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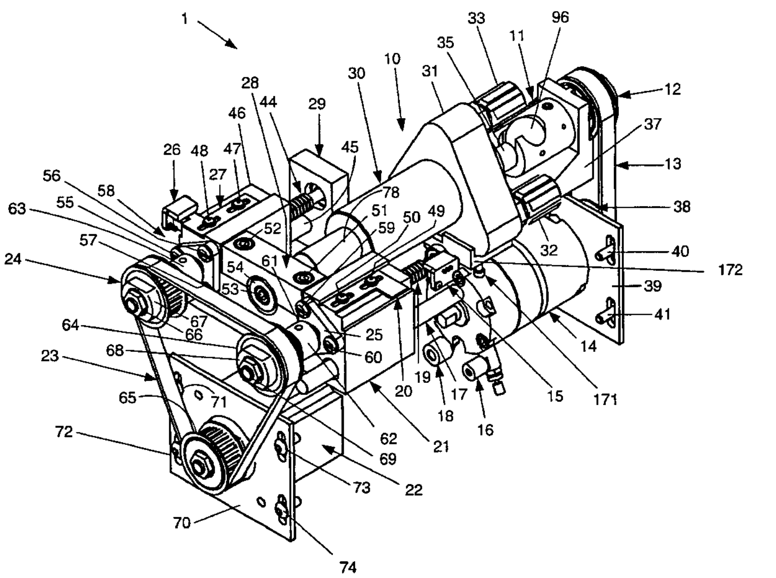

(57) Abstract: The present invention provides systems and methods of dispensing liquids. In one embodiment, the system includes a pump with a removable pump module with at least one displacement piston and at least one piston valve. A motor and base assembly provides the supporting components of the pump, which can be used in environments where precise small volumes of ultra-pure liquids must be transferred from a reservoir to a point of use. The preferred embodiment of the system prevents contaminants and air bubbles from being introduced into the liquid to be dispensed by placing a filter across the discharge line downstream from the pump, and providing a separate drawback line for performing the drawback of the liquid in the dispensing nozzle.

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LIQUID DISPENSING SYSTEMS AND METHODS

Background of the Invention

This application is a continuation-in-part of Application No. 09/360,851, filed July 24, 1999, which is incorporated herein by reference. This invention relates to dispensing liquids in precise volumes and more particularly to the transfer of liquid from a reservoir to a point of use by a pump having a displacement piston and a rotating piston valve communicating with one of a plurality of liquid ports.

The ability to deliver precise small volume amounts of liquids without introduction of contaminants is quite important in the manufacture of many products, especially in the electronics industry. A semiconductor foundry has several principal areas—metrology, lithography, and track where resist and developer must be rapidly and precisely dispensed. More specifically, photolithography requires precise repeatable delivery of photoresist and developer at different rates such as volumes of 0-10 ml ± 0.1%, repeatable to within ±0.1 volume% with substantially no contaminants or air bubbles. If these requirements cannot be met consistently, it adversely impacts the yield of the process. See, e.g., Chang & Sze, ULSI Technology (1996) hereby incorporated by reference.

The semiconductor industry provides, for example, different pumps such as piston pumps, diaphragm pumps, and peristalic pumps to transfer liquid from a liquid reservoir to a dispense nozzle above a silicon wafer in a spin station. After the liquid is dispensed any residual liquid left in the tip of the nozzle is drawn back slightly so that the resulting meniscus force prevents uncontrolled drips on the wafer and the wafer is rotated at high rpm to spread the liquid uniformly over the wafer.

The liquid dispensing system must also provide a filter to capture contaminants, which might be introduced in the liquid dispensed. When the filter is upstream of the pump, it captures the contaminants generated for example at the reservoir and/or the reservoir line leading to the pump but will be ineffective at capturing contaminants generated in the pump which then enter the liquid dispensed on the wafer. When the filter is downstream of the pump, the filter may capture pump generated contaminants but may still release air bubbles and contaminants into the dispensing system during draw back mode when the liquid reverses direction through the filter, which tends to dislodge some of the particles caught in the filter.

Summary of the Invention

The invention provides systems and methods of rapid delivery of liquids in precise volumes and with accuracy. The systems include a pump operating under the positive displacement principle. The pump includes at least one displacement piston, and at least one piston valve with a fluid slot, where the pistons in a cylinder define a pumping chamber. In general the displacement piston travels back and forth in the cylinder, producing suction, and discharging pumping action. The distance traveled by the displacement piston determines the dispensing volume of the pumping chamber and the direction of travel determines the direction of flow through any cylinder port. The piston valve rotates to align the fluid slot with a given cylinder port to communicate with the pumping chamber.

In refill mode, the piston valve rotates until the slot aligns with the intake port of the cylinder so the pumping chamber can communicate with the reservoir. The displacement piston retracts in the cylinder, expanding the pumping chamber, and drawing liquid from the reservoir though the intake port and into the pumping chamber. In dispense mode, the piston valve rotates closing the intake port so that the pumping chamber no longer communicates with the reservoir until the piston valve slot aligns with the discharge port out of the pumping chamber. The displacement piston slides forward, reducing the volume of the pumping chamber, expelling liquid through the discharge port.

In one embodiment, the piston valve includes a plurality of ports, such as an intake port, a discharge port, and a drawback port to permit precise delivery of liquids through a dispense nozzle without introducing contaminants, air bubbles, or liquid dripping. In drawback mode, in this embodiment, after the discharge step, the piston valve rotates closing the discharge port and the piston valve slot aligns with the drawback port, then the displacement piston slides back, expanding the volume of the pumping chamber, drawing liquid back in the dispense nozzle. The embodiment of the system also prevents contaminants and air bubbles from being introduced into the liquid to be dispensed from the nozzle by placing a filter across the discharge line downstream from the pump, and providing a separate drawback line for performing the drawback of the liquid in the dispensing nozzle so that drawback does not occur through the filter. This embodiment has special advantage in the precise control of semiconductor equipment used in dispensing liquid chemicals in ULSI technology.

Brief Description of the Drawings

Figure 1 is a perspective drawing of an embodiment of the pump, and illustrates the assembled pump including the pump module and the motor and base assembly.

Figure 2 is a partial cross-section taken along A-A of Figure 5 and a perspective drawing of an embodiment of the pump module.

Figure 3 is an exploded view of the components of the pump module shown in Figure 2.

Figure 4 is an exploded perspective view illustrating a preferred universal coupling for the piston valve.

Figure 5 is an end view of the port fitting case, the valve bearing ball, the three ports of the port fitting case, and a clamp band around the port fitting case.

Figure 6 is a schematic diagram illustrating the basic components of one embodiment of the precision liquid dispensing system.

Figure 7 is an exploded perspective view with partial cross-sections of a ratchet-actuator assembly. The ratchet housing is on the left and the pneumatic actuator on the right.

Figure 8 illustrates another view of the ratchet-actuator assembly of Figure 7. The pneumatic actuator now is on the left and the ratchet housing on the right.

Figure 9 is a perspective view of the inner parts of the ratchet-actuator.

Figure 10 is an exploded perspective view of the ratchet-actuator assembly.

Detailed Description of the Preferred Embodiments

Figure 1 illustrates an embodiment of a pump 1 capable of transferring precise small volumes, e.g., 0-10 ml, of a liquid from a liquid reservoir to a dispense nozzle. The pump 1 can be used in a system such as that depicted in Figure 6 to deliver resist and developer to semiconductor wafers. As shown in Figure 6, the components of the system include a liquid supply reservoir 143, a liquid supply line 144, a three-port pump 1, an upstream discharge line 148, a filter 149, a downstream discharge line 150, a dispense line 151, a dispense nozzle 152, and a drawback line 147. The liquid reservoir 143 can be a variety of well known reservoirs, the liquid lines are preferably of Teflon, the tube hardware and fittings can be Parker, Parabound Adaptor, Paraflare x Pipe BA-4F4, one suitable filter 149 is the Pall model no. MCD9116UFTEH, and the materials of the pump 1 will be described in detail below.

