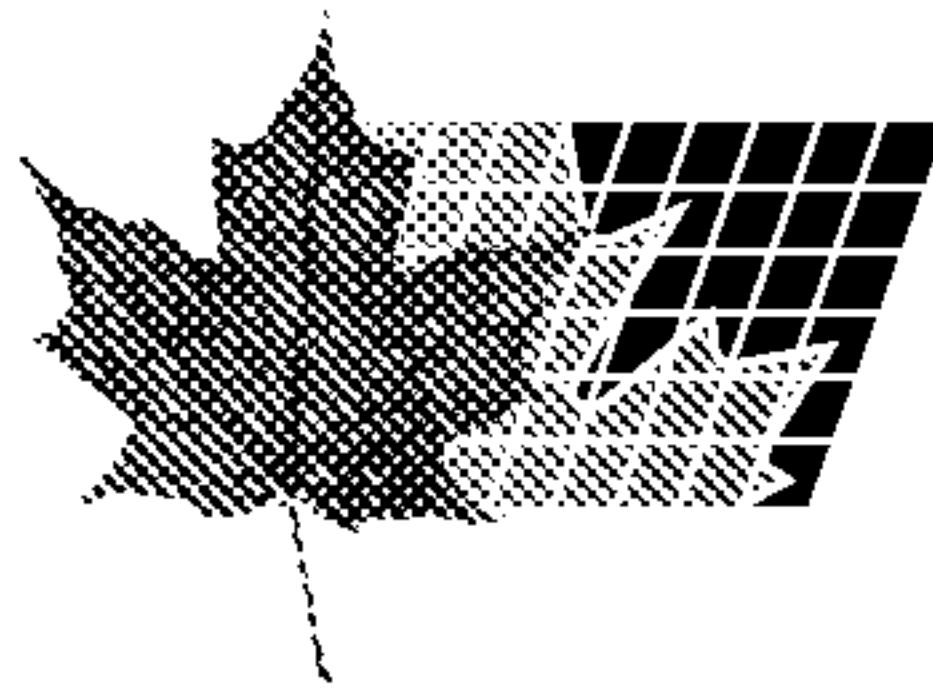
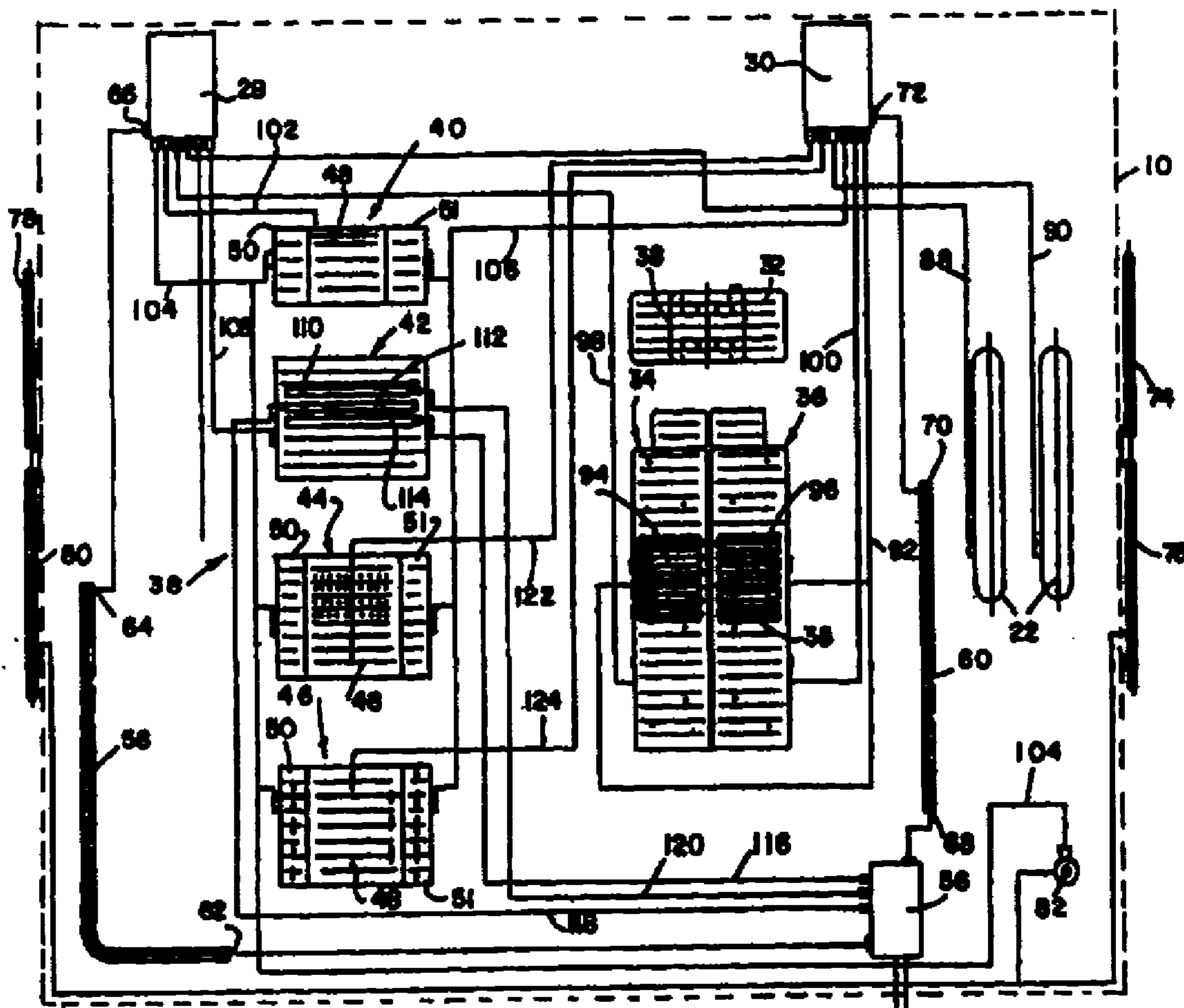
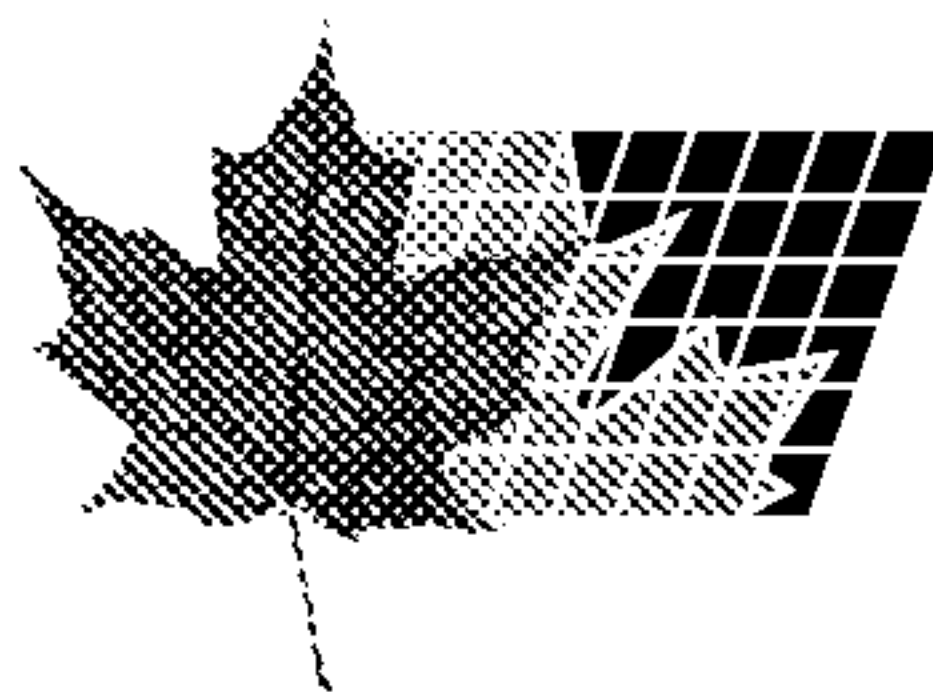




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(54) **ENSEMBLE A VALVES**
(54) **VALVE ASSEMBLY**





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(57) L'invention concerne un ensemble à valves (28, 30) pour matelas pneumatique (10), lequel ensemble est pourvu d'un actionneur commun (226) monté sur un collecteur (200) situé entre des soupapes (238, 240) d'alimentation et d'échappement opposées, qui permet de déplacer les soupapes (238, 240) le long d'axes d'actionnement. Le système comprend une pluralité de combinaisons actionneur/valve destinés à différentes parties du matelas pneumatique (10). L'invention concerne également une valve (56) à pulsation comprenant un logement (330) à l'intérieur duquel se trouvent les soupapes (352, 354) d'alimentation et d'échappement, chacune étant commandée directement par des solénoïdes d'alimentation et d'échappement.

