forward valve pin shut-off is used;

Figure 7 shows an enlarged fragmentary view of the embodiment of Figure 6, showing the valve pin in the open and closed positions, respectively;

Figure 8 is a cross-sectional view of an alternative embodiment of the present invention similar to Figure 6, in which a threaded nozzle is used with a plug for easy removal of the valve pin;

Figure 9 is an enlarged fragmentary view of the embodiment of Figure 8, in which the valve pin is shown in the open and closed positions;

Figure 10 is an enlarged view of an alternative embodiment of the valve pin, shown in the closed position;

Figure 11 is a fragmentary cross sectional view of an alternative embodiment of an injection molding system having flow control that includes a valve pin that extends to the gate; and

Figure 12 is an enlarged fragmentary cross-sectional detail of the flow control area;

Figure 13 is a side cross-section of the lower end of another nozzle having a straight valve pin;

Figure 13a is a view along lines 13a-13a of Fig. 13;

Figure 14 is a schematic side cross sectional view of a sensor monitored injection molding system having rotary valves disposed in the manifold flow channels for controlling melt flow into a mold cavity;

Figure 15 is a top plan cross sectional view of one of rotary valves of Figure 14 along lines 15-15 showing the rotary valve in a shut off position;

Figure 16 is a side cross-sectional view of one of the rotary valves of Figure 14;

Figure 17 is top view of one of the rotary valves of Figure 14 showing limit stops for limiting the rotation of the rotary cylinder of the rotary valves;

Figure 18 is a top view of one of the drive actuator-controllers of Figure 14 showing the position of bolts for connecting the drive-actuator relative to the valve;

Figure 19 is a schematic side cross-sectional view of an alternative rotary valve flow controlled system showing a dual drive actuator which simultaneously drives/controls a rotary valve and a valve pin which is additionally used in the bore of one of the down bores feeding into the cavity of the mold;

Figure 20 is a more detailed view of the mechanical interconnection between the dual drive actuator of Figure 19 and the rotary valve and the valve pin;

Figure 21 is a schematic top view of a drive wheel component of the drive actuator of Figure 19 showing the gear mesh relationship between the drive wheel and the follower wheel of the rotary valve;

Figure 22 is a side cross-sectional view of a shaftless motor for use as an alternative actuator for a valve or other flow control mechanism in accordance with the invention, the motor having an axially movable screw for driving the flow controller;

Figure 23 is a side cross sectional view of a sensor monitored nozzle having a straight valve pin interconnected to a readily detachable actuator having a readily attachable and detachable valve pin, the actuator being fed with pressurized drive fluid by a manifold which commonly feeds pressurized drive fluid to a plurality of actuators;

Figure 24 is an exploded view of the actuator interconnection components to the manifold shown in Fig. 23;

Figure 25 is an exploded view of the actuator interconnection to the drive fluid manifold of Fig. 23;

Figure 26 is an isometric view of a modular embodiment of a pressurized drive fluid manifold showing a modular configuration for the manifold;

Figure 27 is an isometric close-up view of a modular arm and actuator interconnection according to the Fig. 26 embodiment showing the alignment of a modular manifold with the fluid input/output ports of the actuator;

Figure 28 is a schematic side cross-sectional view of a sensor monitored valve gated nozzle having an actuator fed by a drive fluid delivery manifold and a proportional valve mounted on the manifold above the valve for precisely controlling the delivery of drive fluid to the individual actuator from the manifold;

Figure 29 is a side cross-sectional view of an embodiment having an Edge-Gated nozzle tip having sensor feedback control loop control over the actuator;

Figure 30 is a more detailed close-up view of the interface between the edge gated nozzle tip of Fig. 29 and the gate area of a mold cavity;

Figure 31 is a side cross-sectional view of an embodiment of the invention having a defined volume reservoir disposed in the melt flow channel leading from the main injection screw to the output of an injection nozzle.

Detailed Description

Figures 1-2 show one embodiment of an injection molding system according to the present invention having two nozzles 21, 23 the plastic flow through which are to be controlled dynamically according to an algorithm as described below. Although only two nozzles are shown in Figs. 1-2, the invention contemplates simultaneously controlling the material flow through at least two and also through a plurality of more than two nozzles. In the embodiment shown, the injection molding system 1 is a multi-gate single cavity system in which melt material 3 is injected into a cavity 5 from the two gates 7 and 9. Melt material 3 is injected from an injection molding machine 11 through

an extended inlet 13 and into a manifold 15. Manifold 15 distributes the melt through channels 17 and 19. Although a hot runner system is shown in which plastic melt is injected, the invention is applicable to other types of injection systems in which it is useful to control the rate at which a material (e.g., metallic or composite materials) is delivered to a cavity.

Melt is distributed by the manifold through channels 17 and 19 and into bores 18 and 20 of the two nozzles 21 and 23, respectively. Melt is injected out of nozzles 21 and 23 and into cavity 5 (where the part is formed) which is formed by mold plates 25 and 27. Although a multi-gate single-cavity system is shown, the invention is not limited to this type of system, and is also applicable to, for example, multi-cavity systems, as discussed in greater detail below.

The injection nozzles 21 and 23 are received in respective wells 28 and 29 formed in the mold plate 27. The nozzles 21 and 23 are each seated in support rings 31 and 33. The support rings serve to align the nozzles with the gates 7 and 9 and insulate the nozzles from the mold. The manifold 15 sits atop the rear end of the nozzles and maintains sealing contact with the nozzles via compression forces exerted on the assembly by clamps (not shown) of the injection molding machine. An O-ring 36 is provided to prevent melt leakage between the nozzles and the manifold. A dowel 73 centers the manifold on the mold plate 27. Dowels 32 and 34 prevent the nozzle 23 and support ring 33, respectively, from rotating with respect to the mold 27.

In the embodiment shown in Figs. 1-3 an electric band heater 35 for heating the nozzles is shown. In other embodiments, heat pipes, such as those disclosed in U.S. Patent No. 4,389,002, discussed below, may be disposed in a nozzle and used alone or in conjunction with a band heater 35. The heater is used to maintain the melt material at its processing.

temperature as far up to the point of exit through/into gates 7 and 9 as possible. As shown, the manifold is heated to elevated temperatures sufficient to maintain the plastic or other fluid which is injected into the manifold distribution ducts 17, 19 at a preferred preselected flow and processing temperature. A plurality of heat pipes 4 (only one of which is shown in Figs 2, 3) are preferably disposed throughout the manifold/hotrunner 15 so as to more uniformly heat and maintain the manifold at the desired processing temperature.

The mold plate or body 27 is, on the other hand, typically cooled to a preselected temperature and maintained at such cooled temperature relative to the temperature of the manifold 15 via cooling ducts 2 through which water or some other selected fluid is pumped during the injection molding process in order to effect the most efficient formation of the part within the mold cavity.

As shown in Figs. 1-5b, the injection nozzle(s) is/are mounted within well 29 so as to be held in firmly stationary alignment with the gate(s) 7, 9 which lead into the mold cavities. The mounting of the heated nozzle(s) is/are arranged so as to minimize contact of the nozzle(s) body and its associated components with the cooled mold plate 27 but at the same time form a seal against fluid leakage back into an insulative air space in which the nozzle is disposed thus maintaining the fluid pressure within the flow bore or channel against loss of pressure due to leakage. Figs 5a, 5b show a more detailed schematic view of the nozzle mountings of Figs. 1-5. As shown, there is preferably provided a small, laterally disposed, localized area 39a at the end of the nozzle for making compressed contact with a complementary surface 27a of the plate 27. This area of compressed contact acts both as a mount for maintaining the nozzle in a stationary, aligned and spaced apart from the plate 27 relationship and also as a seal against leakage of fluid

back from the gate area into the insulative space in well 29 left between the nozzle and the mold

plate 27. In the embodiment shown the mating area of the nozzle 39a is a laterally facing surface although a longitudinally facing surface may also be selected for effecting such a seal. The dimensions of the inner and outer pieces are machined so that compression mating between the laterally facing nozzle surface 39a and plate surface 27a occurs upon heating of the nozzle to its operating temperature which expands both laterally and longitudinally upon heating. The lateral mating surfaces 27a and 39a typically enables more ready machining of the parts, although compression mating between axially or longitudinally facing surfaces such as 39b and 27b can be provided for in the alternative. As shown in Figs 5a, 5b an insulative space 6a is also left between the most distal tip end surfaces of the nozzle and the mold such that as little direct contact as possible between the heated nozzle and the relatively cooler plate 27 is made.

Another example of lateral surface mating upon heating of the nozzle to operating process temperature can be seen in the embodiment shown in Figs 13, 13a. In this elastically deformable nozzle which is described in detail in US Patent No. 6261084, inner nozzle piece 37 is forced downwardly DF, Figs. 13, 13a upon heating of the apparatus to operating temperature whereby the undersurface 15a of manifold 15 compresses downwardly against the upper surface 37a of piece 37 causing the undersurface of step 37b to press downwardly DF, Fig. 13a, on the upper surface 39a of piece 39 which in turn causes the leg portion 39c, Fig 13a, to pivot P laterally and thus cause compressed mating between laterally facing surface 39d and laterally facing surface 27a of mold 27 to occur thus forming a seal against fluid leakage.

In an alternative embodiment shown in Fig. 5c, the nozzles may be machined or configured so as to leave a predetermined gap between or a non-compressed mating between two axially or longitudinally facing surfaces 27b and 39c (in the initially

assembled cold state) which gap will close upon heating the apparatus up to its operating plastic processing temperature such that the two surfaces 27b and 39c mate under compression to form a seal. As shown in Fig. 5c the insulative air gap 6a is maintained along the lateral edges of the outer piece 39 of the nozzle into which plastic melt does not flow by virtue of a seal which is formed between the surfaces 27b and 39c upon heating of the apparatus up. The same sort of longitudinal/axial seal may be formed using another alternative nozzle embodiment such as disclosed in US Patent No. 5,885,628, where the outer nozzle piece forms a flange like member around the centre portion of the nozzle. In any case, a relatively small surface on the outside of the distal tip end of the nozzles makes compression contact with a surface of the mold plate by virtue of thermally induced expansion of the nozzles such that a seal against melt flow is formed.

The nozzles may comprise a single unitary piece or, as shown in the embodiments in Figs. 1-5b, the nozzles 21 and 23 may comprise two (or more) separate unitary pieces such as insert 37 and tip 39. The insert 37 is typically made of a material (for example beryllium copper) having a relatively high thermal conductivity in order to maintain the melt at its most preferred high processing temperature as far up to the gate as possible by imparting heat to the melt from the heater 35 and/or via heat pipes as discussed below. In the embodiments shown, the outer tip piece 39 is used to form the seal with the mold plate 27 and preferably comprises a material (for example titanium alloy or stainless steel) having a substantially lower thermal conductivity relative to the material comprising the inner piece 37 so as reduce/minimize heat transfer from the nozzle (and manifold) to the mold as much as possible.

A seal or ring R, Figs. 5a-5c, is provided in the embodiment shown between the inner 37 and outer 39 pieces. As described in US Patent Nos. 5,554,395 and 5,885,628,

seal/ring R serves to insulate the two nozzle pieces 37, 39 from each other minimizing heat transfer between the two pieces and also by providing an insulative air gap 6b between the two nozzle pieces. The R comprises a member made of a metallic alloy or like material which may be substantially less heat conductive than the material of which pieces 37, 39 are comprised. The sealing member R is preferably a thin-walled, substantially resilient structure, and may be adapted for engagement by the seal mounting means so as to be carried by the nozzle piece 39. The sealing member R extends a preselected distance outwardly from the tip portion of the bushing so as to form a sealing engagement along a limited contact area located on the adjoining bore in the mold when the nozzle is operatively disposed therein. More particularly, in one preferred embodiment, it is contemplated that the sealing member R will include at least one portion having a partially open, generally C-shaped or arc-shaped transverse cross-section. Accordingly, the sealing member R may be formed as an O-ring, or as an O-ring defining spaced, aligned openings in its surface. Similarly, the sealing member may be formed as an O-ring having an annular portion removed from its inner wall so as to form a C-shaped or arc-shaped cross-sectional structure. Further, the sealing member may have a generally V-shaped or U-shaped or other cross-section which is dimensionally compatible with the mating areas with nozzle pieces 37, 39, if desired. In addition, the sealing member may be formed as a flexible length of hollow tubing or a flexible length of material having the desired generally C-shaped or arc-shaped or V-shaped or U-shaped transverse cross-section. Other possible configurations also will occur to those skilled in the art in view of the following detailed description of the present invention.

As shown in Fig 5a, the nozzles may include one or more heat pipes 4a embedded within the body of the nozzles for purposes of more efficiently and uniformly

maintaining the nozzle at an elevated temperature. In the Fig. 5a embodiment the heat pipes 4a are disposed in the nozzle body part 23 which typically comprises a high strength tool steel which has a predetermined high heat conductivity and strength. The heat pipes 4 mounted in the manifold, Figs. 2,3 and heat pipes 4a, Fig. 5a, preferably comprise sealed tubes comprised of copper or steel within which any vaporizable and condensable liquid such as water is enclosed. Mercury may be used as the vaporizable heat transferring medium in the heat pipes 4, 4a, however, it is more preferable to use an inert liquid material such as water. One drawback to the use of water is that there can be a tendency for a reaction to occur between the iron in the steel and the water whereby the iron combines with the oxygen of the water leaving a residue of hydrogen which is an incondensable gas under the conditions of operation of the heat pipe. The presence of hydrogen in the heat pipe is deleterious to its effective operation. For the purposes of this invention any material, such as iron or an alloy of iron, which tends to release hydrogen from water is referred to as "water incompatible material."

The use of high strength steel is made practicable by plating or otherwise covering the interior wall of each heat pipe with a material which is non-reactive with water. Examples of such materials are nickel, copper, and alloys of nickel and copper, such as monel. Such materials are referred to herein as "water compatible materials." The inner wall of each heat pipe 4, 4a is preferably plated with a water compatible material, preferably nickel. Such plating is preferably made thick enough to be impermeable to water and water vapor. A wick structure 4c is inserted into each heat pipe, the wick typically comprising a water compatible cylindrical metal screen which is forced into and tightly pressed against the interior wall of a heat pipe. The wick preferably comprises a water compatible material such as monel. The elevated temperature at which the manifold and/or nozzles are maintained during an injection

cycle typically ranges between about 200 and about 400 degrees centigrade. The vapor pressure of water at these temperatures, although quite high, is readily and safely contained with the enclosed tubular heat pipes. In practice, less than the total volume of the enclosed heat pipes is filled with the selected fluid, typically less than about 70% of such volume, and more typically less than 50%. Following the insertion of the water, the outer end of each heat pipe is sealed by conventional means. In a preferred embodiment the tubular heat pipes are sealed at one end via a plug as described in US Patent No. 4,389,002. In operation, the fluid contained within the heat pipes 4, 4a is vaporized by heat conduction from the manifold. The fluid vaporizes and travels to each portion of the heat pipe from which heat is being extracted and the vapor condenses at each such portion to yield up its heat of condensation to maintain the entire length of the heat pipe at the same temperature. The vaporization of water from the inner end of the wick structure 4c creates a capillary attraction to draw condensed water from the rest of the wick structure back to the evaporator portion of the wick thus completing the cycle of water flow to maintain the heat pipe action. Where a plurality of heat pipes are disposed around the nozzle, there is maintained a uniform temperature around the axis X of the nozzle bores, particularly in embodiments where the heat pipes are disposed longitudinally as close to the exit end of the nozzle as possible.

In one embodiment, Figs. 1-5, a valve pin 41 having a tapered head 43 controllably engagable with a surface upstream of the exit end of the nozzle may be used to control the rate of flow of the melt material to and through the respective gates 7 and 9. The valve pin reciprocates through the flow channel 100 in the manifold 15. A valve pin bushing 44 is provided to prevent melt from leaking along stem 102 of the valve pin. The valve pin bushing is held in place by a threadably mounted cap 46. The valve pin is

opened at the beginning of the injection cycle and closed at the end of the cycle. During the cycle, the valve pin can assume intermediate positions between the fully open and closed positions, in order to decrease or increase the rate of flow of the melt. The head includes a tapered portion 45 that forms a gap 81 with a surface 47 of the bore 19 of the manifold. Increasing or decreasing the size of the gap by displacing the valve pin correspondingly increases or decreases the flow of melt material to the gate. When the valve pin is closed the tapered portion 45 of the valve pin head contacts and seals with the surface 47 of the bore of the manifold.

Figure 2 shows the head of the valve pin in a Phantom dashed line in the closed position and a solid line in the fully opened position in which the melt is permitted to flow at a maximum rate. To reduce the flow of melt, the pin is retracted away from the gate by an actuator 49, to thereby decrease the width of the gap 81 between the valve pin and the bore 19 of the manifold.

The actuator 49 (for example, the type disclosed in US Patent No. 5,894,025) is mounted in a clamp plate 51 which covers the injection molding system 1. In the embodiment shown, the actuator 49 is a hydraulic actuator, however, pneumatic or electronic actuators can also be used. Other actuator configurations having ready detachability may also be employed such as those described in US Patent No. 5,948,448. An electronic or electrically powered actuator may also be employed such as disclosed in US Patent No. 6,294,122. In the embodiment shown, the actuator 49 includes a hydraulic circuit that includes a movable piston 53 in which the valve pin 41 is threadably mounted at 55. Thus, as the piston 53 moves, the valve pin 41

moves with it. The actuator 49 includes hydraulic lines 57 and 59 which are controlled by servo valves 1 and 2. Hydraulic line 57 is energized to move the valve pin 41 toward the gate to the open position, and hydraulic line 59 is energized to retract the valve pin away from the gate toward the close position. An actuator cap 61 limits longitudinal movement in the vertical direction of the piston 53. O-rings 63 provide respective seals to prevent hydraulic fluid from leaking out of the actuator. The actuator body 65 is mounted to the manifold via screws 67.

In embodiments where a pneumatically or electrically powered actuator is employed, suitable pneumatic (air supply) or electrical power inputs to the actuator are provided, such inputs being controllable to precisely control the movement of the actuator via the same computer generated signals which are output from the PID1 and PID2 controllers and the same or similar control algorithm/program used in the CPU of FIG. 1 such that precise control of the movement of the valve pin used to control plastic flow is achieved according to the predetermined algorithm selected for the particular application.

In the embodiment shown, a pressure transducer 69 is used to sense the pressure in the manifold bore 19 downstream of the valve pin head 43. In operation, the conditions sensed by the pressure transducer 69 associated with each nozzle are fed back to a control system that includes controllers PID 1 and PID 2 and a CPU shown schematically in Figure 1. The CPU executes a PID (proportional, integral, derivative) algorithm which compares the sensed pressure (at a given time) from the pressure transducer to a programmed target pressure (for the given time). The CPU instructs the PID controller to adjust the valve pin using the actuator 49 in order to mirror the target pressure for that given time. In this way a programmed target pressure profile for an injection cycle for a particular part for each gate 7 and 9 can be followed.

As to each separate nozzle, the target pressure or pressure profile may be different, particularly where the nozzles are injecting into separate cavities, and thus separate algorithms or programs for achieving the target pressures at each nozzle may be employed. As can be readily imagined, a single computer or CPU may be used to execute multiple programs/algorithms for each nozzle or separate computers may be utilized. The embodiment shown in Fig. 1 is shown for purposes of ease of explanation.

Although in the disclosed embodiment the sensed condition is pressure, other sensed conditions can be used which relate to melt flow rate. For example, the position of the valve pin or the load on the valve pin could be the sensed condition. If so, a position sensor or load sensor, respectively, could be used to feed back the sensed condition to the PID controller. In the same manner as explained above, the CPU would use a PID algorithm to compare the sensed condition to a programmed target position profile or load profile for the particular gate to the mold cavity, and adjust the valve pin accordingly. Similarly the location of the sensor and the sensed condition may be other than in the nozzle itself. The location of the measurement may, for example, be somewhere in the cavity of the mold or upstream of the nozzle somewhere in the manifold flow channel or even further upstream in the melt flow.

Melt flow rate is directly related to the pressure sensed in bore 19. Thus, using the controllers PID 1 and PID 2, the rate at which the melt flows into the gates 7 and 9 can be adjusted during a given injection molding cycle, according to the desired pressure profile. The pressure (and rate of melt flow) is decreased by retracting the valve pin and decreasing the width of the gap 81 between the valve pin and the manifold bore, while the pressure (and rate of melt flow) is increased by displacing the valve pin toward the gate 9, and increasing the width of the gap 81. The PID controllers adjust the position of the actuator piston 53 by sending instructions to servo valves 1 and 2.

By controlling the pressure in a single cavity system (as shown in Figure 1) it is possible to adjust the location and shape of the weld line formed when melt flow 75 from gate 7 meets melt flow 77 from gate 9 as disclosed in U.S. Patent No. 5,556,582. However, the invention also is useful in a multi-cavity system. In a multi-cavity system the invention can be used to balance fill rates and packing profiles in the respective cavities. This is useful, for example, when molding a plurality of like parts in different cavities. In such a system, to achieve a uniformity in the parts, the fill rates and packing profiles of the cavities should be as close to identical as possible. Using the same programmed pressure profile for each nozzle, unpredictable fill rate variations from cavity to cavity are overcome, and consistently uniform parts are produced from each cavity.

Another advantage of the present invention is seen in a multi-cavity system in which the nozzles are injecting into cavities which form different sized parts that require different fill rates and packing profiles. In this case, different pressure profiles can be programmed for each respective controller of each respective cavity. Still another advantage is when the size of the cavity is constantly changing, i.e., when making different size parts by changing a mold insert in which the part is formed. Rather than change the hardware (e.g., the nozzle) involved in order to change the fill rate and packing profile for the new part, a new program is chosen by the user corresponding to the new part to be formed.

The embodiment of Figures 1 and 2 has the advantage of controlling the rate of melt flow away from the gate inside manifold 15 rather than at the gates 7 and 9. Controlling the melt flow away from the gate enables the pressure transducer to be located away from the gate (in Figures 1-5). In this way, the pressure transducer does not have to be placed inside the mold cavity, and is not susceptible to pressure spikes

which can occur when the pressure transducer is located in the mold cavity or near the gate. Pressure spikes in the mold cavity result from the valve pin being closed at the gate. This pressure spike could cause an unintended response from the control system, for example, an opening of the valve pin to reduce the pressure -- when the valve pin should be closed.

Avoidance of the effects of a pressure spike resulting from closing the gate to the mold makes the control system behave more accurately and predictably. Controlling flow away from the gate enables accurate control using only a single sensed condition (e.g., pressure) as a variable. The '582 patent disclosed the use of two sensed conditions (valve position and pressure) to compensate for an unintended response from the pressure spike. Sensing two conditions resulted in a more complex control algorithm (which used two variables) and more complicated hardware (pressure and position sensors).

Another advantage of controlling the melt flow away from the gate is the use of a larger valve pin head 43 than would be used if the valve pin closed at the gate. A larger valve pin head can be used because it is disposed in the manifold in which the melt flow bore 19 can be made larger to accommodate the larger valve pin head. It is generally undesirable to accommodate a large size valve pin head in the gate area within the end of the nozzle 23, tip 39 and insert 37. This is because the increased size of the nozzle, tip and insert in the gate area could interfere with the construction of the mold, for example, the placement of water lines within the mold which are preferably located close to the gate. Thus, a larger valve pin head can be accommodated away from the gate.