In operation, the pump 1 and the liquid lines are preferably charged with liquid. In dispensing mode, the pump 1 displaces liquid through the upstream discharge line 148, the filter 149, the downstream discharge line 150, the dispense line 151, and out of the dispense nozzle 152 onto the wafer. In drawback mode, occurring preferably a short time after the dispense mode, the three-port pump 1 valve is actuated to communicate with the drawback line 147 and the displacement piston in the cylinder of pump 1 reverses direction to enable drip-free dispense by drawing the liquid back inside the nozzle 152 through the drawback line 147 avoiding the need to reverse the flow through the filter 149. This feature helps to prevent contaminants from being dislodged from the filter 149. In purge mode, the system can use the drawback line 147 to prime any air out of the nozzle 152 also without going through the filter 149. This feature reduces air bubbles from being introduced into the liquid dispensed. Alternatively, the pump 1 might add a fourth port to allow purge of air from entering into the liquid supply reservoir 143 through a liquid purge back line (not shown) to conserve resist.

Referring again to the embodiment shown in Figure 1, the pump 1 includes a pump module, a motor and base assembly, and an electronic controller (not shown), and operates by the positive displacement principle. As shown in Figure 2, the displacement piston 80 pumps the liquid by traveling back and forth in a cylinder liner 30, as indicated by the arrows, producing suction and discharging action. The distance traveled by the displacement piston 80 in the cylinder liner 30 is proportional to the volume of the pumping chamber 87. For liquid intake the piston valve 81 rotates so that the fluid slot 82 aligns with an intake port 85 (Figure 5) so that the pumping chamber 87 communicates with the liquid reservoir 143 (Figure 6). The displacement piston 80 retracts in the cylinder liner 30, expanding the pumping chamber 87, drawing liquid from the reservoir 143 (Figure 6) though the intake port 85 (Figure 5) and into the pumping chamber 87. The piston valve 81 rotates closing the intake port 85 (Figure 5) so that the pumping chamber 87 no longer communicates with the reservoir 143 (Figure 6).

To discharge the liquid drawn into the pumping chamber 87, the piston valve 81 rotates to align the fluid slot 82 with the discharge port 83, and the displacement piston 80 extends into the cylinder liner 30, expelling liquid from pumping chamber 87 through the discharge port 83. To draw back liquid in the discharge line, the displacement piston 80 can retract immediately after the discharge step. However, in the preferred embodiment, the pump 1 draws back the liquid in the dispense nozzle 152 (Figure 6) by rotating the piston valve 81 to align the fluid slot 82 with a drawback port 90, and then retracting the displacement piston 80.

Figure 3 is an exploded view of the parts making up the pump module 10. A valve bearing ball 96 is attached on a neck 35 (Figure 1) of the piston valve 81 by a cone point socket set screw 161. To form a liquid seal the pump module 10 preferably provides a cylinder end cap 160, a Teflon thrust washer 158, a flange 157 on the piston valve 81, a Teflon thrust washer 163, and a lip seal 162. A conventional clamp band 43 is provided to hold a port fitting case 31 on the cylinder liner 30. As shown in Figure 1, a support 172, preferably including a spacer 171, is located under the port fitting case 31 to prevent rotation of the port fitting case 31 from torque produced by rotation of the motor 14. The port fitting case 31 is preferably made of Teflon. Another liquid seal is provided by assembly of a cylinder end cap 79, a lip seal 89, and a cylinder liner 30. A socket head cap screw 53 is provided which is inserted into a spherical bearing retainer 54 and a spherical bearing 75 with a race 154 (Figure 2) and into the end of the displacement piston 80 to hold the retainer 54, the bearing 75, and the displacement piston 80 in fixed relationship with each other.

When the various parts shown in Figure 3 are assembled, the pump module 10 appears as shown in Figure 2. Figure 2 illustrates that the fluid seal includes a cylinder end cap 79 holding a lip seal 89 against the cylinder liner 30 and a contact surface 78 of the displacement piston 80. Figure 2 illustrates when the fluid slot 82 described earlier is aligned with the drawback port 90. The clamp band 43 holds the port fitting case 31 to the cylinder liner 30 so that the drawback port 90 aligns with the L-shaped port 91 of the port fitting case 31. Similarly, the clamp band 43 holds the port fitting case 31 to the cylinder liner 30 so that the discharge port 83 aligns with the L-shaped port 84. The L-shaped port 91 narrows to a passage 92 in a male connector 94, and threads 93 engage a twist tight collar 33 (Figure 1). Likewise, the L-shaped port 84 narrows to a passage 99 of a male connector 101 and threads 100 engage a twist tight collar 32 (Figure 1). Again, the fluid seal at the valve bearing ball 96 end preferably uses the parts discussed earlier in connection with Figure 3. The piston valve 81 includes a relief band 156, which is slightly smaller in diameter than the rest of piston valve 81 to permit liquid to enter in the gap to prevent the curing of the liquid under the pressures and temperatures created by the tight fit and movement of the piston valve 81. The piston valve 81 also includes an inner neck 159, an outer neck 35 and is attached to the valve bearing ball 96 which has two slots 98 and 164 and a flat surface 97 for reasons discussed below.

Figure 2 also shows that the spherical bearing 75 is held to a piston end cap 76 preferably made of stainless steel 316. The piston end cap 76 is heat shrunk or glued on the end of the displacement piston 80 as shown in Figures 2-3. The displacement piston 80, the piston valve 81, and the cylinder liner 30 are preferably made of aluminum oxide or polished zirconia (YTZP) but can be also made of another suitable ceramic, a stainless steel, Delrin™, Tefzel™, or Kynar™. The advantage of aluminum oxide is it may not require lubrication beyond that provided by the liquid being dispensed or metered, it is extremely hard and resists abrasion, it exhibits little wear after many cycles, it is chemically stable, and it allows precision machining and diamond tooling with close running fits (100 millionths of an inch). Aluminum oxide's properties of low friction, hardness, and stability allow the pump module 10 to be primarily sealed by close clearance of the pistons 80, 81, and the cylinder liner 30. This means no compliant seals may be needed which eliminates a set of parts, which frequently fail and require replacement in conventional pumps.

As shown in Figures 1-2, the pump 1 includes motors 14 and 22 for driving the pump module 10. First, a stepper motor 22 drives the displacement piston 80 by rotating a bottom pulley 65 coupled by a drive belt 23 to a set of pulleys 24 and 64. In alternative embodiments, the motor 22 can be a servo motor or another suitable positioning motor. The pulleys contact the drive belt 23 with sufficient friction and tension to prevent slippage between the pulleys and the belt. One suitable drive belt is the Breco-flex 10T5/390. A suitable pulley is the LS21T5/20-2 made by Breco-flex. The tension of the drive belt 23 can be adjusted by loosening bolts 71-74 residing in the vertical slots of rigid plate 70 so that the pulley 65 can move up to reduce or down to increase the tension of the drive belt 23. Thus, the rigid plate 70 provides an adjustable support structure for mounting the pulley 65 and the stepper motor 22.

In a preferred embodiment if the stepper motor 22 rotates, the drive belt 23 transfers that force to the pulleys 24 and 64, which rotate precision lead screws 44 and 19. Eastern Air Devices, Inc., motor series LH2318 together with Intelligent Motion Systems, Inc. Model IM483 drive electronics provide a compatible motor and controller combination for this purpose. One end of precision lead screw 44 attaches to the pulley 24 and the other end rotates in a lead screw and linear shaft bearing block 29. One end of precision lead screw 19 attaches to the pulley 64 and the other end rotates in a lead screw and linear shaft bearing block like block 29 but not shown to expose other parts to view. Spacers 63 and 62 space pulleys 24 and 64 from triangular shaped lead nuts 58 and 25. Lead nut 58 is fixed to a displacement slide block 46 by bolt 57 hidden by drive belt 23 in Figure 1, a bolt 55 partially hidden by spacer 63 in Figure 1, and a bolt 56. The lead nut 25 is bolted to a displacement slide block 21 by bolt 61 hidden by the spacer 62, a bolt 59, and a bolt 60. A pair of parallel linear bearing shafts 17 and 45 guides the displacement slide blocks 21 and 46. A piston coupling 28 is attached by bolts 51 and 52 to the displacement slide blocks 21 and 46 and to the displacement piston 80 by the socket head cap screw 53, the retainer 54, and the bearing 75 described earlier. Thus, the piston coupling 28, and the displacement slide blocks 21 and 46 move as a unit to drive the displacement piston 80 in and out of the cylinder liner 30 as the precision lead screws 44 and 19 rotate and engage the threads of the lead nut 58 and the lead nut 25, respectively. Preferably, the displacement slide blocks 21 and 46 have holes, which are not threaded and therefore do not engage either the threads of the precision lead screw or bind the linear bearing shafts.