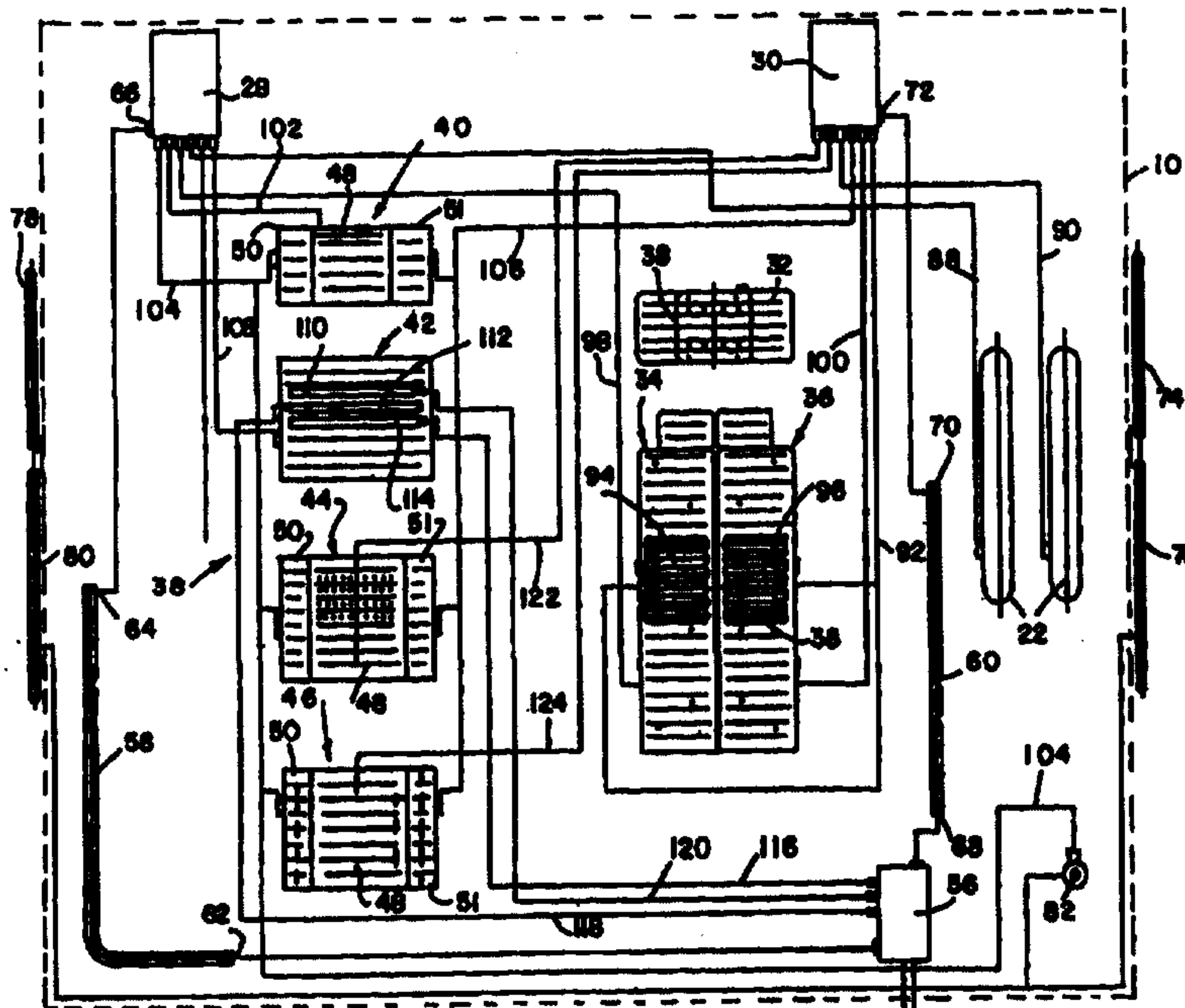
(57) A valve assembly (28, 30) for an air mattress (10) having a common actuator (226) on a manifold (200) between opposed supply and exhaust valves (238, 240) moving the valves (238, 240) along actuating axes. The system includes a plurality of actuator/valve combinations for different portions of the air mattress (10). A pulsating valve (56) is provided which includes a housing (330) having therein supply and exhaust valves (352, 354) each directly controlled by supply and exhaust solenoids.

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(21) International Application Number: PCT/US98/17485 (22) International Filing Date: 24 August 1998 (24.08.98) (30) Priority Data: 60/056,763 25 August 1997 (25.08.97) US 09/093,303 9 June 1998 (09.06.98) US (71) Applicant: HILL-ROM, INC. [US/US]; 1069 State Route 46 East, Batesville, IN 47006-9167 (US). (72) Inventors: ELLIS, Craig, D.; 224 Riverland Drive, Charleston, SC 29412 (US). CHAMBERS, Kenith, W.; 7504 Rock Street, Charleston, SC 29420 (US). McCORMICK, Scott; 3321 Ruther Avenue, Cincinnati, OH 45220 (US). DeRIDDER, Steven, D.; 6255 Skylight Drive, Bartlett, TN 38135 (US). CARRUTH, W., Layne; 1543 River Farms Cove, Cordova, TN 38018 (US). SCHULTE, Stephen, R.; 11487 New Biddinger Road, Harrison, OH 45030 (US). (74) Agent: NIEDNAGEL, Timothy, E.; Barnes & Thornburg, 11 South Meridian Street, Indianapolis, IN 46204 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>Without international search report and to be republished upon receipt of that report.</i>	

(54) Title: VALVE ASSEMBLY



(57) Abstract

A valve assembly (28, 30) for an air mattress (10) having a common actuator (226) on a manifold (200) between opposed supply and exhaust valves (238, 240) moving the valves (238, 240) along actuating axes. The system includes a plurality of actuator/valve combinations for different portions of the air mattress (10). A pulsating valve (56) is provided which includes a housing (330) having therein supply and exhaust valves (352, 354) each directly controlled by supply and exhaust solenoids.

VALVE ASSEMBLY

Background and Summary of the Invention

The present invention relates generally to a control valve system for air
5 mattress or air cushion support surfaces and more specifically to a control valve system
for air mattresses or support surfaces having a plurality of individually controllable
chambers, for example, hospital beds.

Other cushion pressure control designs, which use one valve to isolate
the cushion from a manifold, with either pressure or vacuum then applied to the
10 manifold, cannot simultaneously increase the inflation of one cushion while exhausting
from another. This means that adjusting the cushions in response to patient movement
or changes in bed position takes longer, resulting in reduced comfort and possibly a
less effective therapy. Also, this type of design cannot be used for the most effective
type of patient rotation systems, which increase the pressure in one rotation cushion
15 while simultaneously decreasing the pressure in another.