The use of a larger valve pin head enables the use of a larger surface 45 on the valve pin head and a larger surface 47 on the bore to form the control gap 81. The more "control" surface (45 and 47) and the longer the "control" gap (81) -- the more precise

control of the melt flow rate and pressure can be obtained because the rate of change of melt flow per movement of the valve pin is less. In Figures 1-3 the size of the gap and the rate of melt flow is adjusted by adjusting the width of the gap, however, adjusting the size of the gap and the rate of material flow can also be accomplished by changing the length of the gap, i.e., the longer the gap the more flow is restricted. Thus, changing the size of the gap and controlling the rate of material flow can be accomplished by changing the length or width of the gap.

The valve pin head includes a middle section 83 and a forward cone shaped section 95 which tapers from the middle section to a point 85. This shape assists in facilitating uniform melt flow when the melt flows past the control gap 81. The shape of the valve pin also helps eliminates dead spots in the melt flow downstream of the gap 81.

Figure 3 shows another aspect in which a plug 87 is inserted in the manifold 15 and held in place by a cap 89. A dowel 86 keeps the plug from rotating in the recess of the manifold that the plug is mounted. The plug enables easy removal of the valve pin 41 without disassembling the manifold, nozzles and mold. When the plug is removed from the manifold, the valve pin can be pulled out of the manifold where the plug was seated since the diameter of the recess in the manifold that the plug was in is greater than the diameter of the valve pin head at its widest point. Thus, the valve pin can be easily replaced without significant downtime.

Figures 4 and 5 show additional alternative embodiments of the invention in which a threaded nozzle style is used instead of a support ring nozzle style. In the threaded nozzle style, the nozzle 23 is threaded directly into manifold 15 via threads 91. Also, a coil heater 93 is used instead of the band heater shown in Figures 1-3. The threaded nozzle style is advantageous in that it permits removal of the manifold and nozzles (21 and 23) as a unitary element. There is also less of a possibility of melt

leakage where the nozzle is threaded on the manifold. The support ring style (Figures 1-3) is advantageous in that one does not need to wait for the manifold to cool in order to separate the manifold from the nozzles. Figure 5 also shows the use of the plug 87 for convenient removal of valve pin 41.

Figures 6-10 show an alternative embodiment of the invention in which a "forward" shutoff is used rather than a retracted shutoff as shown in Figures 1-5. In the embodiment of Figures 6 and 7, the forward cone-shaped tapered portion 95 of the valve pin head 43 is used to control the flow of melt with surface 97 of the inner bore 20 of nozzle 23. An advantage of this arrangement is that the valve pin stem 102 does not restrict the flow of melt as in Figures 1-5. As seen in Figures 1-5, the clearance 81 between the stem 102 and the bore 19 of the manifold is not as great as the clearance 98 in Figures 6 and 7. The increased clearance 98 in Figures 6-7 results in a lesser pressure drop and less shear on the plastic.

In Figures 6 and 7 the control gap 98 is formed by the front cone-shaped portion 95 and the surface 97 of the bore 20 of the rear end of the nozzle 23. The pressure transducer 69 is located downstream of the control gap -- thus, in Figures 6 and 7, the nozzle is machined to accommodate the pressure transducer as opposed to the pressure transducer being mounted in the manifold as in Figures 1-5.

Figure 7 shows the valve pin in solid lines in the open position and Phantom dashed lines in the closed position. To restrict the melt flow and thereby reduce the melt pressure, the valve pin is moved forward from the open position towards surface 97 of the bore 20 of the nozzle which reduces the width of the control gap 98. To increase the flow of melt the valve pin is retracted to increase the size of the gap 98.

The rear 45 of the valve pin head 43 remains tapered at an angle from the stem 102 of the valve pin 41. Although the surface 45 performs no sealing function in this

embodiment, it is still tapered from the stem to facilitate even melt flow and reduce dead spots.

As in Figures 1-5, pressure readings are fed back to the control system (CPU and PID controller), which can accordingly adjust the position of the valve pin 41 to follow a target pressure profile. The forward shut-off arrangement shown in Figures 6 and 7 also has the advantages of the embodiment shown in Figures 1-5 in that a large valve pin head 43 is used to create a long control gap 98 and a large control surface 97. As stated above, a longer control gap and greater control surface provides more precise control of the pressure and melt flow rate.

Figures 8 and 9 show a forward shutoff arrangement similar to Figures 6 and 7, but instead of shutting off at the rear of the nozzle 23, the shut-off is located in the manifold at surface 101. Thus, in the embodiment shown in Figures 8 and 9, a conventional threaded nozzle 23 may be used with a manifold 15, since the manifold is machined to accommodate the pressure transducer 69 as in Figures 1-5. A spacer 88 is provided to insulate the manifold from the mold. This embodiment also includes a plug 87 for easy removal of the valve pin head 43.

Figure 10 shows an alternative embodiment of the invention in which a forward shutoff valve pin head is shown as used in Figures 6-9. However, in this embodiment, the forward cone-shaped taper 95 on the valve pin includes a raised section 103 and a recessed section 104. Ridge 105 shows where the raised portion begins and the recessed section ends. Thus, a gap 107 remains between the bore 20 of the nozzle through which the melt flows and the surface of the valve pin head when the valve pin is in the closed position. Thus, a much smaller surface 109 is used to seal and close the valve pin. The gap 107 has the advantage in that it assists opening of the valve pin which is subjected to a substantial force F from the melt when the injection machine begins an injection cycle.

When injection begins melt will flow into gap 107 and provide a force component F1 that assists the actuator in retracting and opening the valve pin. Thus, a smaller actuator, or the same actuator with less hydraulic pressure applied, can be used because it does not need to generate as much force in retracting the valve pin. Further, the stress forces on the head of the valve pin are reduced.

Despite the fact that the gap 107 performs no sealing function, its width is small enough to act as a control gap when the valve pin is open and correspondingly adjust the melt flow pressure with precision as in the embodiments of Figures 1-9.

Figures 11 and 12 show an alternative hot-runner system having flow control in which the control of melt flow is still away from the gate as in previous embodiments. Use of the pressure transducer 69 and PID control system is the same as in previous embodiments. In this embodiment, however, the valve pin 41 extends past the area of flow control via extension 110 to the gate. The valve pin is shown in solid lines in the fully open position and in Phantom dashed lines in the closed position. In addition to the flow control advantages away from the gate described above, the extended valve pin has the advantage of shutting off flow at the gate with a tapered end 112 of the valve pin 41.

Extending the valve pin to close the gate has several advantages. First, it shortens injection cycle time. In previous embodiments thermal gating is used. In thermal gating, plastication does not begin until the part from the previous cycle is ejected from the cavity. This prevents material from exiting the gate when the part is being ejected. When using a valve pin, however, plastication can be performed simultaneously with the opening of the mold when the valve pin is closed, thus shortening cycle time by beginning plastication sooner. Using a valve pin can also result in a smoother gate surface on the part.

The flow control area is shown enlarged in Figure 12. In solid lines the valve pin is shown in the fully open position in which maximum melt flow is permitted. The valve pin includes a convex surface 114 that tapers from edge 128 of the stem 102 of the valve pin 41 to a throat area 116 of reduced diameter. From throat area 116, the valve pin expands in diameter in section 118 to the extension 110 which extends in a uniform diameter to the tapered end of the valve pin.

In the flow control area the manifold includes a first section defined by a surface 120 that tapers to a section of reduced diameter defined by surface 122. From the section of reduced diameter the manifold channel then expands in diameter in a section defined by surface 124 to an outlet of the manifold 126 that communicates with the bore of the nozzle 20. Figures 11 and 12 show the support ring style nozzle similar to Figures 1-3. However, other types of nozzles may be used such as, for example, a threaded nozzle as shown in Figure 8.

As stated above, the valve pin is shown in the fully opened position in solid lines. In Figure 12, flow control is achieved and melt flow reduced by moving the valve pin 41 forward toward the gate thereby reducing the width of the control gap 98. Thus, surface 114 approaches surface 120 of the manifold to reduce the width of the control gap and reduce the rate of melt flow through the manifold to the gate.

To prevent melt flow from the manifold bore 19, and end the injection cycle, the valve pin is moved forward so that edge 128 of the valve pin, i.e., where the stem 102 meets the beginning of curved surface 114, will move past point 130 which is the beginning of surface 122 that defines the section of reduced diameter of the manifold bore 19. When edge 128 extends past point 130 of the manifold bore melt flow is prevented since the surface of the valve stem 102 seals with surface 122 of the manifold. The valve pin is shown in dashed lines where edge 128 is forward enough to form a seal

with surface 122. At this position, however, the valve pin is not yet closed at the gate. To close the gate the valve pin moves further forward, with the surface of the stem 102 moving further along, and continuing to seal with, surface 122 of the manifold until the end 112 of the valve pin closes with the gate.

In this way, the valve pin does not need to be machined to close the gate and the flow bore 19 of the manifold simultaneously, since stem 102 forms a seal with surface 122 before the gate is closed. Further, because the valve pin is closed after the seal is formed in the manifold, the valve pin closure will not create any unwanted pressure spikes. Likewise, when the valve pin is opened at the gate, the end 112 of the valve pin will not interfere with melt flow, since once the valve pin is retracted enough to permit melt flow through gap 98, the valve pin end 112 is a predetermined distance from the gate. The valve pin can, for example, travel 6 mm. from the fully open position to where a seal is first created between stem 102 and surface 122, and another 6 mm. to close the gate. Thus, the valve pin would have 12 mm. of travel, 6 mm. for flow control, and 6 mm. with the flow prevented to close the gate. Of course, the invention is not limited to this range of travel for the valve pin, and other dimensions can be used.

Figs. 13 and 13a show a nozzle having a conventional straight cylindrical pin 41 which may be used as an alternative in conjunction with the automated systems described above. For example, pressure may be measured in the cavity itself by a sensor 69a and a program utilized in CPU, Fig. 1 which simply opens, Fig. 13a, and closes, Fig 13 the exit aperture or gate 9 upon sensing of a certain pressure so as to create certain pressure increase in the cavity when closed, or alternatively the tip end of the pin may be tapered (tapering shown in dashed lines 41b) in some fashion so as to vary the melt flow rate 20b, in accordance with a predetermined program depending on the sensor measurement 69a, as the pin 41 is moved into a predetermined closer proximity to the tip

end surface 20a of bore 20 (complementary tapering of surface 20a not shown) in a similar manner to the way the rate of melt flow may be varied using the tapered conical head 45 of the Figs. 2-5 embodiments.

Figs. 14-21 show an embodiment of the invention using rotary valves 200 as a mechanical component for controlling melt flow from a main feed channel 13 and common manifold feed channel 13d disposed in manifold 15 to a pair of down drop bores or nozzles 20d and exit apertures 9a in housings 20e which lead into cavity 9i. As shown, the rotary valves 200 comprise a rotatable shaft 202 having a melt passageway 204, the shaft being rotatably mounted in outer bearing housing 206. As shown the outer bearing 206 has a converging/diverging passageway 201 to match the inner shaft passageway 204. The rotary shaft 202 is rotatably drivable by its interconnection to actuator 208 which may comprise an electrically, pneumatically, hydraulically or mechanically powered mechanism which is typically mechanically interconnected to shaft 202. Automatic control of the actuators is effected in the same manner as described above via CPU and PID1 and PID2 controllers wherein signals are sent 210 from sensors 69 to the PID controllers and processed via CPU which, according to a predetermined algorithm signals the PID controllers to instruct actuators 208 to adjust the rotation of passageways 204 so as to vary the rate of melt flow through passageways 204 to achieve the predetermined target pressure or pressure profile at the position of sensors 69. Melt flow through passageways 204 can be precisely varied depending on the position of rotation of shaft 202 within bearing 206. As shown in Fig. 15, passageway 204c in the position shown is fully closed off from manifold passageway 201 and flow is completely stopped. As can be readily imagined, rotation of shaft 202, Fig. 15 in direction 202a will eventually open a leading edge of passageway 204 into open communication with manifold passageway 201 allowing melt to flow and gradually

increase to a maximum flow when the passageway 204 reaches the position 204o, Fig. 15. As described above with reference to other embodiments, the nozzle bores 20d may exit into a single cavity 9i or may exit into separate cavities (not shown).

Figs. 16-17 show mechanical limit stops that may be employed whereby prismatic stops 212, 213 attached to the bearing housing 206 serve to engage radial stops 215 of stop member 214 which is attached to the top of shaft 202 and thus serve to limit the rotational travel of shaft 202 in directions 202a and 202b.

Figs. 19-21 show an alternative embodiment where the actuators 208 commonly drive both a rotary valve 200 and a valve pin 41. As shown the valve pins 41 can be arranged so as to reciprocate along their axes X between open, 41', and closed ,41, aperture 9a positions simultaneously with shaft 202 being controllably rotated. Such simultaneous drive is accomplished via drive wheel 220, Figs. 20-21, whose gear teeth 228 are meshed with gear teeth 226 of wheel 218 and the screwable engagement of the threaded head 234 of pins 41, 41' in the shafts 236 of driven wheels 220. As can be readily imagined as shaft 236 is rotated either clockwise or counterclockwise 24, pin 41' will be displaced either up or down 232 simultaneously with rotation of shaft 202 and its associated passageway 204. During a typical operation, the rotary valve may fully stop the melt flow prior to the valve pin closing at the exit 9a. Similarly, the valve pin may open access to the mold cavity 9i prior to the rotary valve permitting melt through the passageway 204.

Fig. 22 shows an example of an electrically powered motor which may be used as an actuator 301, in place of a fluid driven mechanism, for driving a valve pin or rotary valve or other nozzle flow control mechanism. In the embodiment shown in Figs. 22 a shaftless motor 300 mounted in housing 302 has a center ball nut 304 in which a screw 308a is screwably received for controlled reciprocal driving 308 of the screw 308a along

axis X. Other motors which have a fixed shaft in place of the screw may also be employed as described more fully in US Patent No. 6,294,122. As shown in the Fig. 22 embodiment the nut 304 is rigidly interconnected to magnet 310 and mounting components 310a, 310b which are in turn fixedly mounted on the inner race of upper rotational bearing 312 and lower rotational bearing 314 for rotation of the nut 304 relative to housing 302 which is fixedly interconnected to the manifold 15 of the injection molding machine. The axially driven screw 308a is fixedly interconnected to valve pin 41 which reciprocates 308 along axis X together with screw 308a as it is driven. As described more fully below, pin 41 is preferably readily detachably interconnected to the moving component of the particular actuator being used, in this case screw 308a. In the Fig. 22 embodiment, the head 41a of pin 41 is slidably received within a complementary lateral slot 321 provided in interconnecting component 320. The housing 302 may be readily detached from manifold 15 by unscrewing bolts 342 and lifting the housing 302 and sliding the pin head 41a out of slot 321 thus making the pin readily accessible for replacement.

As can be readily imagined other motors may be employed which are suitable for the particular flow control mechanism which is disposed in the flow channel of the manifold or nozzle, e.g. valve pin or rotary valve. For example, motors such as a motor having an axially fixed shaft having a threaded end which rotates together with the other rotating components of the actuator 301 and is screwably received in a complementary threaded nut bore in pin interconnecting component 320, or a motor having an axially fixed shaft which is otherwise screwably interconnected to the valve pin or rotary valve may be employed.

Controlled rotation 318 of screw 308a, Fig 22, is achieved by interconnection of the motor 300 to a motor controller 316 which is in turn interconnected to the CPU, the

algorithm of which (including PID controllers) controls the on/off input of electrical energy to the motor 300, in addition to the direction and speed of rotation 318 and the timing of all of the foregoing. Motor controller 316 may comprise any conventional motor control mechanism(s) which are suitable for the particular motor selected. Typical motor controllers include an interface 316a for processing/interpreting signals received from the CPU; and, the motor controllers typically comprise a voltage, current, power or other regulator receiving the processed/interpreted signals from interface 316a and regulates the speed of rotation of the motor 300 according to the instruction signals received.

Figs. 23, 24 show another embodiment of the invention where a readily detachable valve pin 41 interconnection is shown in detail. Fig. 23 shows a nozzle 21a having a configuration similar in design to the nozzle configuration of Fig. 13. As shown the nozzle 21a is mounted in an aperture in a mold plate 27 having an exit aperture aligned with gate 9a and a sensor 69a for measuring a material property in the cavity 9g which sends recordation signals to electronic controllers (including CPU, PID controllers or the like) for reciprocation of the pin 41 according to a predetermined program. In the embodiment shown the pin 41 is straight, however the pin 41 and the nozzle bore 20 may have other configurations such as shown/described with reference to Figs. 2-5 and the sensor 69 located in the nozzle bore 20 or other location in the path of the melt flow depending on the type and purpose of control desired for the particular application. As described above,, the ready detachability of the pin and actuator of the Figs. 23, 24 embodiment may also be adapted to an electric actuator such as described with reference to Fig. 22.

Figs. 23-28 illustrate another embodiment of the invention wherein certain components provide common fluid feed to a plurality fluid driven actuators and where

certain components are readily attachable and/or detachable as described in US Patent No. 5,948,448. As shown in Figs. 23, 24 a fluid driven actuator 322 is fixedly mounted on a hotrunner manifold 324 having a melt flow channel 326 leading into nozzle bore 20. The actuator comprises a unitary housing 328 which sealably encloses a piston 332 having an O-Ring seal 334 which defines interior sealed fluid chambers, upper chamber 336 and lower chamber 338. The unitary housing 328 is spacedly mounted on and from the manifold 324 by spacers 340 and bolts 342 and an intermediate mounting plate 344 attached to the upper surface of the manifold 324. The heads 343 of the bolts 342 are readily accessible form the top surface 341 of the actuator housing 328 for ready detachment of the housing from plate 344 as shown in Figs. 24. Plate 344 is fixedly attached to the manifold via bolts 330.

The piston 332 has a stem portion 346, Figs. 23-25, which extends outside the interior of the sealed housing 328 and chambers 336, 338. At the end of the stem 346 a lateral slot 321 is provided for readily slidably receiving in a lateral direction the head 41a of the pin. As can be seen the bottom of the slot 321 has an aperture having a width less than the diameter of the pin head 41a such that once the pin head is slid laterally into the slot 321, the pin head is held axially within slot 321. In practice the pin head 41a and slot 321 are configured so that the pin head 41a fits snugly within the slot. As can be readily imagined, the pin head 41a can be readily slid out of the slot 321 upon detachment of the actuator 328, Fig. 24, thus obviating the prior art necessity of having to disassemble the actuator itself to obtain access to the pin head 41a. Once the actuator housing is detached, Fig. 24, the pin 41 is thus readily accessible for removal from and replacement in the manifold 324/nozzle bore 20.

In another embodiment of the invention, where hydraulic or pneumatic actuators are used to drive the pins or rotary valves of two or more nozzles, the drive fluid may be supplied by a common manifold or fluid feed duct. Such common fluid feed ducts are most preferably independent of the fluid driven actuators, i.e. the ducts do not comprise a housing component of the actuators but rather the actuators have a self contained housing, independent of the fluid feed manifold, which houses a sealably enclosed cavity in which a piston is slidably mounted. For example, as shown in Figs. 23-28, the fluid input/output ports 350, 352, 350a, 352a of independent actuators 322, 322a (Fig 28) are sealably mated with the fluid input output ports 354, 356, 354a, 356a of a fluid manifold 358, 358a which commonly delivers actuator drive fluid (such as oil or air) to the sealed drive chambers 336, 338, 336a, 338a of two or more actuators 322, 322a. Most preferably, the ports 354, 356 (or 354a, 356a) of the manifold 358 (or 358a) are sealably mated with their complementary actuator ports 350, 352 (350a, 352a) via compression mating of the undersurface 360 of the manifold 358 (358a) with the upper surface 341 of the actuators 322 (322a) as best shown in Fig. 25. Such compression mating may be achieved by initially connecting the manifold via bolt 363 and threaded holes 351 or similar means to the actuators 322 in their room temperature state (referred to as cold) with their mating surfaces in close or mating contact such that upon heating to operating temperature the manifold and actuators expand and the undersurfaces 360 and upper surfaces 341 compress against each other forming a fluid seal against leakage around the aligned ports 350/354 and 352/356. In most preferred embodiments, a compressible O-ring seal 364 is seated within a complementary receiving groove disposed around the mating area between the ports such that when the manifold and actuators are heated to operating temperature the O-ring is compressed between the undersurface 360 and upper

surface 341 thus forming a more reliable and reproducible seal with less precision in mounting alignment between the manifold and the actuators being required.

As shown in Figs 23, 25-28, the manifold(s) 322 has two feed ducts 365, 367 for delivery of pressurized actuator drive fluid to and from a master tank or other source (not shown) which ducts extend the length of the manifold 358 and commonly feed each actuator 322. In the embodiment shown in Figs. 26, 27 the manifold 358 can be constructed as a modular apparatus having a first distributor arm 358d generally adaptable to be mounted on a hotrunner manifold, to which one or more additional distributor arms 358c may be sealably attached 358e to fit/adapt to the specific configuration of the particular manifold or injection molding machine to be outfitted.

As can be readily imagined a plurality of actuators may also utilize a manifold plate which forms a structural component of one or more of the actuators and serves to deliver drive fluid commonly to the actuators, e.g. the manifold plate forms a structural wall portion of the housings of the actuators which serves to form the fluid sealed cavity within which the piston or other moving mechanism of the actuator is housed.

Precise control over the piston or other moving component of a fluid driven actuator such as actuator 322a, Fig. 28, actuator 49, Fig. 1, actuator 208, Fig. 14 (which more typically comprises an electrically driven actuator), or actuator 322, Figs 23-27 can be more effectively carried out with a proportional valve 370 as shown in Fig. 28, although other valve or drive fluid flow controllers may be employed.

In the Fig. 28 embodiment, a separate proportional valve 370 for each individual actuator 322a is mounted on a common drive fluid delivery manifold 358a. The manifold 358a has a single pressurized fluid delivery duct 372 which feeds pressurized drive fluid first into the distributor cavity 370a of the valve 370. The pressurized fluid from duct 372 is selectively routed via left 375 or right 374 movement of plunger or

spool 380 either through port 370b into piston chamber 338a or through port 370c into piston chamber 336a. The plunger or spool 380 is controllably movable to any left to right 375, 374 position within sealed housing 381 via servo drive 370e which receives control signals 382 from the CPU. The servo drive mechanism 370e typically comprises an electrically driven mechanism such as a solenoid drive, linear force motor or permanent magnet differential motor which is, in turn, controlled by and interconnected to CPU via interface 384 which interprets and communicates control signals from the CPU to the servo drive 370e. Restrictors or projections 370d and 370g of plunger/spool 380 are slidable over the port apertures 370 b and c to any desired degree such that the rate of flow of pressurized fluid from chamber 370a through the ports can be varied to any desired degree by the degree to which the aperture ports 370b, 370g are covered over or restricted by restrictors 370d, 370g. The valve 370 includes left and right vent ports which communicate with manifold fluid vent channels 371, 373 respectively for venting pressurized fluid arising from the left 375 or right 374 movement of the plunger/spool 380. Thus, depending on the precise positioning of restrictors 370d and 370g over apertures 370b and 370c, the rate and direction of axial movement of piston 385 and pin 41/head 43, can be selectively varied and controlled which in turn controls the rate of melt material from manifold channel 19 through nozzle bore 20 and gate 9. The nozzle and pin 41, head 43, and mounting component 87, 89 configurations shown in Fig. 28 correspond to the configurations shown in Fig. 5 and the description above with regard to the manner in which the melt material is controllable by such head 43, configurations are applicable to the Fig. 28 embodiment. A pressurized fluid distributing valve and a fluid driven actuator having a configuration other than the proportional valve 370 and actuator shown in Fig. 28 may be utilized, the essential requirements of such components being that the valve include a fluid flow control mechanism which is capable of varying

the rate of flow to the drive fluid chambers of the actuator to any desired rate and direction of flow into and out of the fluid drive chambers of the actuator.