An adjustable flag 20 is held by bolts 49 and 50 to the displacement slide block 21 and overlaps an adjacent piston extended position sensor 15 when the displacement piston 80 fully extends into the cylinder liner 30. Similarly, an adjustable flag 27 is held by bolts 47 and 48 to the displacement slide block 46 and overlaps an adjacent piston retracted position sensor 26 when the displacement piston 80 fully retracts in the cylinder liner 30. One suitable sensor uses the Hall effect to detect when the metal flag interrupts a magnetic field emanating from the sensor. Another uses the photoelectric effect where an object fixed to the displacement block serves to partially or fully interrupt a light beam aimed at a photo detector. The Honeywell Microswitch 4AV series is suitable for performing this function.

Figures 1-2 illustrate that the pump 1 also includes a motor 14 for driving the piston valve 81 of the pump module 10 by rotating a pulley 38 coupled by a belt 13 to a pulley 12. The pulleys 12 and 38 have sufficient friction with the belt 13 to avoid slippage. The motor 14 is preferably an air-powered rotary indexer because it quickly rotates the fluid slot 82 into alignment with a port when commanded by a conventional controller. In such a motor such as that manufactured by SMC, for example, the NCRBI-W30-1805 series motor, pneumatic air enters input 18 and a well known ratchet-gear mechanism converts the 180 degree movements of the motor 14 into the desired angular increment, e.g., 120 degrees for a three-port embodiment as shown in Figure 1. After an angular increment occurs the air is relieved at air exhaust 16. In alternative embodiments, the motor 14 can be a servomotor or another suitable positioning motor. Preferably, a conventional controller using advanced solid-state electronics with microprocessor technology and sensors can be used to control the pump 1, including the motors 22 and 14 to actuate the movement of the displacement piston 80 and the piston valve 81 at appropriate velocities, distances, and times.

Figure 7 is a partially exploded cross-sectional view of an embodiment of the ratchet-actuator assembly 200. The ratchet-actuator assembly 200 includes a ratchet housing 202, a pneumatic actuator 204, and an adapter ring 242. The adapter ring 242 locates the pneumatic actuator 204 on the ratchet housing 202. The assembly 200 is held together by socket cap screws 206, 208, and 210 in the following manner. Screw 210, for example, butts against a counterbore 220 in the ratchet housing 202, travels through a ratchet hole 222, then into a hole in an adapter ring 242, and into a threaded hole 244 in the pneumatic actuator 204. Screws 206 and 208 are similarly inserted and/or threaded through their respective holes in the same parts. In a preferred arrangement, the three screws 206, 208, and 210 are spaced apart from each other 120 degrees. The screws 206, 208, and 210 are held in the assembly 200 by internal threads in the pneumatic actuator 204. Screws 206, 208, and 210 use the leftover thread on the backside of cap screws 255 and 257 (Figure 8).

Ratchet housing 202 houses a ratchet 234 integral or fixed to a ratchet shaft 214. The shaft 214 has a groove 212, functioning as a key seat. The ratchet 234/shaft 214 rotate within the housing 202, via a roller clutch/ bearing assembly 218 press-fit into a collar 216 of the housing 202. As shown in Figure 8, the opposite end of the ratchet 234 has three teeth 223, 224, and 225, spaced 120 degrees apart from each other. The ratchet housing 202 includes a pawl 226 held to the ratchet housing 202 by a pin 227. The pin 227 is fixed to the pawl 226. Socket cap screws 232 and 235 shown in Figure 10 hold a spring plunger block 230 to the ratchet housing 202. The spring plunger block 230 laterally supports a spring plunger 228, which biases the pawl 226 against a cam 240 as discussed below.

The pneumatic actuator 204 is a conventional pneumatic vane type actuator such as the SMC NCRB1BW30, including a vane blade 246 fixed and extending from a vane hub 249 attached or integral with a vane shaft 248. A vane shaft collar 251 locates the vane shaft 248 axially in the pneumatic actuator 204. A cam 240 preferably attached to the vane shaft 248 raises and lowers the pawl 226 off the ratchet 234 depending on the rotational position of the cam 240.

Figure 8 illustrates the same ratchet-actuator assembly 200 shown in Figure 7, with a better view of the pneumatic actuator 204 and the internal parts of the ratchet housing 202. In particular, Figure 8 shows the end of the vane shaft 253 and the collar 251 holding the vane shaft 253, the socket cap screws 255 and 257 holding the pneumatic actuator together, the location of port 18, and the three ratchet teeth 223, 224, and 225.

Air pressure (e.g., 100 psi max) is applied through a conventional four-way solenoid valve (not shown) into the port 16 against the vane blade 246. This rotates the vane blade 246 until it runs into a mechanical stop as shown in Figure 8 in the pneumatic actuator 204 such that the lobe 241 of the cam 240 raises the pawl 226 off the ratchet 234. This is the ratchet-gear actuator's normal pressurized state. When the air pressure switches into the port 18 and exhausts air through the port 16, the vane blade 246 rotates forward as indicated by the arrow above the camshaft 238 shown in Figure 8. During this rotation the cam 240 lowers the pawl 226 back onto the ratchet 234, which shortens the rotation of the vane shaft 248 from 180 degrees to 120 degrees when the pawl 226 engages one of the teeth 223, 224, or 225, spaced 120 degrees apart. Thus, as the ratchet 234 rotates, each ratchet tooth consecutively catches on the pawl 226, which is swiveled axially about the pin 227 (shown Figures 8-10)

A roller clutch 259 such as a Torrington, type DC roller clutch transfers rotational motion from the cam 240 to the ratchet 234 (Figure 8). The roller clutch 259 engages the camshaft 238 when the cam 240 and the camshaft 238 rotate forward as shown by arrow, which rotates the ratchet 234 in the same direction. During a reverse rotation, the roller clutch 259 disengages and acts as a bearing to the camshaft 238, which allows the cam 240, the camshaft 238, and the vane shaft 248, all fixed together, to rotate back to the normal position. To prevent reverse rotation on the ratchet 234, a roller clutch/bearing assembly 218 such as Torrington, type DC roller clutch and bearing assembly, FCBL-8-K, is press-fit into the ratchet housing 202, and acts on the ratchet shaft 214. In a preferred embodiment, one alternation (i.e., forward rotation) of the pneumatic actuator shaft 248 produces one increment of direct rotation of the ratchet shaft 214.

Figure 9 is a perspective view of the inner parts of the ratchet-actuator assembly. It shows the vane shaft 248 having an end 253, a hub 249, and a vane blade 246. It shows the cam 240 attached to the vane shaft 248, and the lobe 241 at peak rotation to raise the pawl 226 around the pin 227 against the biasing force being applied by the spring plunger 228 at a contact point 231. The plunger block 230 laterally holds the spring plunger 228 so that it can move up and down in response to the rotation of the cam 240. A screw 201 is turned to adjust the amount of biasing force being applied to the pawl 226. When the cam 240 raises the pawl 226, the pawl 226 disengages from the ratchet tooth, here shown as tooth 224. Rotation of the ratchet shaft 248 has the same affect with respect to the other teeth 223 and 225.

Figure 10 is an exploded view of the ratchet-actuator assembly 200 shown in Figures 7-9. The same parts shown in Figures 7-10 have the same part numbers. Roller clutch/ bearing assembly 218 is shown before it is press-fit into ratchet housing 202. The spring plunger block 230 is shown before a set of screws 232 and 235 are inserted in holes 221 and 233 of the spring plunger block 230, and into the threaded holes 229 and 203 of the ratchet housing 202. The ratchet housing 202 includes a notch to give access to the pawl and to secure the spring plunger block 230 to the ratchet housing 202. Figure 10 shows the ratchet 234, the ratchet shaft 214 apart from the ratchet housing 202 and before the ratchet shaft 214 is inserted into the bearing 218. The pin 227 fixed to the pawl 226 has two ends, including shown end 217, both of which extend beyond the edges of the pawl 226. Figure 10 shows the camshaft 238 before insertion into the bearing 259 where the camshaft 238 contacts the inner bearing surface 258. In this embodiment, the cam 240 is attached to the pneumatic actuator shaft 248 by socket cup point set screw 243, being inserted into the camshaft 238, and tightened against a flat surface 260 of the pneumatic actuator shaft 248. The adapter ring 242 includes holes 245, 256, and 262, which correspond to the socket cap screws 206, 208, and 210, which in turn, are inserted into holes 268, 266, and 270 in the pneumatic actuator 204. An adapter ring dowel pin 247 is later force-fit in the adapter ring 242 and orients the ratchet housing 202.