Other designs may use multiple valves with independent actuators to
achieve the desired control conditions. This requires control wiring and space for each
actuator. Also this does not insure that only one of the valves per pair is actuated at
one time.

20 Bed cushions are typically inflated to pressures between 1/2 psi and 1
psi (25.9 and 51.7 mmHg). At these low pressures, the size of the flow opening in the
valve must be relatively large in order to pass an adequate volume of air to inflate or
deflate the cushion in a reasonable amount of time.

Existing valves which have large flow openings either have very large
25 actuators, or are "pilot operated". A pilot-operated valve uses a small actuator such as
a solenoid to create a condition that causes a larger valve section to open. An example
of this would be to use a solenoid to open a tiny valve which allows pressurized air to
flow through into a chamber where it actuates a larger valve by pressing against a
diaphragm. This type of pilot-operated valve generally requires that the minimum air
30 pressure be 3 psi (155.1 mmHg) or higher, in order to create enough force to actuate
the larger valve. The types of pressurized air sources that are most desirable for

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hospital bed cushions (high-flow low-pressure blowers) do not generally create a high enough pressure to actuate a pilot-operated valve unless the pilot device is very large.

Existing direct acting valves typically use electrical solenoids to operate a valve with a small opening. Since these valves are typically designed for higher
5 pressures encountered in industrial and commercial applications, the valve openings are small.

The force acting against the operator for a direct-acting valve is typically equal to the pressure the valve is sealing against multiplied by the cross-sectional sealing area of the valve ($F=P \times A$). In an industrial valve, this force might be
10 100 psi (5171.5 mmHg); if a valve had a cross-sectional sealing area of 0.20 inch (0.51 cm) (a practical area for the flows and pressures required by a hospital bed), the force to be overcome by the actuator would be 20 lbs (9.07 kg). However, in a hospital bed, the pressure would be on the order of 1 psi (51.7 mmHg), for a total force of only 0.2 lb (0.091 kg).

15 Because it is impractical to consider using a solenoid developing 20 lbs. (9.07 kg) of force due to the physical size and high electrical power consumption in high pressure industrial applications, these valves are generally designed with flow openings (valve orifices) having a cross-sectional area of on the order of 0.01 square inch (0.065 cm²). This size opening is too small for the flow rates required at the
20 lower pressures found in a hospital bed system.

Another limitation of prior art valve control structures is the ability to provide proportional flow control.

The valve seat and valve disk can be designed to be either flat, round or with varying amounts of taper. With a flat valve seat, a small amount of movement
25 from the actuator causes a significant increase in flow through the valve. This type of seat and disk design is most useful when it is desirable to inflate a cushion as quickly as possible, or when it is desirable to create a pressure "pulse" with the sudden opening of the valve to high flow conditions.

As the amount of taper is increased on the valve seat and disk, a smaller
30 change in flow is created for a given movement of the actuator. This makes it possible to control the rate of flow through the valve by controlling the positioning of the actuator. This characteristic is particularly useful in "low air loss" cushions, where air

is continuously exiting the cushion through a fixed or variable size orifice. A valve with proportioning characteristics can be actuated to where it just provides sufficient air flow to balance against the loss of air from the cushion. As an alternative, the proportioning valve can be used on the discharge side of the cushion to create a
5 variable size orifice to control the rate of discharge from the cushion.

Another use for the proportional flow control characteristics is to control rotation of the patient on the air cushion support surface. Studies have shown that a slow rotation created by simultaneously inflating one cushion while deflating another cushion is preferable to rapid rotation.

10 When an on/off type of valve is used to inflate or deflate a cushion, the delay time between sensing that the desired pressure has been reached and the time the valve is closed can cause "overshoot" that requires additional correction and adjustment.

A proportional valve can be opened to a full flow position initially to
15 achieve a high rate of flow; then as the desired pressure is approached, the valve can be changed to a partial flow position to reduce or to eliminate the overshoot condition as the pressure sensor and bed controls detect the desired pressure being approached.

Proportional opening of valves will result in smoother initial inflation, avoiding pressure peaks or shock waves that may cause patient discomfort. Controlled
20 proportional opening and closing of valves can also reduce the mechanical and air flow noise caused by valves which suddenly open and close.

In controlling the surface pressures of a multiple zone, bed conditions often arise that make it desirable that some cushions receive a higher rate of air flow than others. This may occur because one cushion has a higher volume than others,
25 because the patient weight shifts from one cushion or set of cushions to another, or because of an operating mode change in the bed (for example, by going into a patient rotation mode).

With on/off valves, this can only be achieved by turning the valves on and off at different rates. Such a method of operation can cause uneven inflation,
30 pressure surges, additional noise, and longer response times to achieve the desired cushion inflation rates.

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In some circumstances, it is desirable to inflate some zones (e.g., side bolsters, head supports, and rotational cushions) to significantly higher pressures than other zones. This is often accomplished by increasing the pressure levels in the pressure supply manifold to serve the requirements of these "hyperinflated zones".

- 5 With valves having proportional control characteristics, it is possible to maintain accurate inflation control to the lower pressure zones by reducing the amount these valves open while the pressure manifold is in a hyperinflation state.

In other cases, the air supply may be limited for certain operational modes. For example, it may be desirable to inflate one or more cushion zones very
10 quickly. If a less critical zone requires pressure at the same time, it may "rob" available air from the system, affecting the performance of the bed in meeting the requirements of the zone needing rapid inflation. Using a proportional valve allows the bed control system to restrict the opening of the less critical valves to allocate available air to the more critical locations.

- 15 This air apportioning capability can allow the use of small air sources, which require less electrical power, generate less noise, and occupy less space.

In the air cushion environment, an economic and effective actuator has not been found to proportionally position the valve. Solenoid control has been used for the on/off style control valves. Thus, the systems have not taken advantage of the
20 tapered valve body and valve seat.

A control of an air mattress or cushion according to the present invention provides a unique proportional control valve. The system includes a manifold having at least a supply port, one exhaust port, and one outlet port connected to a chamber in the manifold. A supply valve and an exhaust valve are on the manifold
25 having coaxial actuating axes and connected to the supply and exhaust ports respectively. A common actuator is on the manifold between the supply and exhaust valves so as to move the supply and exhaust valves along their actuating axes. The actuator is a linear actuator having first and second ends spaced from adjacent valve stems of the supply and exhaust valves in the neutral position of the actuator. The
30 linear actuator preferably includes an electric motor. The actuator and valve stems are electrically isolated from each other and complete a circuit when engaged. This

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provides electrical feedback information. The valve bodies are molded from electrically insulated material.

The supply and exhaust valve each include a body having a first outlet connected to a respective port of the manifold, an inlet, and a valve seat having an inlet and an outlet side. A valve element on the outlet side of the seat includes a stem extending therefrom through the valve seat to be engaged at its first end by the actuator. A spring biases the valve onto the valve seat. The valve seat and the first outlet of the valve have generally an orthogonal axis. The valve body has a second outlet on the outlet side of the valve seat. The outlet port of the manifold is the second outlet of one of the valves. The second outlet of the other valve is plugged. The valve element and the valve seat include tapered portions. The valve element has a first tapered portion that defines a first rate of change of the size of valve opening and lower than the rate of change of a second tapered portion. The valve element includes a shoulder portion extending radially from the tapered portion. The valve seat has a cross-sectional area in the order of 0.10 to 0.40 square inch (0.065 to 0.26 cm²).

A second end of the actuator extending from the valve element is one of the seats of the spring. The first end of the actuator extends through and is guided by an aperture in the valve body. The second end of the aperture is received in a guide in the housing. The guide also forms a second stop for the spring. The guide on the housing is either in the outlet port or on the plug of the respective valve housing.

The manifold includes a first and a second portion joined together to form the chamber connecting the valve ports. The first portion includes a flange to which the actuator is mounted. The exhaust and supply valves are mounted to the first portion.