In the embodiment shown in Figs. 29, 30, a nozzle 21 having a main bore 20 having a main axis X terminates in a gate interfacing bore having an axis Y which is not aligned with axis X. As shown the gate 9b of the mold having cavity 9c is an edge gate extending radially outward through a mold cavity plate 27 wherein the nozzle has a bore having a first portion 20 having an inlet for the plastic melt which is not in alignment with the edge gate and a second portion 20f extending radially outward from the first portion 20 terminating in the exit aperture of the radial bore 20f being in alignment with the edge gate 9b. In the preferred embodiment shown and as described more fully in US Patent No. 5,885,628, the disclosure of which is incorporated herein by reference, a small gap 9d is left between the radial tip end of the outer piece 39 of the nozzle and the surface of the mold plate around the cavity 9c such that it is possible for melt material to seep from groove 9k through the gap 9d and into the space 9j circumferentially surrounding the outer piece 39 where the gap 9d is selected to be small enough to prevent seepage of plastic melt backwards from space 9j into the groove area 9k and gate 9b area during ongoing or newly started up pressurized melt injection. The tip end of the nozzle as shown in Figs. 29, 30 comprises an outer 39 piece and an inner 37 piece having a gap 6b therebetween. The two pieces 37, 39 are mounted to nozzle body 410 which is mounted in thermal isolation from mold 27 together with nozzle pieces 37, 39 in a well 408 in the mold 27 via a collar 407 which makes limited mounting contact with the mold at small interface area 412 distally away from the gate 9b area. As shown surfaces 413, 415 of collar 407 support and align nozzle body 410 and its associated/interconnected nozzle components 37, 39 such that the exit passage of nozzle component 37 along axis Y is aligned with the edge gate 9b of cavity 9c.

As shown in Fig. 29 a sensor 69, such as a pressure transducer, records a property of the melt material in bore 20 downstream of the pin head 43 having a configuration similar to the embodiment shown in Fig. 3. The signal from sensor 69 is fed to the CPU and processed as described above with reference to other embodiments and instruction signals based on a predetermined algorithm are sent from the CPU to an interface 400 which sends interpreted signals to the driver 402, such as drive motor 402 which drives the drive fluid feed to actuator 322a (as shown having the same design as the actuator shown in Fig. 28 which is described in detail in US Patent No. 5,894,025. As shown in Fig. 30, a sensor 69d could be positioned so as to sense a property of the melt flow within the passage 20, or within the cavity 9c via a sensor 69i. As shown in Fig. 29 and as described above, the algorithm of the CPU is simultaneously controlling the operation of the actuator 420 associated with another nozzle (not shown) via sensor signals sent by a sensor associated with the other nozzle.

Fig. 31 shows an embodiment of the invention in which a defined volume of plastic melt is initially fed into a channel 585 and pot bore 640, prior to injection to cavity 9g through nozzle bore 20. As shown, a valve pin 580 is used to close off the flow connection from a main bore 620 into a distribution manifold 515, between the manifold channel 582 and bores 585/640/20 thus defining a predetermined defined volume of melt which can be controllably injected via an injection cylinder 565 which is controllably drivable via actuator 514 to shoot/inject the defined volume of melt material through the bore 20 into cavity 9g. The rate of flow of the melt being injected via cylinder 565 may be controlled via controlled operation of any one or more of a rotary valve 512, valve pin 20 or via the drive of the cylinder 565 itself. Cylinder 565 is controllably drivable back and forth 519 within bore 640 via actuator 514 in a

conventional manner to thus control the rate of injection of melt from bore 640 through bore 20.

In accordance with the invention, sensor 69 records a selected condition of the melt and sends signals to CPU which in turn may be programmed according to a predetermined algorithm to control the operation of any one or more of actuator 545 which controls operation of pin 41, actuator 516 which controls operation of rotary valve 512 or actuator 514 which controls operation of cylinder 565. As described above with regard to other embodiments sensor 69 may alternatively be located in other locations, e.g. cavity 9g or bores 640 or 585 depending on the melt properties (typically pressure) to be monitored/controlled and the molding operation(s) to be controlled. As shown in Fig. 31 and as described above, the algorithm of the CPU is simultaneously controlling the operation of the actuator 518 associated with another nozzle (not shown) via sensor signals sent by a sensor associated with the other nozzle.

1. In an injection molding machine having first and second nozzles for delivering melt material from a common manifold to one or more mold cavities, apparatus for controlling delivery of the melt material from the nozzles to the one or more mold cavities, each nozzle having an exit aperture communicating with a gate of a cavity of a mold and being associated with an actuator interconnected to a melt flow controller, the apparatus comprising:

a sensor for sensing a selected condition of the melt material through at least one of the nozzles;

an actuator controller interconnected to each actuator, each actuator controller comprising a computer interconnected to a sensor for receiving a signal representative of the selected condition sensed by the sensor, the computer including an algorithm utilizing a value corresponding to a signal received from the sensor as a variable for controlling operation of an actuator for the at least one nozzle;

wherein at least one of the nozzles has a tip end having a central portion having a central bore in alignment with the gate and an outer circumferential flange portion surrounding the gate and the central portion of the tip end of the at least one nozzle.

2. Apparatus of claim 1 wherein at least one gate is an edge gate extending radially outward through a mold cavity plate, the nozzle having a bore having a first portion having an inlet for the plastic melt which is not in alignment with the edge gate and a second portion extending radially outward from the first portion terminating in the exit aperture being in alignment with the edge gate.

3. Apparatus of claim 1 wherein the sensor comprises a pressure transducer interconnected to at least one of the bore of a nozzle or a mold cavity for detecting the pressure of the melt material.

4. Apparatus of claim 1 wherein the actuator controller further comprises a solenoid having a piston controllably movable between selected positions for selectively delivering a pressurized actuator drive fluid to one or the other of at least two chambers of the actuator.

5. Apparatus of claim 1 wherein at least one of valves has a bore, a valve pin and a surface for forming a gap with a surface of the bore away from the gate, wherein the size of the gap is increased when the valve pin is retracted away from the gate and decreased when the valve pin is displaced toward the gate.

6. Apparatus of claim 1 wherein at least one of the valves has a bore and a valve pin which has a surface for forming a gap with a surface of the bore away from the gate, wherein the size of the gap is decreased when the valve pin is retracted away from the gate and increased when the valve pin is displaced toward the gate.

7. Apparatus of claim 1 wherein at least one of the valves has a bore and a valve pin the apparatus further comprising a plug mounted in a recess of the manifold opposite a side of the manifold where the at least one nozzle is coupled, the plug having a bore through which a stem of the valve pin of the nozzle passes, the valve pin having a head, the bore of the plug through which the stem passes having a smaller diameter than the valve pin head at the valve pin head's largest point and the recess of the manifold having a larger diameter than the diameter of the valve pin head at the valve pin head's largest point, so that the valve pin can be removed from the manifold from a side of the manifold in which the recess is formed when the plug is removed from the manifold.

8. Apparatus of claim 1 further comprising a second sensor for sensing a second selected condition of the melt material through a second nozzle, the computer being interconnected to the second sensor for receiving a signal representative of the selected condition sensed by the second sensor, the computer including an algorithm utilizing a

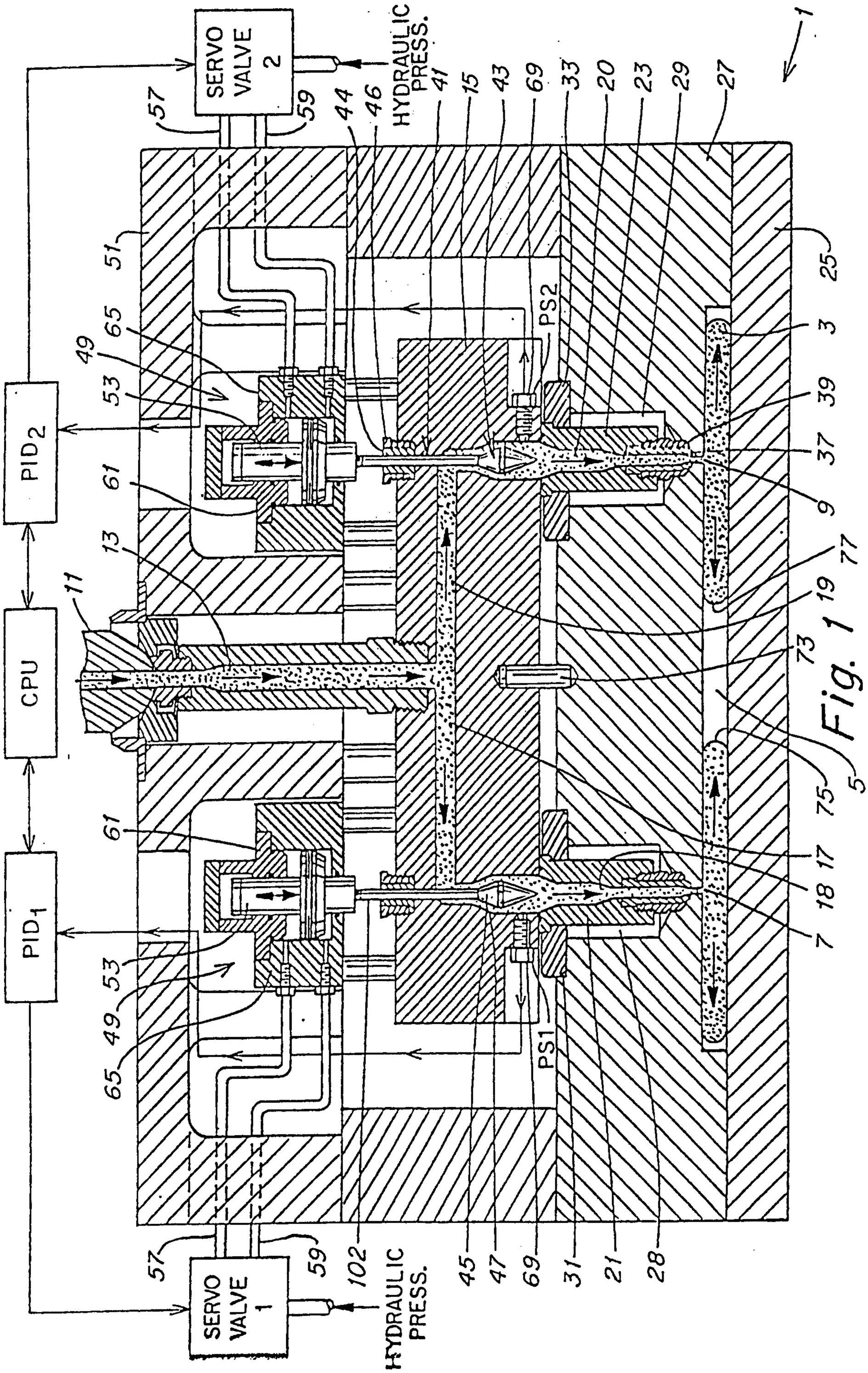
value corresponding to a signal received from the second sensor as a variable for controlling operation of an actuator for the second nozzle.

9. Apparatus of claim 1 wherein the at least one nozzle has a seal surface disposed on the tip end of the nozzle which is engaged and in compressed contact with a complementary surface surrounding the gate of a cavity of a mold, the engaged surfaces forming a seal against leakage of the melt material around the nozzle.

10. Apparatus of claim 9 wherein the seal surface is disposed on a longitudinally disposed tip end surface of the flange portion of the nozzle.

11. Apparatus of claim 9 wherein the seal surface is a radially disposed surface around the flange portion.

12. Apparatus of claim 1 wherein the sensor is selected from the group consisting of a pressure transducer, a load cell, a valve pin position sensor, a temperature sensor, a flowmeter and a barrel screw position sensor.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HYDRAULIC PRESS.
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Fig. 1

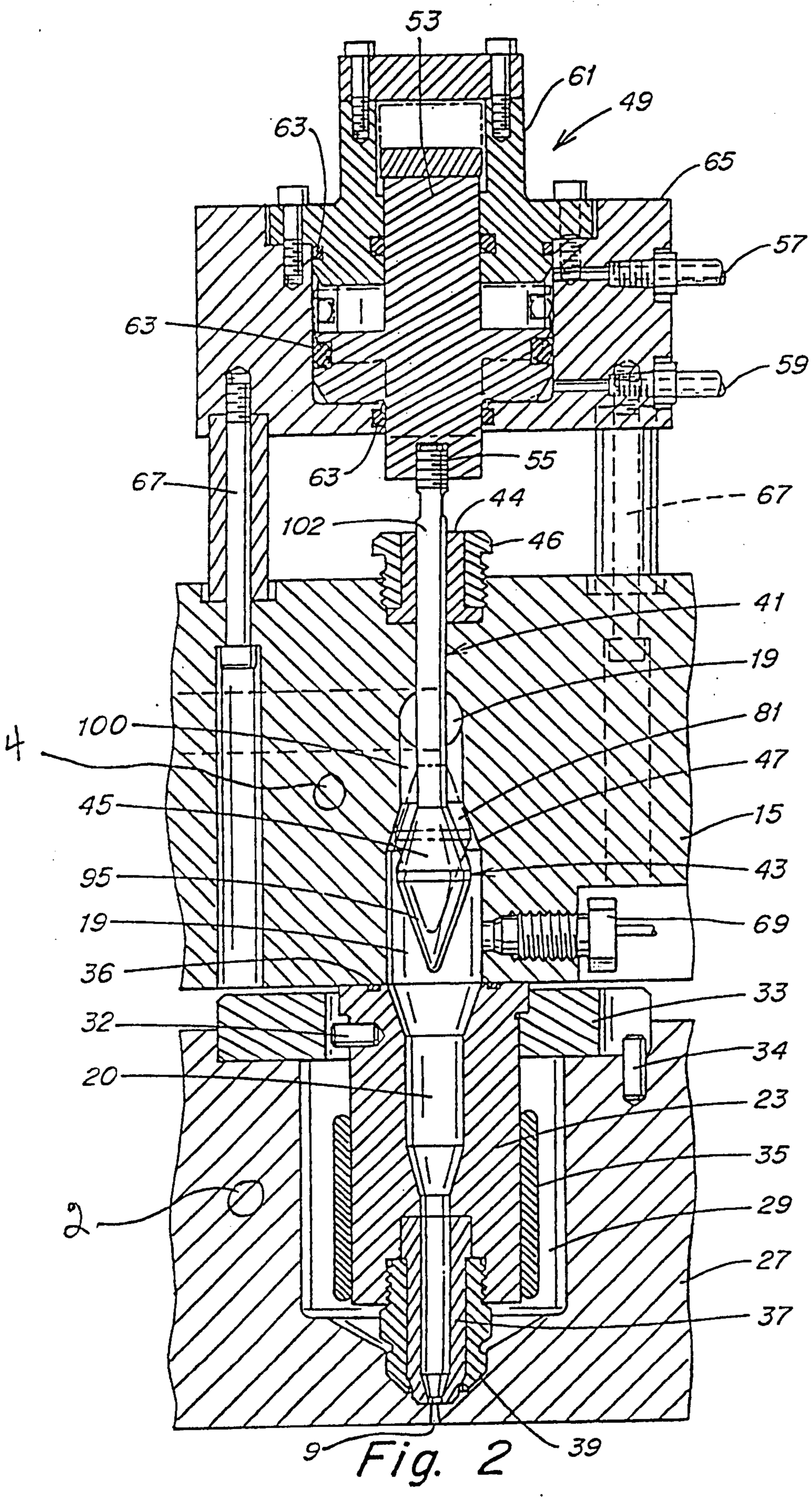
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Fig. 2

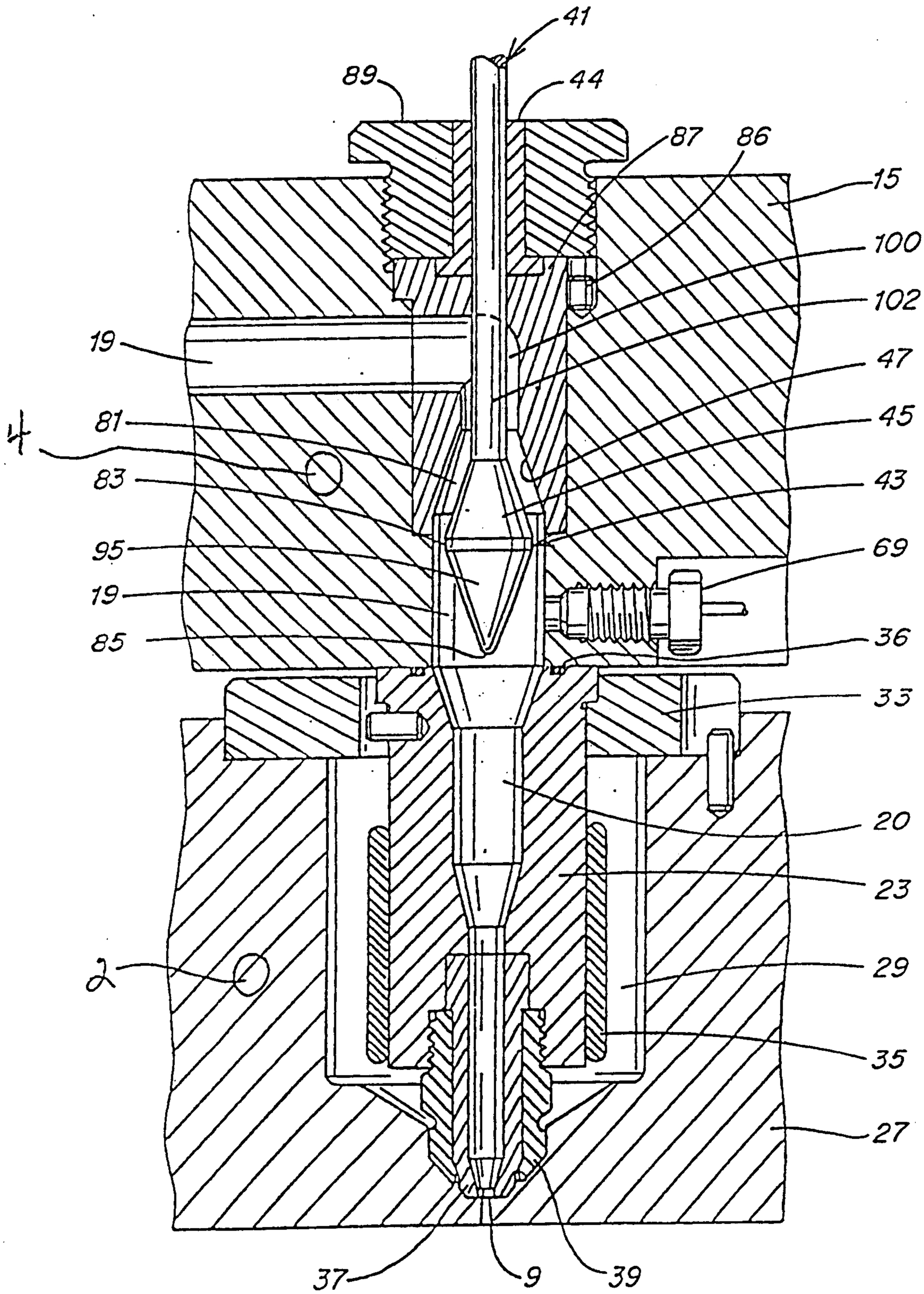
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Fig. 3

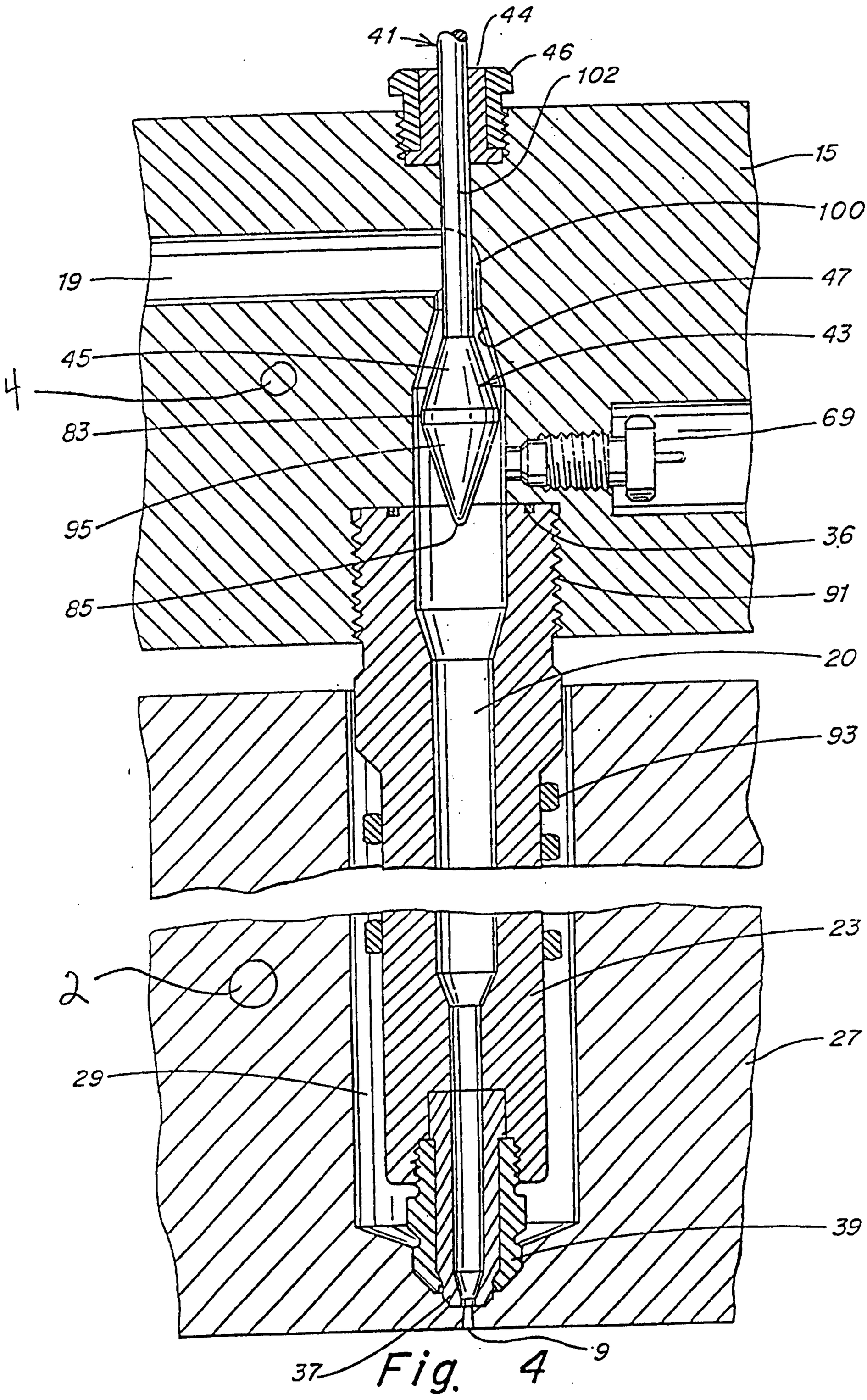
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Fig. 4