A suitable drive belt 13 is the Breco-flex 10T5/390 and one suitable pulley is the LS21T5/20-2 made by Breco-flex. The tension of the drive belt 13 can be easily adjusted by loosening bolts such as bolts 40-41 in the vertical slots at corners of a rigid plate 39 and moving the rigid plate 39 supporting the pulley 38 up to reduce the tension or down to increase the tension of the drive belt 13. Thus, the rigid plate 39 provides an adjustable support structure for mounting the pulley 38 and the motor 14. A L-shaped bracket 37 includes a conventional sealed bearing for supporting the shaft of the pulley 12 and a universal coupling 11 shown in Figure 1.

The universal coupling 11 eliminates the problem of how to exactly align the axis of the pulley 12 with that of the piston valve 81. The location of the universal coupling 11 in the pump 1 is best shown in Figure 1, but the details are in Figure 4. As shown in Figure 4, an exploded view, the universal coupling 11 includes a coupling body 8 with a receptacle for the valve bearing ball 96, and a set of pins 2 and 9 to hold the valve bearing ball 96 in the receptacle. Pin 2 engages slot 98 and pin 9 engages slot 164 on valve bearing ball 96 to provide a positive rotational coupling. Thus, the pump module 10 is held by the universal coupling 11 on one end and by the piston coupling 28 on the other. This permits the pump module 10 to be quickly removed from the rest of the pump 1 for cleaning or autoclaving. For example, to remove the pump module 10, one would remove piston coupling 28, then pivot the pump module 10 approximately 90 degrees with respect to the operational axis on pins 2 and 9 to the dotted line position shown in Figure 4. When slots 98 and 164 are aligned perpendicular to coupling 8, the pump module 10 can be removed. To assist in that removal, the flat surface 97 of the valve bearing ball 96 provides clearance to the button 5 in universal coupling 11 when the pump module 10 is pivoted 90 degrees.

A biasing means holds the valve bearing ball 96 in place during operation and includes a button 5 biased by a Belleville washer 6 (i.e., domed shaped for spring action) and held by a retainer washer 7. To install the biasing means in the coupling body 8 the following steps are taken. The Belleville washer 6 is inserted in the retainer washer 7, the button 5 is placed on the washer 6, and preferably three dowel pins such as dowel pin 3 are partially inserted in holes 120 degrees apart to protrude in the coupling body 8 to guide the retainer washer 7 along corresponding slots 174, 176, and 178. When each pin hits the end of its slot, where a hole exists, the pin can be driven into the hole of the retainer washer 7. Because of the tight fit and flared shape of the pins, this technique firmly attaches the retainer washer 7 in the coupling body 8. A cone point set screw 4 travels through the larger top hole in coupling body 8 and engages in threaded hole 180 in the retainer washer 7, acting to fix the coupling body 8 to the shaft of the pulley 12. As shown in Figure 1, conventional spacers (not shown) maintain pulleys 12 and 38 at an appropriate distance from respectively the L-shaped bracket 37 and the plate 39.

Figure 5 is a detail end view of one embodiment of a three-port case fitting 31. It shows where the cross-section A-A is taken in the embodiment illustrated in Figure 2 and can be understood in conjunction with embodiments illustrated in Figures 1-2. In those embodiments, the top port dedicated to a drawback line, includes a male connector 94 defining a passage 92 and having threads 93. The bottom right port, almost completely hidden in Figure 2, and dedicated to an intake line, includes a male connector 168 defining a passage 167 and with threads 169. The bottom right port communicates with the fluid slot 82 by the port 85 represented by dotted lines. The bottom left port, dedicated to a discharge line, includes a male connector 101 defining a passage 99 and with threads 100. Figure 5 also illustrates an embodiment for the valve bearing ball 96 including the flat surface 97 as well as the slots 98 and 164 for engaging pins 2 and 9 of the universal coupling 11 as discussed earlier.

Any given port can function as an intake or a discharge liquid depending on whether the displacement piston 80 retracts or extends into the cylinder liner 30 after alignment. Further, the port fitting case 31 is not limited to three ports as illustrated but could be a plurality of ports depending on the application. Accordingly, the pump module 10 could have multiple outputs and/or multiple inputs and/or multiple drawbacks and/or purge lines. In addition, a pump 1 could have a plurality of pump modules 10 disposed in parallel each having a stepper motor 22 or driven by the same stepper motor 22 and each having their own piston valve 81 and motor 14 or driven by the same motor 14. Of course, this permits the compact pumping of different liquid chemicals with isolation between the chemicals. The design of the piston valve 81 dispenses and meters liquid without any secondary mechanism such as check valves which allows for longer life, higher reliability, and greater accuracy.

What is Claimed:

1. A liquid dispensing pump system, comprising:

a pump module including a displacement piston and a piston valve disposed in a cylinder and defining a pumping chamber, wherein the displacement piston travels back and forth in the cylinder, producing suction, and discharging pumping action, a port case fitting with a plurality of ports able to communicate one at a time with a fluid slot in the piston valve based on rotation of the piston valve, and the direction of travel of the displacement piston determines the direction of flow out of any port;

means for driving the displacement piston; means for rotating the piston valve so that the fluid slot of the piston valve communicates with one of the plurality of ports in the port case fitting; and

means for supporting the pump module, means for driving, and means for rotating.