To control a plurality of air cushions, the manifold includes a plurality of chambers, each chamber having a supply and exhaust valve mounted to a supply and exhaust port of each of the chambers. The supply valves have a common supply plenum connected in its inlet. The supply valves and the supply plenum are formed as an integral structure. The exhaust valves also include an integral common supply plenum. The supply plenum may include a divider partitioning the plenum into two supply plenums. Electrical controls are mounted on the manifold and are connected to the actuators for each pair of valves. The electrical controls include a plurality of

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pressure sensors, each connected to a respective chamber. A pressure sensor is also connected to the supply plenum.

A unique pulsating valve is provided and is used in a system with the control valve for an air mattress with a plurality of bladders.

5 The pulsating valve includes a supply chamber, exhaust chamber and plenum in a housing. A supply valve and exhaust valve in the housing connect the supply and exhaust chambers, respectively, to the plenum. Supply and exhaust solenoids are connected to and control the supply and exhaust valves. The valves are in and the solenoids are mounted to an interior housing and are covered by an exterior
10 housing. The exterior housing defines the chambers with the interior housing. The housing includes at least one supply port, one exhaust port, and an outlet port and may include additionally a supply outlet.

 The solenoids include a coil and a core in a casing, and the valves are connected to a first end of the core through a first aperture in the casing. The casing
15 includes a second aperture opposed a second end of the core. The core is substantially hollow along its length. A resilient stop is provided between the casing and the second end of the core to act as a shock absorber. A resilient element is placed between the solenoid and interior housing also to provide isolation and vibration absorption. Vibration dampening mounts connect the housing to a support surface.

20 A valve assembly for an air mattress having a plurality of bladders includes a supply inlet, a first valve connected to the supply inlet, and at least one outlet to be connected to a first bladder for pulsating air signals to the first bladder. A second valve is provided connected to the supply inlet and least one outlet is to be connected to a second bladder for inflating and deflating the second bladder. The first
25 valve has a supply outlet and the second valve is connected to the supply outlet of the first valve. The second valve includes a linear actuator for positioning the valve and the first valve includes a solenoid for operating the valve. The first valve produces pulses in the range of 1-25 Hertz.

 Other objects, advantages and novel features of the present invention
30 will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a schematic view of a multiple cushion mattress in which proportional and pulsing valves of the present invention can be used;

Fig. 2 is an exploded view of a proportional valve incorporating the principles of the present invention;

Fig. 3 is a top cut-away view of the assembled proportional valve of Fig. 2 according to the principles of the present invention;

Fig. 4 is a side cut-away view of the assembled proportion valve of Fig. 3;

Fig. 4A is a cut-away of valve and manifold of Fig. 4;

Fig. 5 is a schematic of a pulsating valve according to the principles of the present invention;

Fig. 6 is an exploded view of a pulsating valve according to the principles of the present invention;

Fig. 7 is a side view of the assembly pulsating valve of Fig 6;

Fig. 8 is an end cut-away view of the pulsating valve of Fig. 7; and

Fig. 9 is a cross-sectional view of a solenoid incorporating the principles of the present invention.

Detailed Description of the Preferred Embodiments

As illustrated in Fig. 1, a mattress assembly 10 in which the valves of the present invention are to be used is illustrated. A pair of rotational cushions 22 is located in the bottom and run the longitudinal axis of the mattress assembly 10. The rotational cushions 22 are selectively inflated and deflated to control the rotation therapy of a patient located on the mattress. A pair of identical proportional valves 28 and 30 is provided in the mattress and is to be discussed with respect to Figs. 2-4. The lower cushion structure includes a lower head cushion 32 and lower body cushions 34 and 36. Support surface bladder 38 is located on top of the cushions 32, 34, and 36 and includes a head cushion 40, a chest cushion 42, a seat cushion 44, and a foot cushion 46. Support cushions 40, 44, and 46 include an inner bladder section 48 and another bladder section 50 and 51 which are controllable from an air supply source. Air enters the mattress assembly 10 from a blower through inlet 54 coupled to a

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pulsating or a percussion/vibration valve 56 to be discussed in detail with respect to Figs 5-9. The air supply inlet 54 is also coupled to proportional valves 28 and 30 via hoses 58 and 60 respectively. Alternatively, a T-fitting could be used.

The mattress assembly further includes width extension cushions 74, 76, 78, and 80 which are positioned outside the exterior of the mattress walls. The extension cushions 74, 76, 78, and 80 are coupled together and to a select valve 82 which selectively connects the extension cushions to exhaust or via hose 104 to the proportional control valve 28. The rotational bladders 22 are coupled to valves 28 and 30 by lines 88 and 90. The lower body cushions 34 and 36 include internal bladders 94 and 96, respectively, which are each coupled to a supply line 92 of the valve 30. The external cushions 34 and 36 are coupled to outlets of valves 28 and 30 via lines 98 and 100, respectively.

The central section 48 of the head support cushion 90 is coupled to an outlet of valve 28 by line 102. Opposite sections 50 and 51 of the head support surface cushions are coupled to valves 28 and 30 by lines 104 and 106, respectively. The chest support surface cushion 42 is coupled to valve 28 by line 108. The chest support surface cushion includes internal bladders 110, 112, and 114. Bladder 110 is coupled to a first outlet of the pulsating valve 56 by line 116; bladder 112 is coupled to valve 156 by line 118; and bladder 114 is coupled to valve 56 via line 120.

Side portions 50 and 51 of the seat support section 44 are coupled to valves 28 and 30 via lines 104 and 106, respectively. The central portion of the seat support cushion 44 is coupled to valve 30 by line 122. Opposite side sections 50 and 51 of the foot support cushions 46 are coupled by supply lines 104 and 106 to valves 28 and 30, respectively. The central section 48 of the foot support cushion 46 is coupled to the valve 30 by supply line 124.

Further details of the mattress 110 are disclosed in U.S. Application Serial No. 08/917,145, entitled "Mattress Assembly" (attorney docket number 7175/27290), the disclosure of which is incorporated herein by reference. This mattress structure is but one of many structures of which the improved valves of the present invention are used. The valves to be described may be used with other cushions or air mattress structures.

Details of the proportional valves 28 and 30 will be described with respect to Figs. 2, 3, and 4. The proportional valve includes a manifold 200 having a first manifold portion 202 and a second manifold portion 204 joined together by fasteners 206 through matching openings 208. A gasket (not shown) is positioned
5 between the first and second manifold portions. The first manifold portion 202 includes a flange 210 having actuator apertures 212. The first manifold portion 202 also includes a plurality of apertures 214 for the supply valves, 216 for the exhaust valves, and 218 for the pressure sensor of the individual manifold chambers.

The second manifold portion 204 has a plurality of chambers 222 which
10 align with the supply and exhaust apertures 214 and 216 of the first manifold section 202. A sensing area 224 aligns with apertures 218 for pressure sensor nipple 220. The actuators 226 are mounted in actuator aperture 212 of flange 210 of the first manifold portion 202 by fasteners 228 through aligned openings 230 on mounting bracket 232 and flange 210.

15 The actuator 226 is a linear actuator having a pair of opposite extending arms 234 and 236. Preferably, the actuator 226 is a stepper motor turning a threaded bushing that causes a threaded shaft to move in either of two directions, depending upon the rotational direction of the motor. Preferably, the shaft includes arms 234 and 236 which include splines to prevent rotation of the threadable shaft.
20 The stepper motor is designed to provide precise control of the amount of rotation and can be rotated in increments of one step or microsteps. The rate of stepping or the number of steps can be controlled by motor drive controls. This control of the rating stepping and the number of stepping provides precise control of the movement of the valve actuator arms 234 and 236 to provide the precise control of the valve and
25 therefore the air flow control. The movement of the actuator is linear in the order of 0.001 inch (0.00254 cm) per step on the motor, for example. Servomotors or other electrical or pneumatic motors in a closed loop system with pressure sensors could be used.