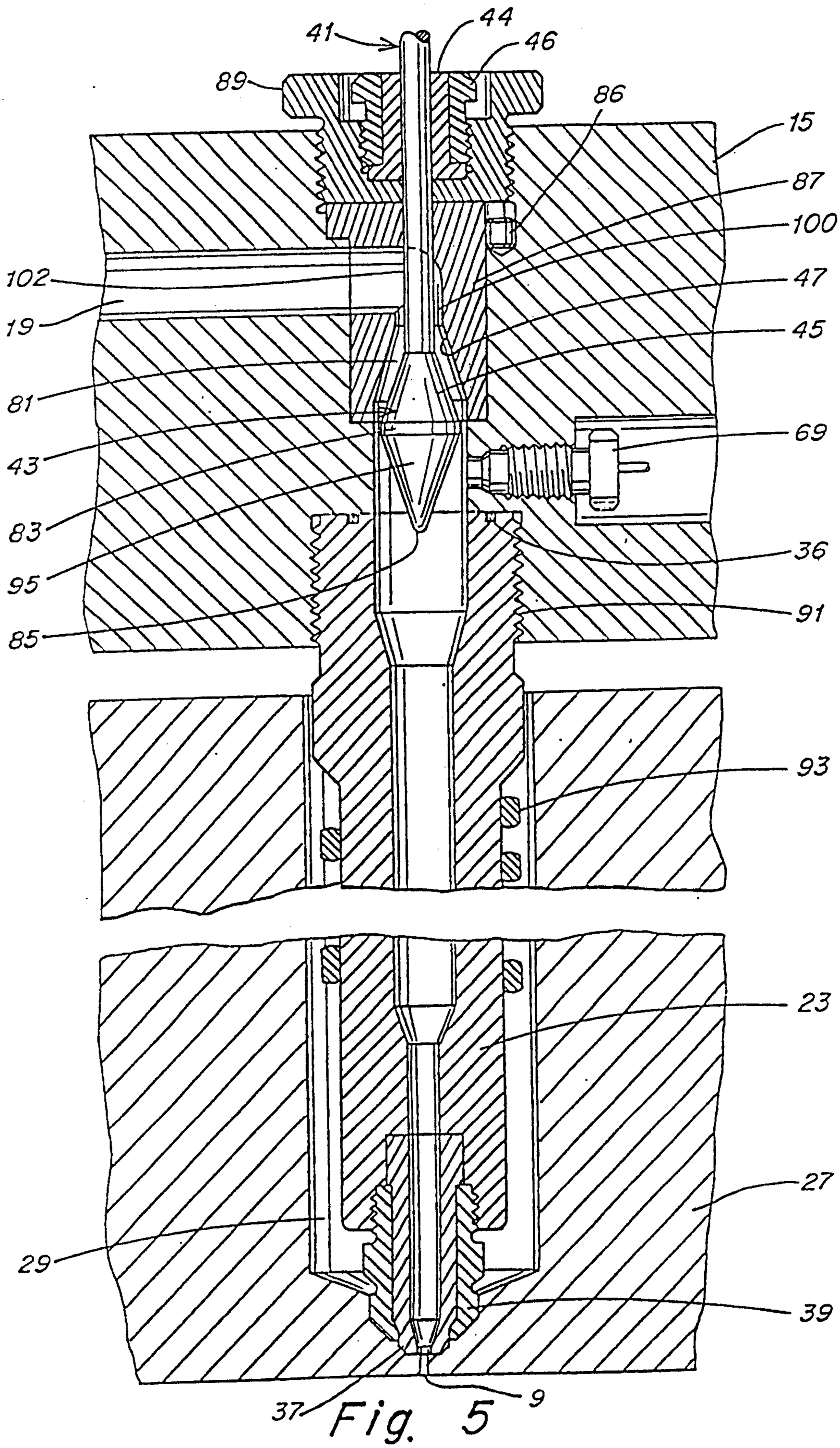
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Fig. 5

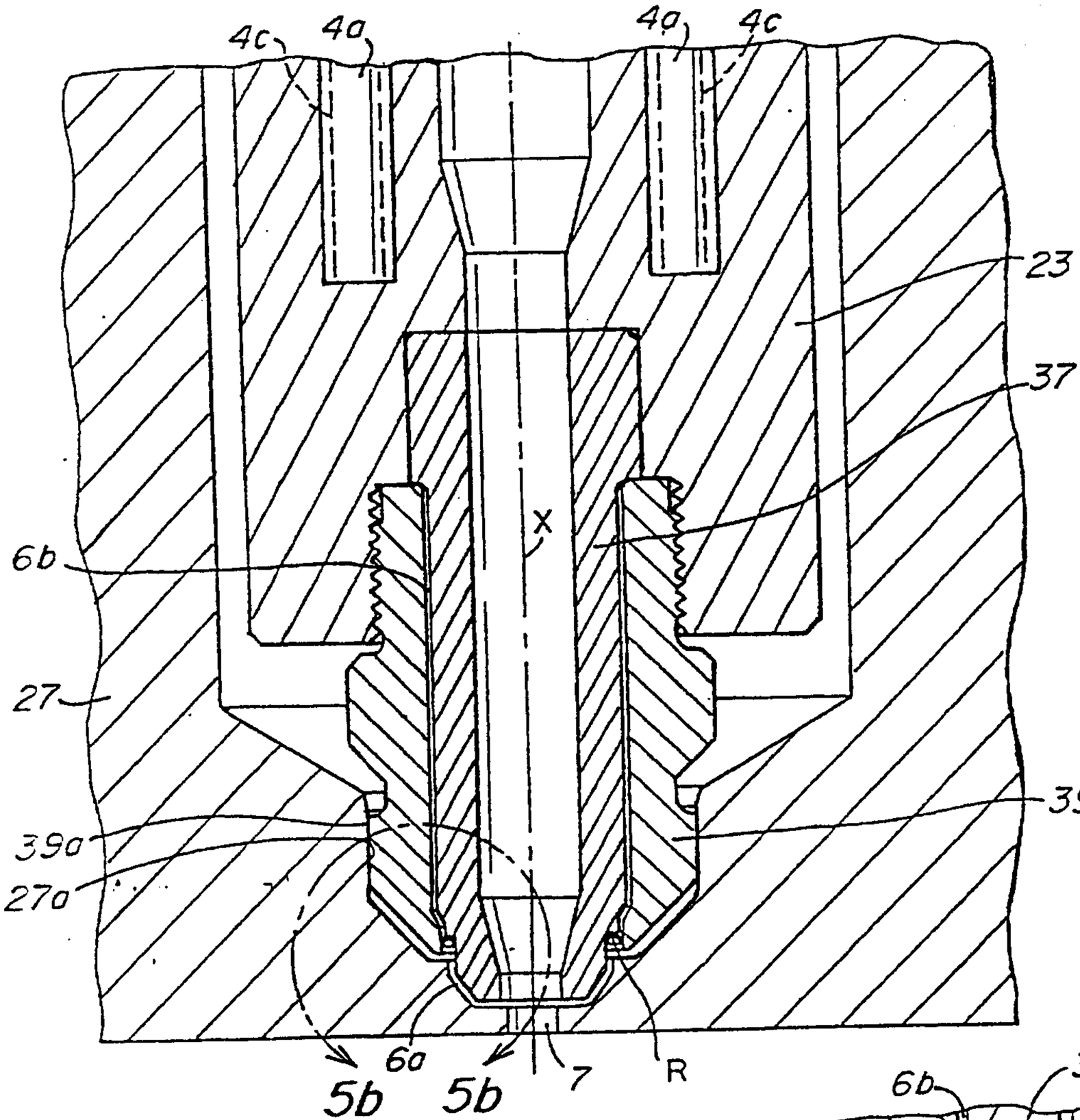

Fig. 5a

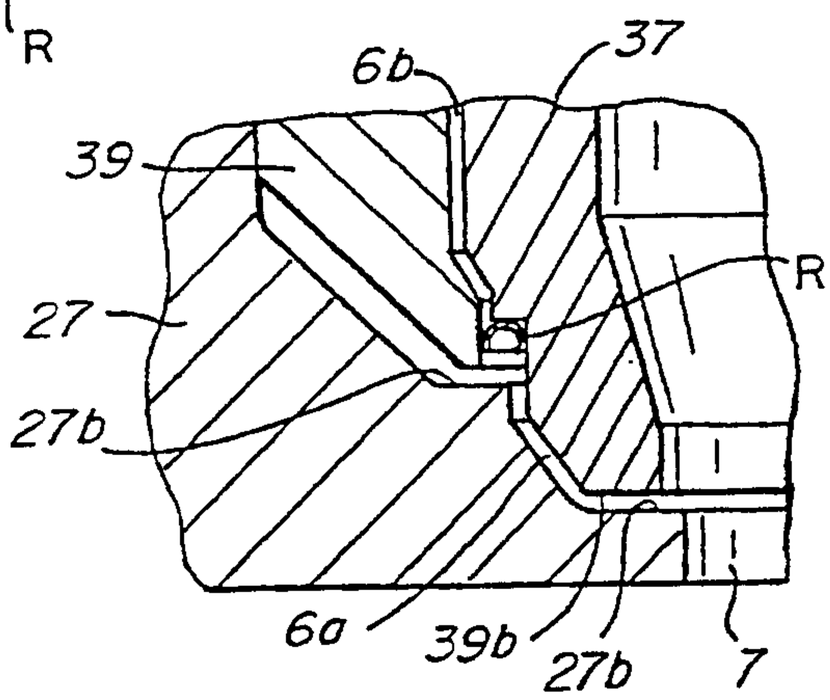

Fig. 5b

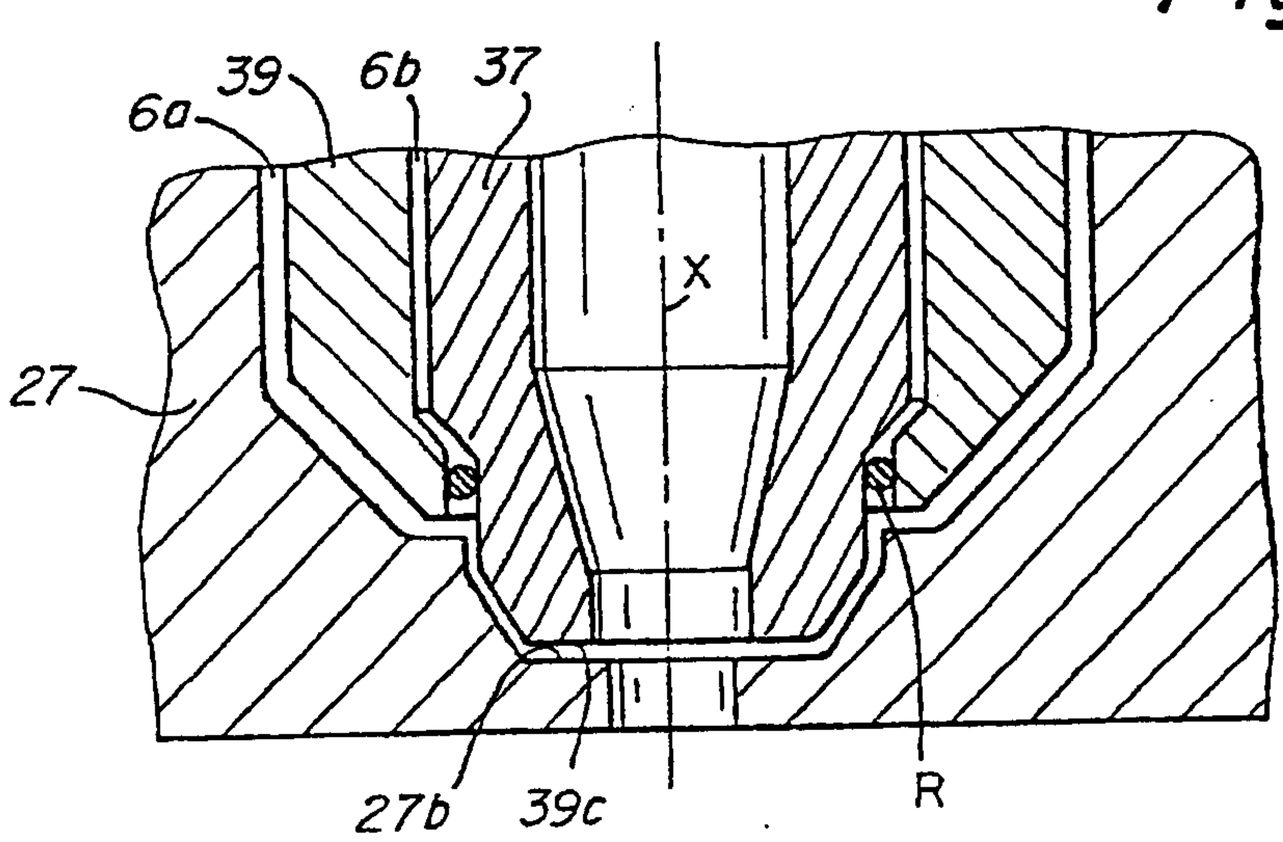

Fig. 5c

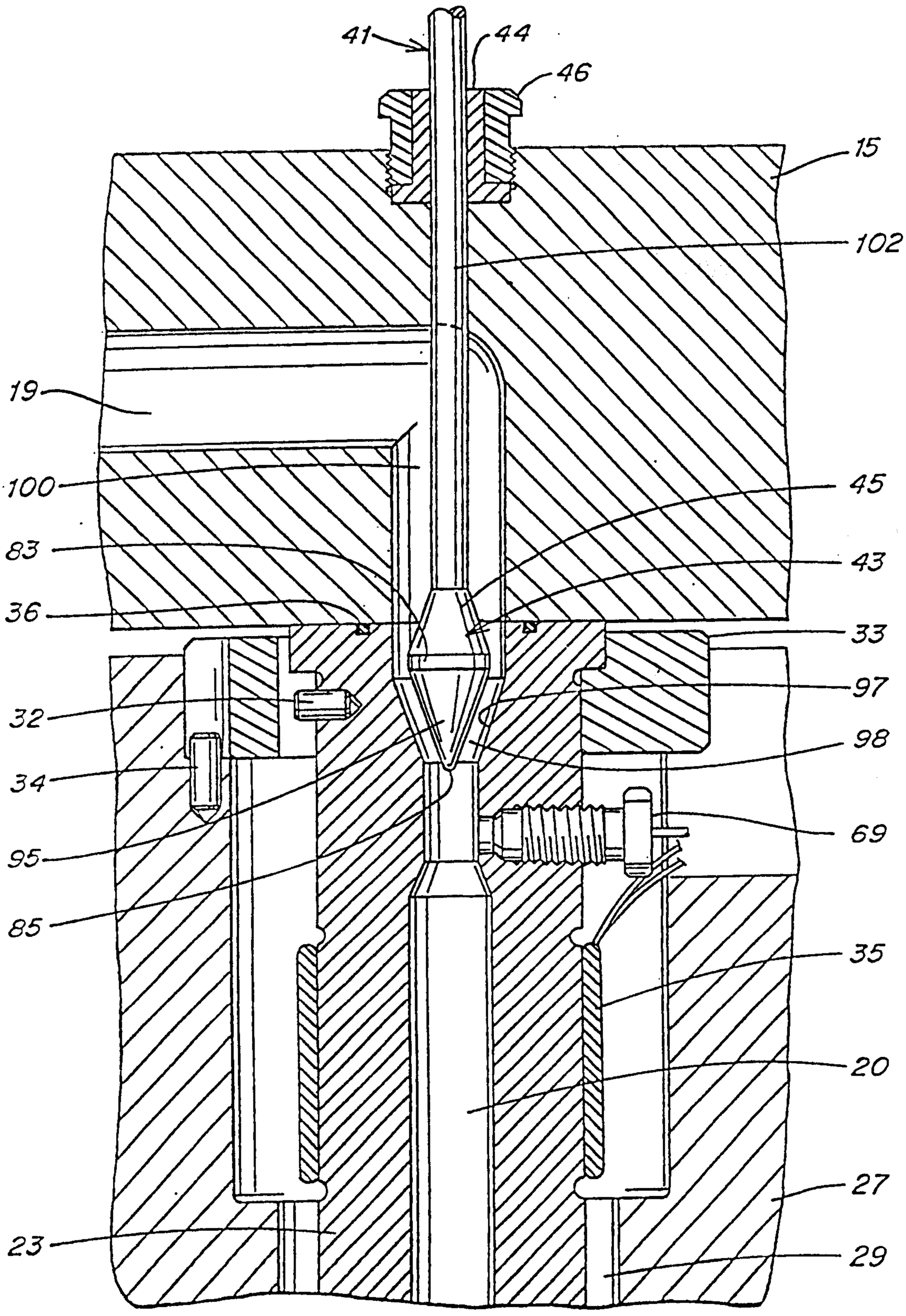
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Fig. 6

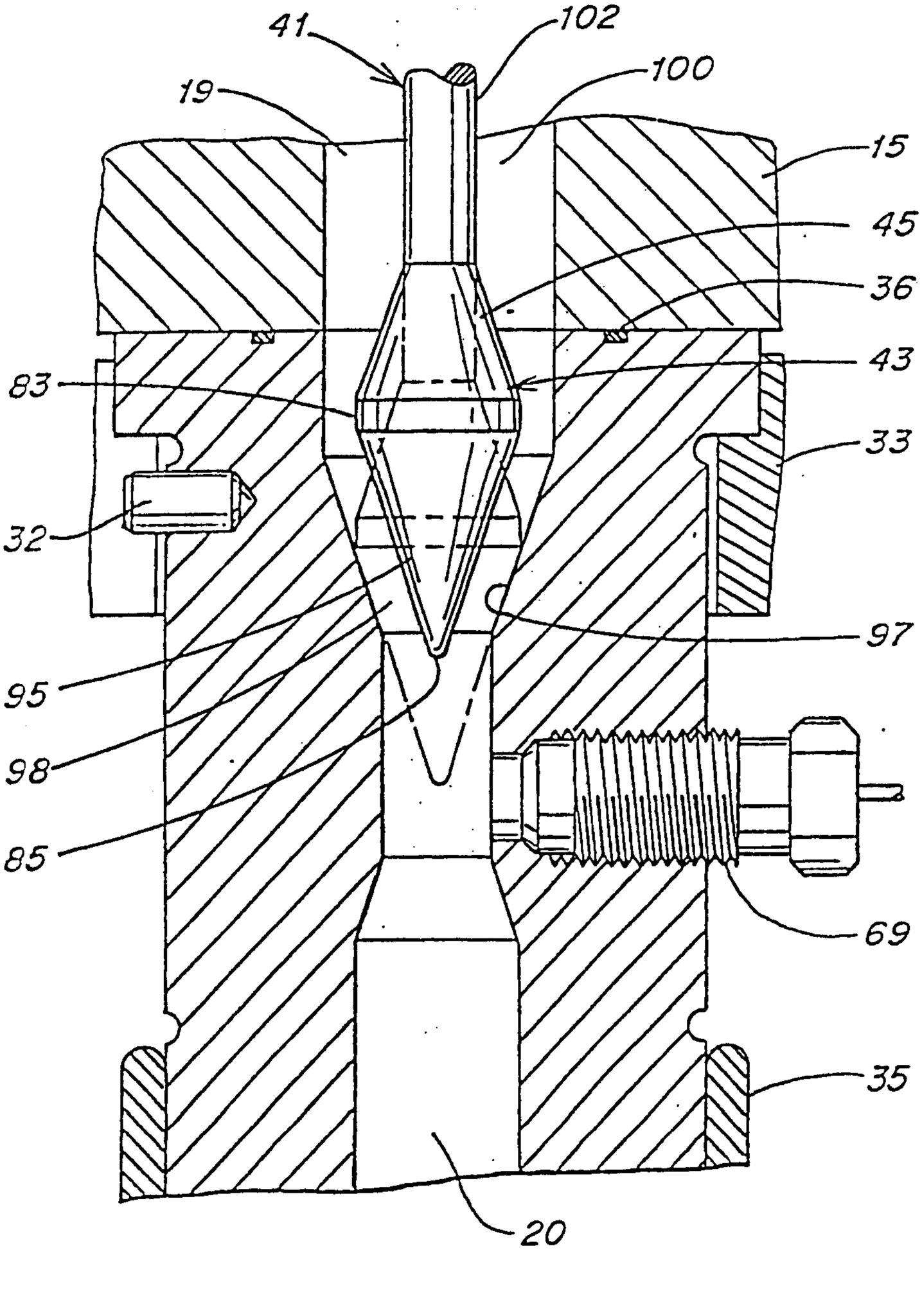

Fig. 7

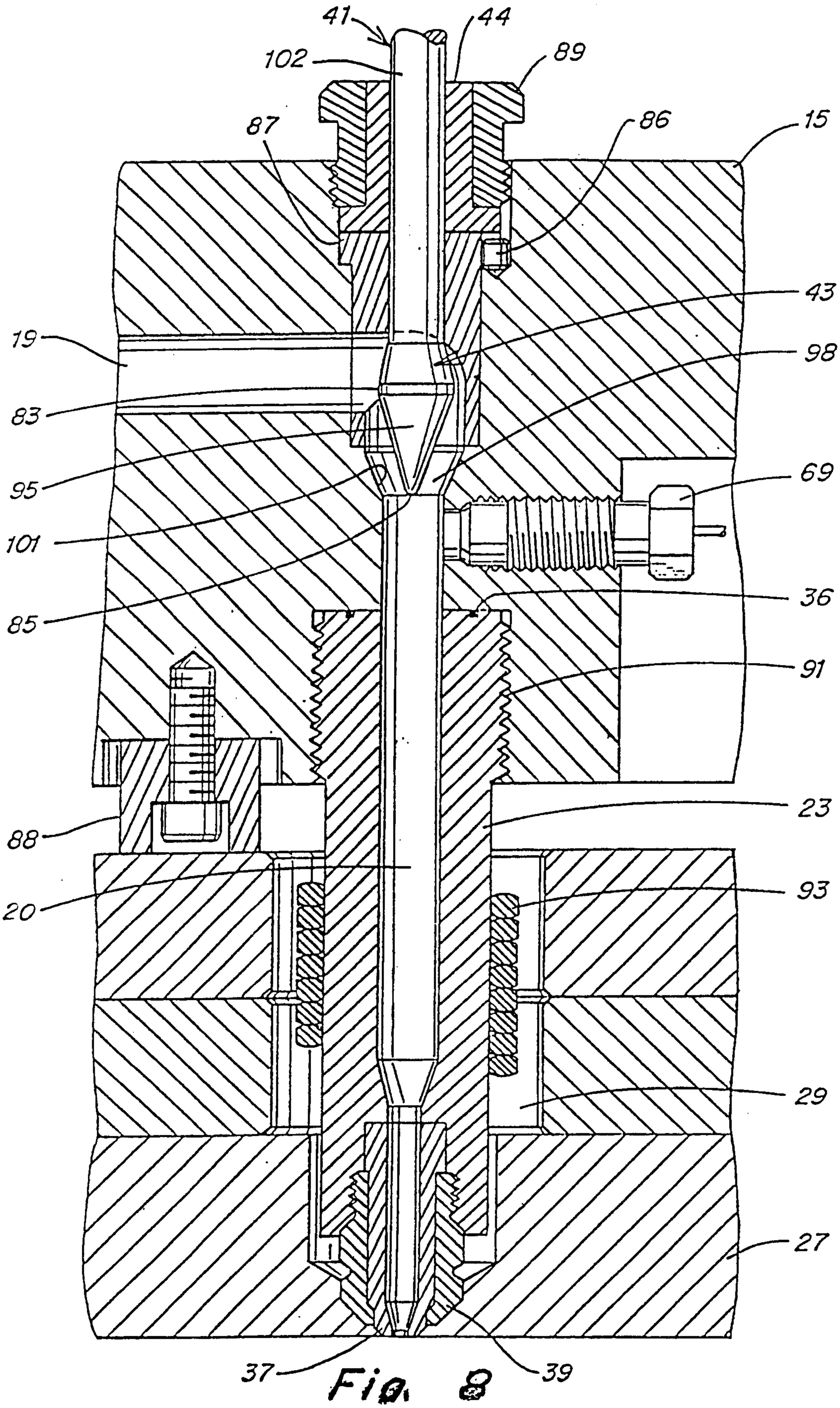
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Fig. 8