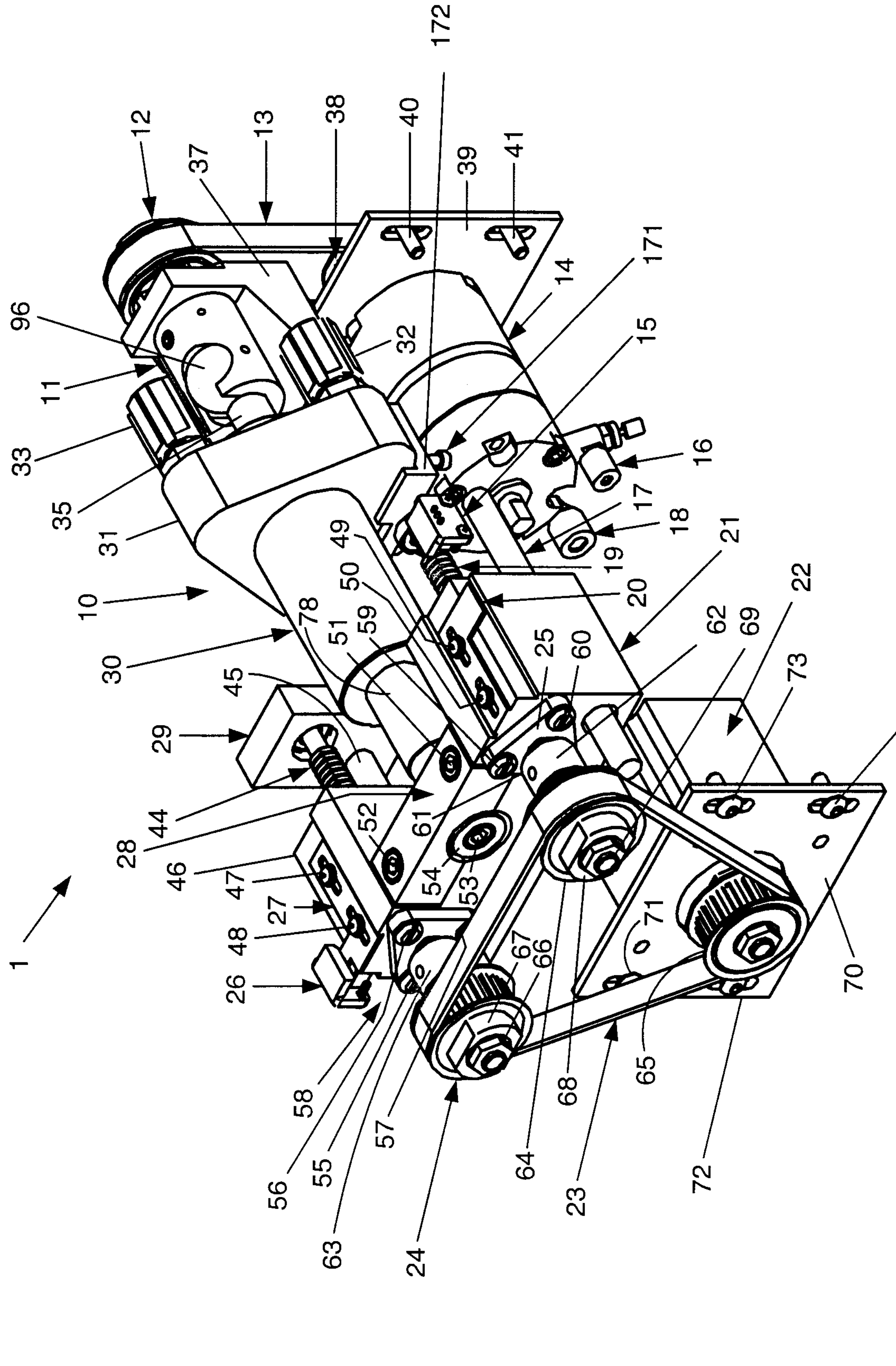
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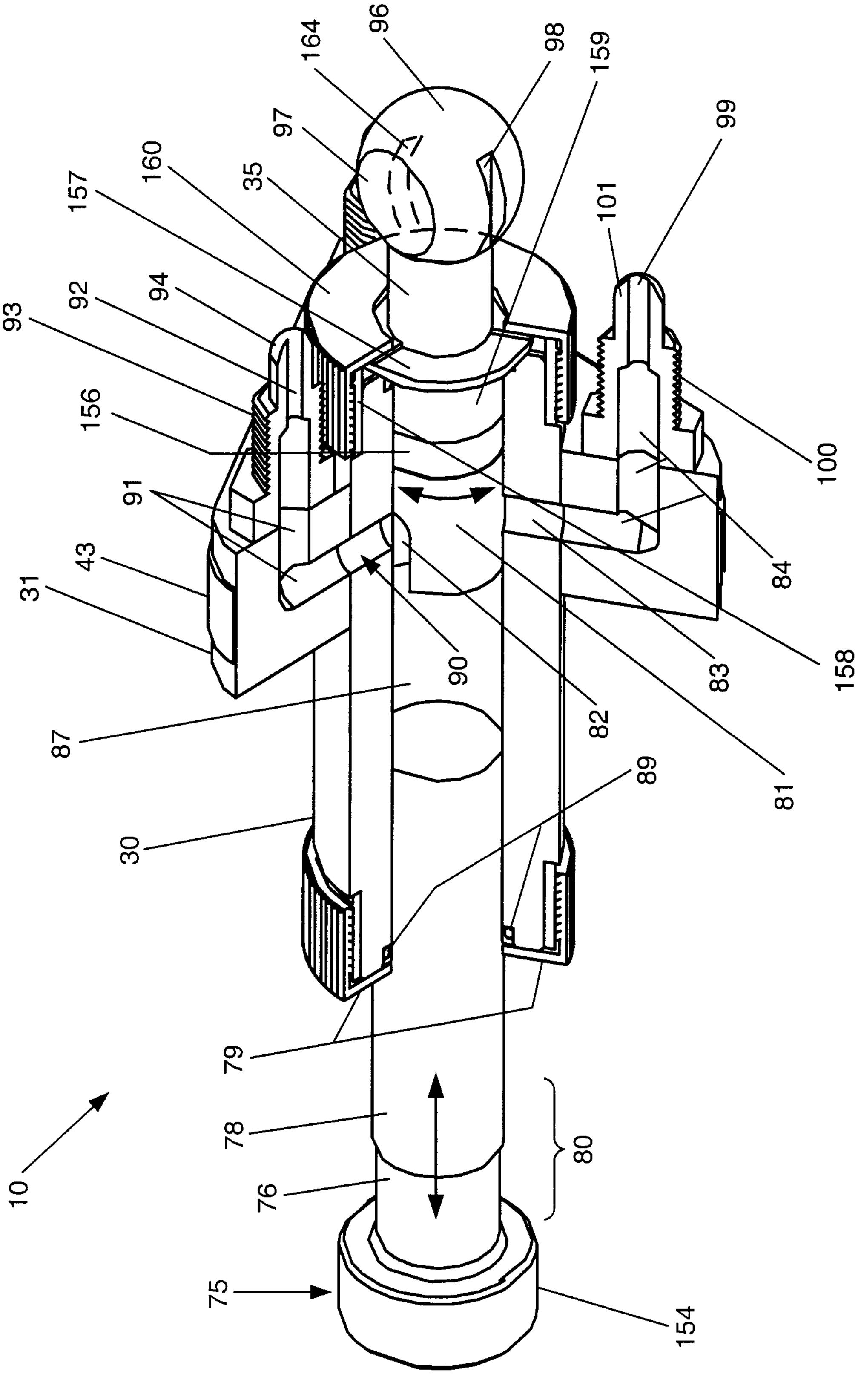
FIGURE 1