The stepper motor of the linear actuator 226 uses a gear ratio affect to
30 multiply the actuation force supplied to the valves relative to the amount of power applied to the drive motor. Thus, an actuator 26 with a power consumption of 3-5 watts can be used instead of a solenoid or other actuators with power consumptions of

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10-30 watts. With the six pairs of valve structure illustrated in Figs. 3 and 4, this is a considerable savings in power. An example of a stepper motor is Model Z26561-12-004 from Haydon Switch and Instrument, Inc.

5 The gear ratio on the actuators also provides a mechanical lock for the actuator at a fixed position if power is removed from the actuator. The gears oppose and resist movement from a restoring spring of the valves to be discussed.

Supply valves 238 and exhaust valves 240 are also mounted to the first manifold portion 202. The supply valves 238 and the exhaust valves 240 are identical except for the areas to be noted. They each include a plenum 242. The supply
10 element 242 includes at one end a supply connector 244 which is connected to a source and a plug 246 at the other end. For the exhaust valve 240, both ends of the plenum 242 may be opened or one end selectively plugged. It should also be noted that the plenum 242 may be divided into two plenums by providing a partition in the plenum and by including a supply connector 244 at each end of the plenum.

15 Also, connected to each of the plenums 242 are a plurality of valve bodies 248. Six valve bodies are illustrated. The plenum 242 and the valve bodies 248 are formed as a single piece and preferably are a molded piece of electrically insulated material. The supply valves 238, the exhaust valves 240, and the plenums 242 are mounted to the first manifold portion 202 by a plurality of hold downs 250 of fastener
20 252. Hold downs 250 have radius surfaces 254 to engage adjacent surfaces of the valve bodies 248. In the preferred embodiment, three hold downs 250 are used for each of the integral valve/plenum structure, each engaging a pair of valve bodies 248. Less or more than three may be used. It should be noted that the hold downs 250 are not shown in Figs. 3 and 4.

25 Referring to Figs. 4 and 4A, the valve body 248 has a valve seat 256 which is connected to the inlet or plenum 244 on one side and connected to a pair of outlets 258 and 260 on the other side. The outlet 258 is received in and connected to apertures 214 and 216 of the first manifold portion 202, thereby connecting the other side of the valve seat to chamber 222. The second outlet 260 of the exhaust valve is
30 blocked by a plug 262. The second outlet 260 of the supply valve includes an outlet connector 264. A hose connector 266 is secured to the outlet connector 264 by a staple 268 to form thereby a quick disconnect. Although the supply valve's second

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outlet 260 is shown as the output of the manifold, alternatively the exhaust valve's second outlet 260 may be the output of the manifold in chamber 222.

The cross-sectional area of the valve seat 256 is in the order of 0.20 square inch (1.29 cm²) and may be in the range of 0.01 to 0.04 square inch (0.065 to 0.26 cm²). This cross section provides the appropriate high flow volume at low pressure drops across the valve. Typical air flow is in the range of 5 to 45 cubic feet (141.6 to 1274.3 liters) per minute with pressure drops of 5 to 6 inches of water column (127.0 to 152.4 mmHg).

The valves further include a valve element 270 to be received on valve seat 256. As shown in Fig. 4A, the valve element 270 includes a tapered portion 272 and a shoulder portion 274 extending radially from the tapered portion 272. The tapered portion 272 includes a first taper 271, a second greater taper 273, and a third taper 275 greater than the second taper 273. As the valve opens, the different tapers provide different rates of change of the size of the valve opening. By way of example only, the first taper is substantially zero for an axis distance of 0.015 inch (0.038 cm) and has a diameter smaller than the diameter of the valve seat. The second taper 273 is at 11° for an axial length of 0.044 inch (0.11 cm). The third taper 275 is at 45° for an axial length of 0.038 inch (0.097 cm). The shoulder 274 includes a taper 277 to make a more conformal sealing against the valve seat 256 when the valve is closed. For example, the taper 277 is at 50°. The taper angle of the valve seat 256 is greater than the tapered angle of the tapered portion 272 of the valve element. This allows the valve element to seat and seal better with less opportunity to stick to the seat.

The valve element 270 is mounted to a valve stem 276 in a recess 278. A threaded bore 280 in a first end of the stem 276 receives a threaded portion of a tip 282. One side of the valve stem 276 extends through the valve seat 256 and the plenum 242 and through an aperture 286 in the wall of the plenum 242. The tip 282 is then screwed into the threaded port 280. The aperture 286 acts as a guide and support for the one side of the stem 276. The opening 286 is a few thousands of an inch (cm) larger in diameter than the valve stem 276. Since the plenum 242 is not connected to the outlet for the bed cushions when the valve is closed, it is not essential that the opening 286 be air tight. If more capacity is needed, opening 286 may be sealed.

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When both the supply valve 238 and the exhaust valve 240 are closed, and the actuator 226 is in its neutral position, the ends of the arms 234 and 236 of the actuator are evenly spaced from the tips 282 of the valve the stems 276. The actuator 226 rotates in one or the other direction to extend one of the arms 234, 236 to engage
5 the tips 282 of the valve stem 276 in opening 284 to open the respective valve.

Thus, in effect, the electrical actuator 226 in combination with location of the spring closed valves produces the effect of a three-way valve with a lap position. It does it without any pilot pressure and merely by the use of springs and electrical mechanical actuator.

10 The other end of the valve stem 276 includes a bore 288 to receive and be a stop for one end of a spring 290. The plug 262 and the outlet connector 264 in the outlet 260 of the valve housing includes a bore 292 in a cylindrical section which receives the other end of the spring 290 and the end of the actuator 276. The end of valve stem 276 rests in bore 292 for its total length of travel between its open and
15 closed position. On the connector 264, the cylindrical portion with bore 292 is suspended in the outlet 260 by support vanes 294. The bore 292, by receiving the other end of the valve stem 276, provides a guide and support for the other end. Thus, the valve stem 276 is guided and supported on both of its ends. This improves the stability and alignment of the valve element 270 on the seat 256.

20 As can be seen from Fig. 4, the valve seat 256 is coaxial with the outlet 260 and generally orthogonal to the outlet 258 which connects to the chamber 222. It should also be noted that the actuator or valve stem 276 of the supply and exhaust valves are coaxial so as to be easily operated by a single actuator 226. If the outlet 260 were placed orthogonal to the valve seat 256, a separate support structure for the
25 other end of the actuator 276 would have to be provided. If the outlet 258 to chamber 220 was coaxial to the valve seat 256, it would include the appropriate guide 292.

The spring 290 provides force needed to close the valve and to press the valve element 270 on the valve seat 256 against any air leakage when the valve is closed. The location of the valve element on the outlet side of the valve seat allows
30 any additional pressure placed on the cushion or mattress and being fed back to the inlet 260 to apply further pressure on the valve and maintain them closed. It also

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allows the use of a vacuum instead of an exhaust on the plenum 242 of the exhaust 240. This will also further increase the closure of the valve.

The electrical control portion 296 is in a housing and secured to the second manifold portion 204 by fasteners 298. The electrical controls include the appropriate electronics to operate the actuator based on commands and feedback or measured signals. The electronic control 296 includes a plurality of pressure sensors 300 connected by a hose 302 to the nipple 220, one for each of the chambers 222. An additional pressure sensor 304 to monitor the supply is connected by a hose 306 to nipple 308 in the supply plenum 242.

Preferably, the valve shaft 276 is made of metal, and the valve housing and plenum is made of a molded dimensionally stable thermo-plastic, for example, glass-filled nylon. To determine when one of the arms 234, 236 of the actuator engages one of the valve stems 276, electrical slide connections 310 and 312 are mounted to, for example, the metal arm 236 of the actuator and the metal valve stems 276 as illustrated in Fig. 4 for the exhaust valve 240. Since the valve housing and plenum are made of electrically insulated material, the arms 234 and 236 are electrically isolated from the valve stems 276. The connection completes a circuit in the control electronics 296.