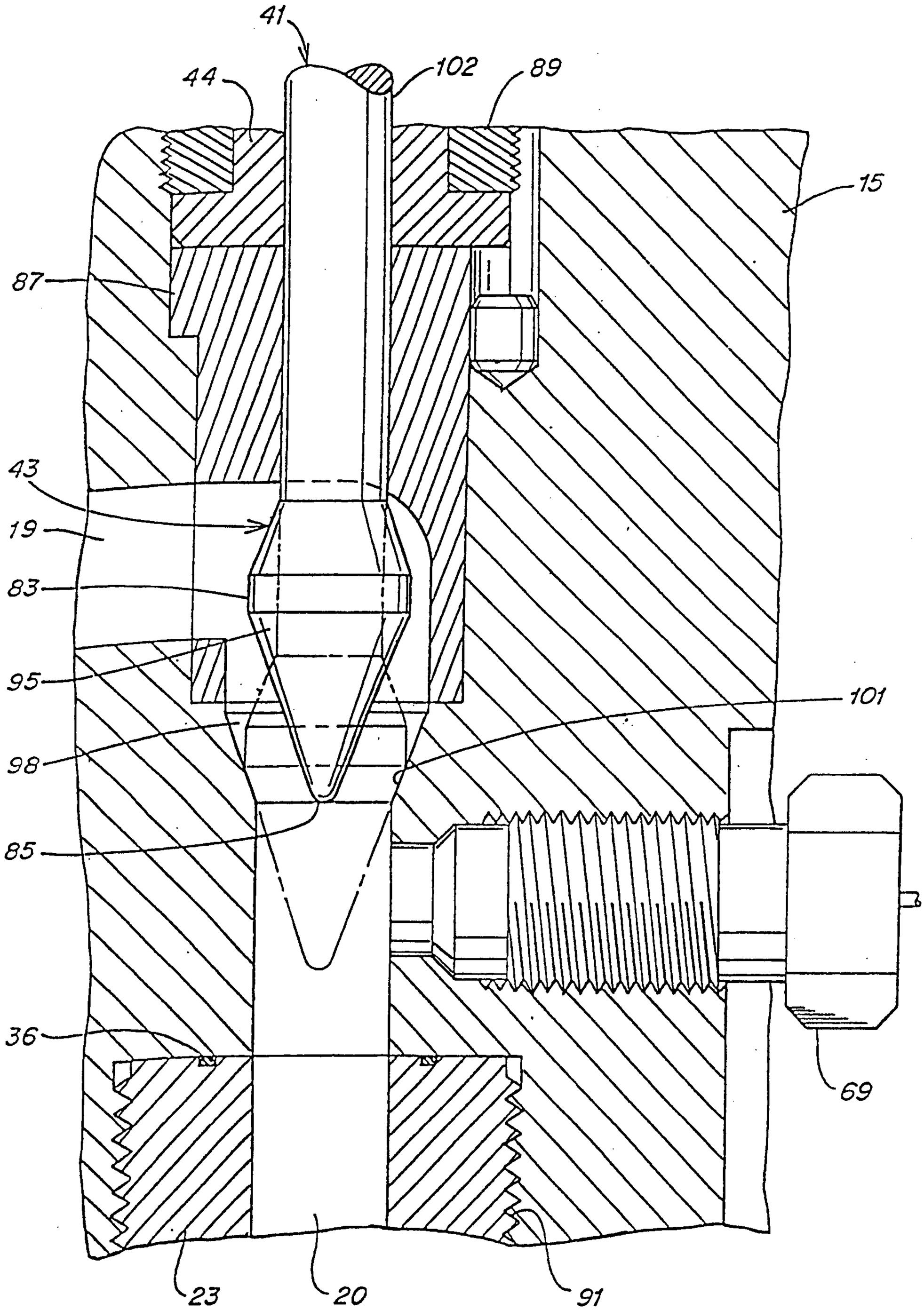

Fig. 9

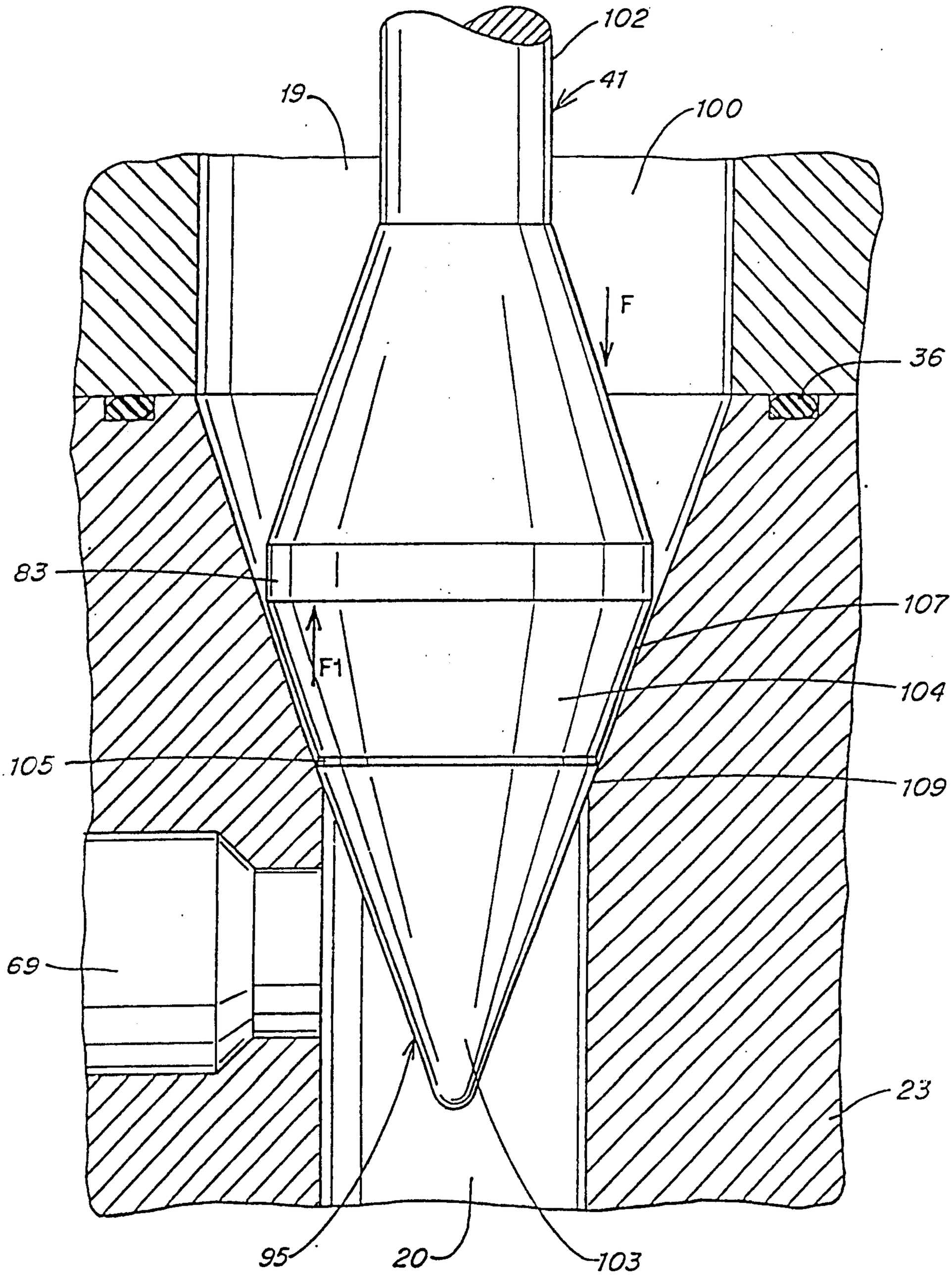

Fig. 10

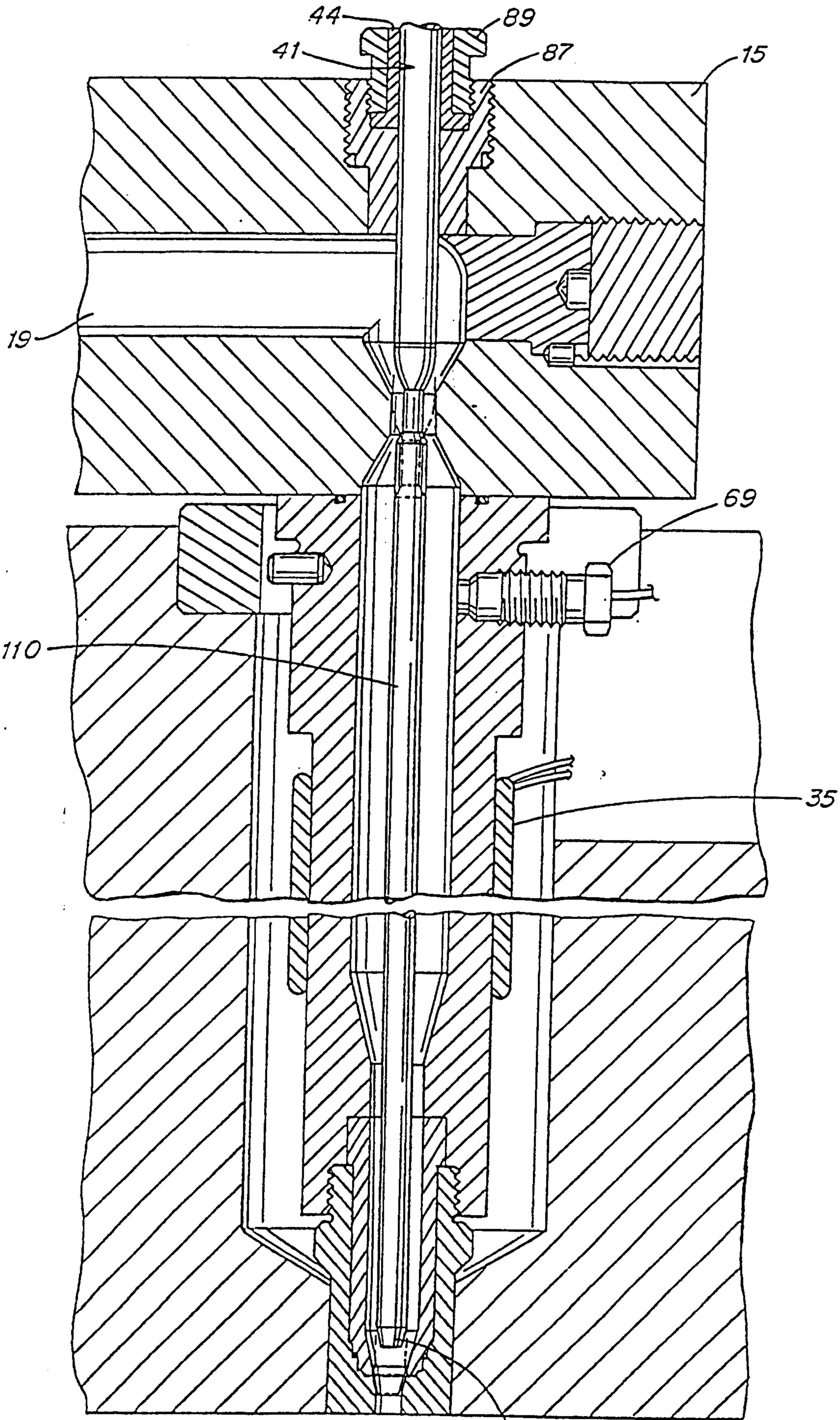

Fig. 11

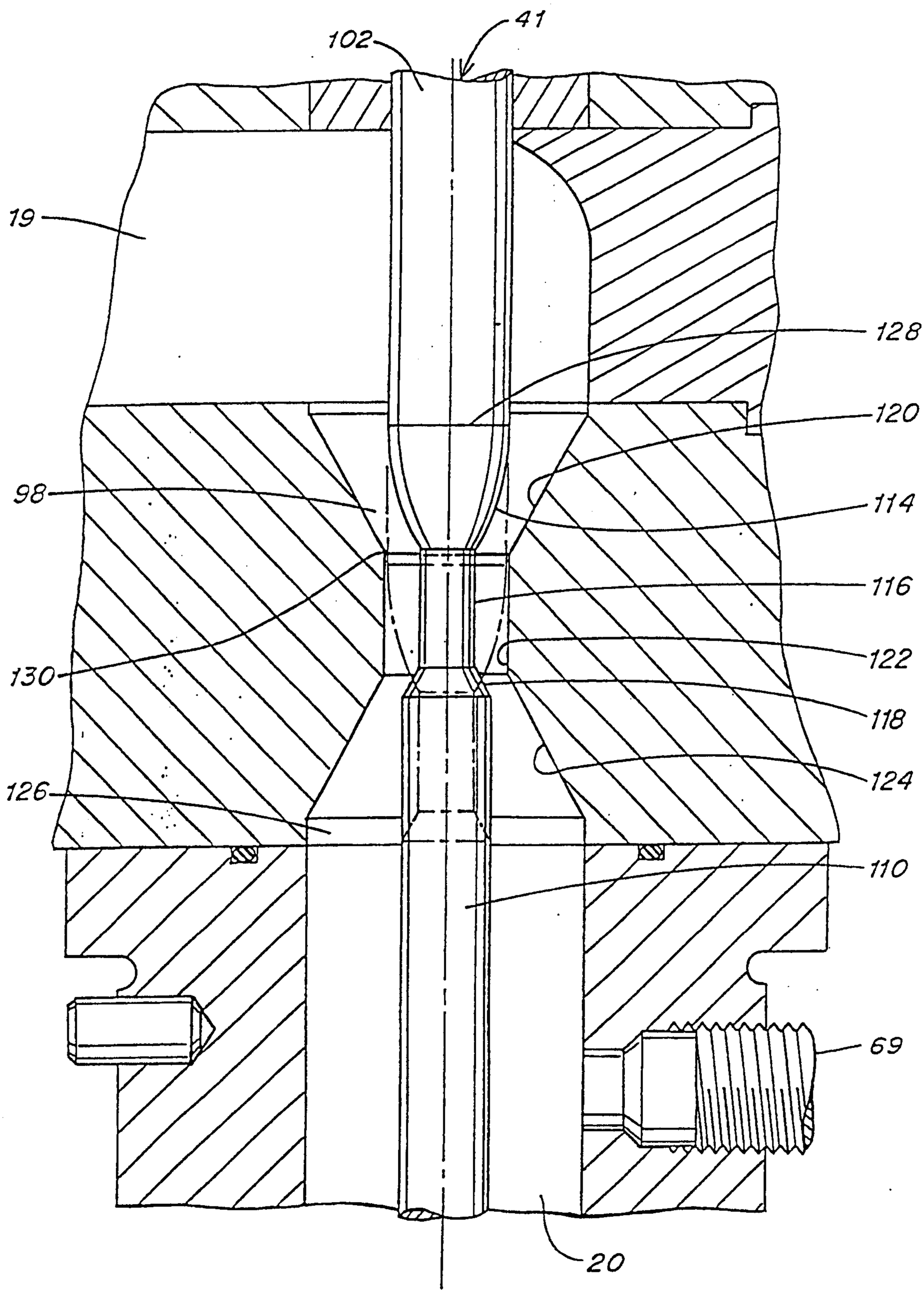

Fig. 12

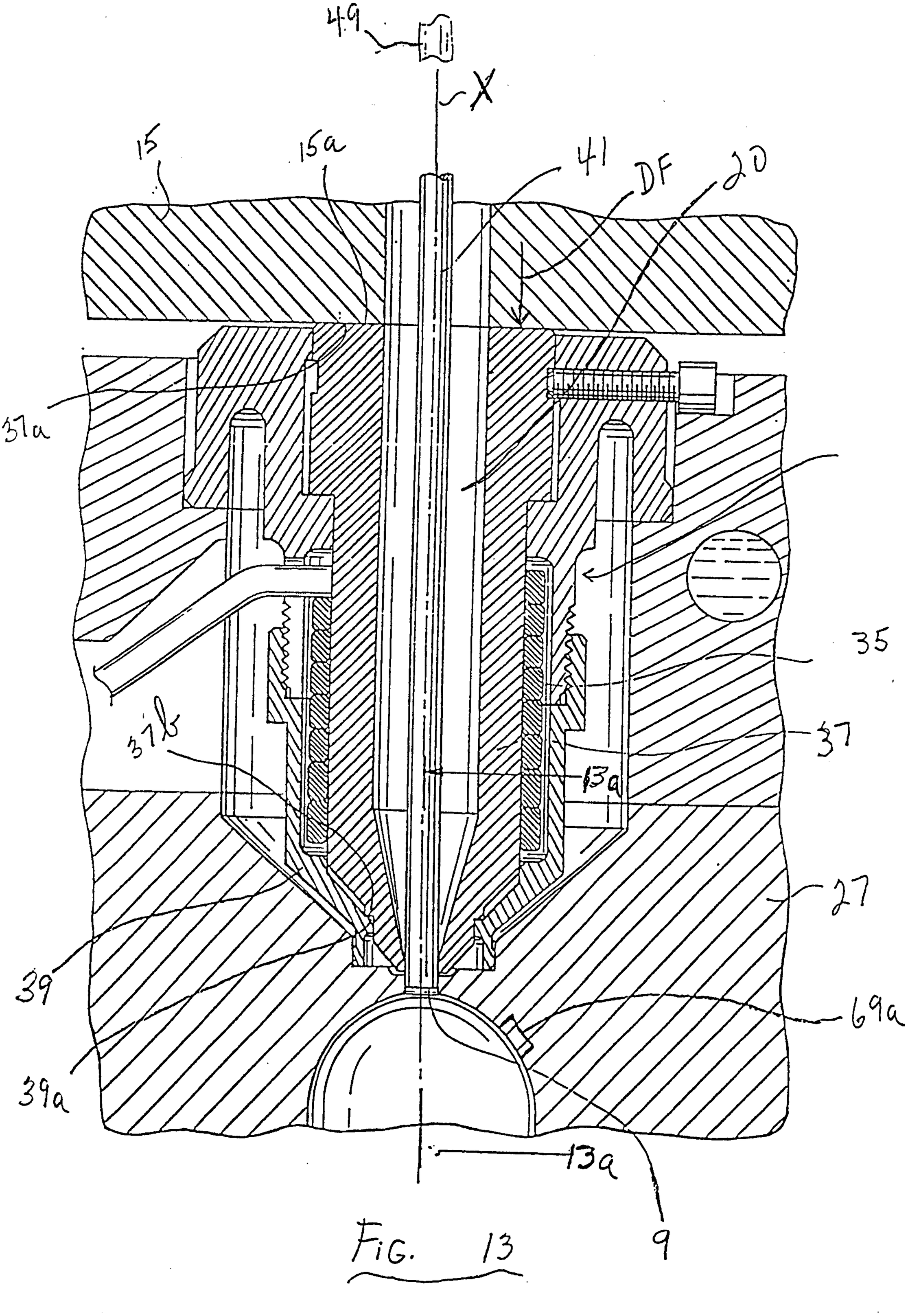

FIG. 13

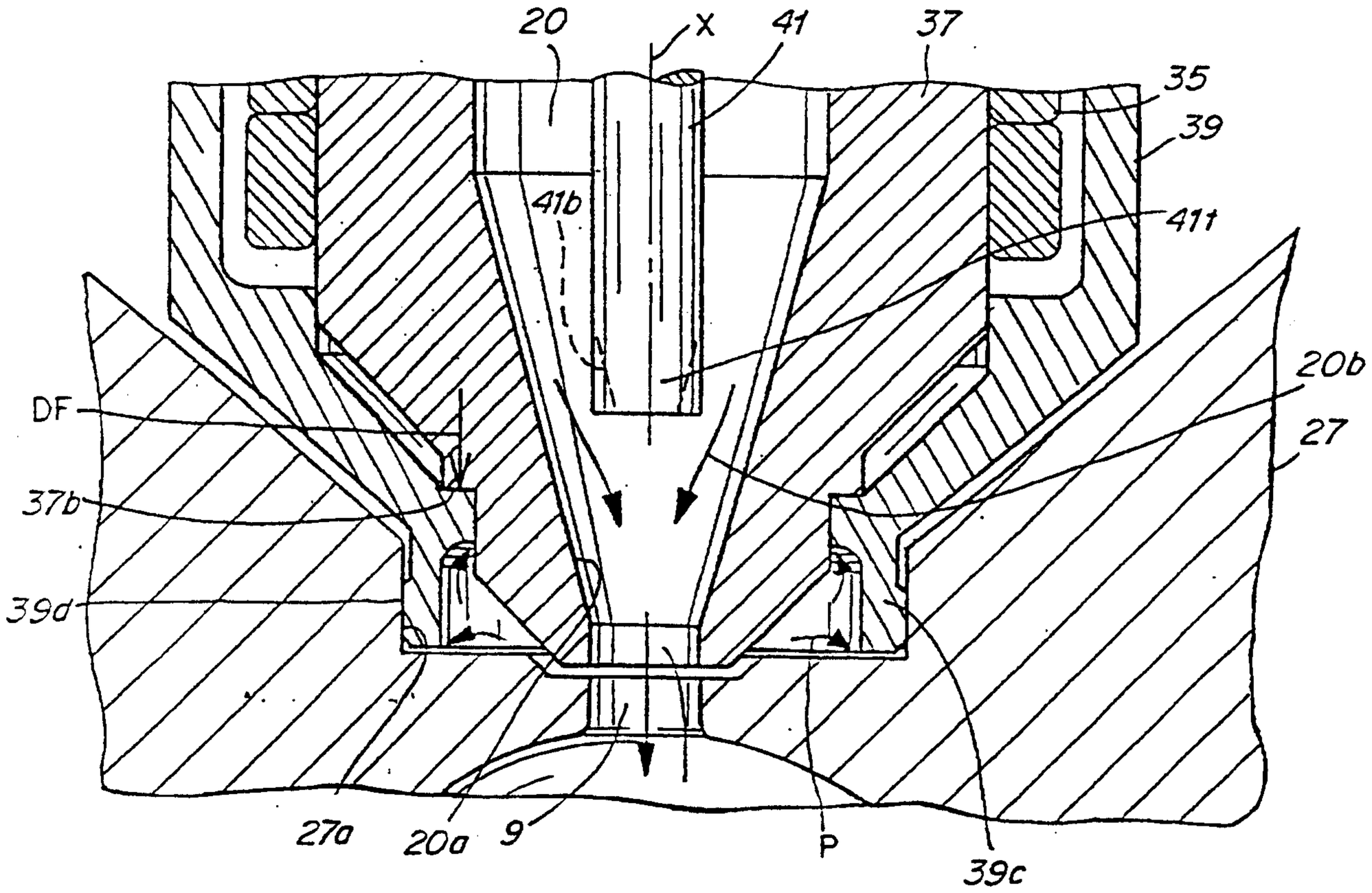

Fig. 13a

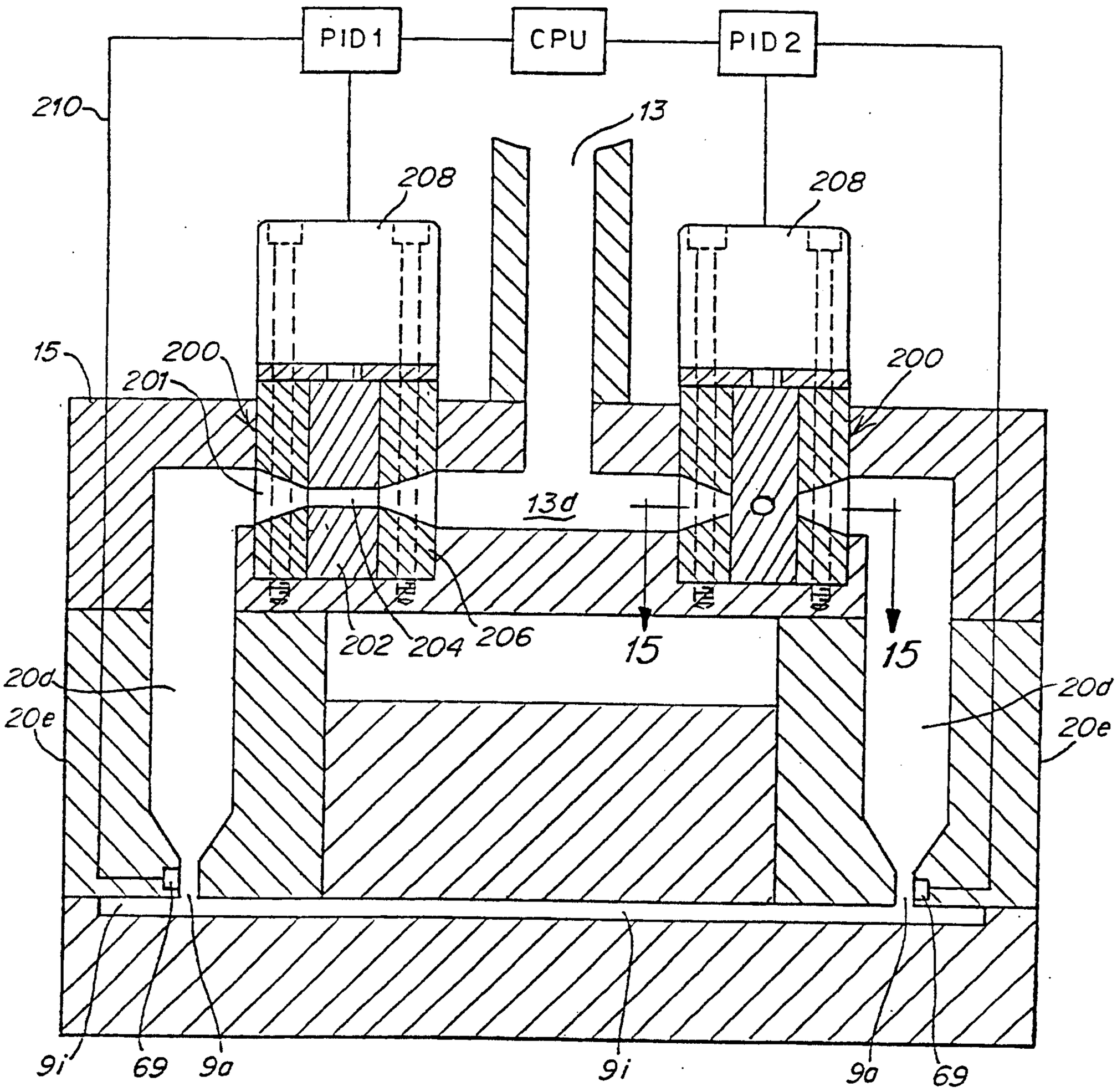
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Fig. 14