VIEW A-A

FIGURE 2

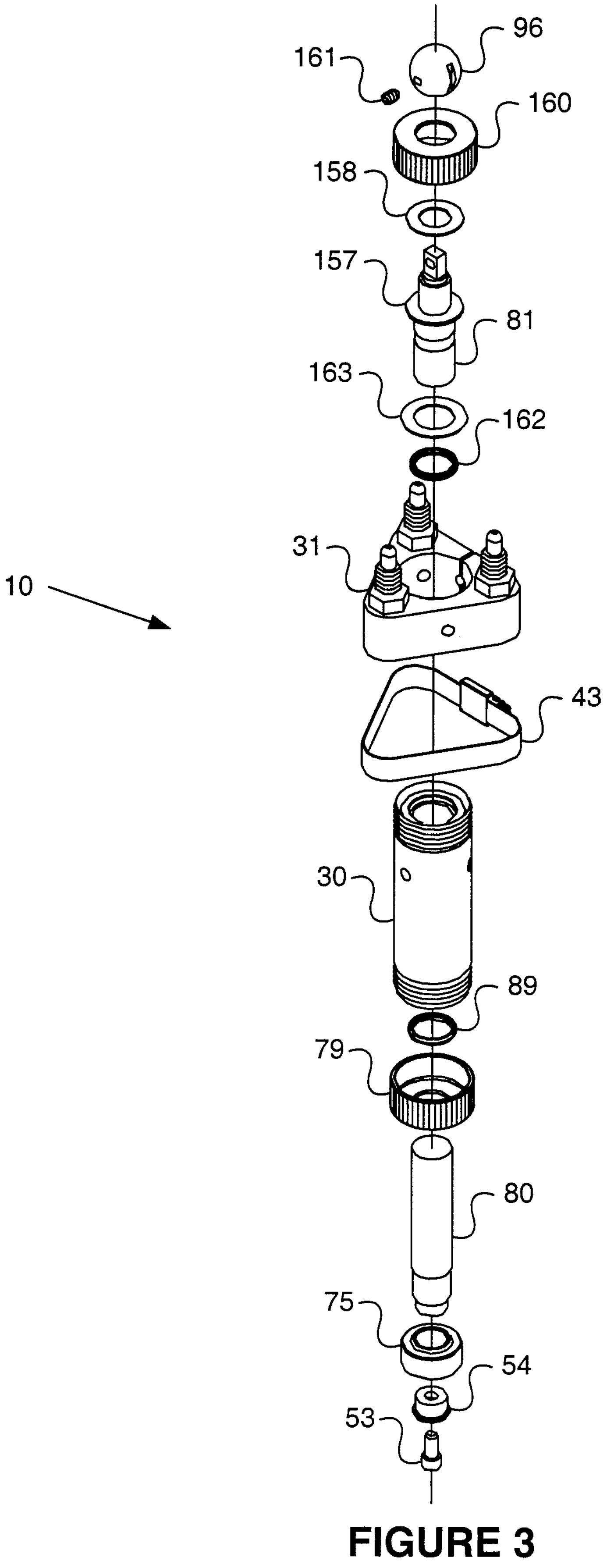


FIGURE 3

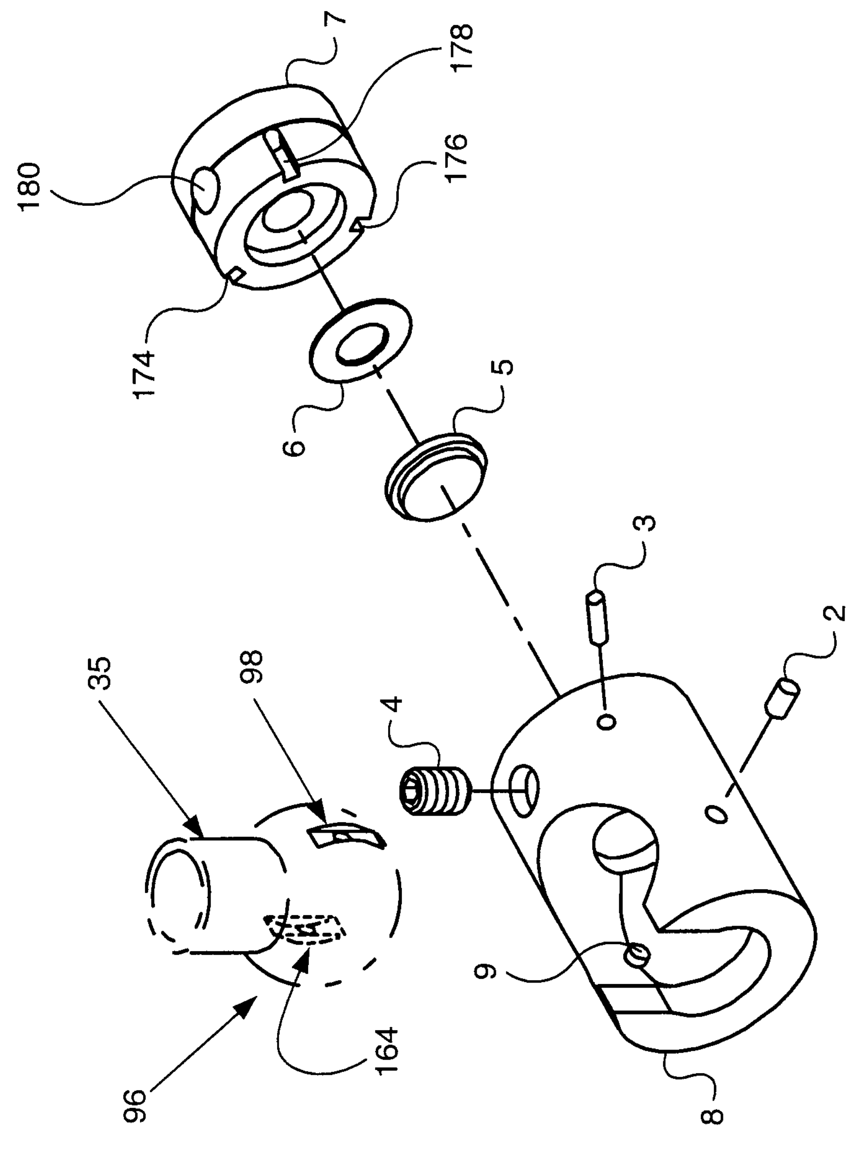


FIGURE 4

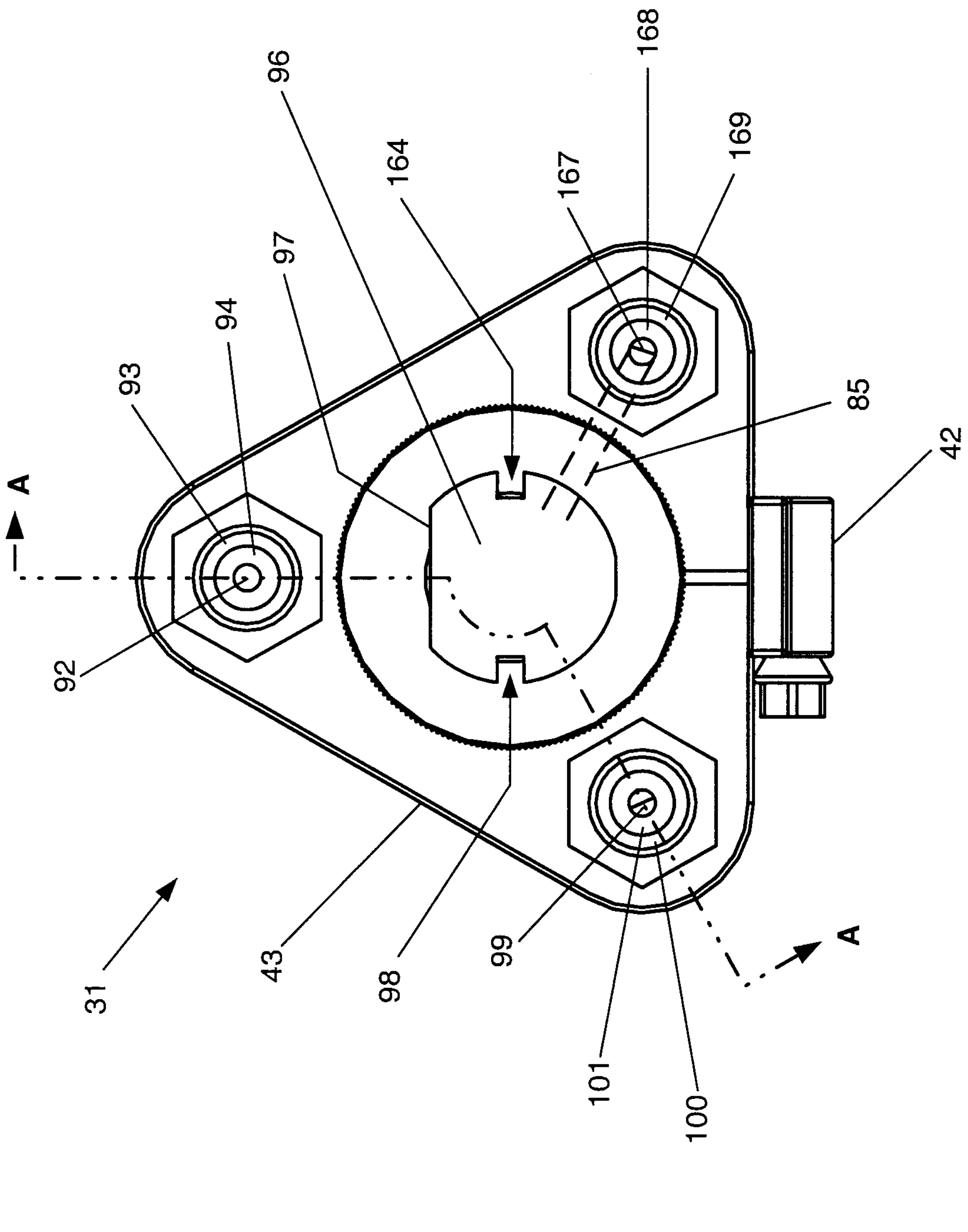
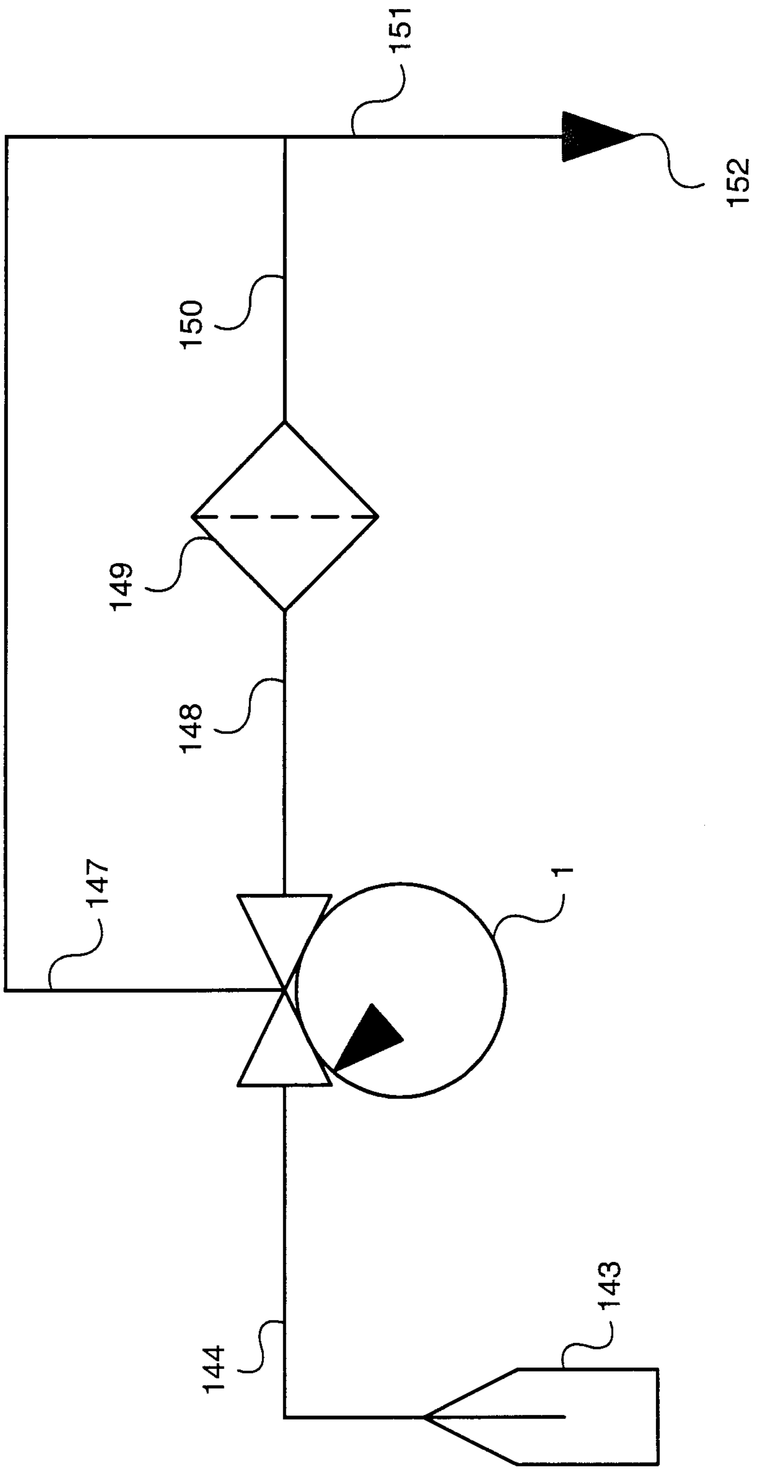