By monitoring these connections, the control electronics 296 can determine just when the valve actuator arms touch the valve stem 276 to begin to open the valves. The controls can then use this information to establish a zero positioning for opening the valve element 270. By counting pulses or steps into the stepper motor from this point forward, the controller can estimate the valve disposition and the orifice opening with great precision. With knowledge of the taper, the valve and the seat relative axial position, control and regulation may be performed. If space or cost is not a factor, additional encoders can be provided to the stepper motor and provide closed loop positioning control.

A cover 314 is secured to the second manifold portion 204 by fasteners 316 through aligned openings 318. Fasteners 320 provided through openings 322 secure the manifold and all of the elements mounted thereto to a mattress or other support structure. The cross-sectional area of the valve seat 256 is in the order of 0.20

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350 in the side wall of the housing 360. The connectors 376 in combination with hose connectors 378 and staples 380 form a quick disconnect.

An interior housing 382 includes a top wall 384, a first intermediate wall 386, a second intermediate wall 388, and a bottom wall 390. It also includes a solid back wall 392, a front face 394 having an opening area, a first side wall 396 having an opening area, and a solid side wall 398. Interior wall 400 between intermediate walls 386 and 388 define the supply chamber 332 and exhaust chamber 334. The second intermediate wall 388 and the bottom wall 390 define the plenum 336. Apertures 404 in the first intermediate wall 386 and apertures 402 in the top wall 384 receive the body of the solenoid valves 352 and 356. An O-ring 406 positions the body of the solenoids 352 and 356 in a recess or shoulder in aperture 402 in the top wall 384 and provides vibration isolation and maintains equal radial distance of solenoid to housing. Other noise reduction measures include a soft rubber, fabric or leather disc between the face of solenoids 352 and 356 and the solenoid mounting surface adjacent openings 404 in intermediate wall 386. A strap 408 secures each of the solenoids 352 and 356 to the interior housing 82 by fasteners (not shown) through aligned fastener opening 410. Valve seats 412 are provided in ports 354 and 358 in the intermediate wall 388 and mate with valve elements 414 mounted to plungers 416 of the solenoid valves 352 and 356 by fastener 418.

The interior housing 382 and the solenoid valves 352 and 356 mounted thereon are slid into the exterior housing 360 with a gasket 420 on a portion of the front face 394 and secured thereto by the fasteners which secure the mounting plate 374 as well as three additional fasteners. This aligns the plenum 336 adjacent the outlets 346, 348, and 350. It also aligns the exhaust port 344 with respect to the exhaust chamber 334. Since the interior housing 382 does not extend the full length of the exterior housing 360, the area between the interior housing and exterior housing forms a continuation of the supply chamber 332 and connects the supply inlet 338 to the supply outlets 340 and 342.

Preferably, the interior housing 382 is a cast aluminum block to operate as a heat sink for the solenoids 352 and 356. Also, the valve seats 412 are preferably rubber while the valve elements 414 are also aluminum. Driver card 422 is mounted to the exterior housing 360 and covered by cover plate 424 shown in Fig. 8.

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Details of the solenoid are shown in Fig. 9. The solenoids include a casing 426 and a coil 428 in which the core 444 rides. The plunger 416 is press fit in a bore 442 with a magnetic core 444. A nylon sleeve or bearing 430 separates the core 444 from the coil 428. Because of the high frequency of operation, the standard brass sleeve or bushing is not used. Spring 436 rests in a bore 432 in core 444 and bore 434 in the top wall of the casing 426. An O-ring 438 acts as a stop/shock absorber between the top wall of the casing 426 and the core 444. An opening 440 is provided in the top wall exposing the cavity between the top of the core 444 and the bottom of the top wall of the casing 426. It has been found that this vent is needed to prevent pressure/vacuum locking of the plunger. This substantially increases the speed or frequency capability of the solenoid.

As illustrated in Fig. 7, the exterior housing is mounted by a vibration dampening mount 446 to a surface 448 through extensions 450 of end walls 363 and 364.

Although the present invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only, and is not to be taken by way of limitation. The spirit and scope of the present invention are to be limited only by the terms of the appended claims.

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CLAIMS:

1. A control of an air mattress (10) comprising:
a manifold (200) having at least one supply port (214), one exhaust port
5 (216), and one outlet port connected to a chamber (222);
a supply valve (238) and an exhaust valve (240) on the manifold (200),
having coaxial actuating axes and connected to the supply and exhaust ports (214, 216)
respectively; and
a common actuator (226) on the manifold (200) between the supply and
10 exhaust valves (238, 240) so as to move the supply and exhaust valves (238, 240) along
their actuating axes.
2. A control according to claim 1, wherein the supply and exhaust
valves (238, 240) each have a stem (276) extending toward each other; and the actuator
(226) is a linear actuator having first and second ends (234, 236) spaced from an adjacent
15 valve stem (276) in a neutral position of the actuator (226).
3. A control according to claim 2, wherein the linear actuator (226)
includes an electric motor.
4. A control according to claim 2, wherein the actuator (226) and the
valve stems (276) are electrically isolated from each other to complete a circuit when
20 they engage.
5. A control according to claim 1, wherein the manifold (200)
includes a first and second portion (202, 204) joined together to form the chamber; the
first portion (202) includes a flange (210) to which the actuator (226) is mounted; and the
supply and exhaust valves (238, 240) are mounted to the first portion (202).
- 25 6. A control according to claim 1, wherein the supply and exhaust
valves (238, 240) each include:
a body (248) having an outlet (258) connected to a respective port (214,
216) of the manifold (200), an inlet (242) and a valve seat (256) having an inlet and an
outlet side;
30 a valve element (270) on the outlet side of the valve seat (256);
a valve stem (276) extending from the valve element (270) through the
valve seat (256) to be engaged at a first end (282) by the actuator (226); and
a spring (290) biasing the valve element (270) to engage the valve seat
(256).

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7. A control according to claim 6, wherein the outlet port (260) of the manifold (200) is on one of the valve bodies (248) on the outlet side of the valve seat (256).
8. A control according to claim 6, wherein the valve body (248) has a second outlet (260) on the outlet side of the valve seat (256) and the outlet port of the manifold (200) is the second outlet (260) of one of the valve bodies (248).
9. A control according to claim 8, wherein the second outlet (260) of the other valve body (248) is blocked by plug (262).
10. A control according to claim 6, wherein the valve seats (256) have a cross-sectional area in the order of 0.10 to 0.40 square inch (0.065 to 0.26 cm²).
11. A control according to claim 6, wherein the valve element (270) and valve seat (256) are shaped to define a first rate of change of the size of valve opening and subsequent second rate of change of the size of valve opening.
12. A control according to claim 11, wherein the first rate is less than the second rate.
13. A control according to claim 11, wherein the valve seat (256) is tapered at a greater angle than a taper (275) of the valve element (270).
14. A control according to claim 6, wherein the valve stem (276) extends through the valve element (270) and terminates at an end in a seat (292) for one end of the spring (290).
15. A control according to claim 6, wherein the first end of the valve stem (276) extends through and is guided by an aperture (286) in the valve body (248); and the valve stem (276) extends through the valve element (270) and terminates at a second end which is received in a guide (292) in the valve body (248).
16. A control according to claim 15, wherein the valve body (248) has a second outlet (260) on the outlet side of the valve seat (256); the outlet port of the manifold (200) is the second outlet (260) of one of the valve bodies and the second outlet (260) of the other valve body (248) is blocked by a plug (262); and said guide (292) for the second end of the valve stem (276) is formed on the plug (262).
17. A control according to claim 16, wherein the outlet port (260) of the manifold (200) in the second outlet (260) includes a hose connection (264) extending from the valve body (248) and the guide (292) is integral to the hose connection (264).
18. A control according to claim 1, wherein:

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manifold (200) has a plurality of chambers (222) and each chamber (222) has a supply port (214) and an exhaust port (216);

a plurality of supply valves (238) have a first outlet (258) mounted to a respective supply port (214) and an inlet connected to a common supply plenum (242);

5 a plurality of exhaust valves (240) have a first outlet (258) mounted to a respective exhaust port (216);

at least one of the supply and exhaust valves (238, 240) per pair having a second outlet (260) to be connected to a chamber of the air mattress; and

10 a plurality of common actuators (226) are located on the manifold (200) each operably connected to a respective pair of supply and exhaust valves (238, 240).