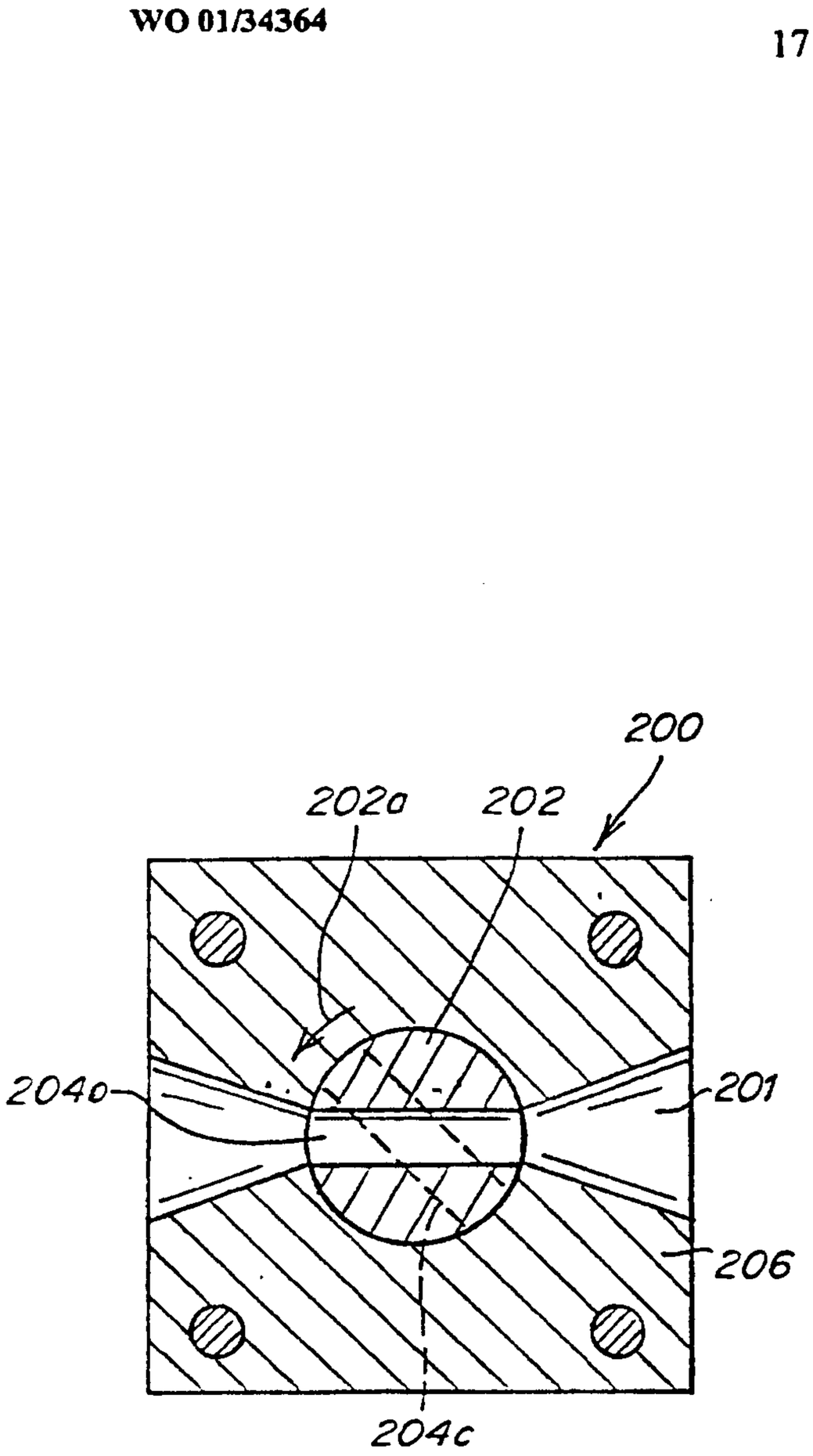

Fig. 15

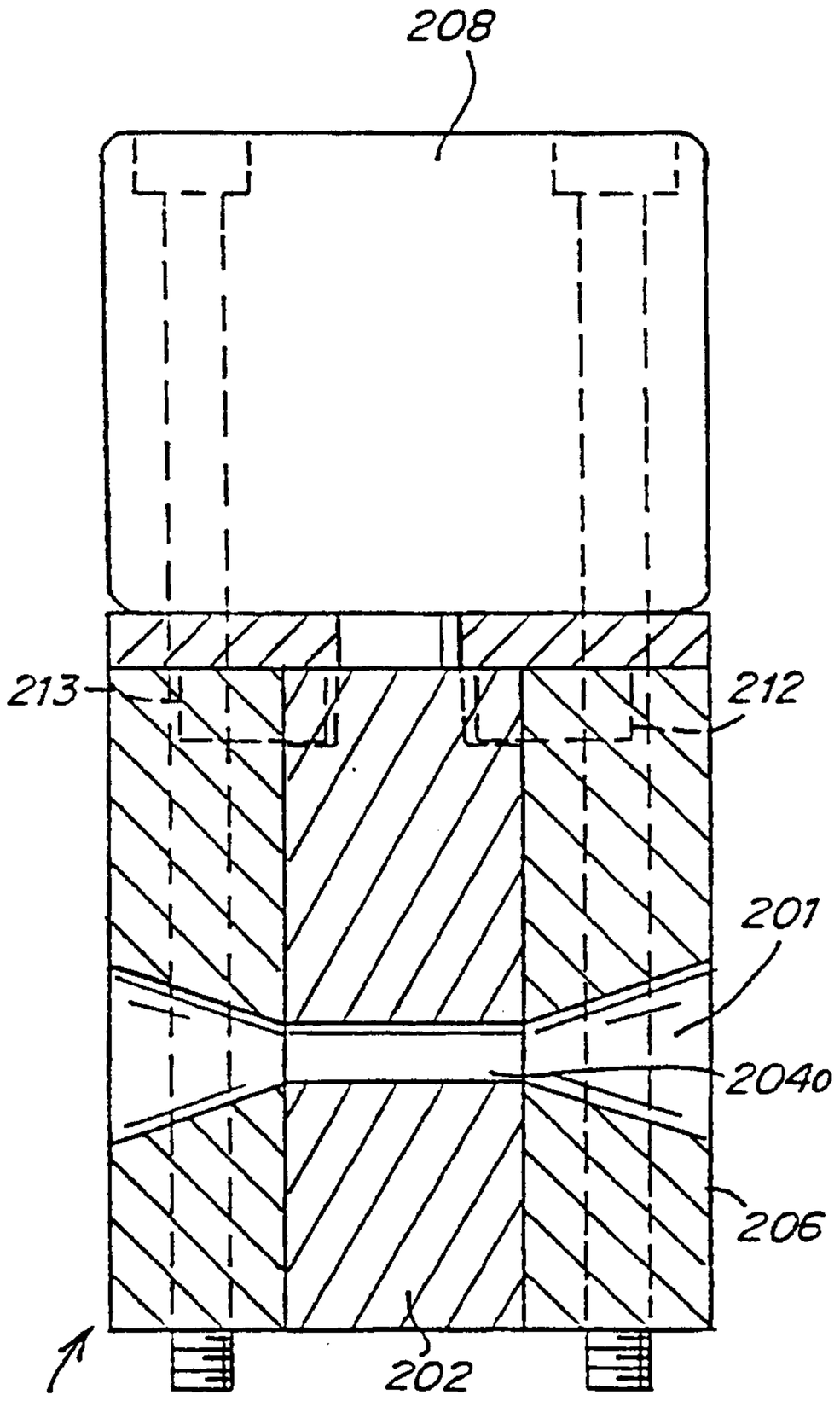

Fig. 16

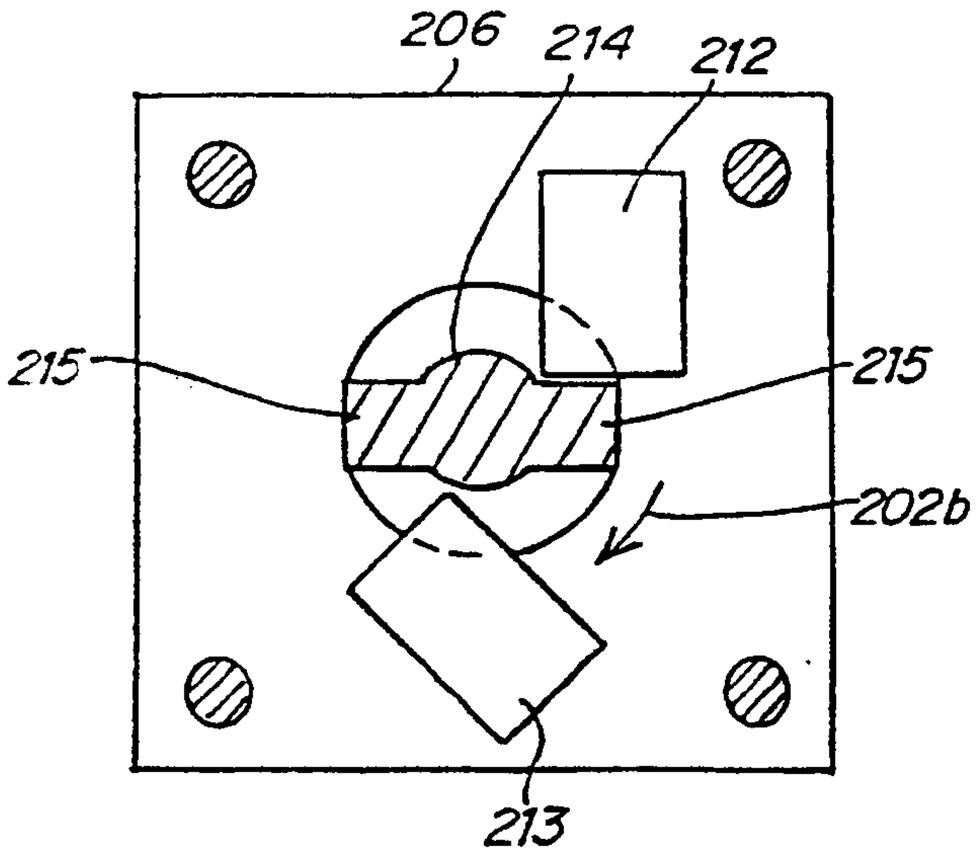

Fig. 17

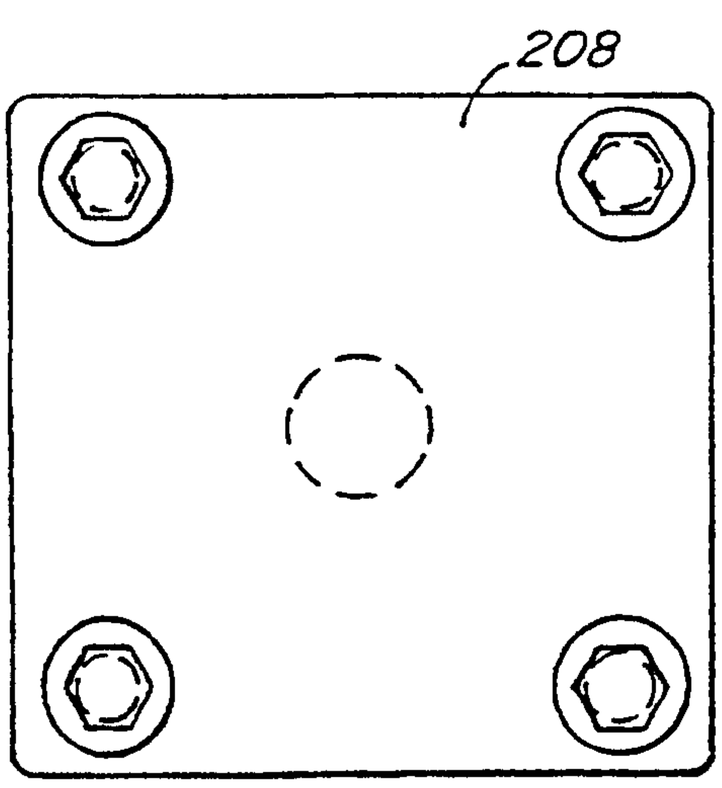

Fig. 18

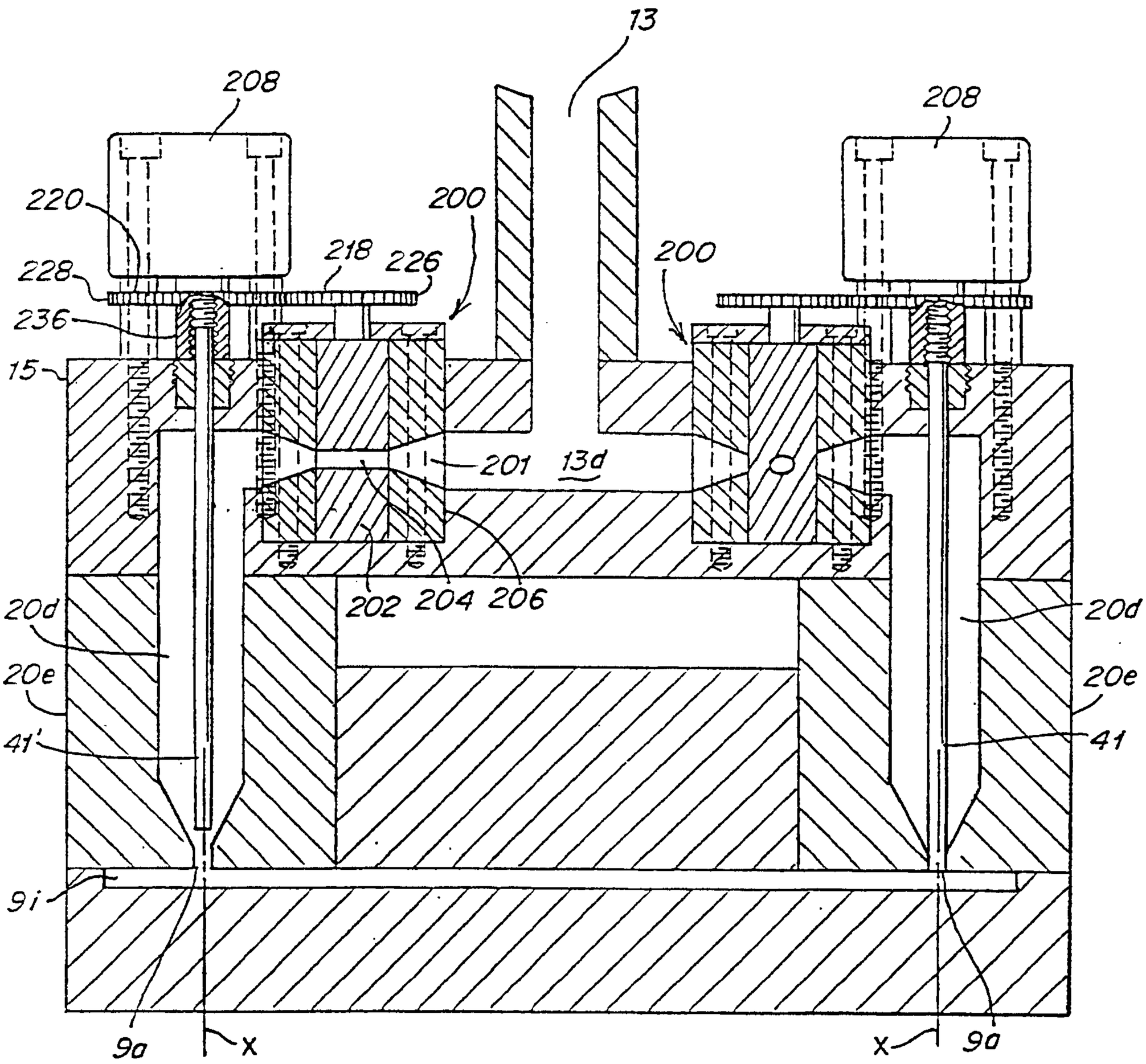
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Fig. 19

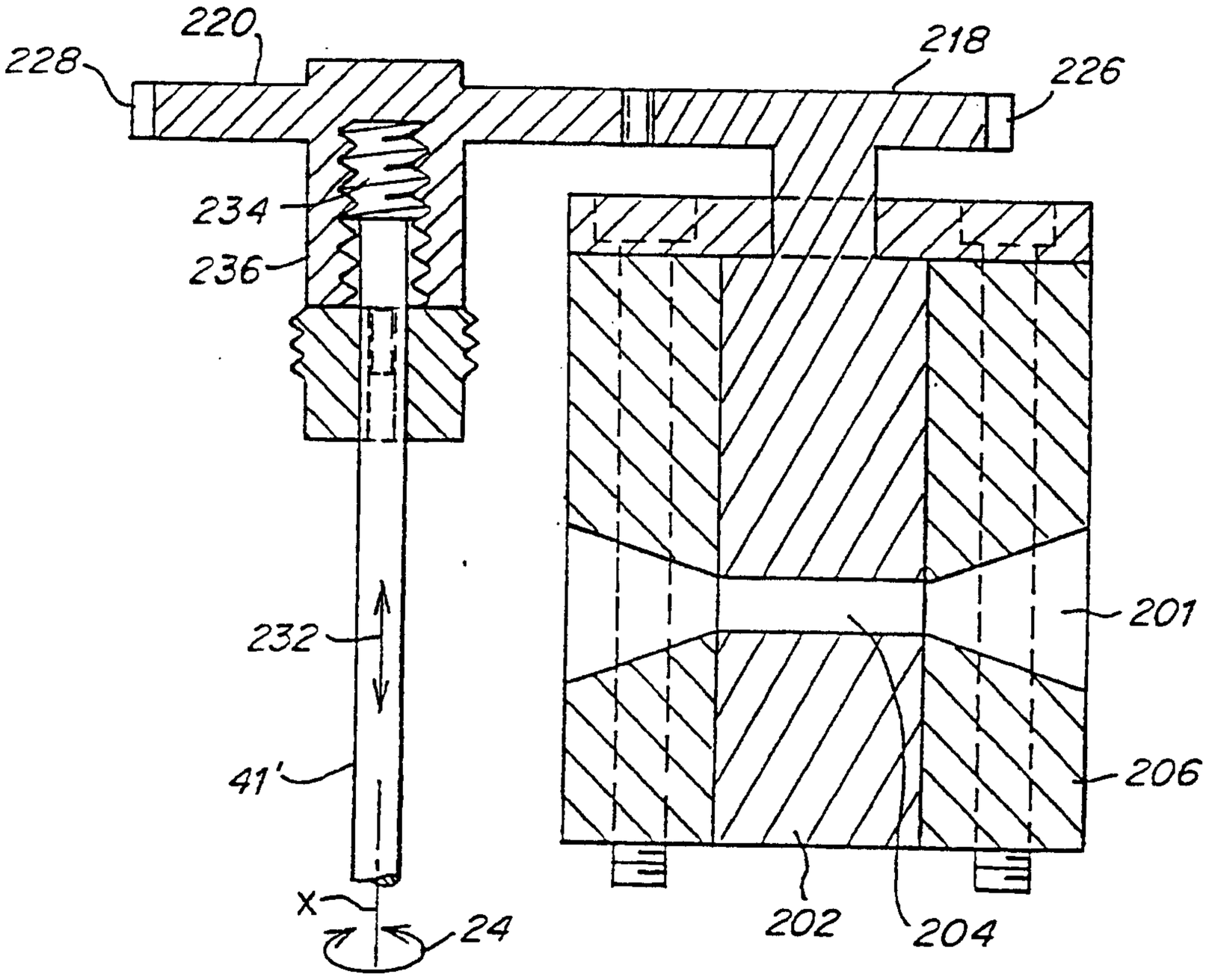
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Fig. 20