FIGURE 5



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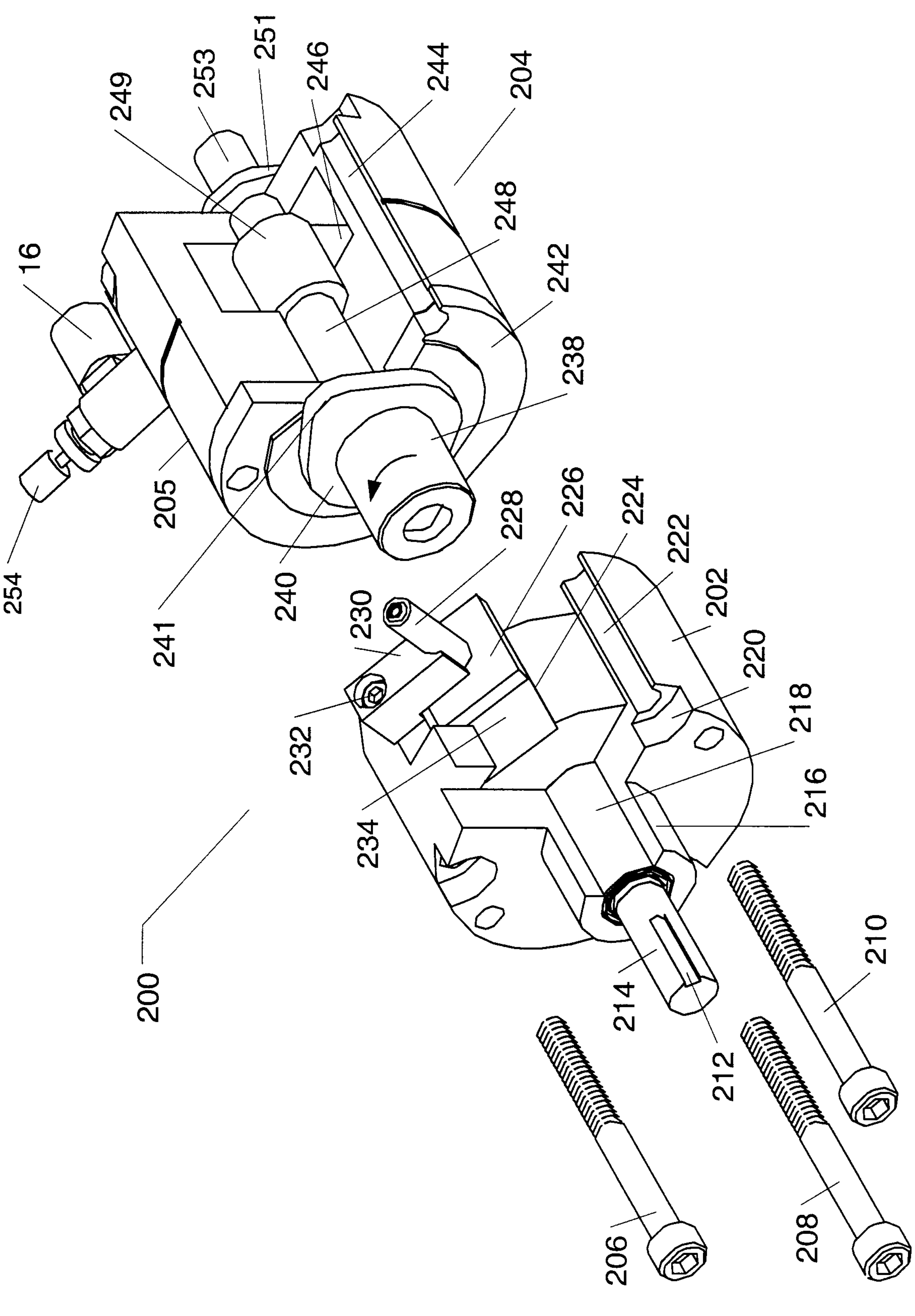
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FIGURE 7

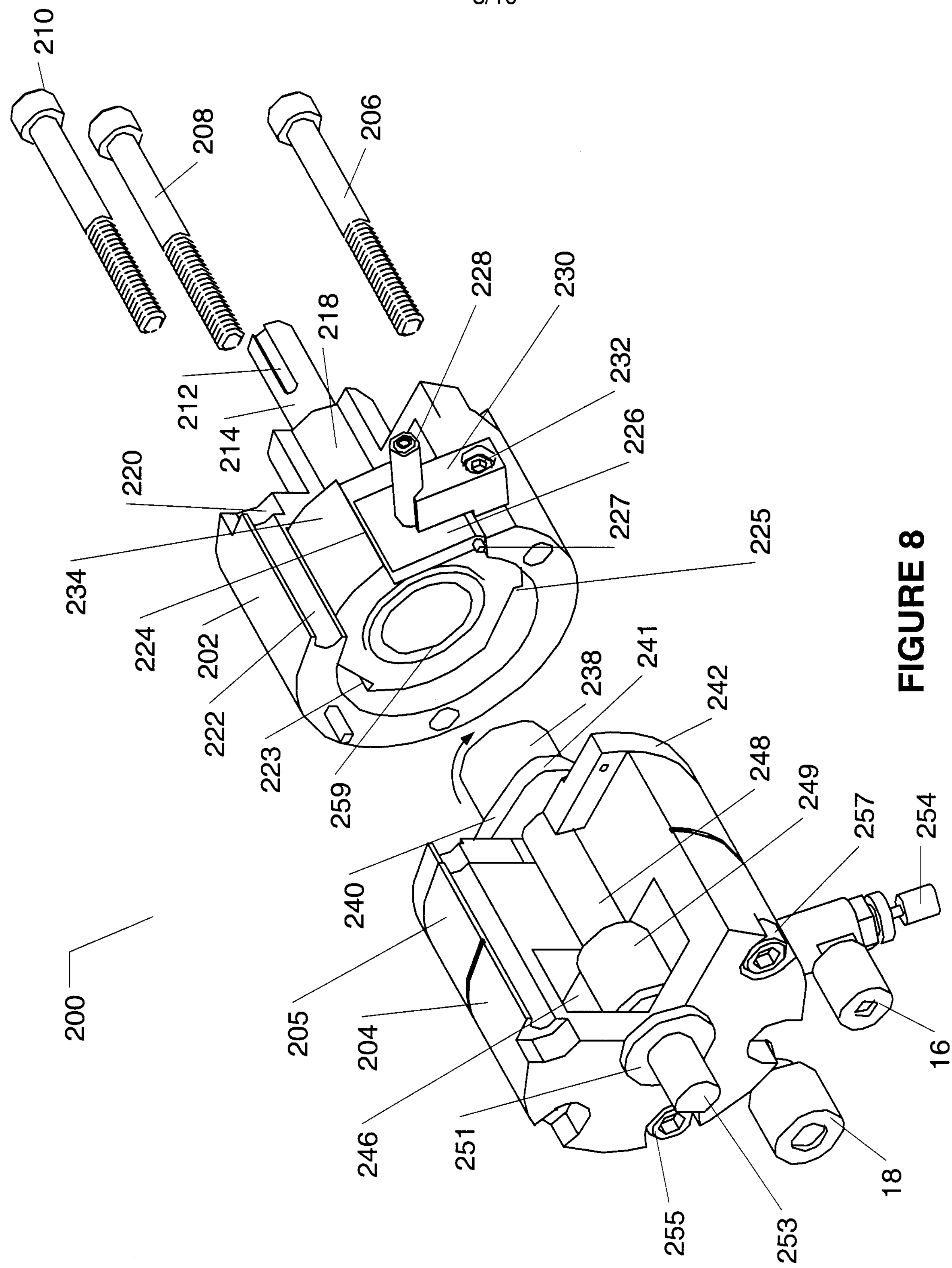
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FIGURE 8