19. A control according to claim 18, wherein the supply valves (238) are integral to the supply plenum (242).

20. A control according to claim 19, wherein the exhaust valves (240) are integral to a common supply plenum (242).

15 21. A control according to claim 20, wherein valve bodies (248) of the valves (238, 240) and the plenums (242) are molded as a single piece.

22. A control according to claim 18, wherein the supply plenum (242) includes a divider portioning the plenum (242) into two supply plenums.

20 23. A control according to claim 18, including electronic controls mounted on the manifold (200) and connected to the actuators (226).

24. A control according to claim 23, wherein the electronic controls include a plurality of pressure sensors (220) each connected to a respective chamber (222).

25 25. A control according to claim 24, wherein the electronic controls include a pressure sensor (220) each connected to the supply plenum (242).

26. A control of an air mattress (10) comprising:

a housing (330) having a supply chamber (332), an exhaust chamber (334) and a plenum (336);

30 at least one supply port (338), one exhaust port (344) and one outlet port (346, 348 or 350) on the housing (330) and connected to the respective supply, exhaust and plenum chambers;

a supply valve (414) and an exhaust valve (414) in the housing (330) and connecting respectively the supply and exhaust chambers (332, 334) to the plenum (336); and

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a supply solenoid (352) and an exhaust solenoid (356) connected to the supply and exhaust valves (414), respectively.

27. A control according to claim 26, wherein the housing (330) includes an exterior housing (360) and a separate interior housing (382); the valves (414) being in the interior housing (360) and the solenoids (352, 356) being mounted to the interior housing (382) and covered by the exterior housing (360).

28. A control according to claim 27, wherein the interior housing (382) defines the chambers (332, 334) within the exterior housing (360).

29. A control according to claim 27, wherein the ports (338, 344, 346, 348, 350) are formed in the exterior housing (360).

30. A control according to claim 27, wherein the interior housing (382) is a metal block forming a heat sink for the solenoids (352, 356).

31. A control according to claim 26, including at least one supply outlet (340) connected to the supply chamber (332).

32. A control according to claim 26, wherein the solenoids (352, 356) include a coil (428) and a core (444) in a casing (426) and the valves (414) are connected to a first end of the core (444) through a first aperture in the casing (426).

33. A control according to claim 32, wherein the casing (426) includes a second aperture opposed a second end of the core (444).

34. A control according to claim 32, wherein the core (444) is hollow substantially along its length.

35. A control according to claim 32, including a resilient stop (438) between the casing (426) and a second end of the core (444).

36. A control according to claim 27, including a resilient element between the solenoid (352, 356) and the interior housing (382).

37. A control according to claim 26, including a vibration dampening mount (446) connected to the housing (330).

38. A valve assembly for an air mattress having a plurality of bladders, the assembly comprising:

a supply inlet;

a first valve connected to the supply inlet and having at least one outlet to be connected to a first bladder for providing pulsating air signals to the first bladder; and

a second valve connected to the supply inlet and having at least one outlet to be connected to a second bladder for inflating and deflating the second bladder.

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39. A valve assembly according to claim 38, wherein the first valve has a supply outlet and the second valve is connected to the supply outlet of the first valve.

40. A valve assembly according to claim 38, wherein the second valve includes a linear actuator for positioning the valve and the first valve includes a solenoid for operating the valve.

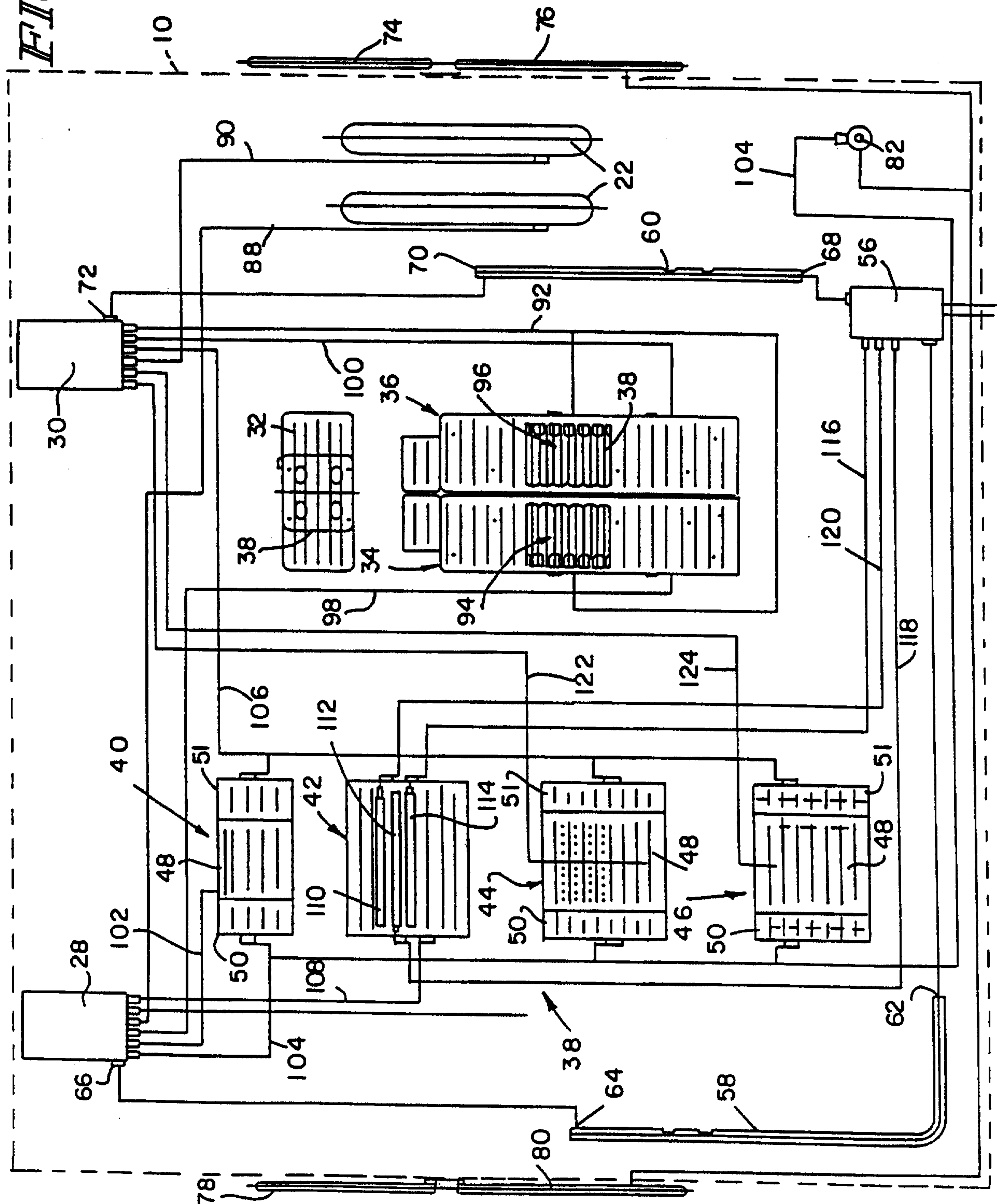
41. A valve assembly according to claim 38, wherein the first valve produces pulses in the range of 1 to 25 Hertz.