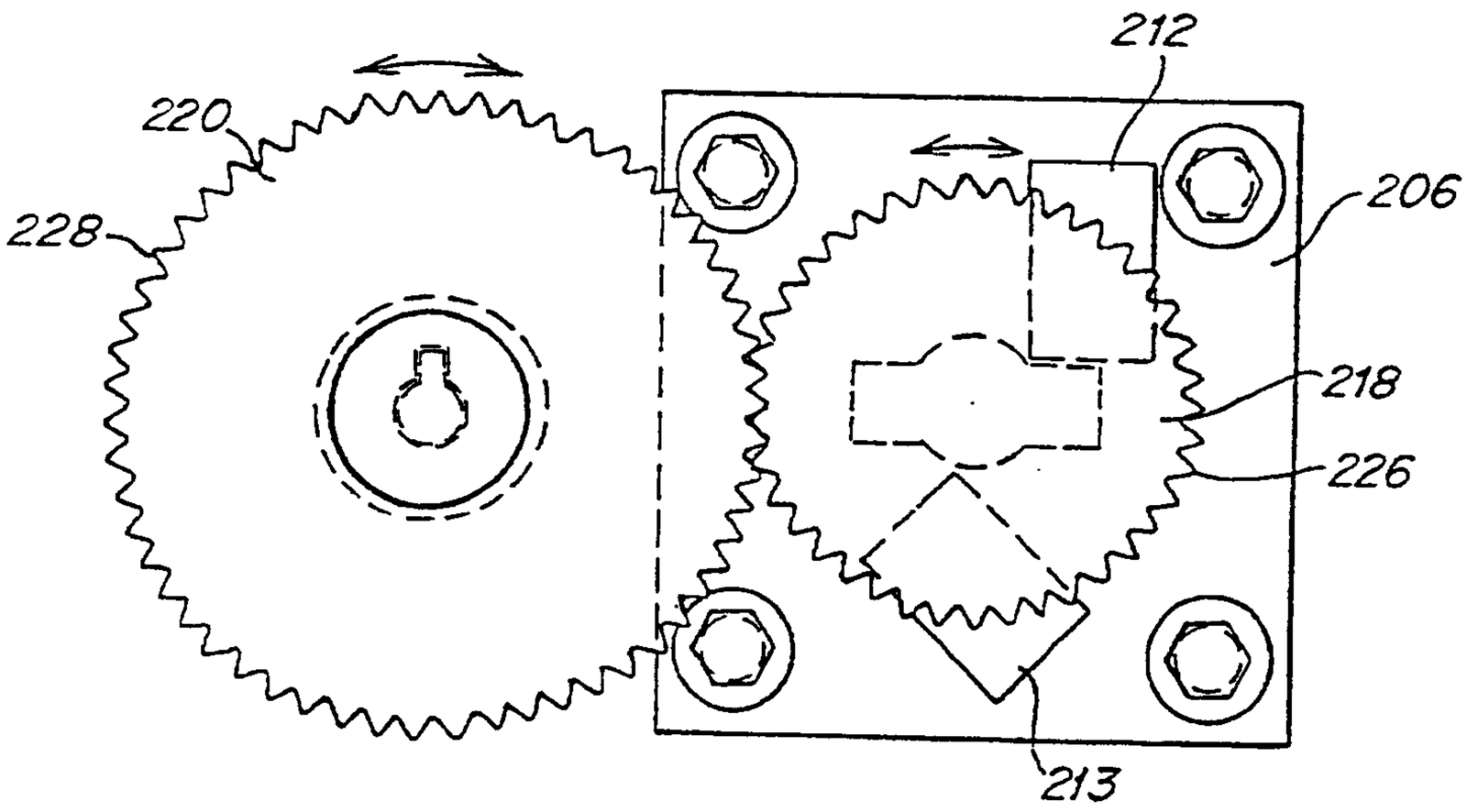
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Fig. 21

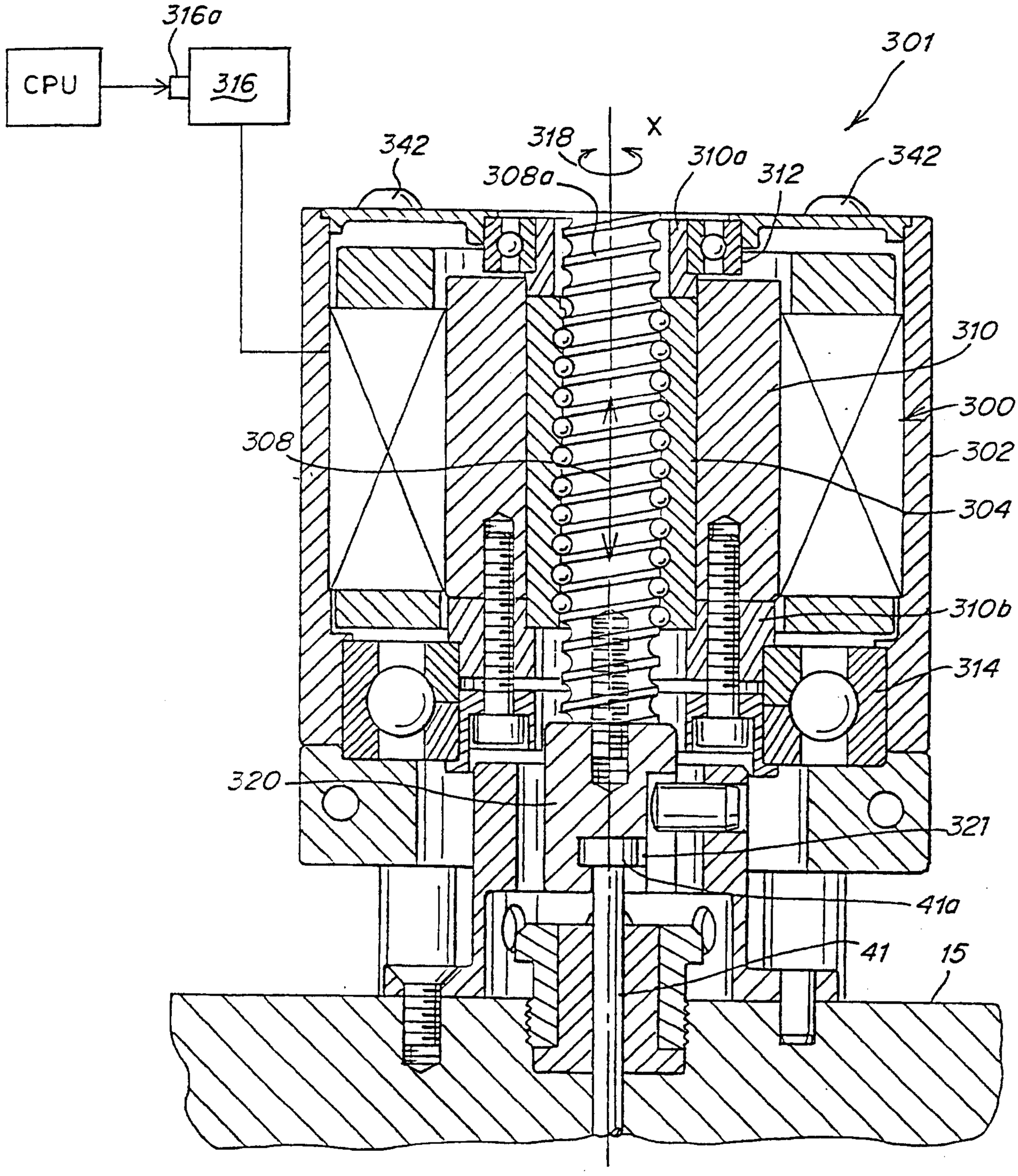
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Fig. 22

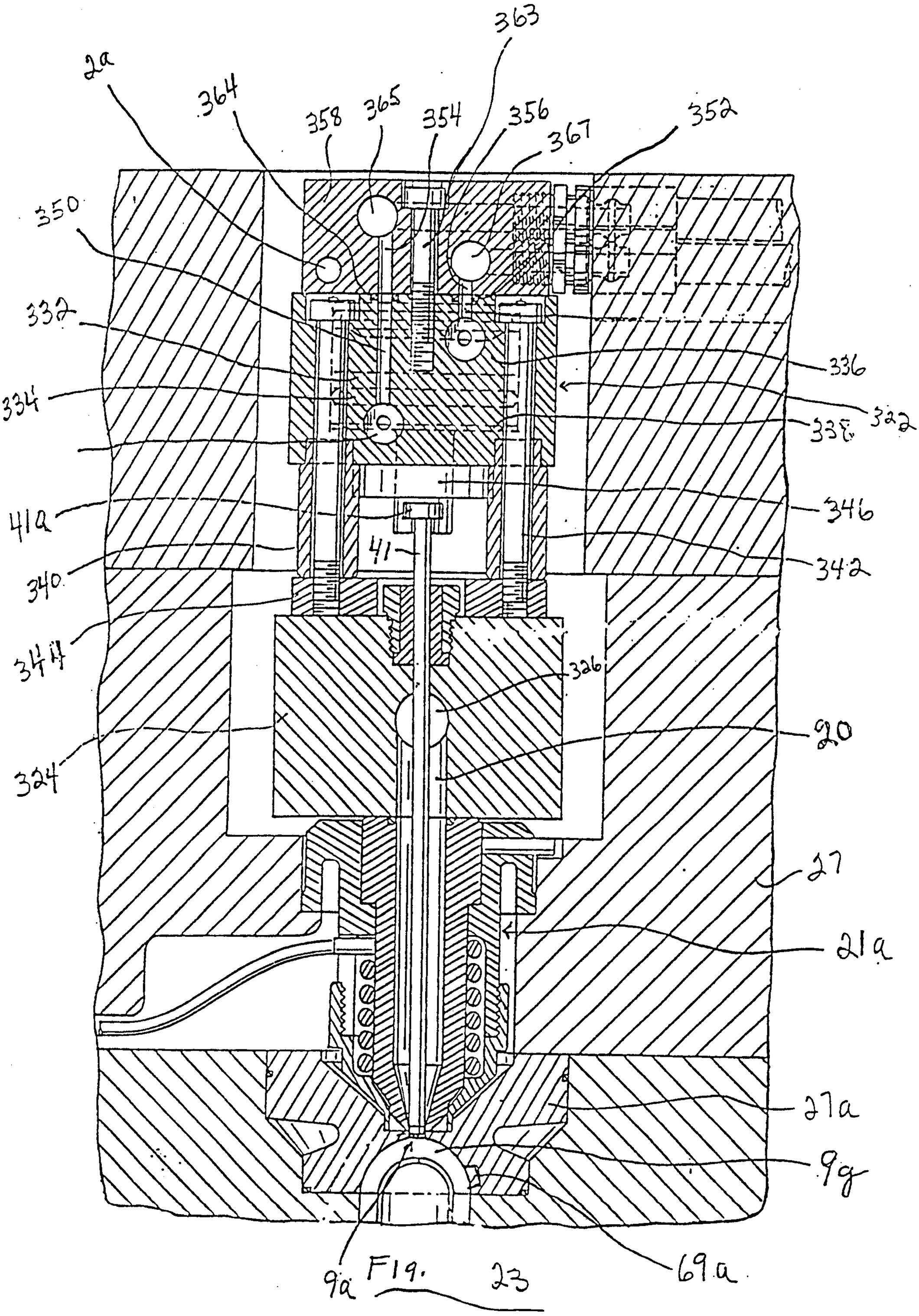
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Fig. 23

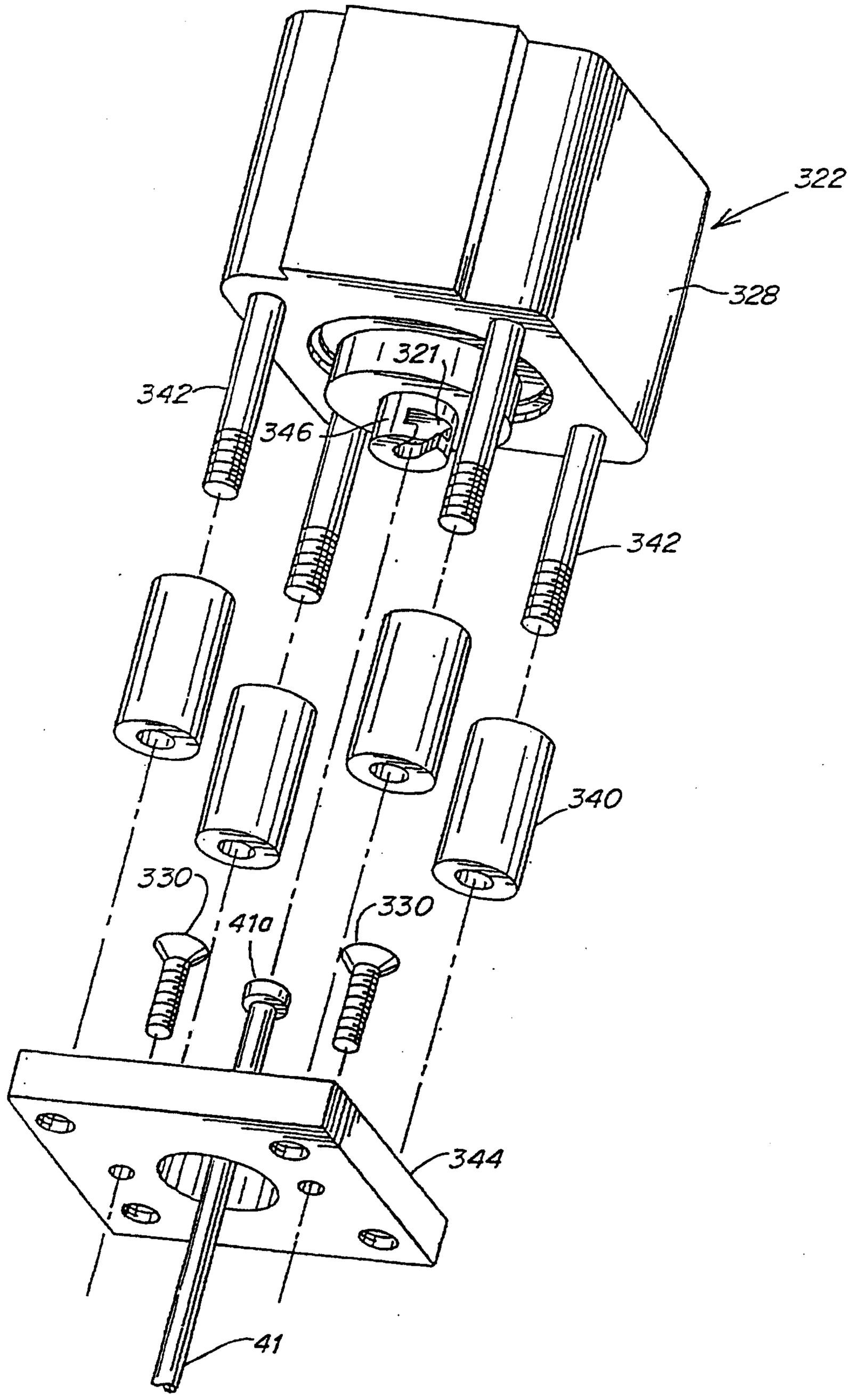

Fig. 24

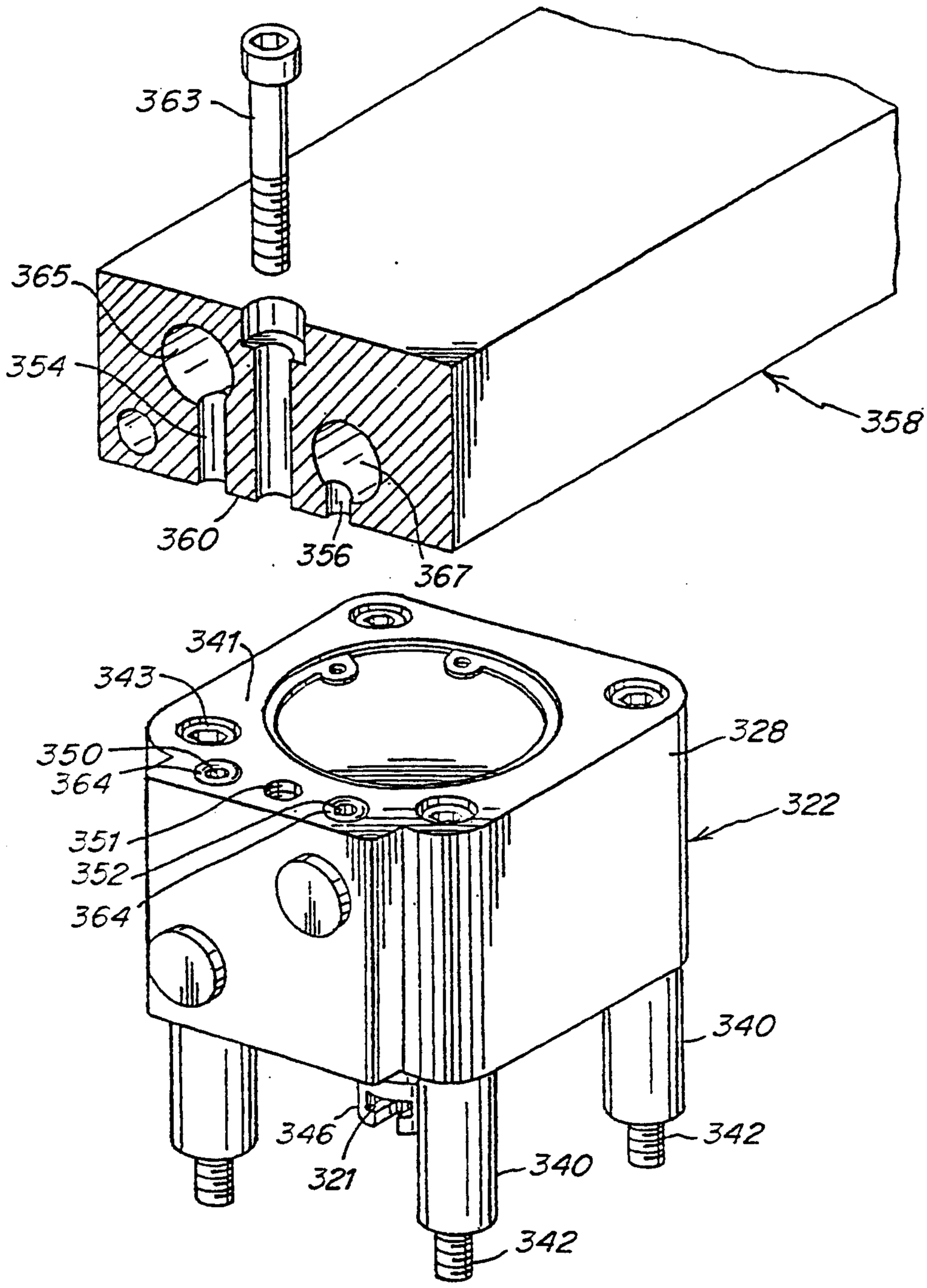
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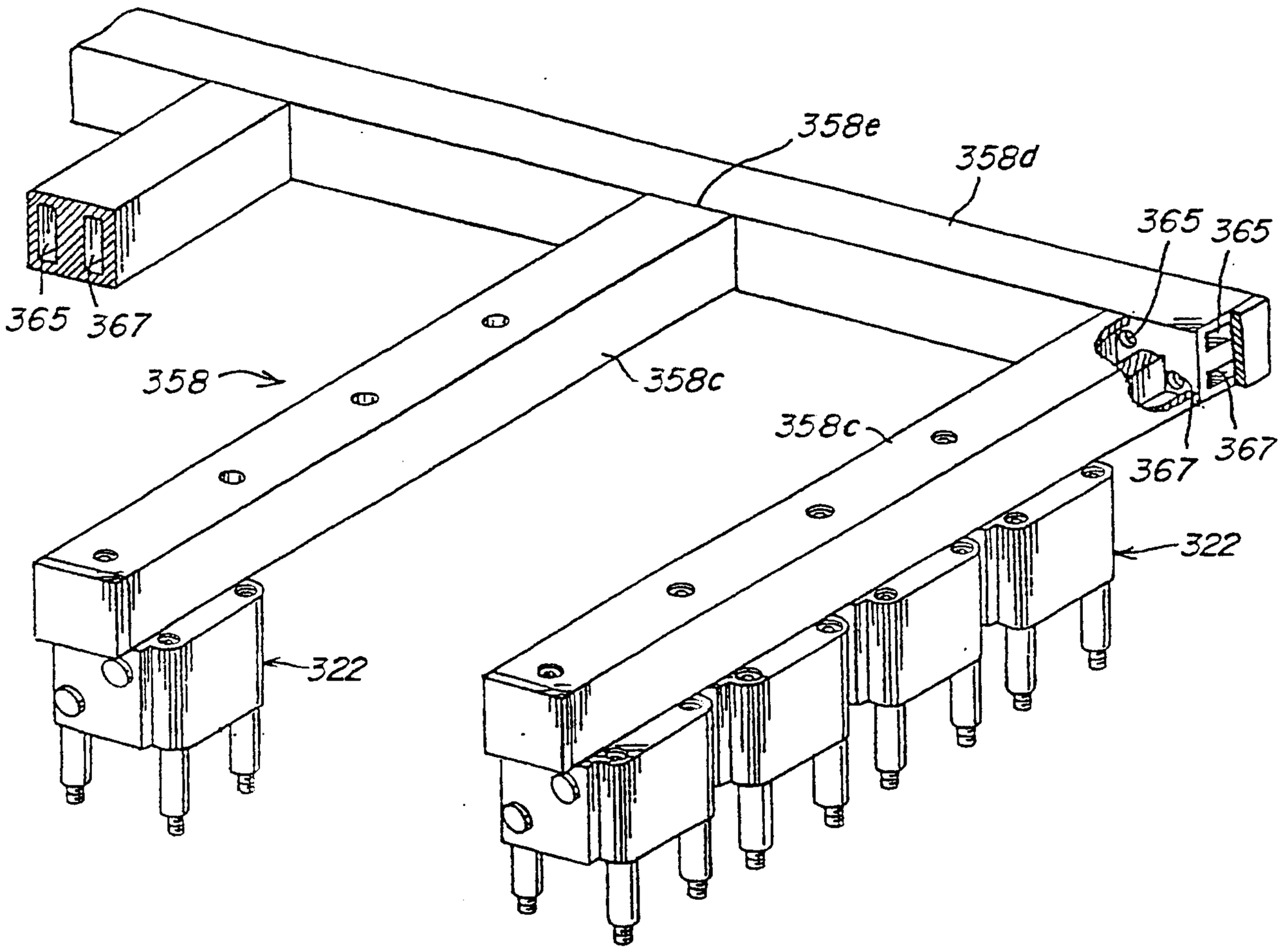
Fig. 25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322