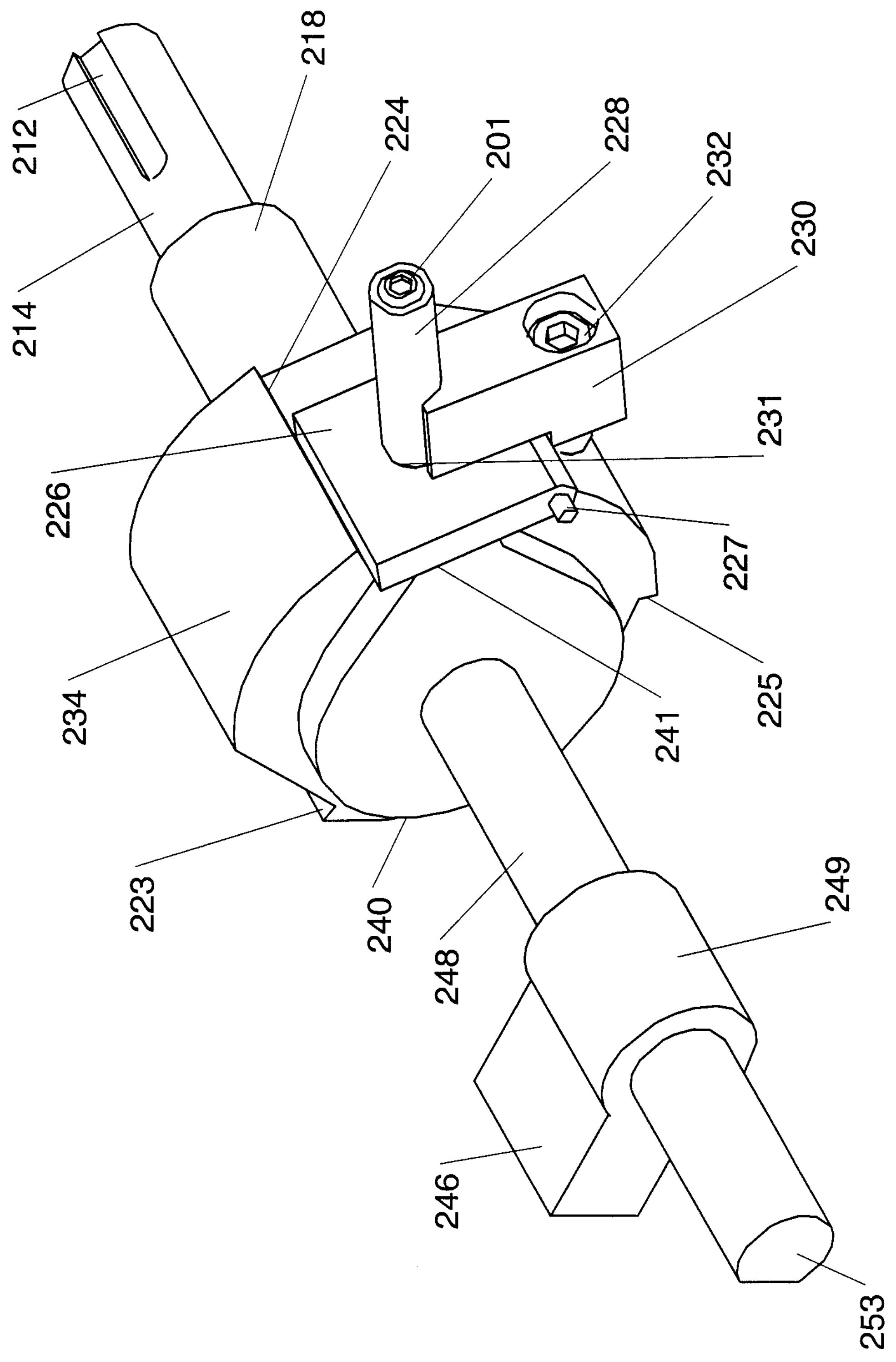
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FIGURE 9

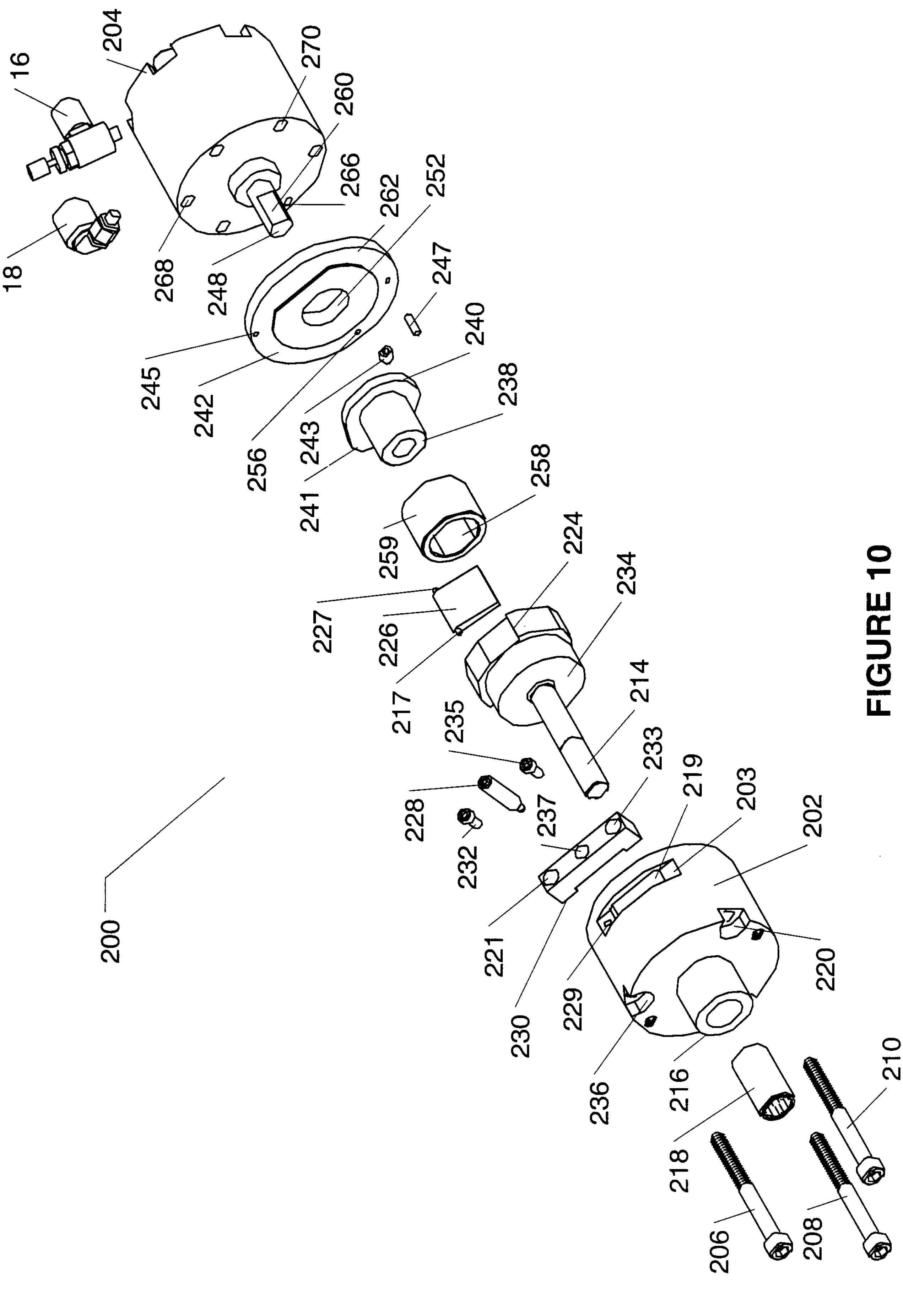
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FIGURE 10