Fig. 26

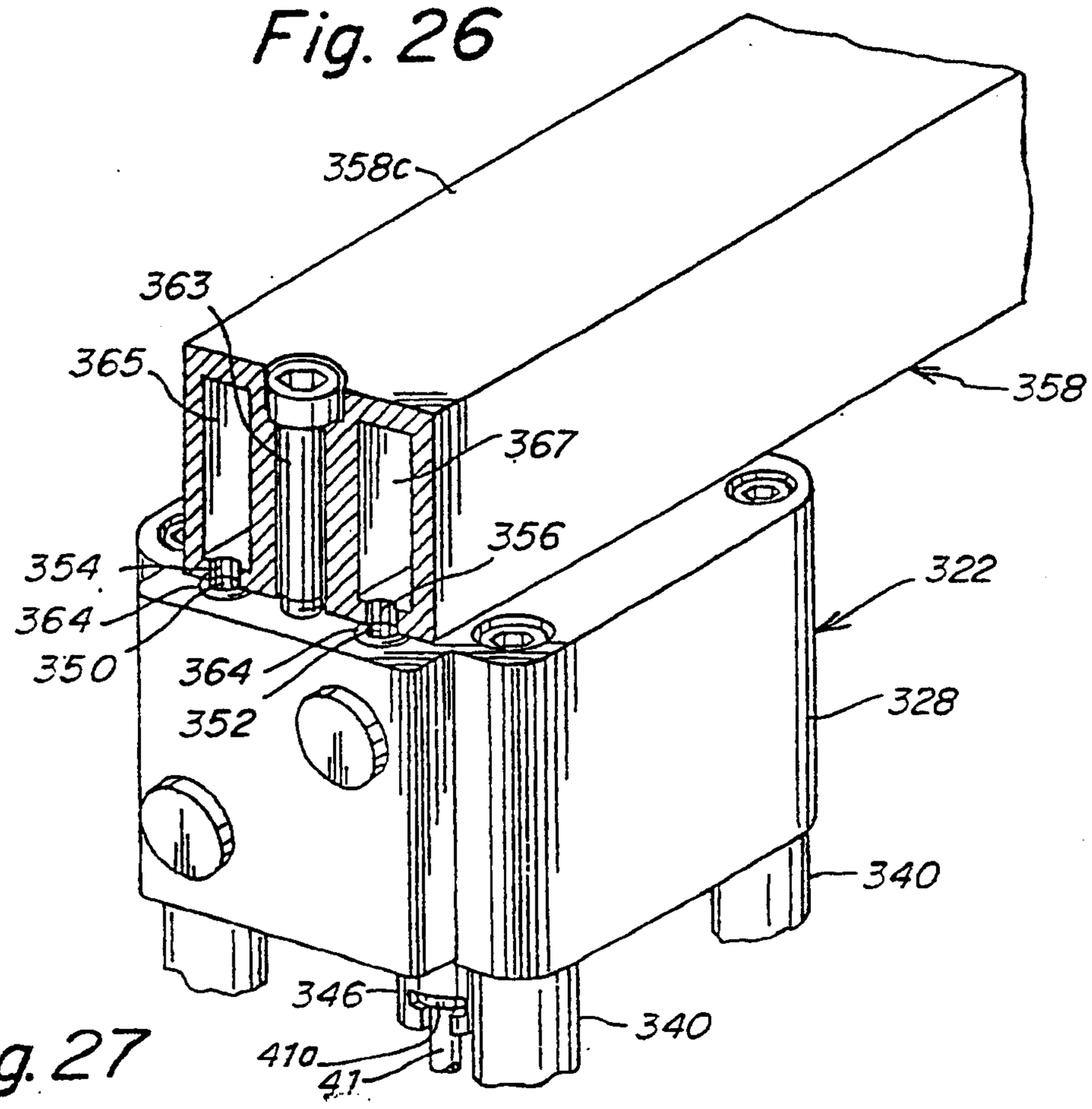

358c
363
365
358
367
356
354
322
364
350
364
352
328
340
346
340
410
41

Fig. 27

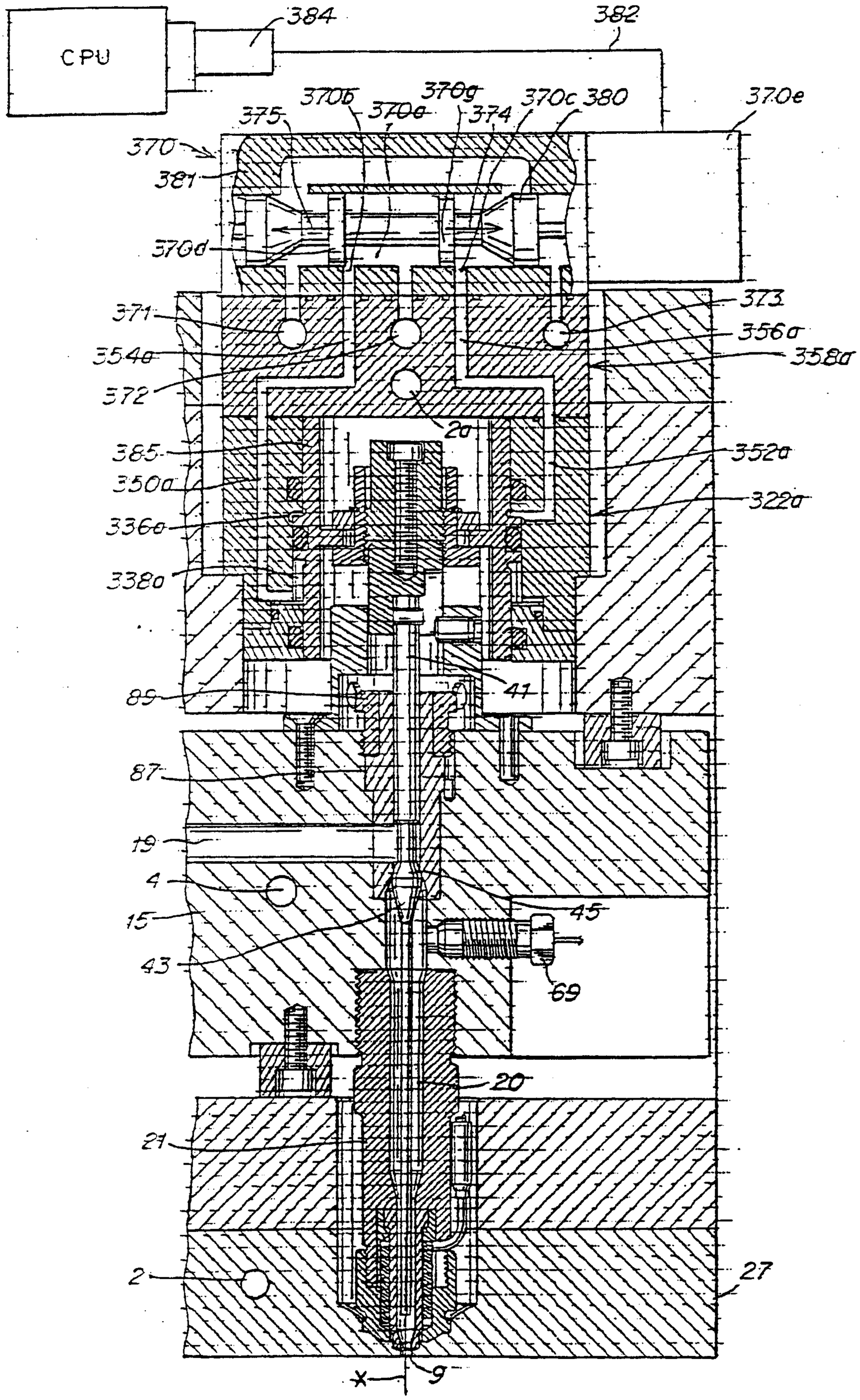

CPU
384
382
370b
370g
370a
374
370c
380
370e
375
370
381
370d
371
373
356a
354a
358a
372
20
385
352a
350a
322a
336a
338a
89
41
87
19
4
45
15
43
69
20
21
2
27
x
g

Fig. 28

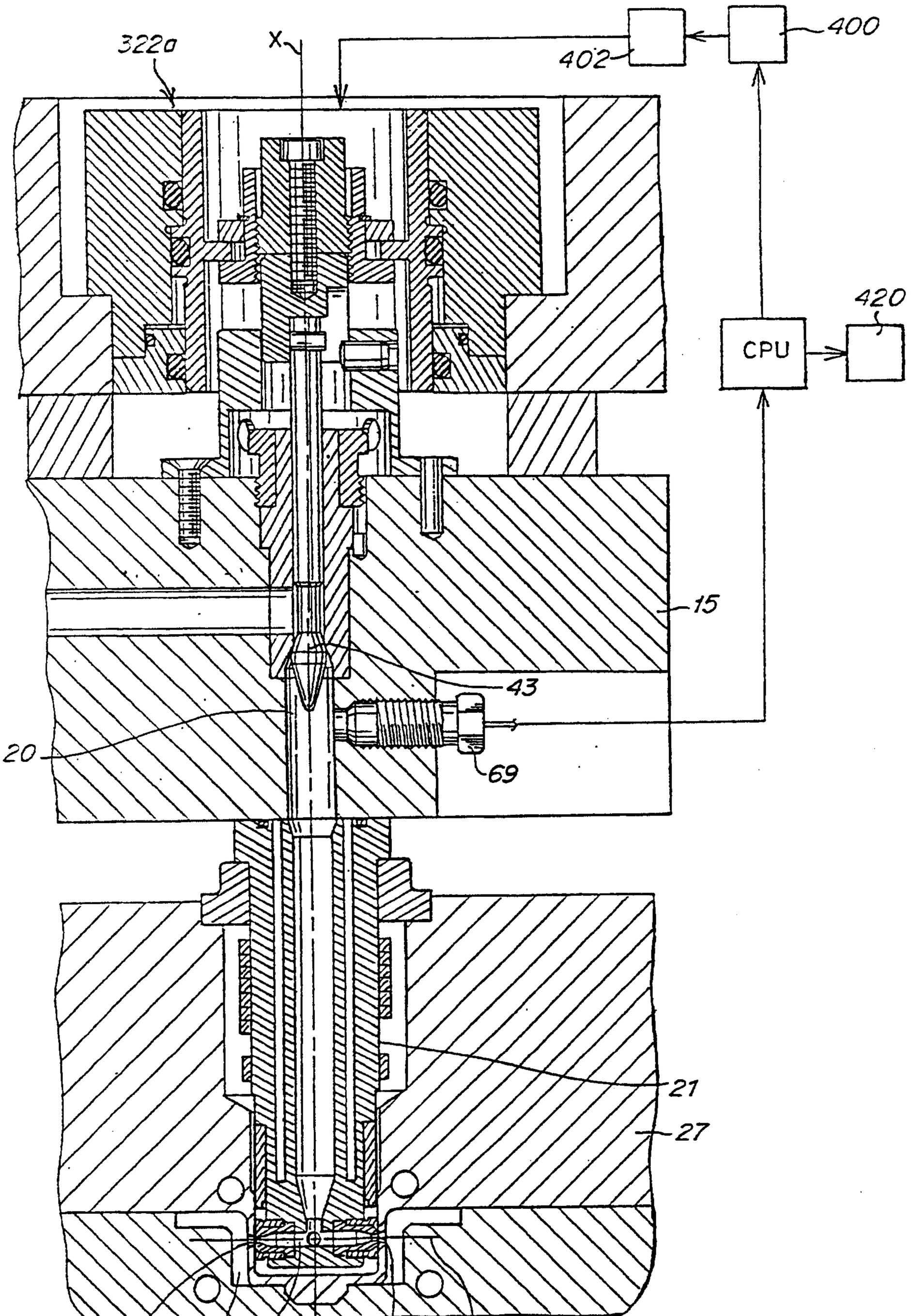


Fig. 29

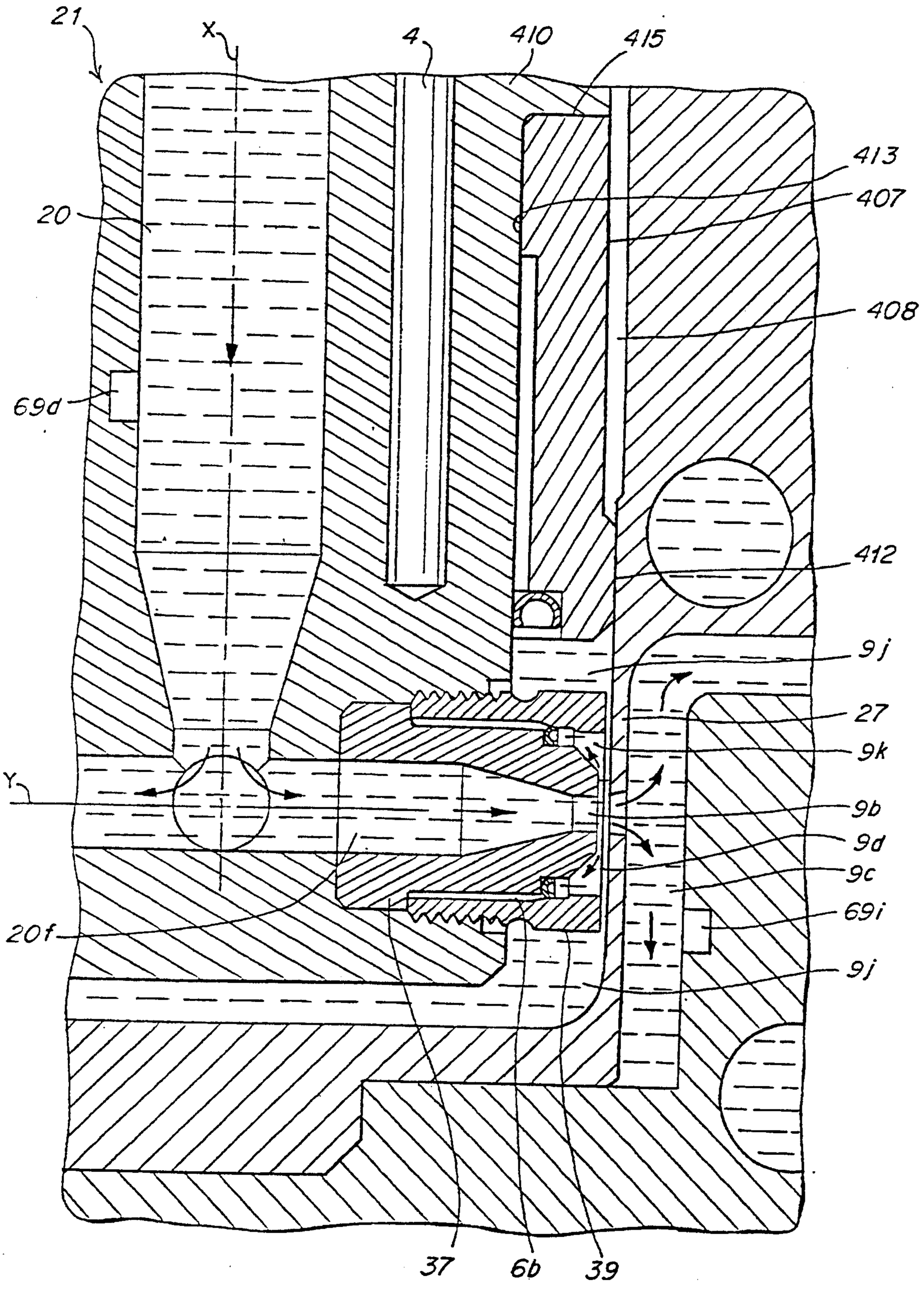

21
X
4
410
415
413
407
20
408
69d
412
9j
27
9k
Y
9b
9d
9c
69i
20f
9j
37
6b
39

Fig. 30

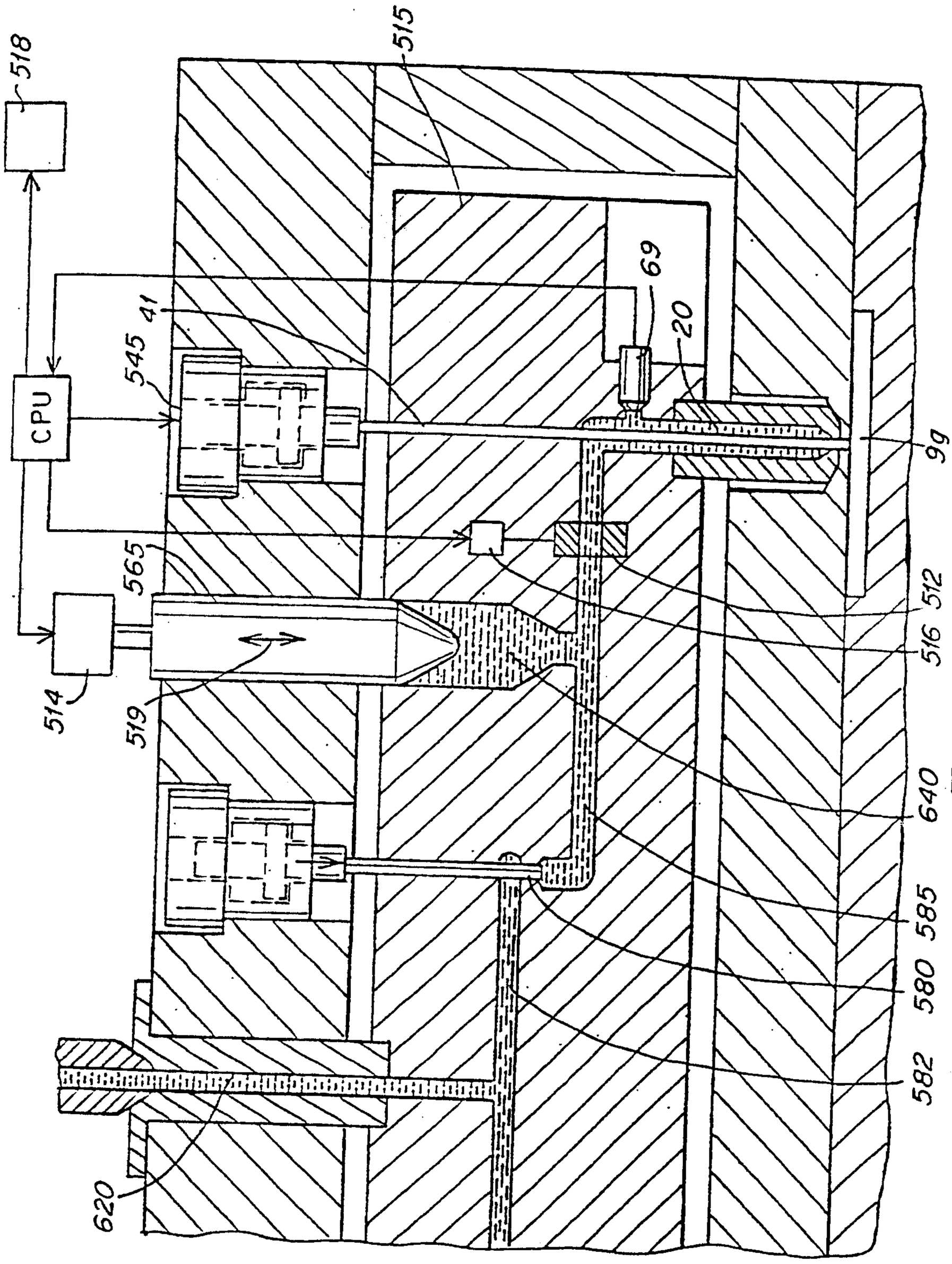
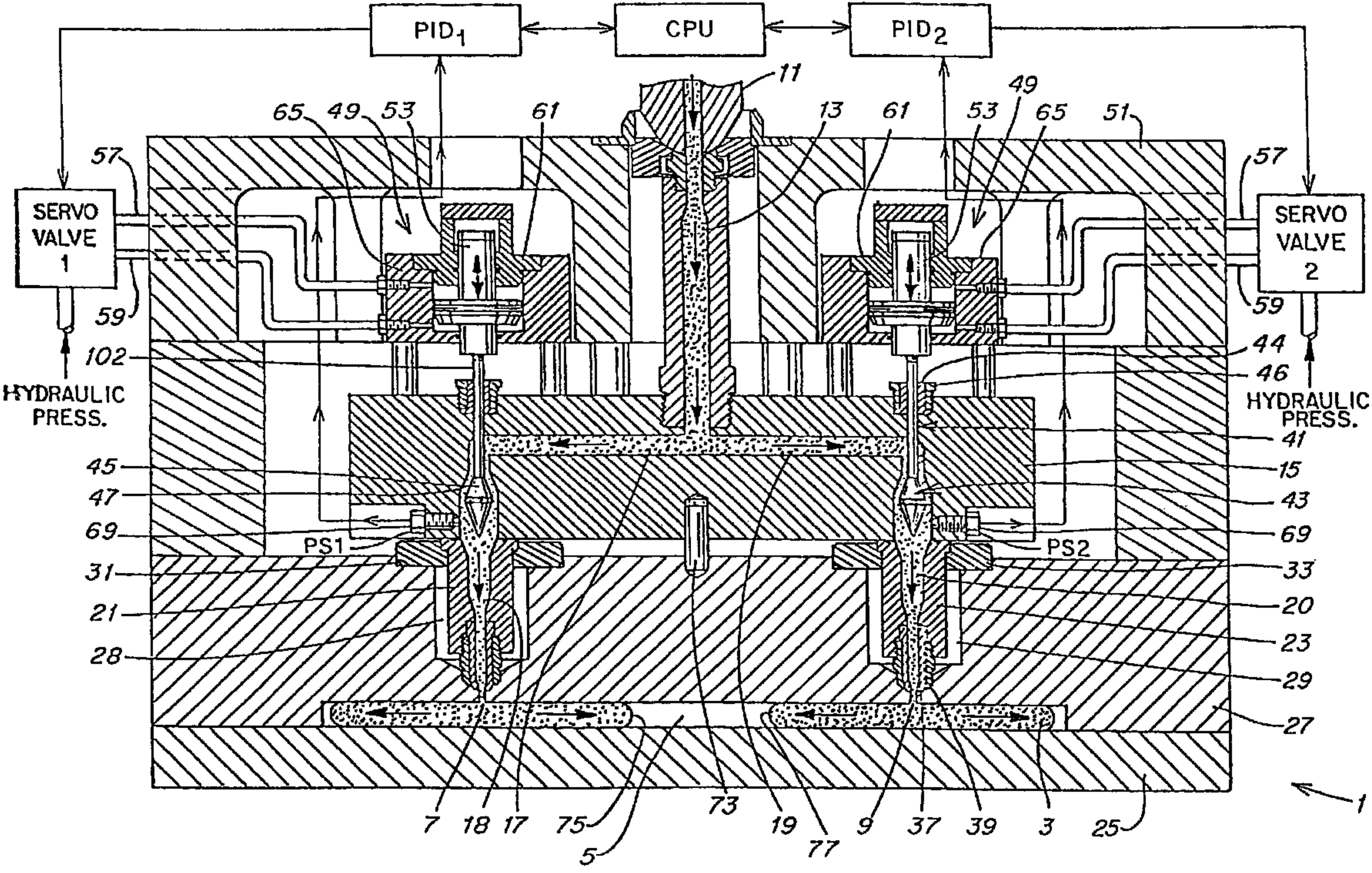

518
515
69
20
41
545
99
CPU
565
512
516
514
519
640
585
580
582
620

Fig. 31


PID1
CPU
PID2
SERVO VALVE 1
SERVO VALVE 2
HYDRAULIC PRESS.
HYDRAULIC PRESS.
PS1
PS2
11
13
49
53
61
65
51
57
59
102
44
46
41
15
43
69
45
47
31
33
21
20
23
28
29
27
1
7
18
17
75
5
73
19
77
9
37
39
3
25