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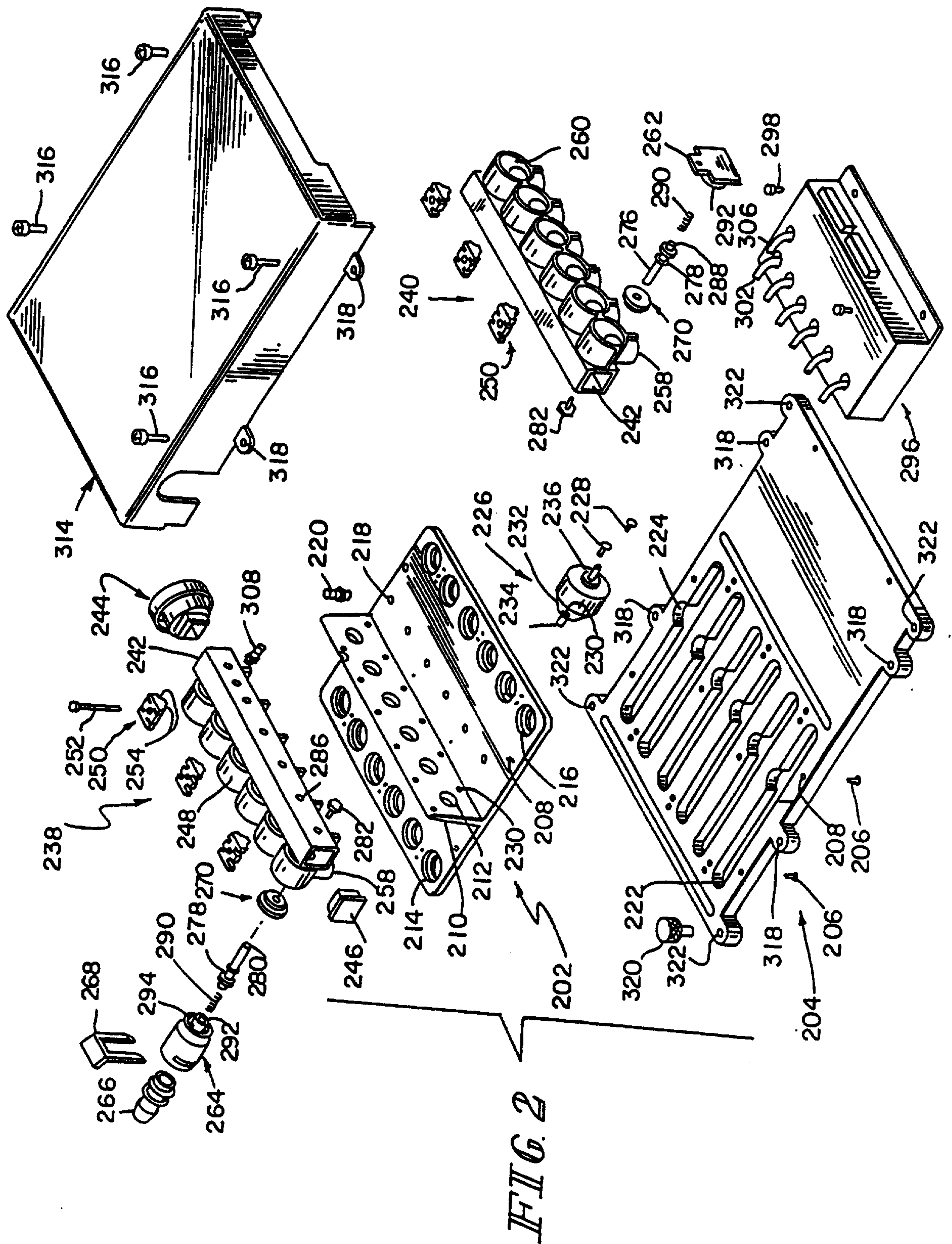
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FIG. 1

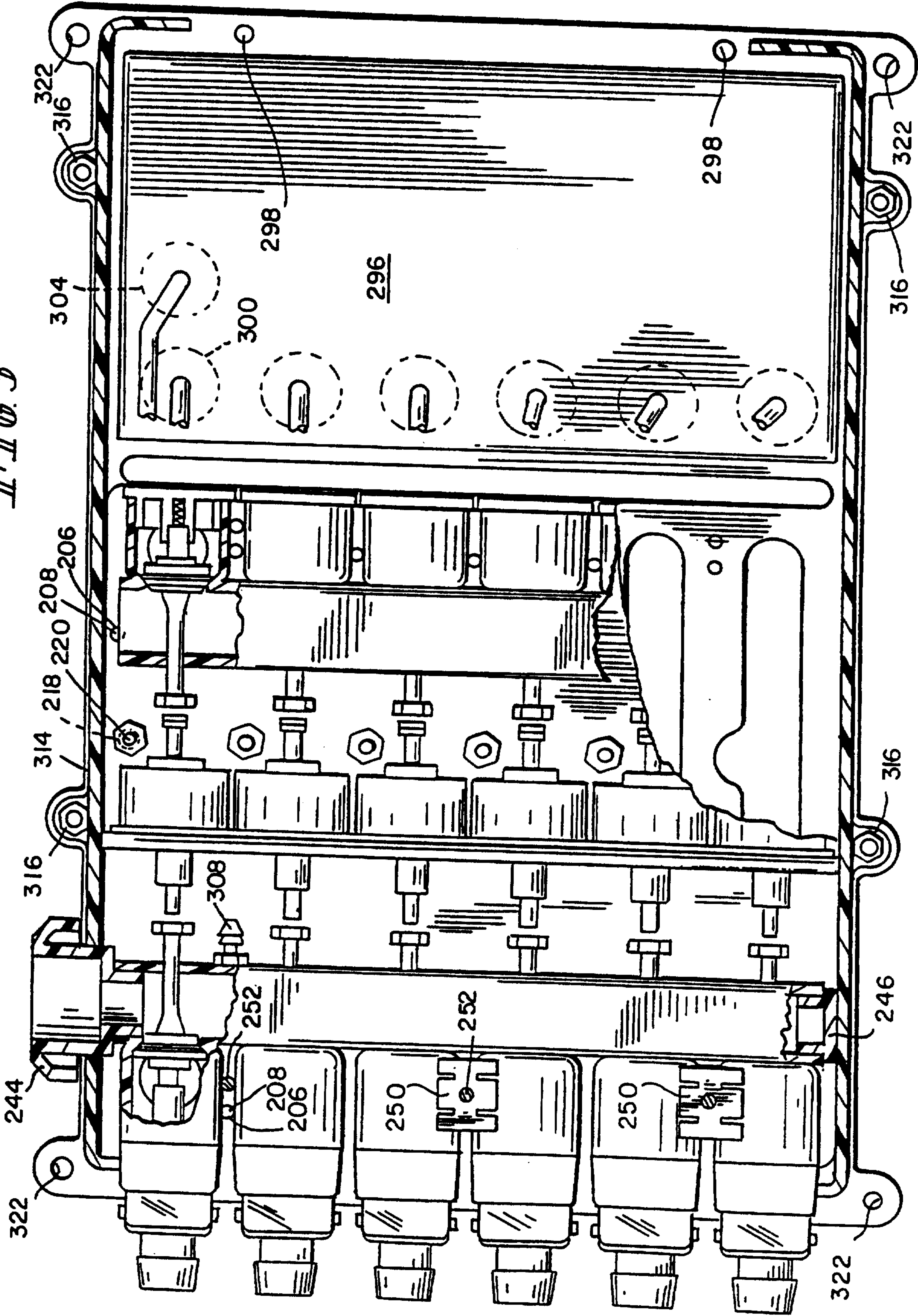


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FIG. 3



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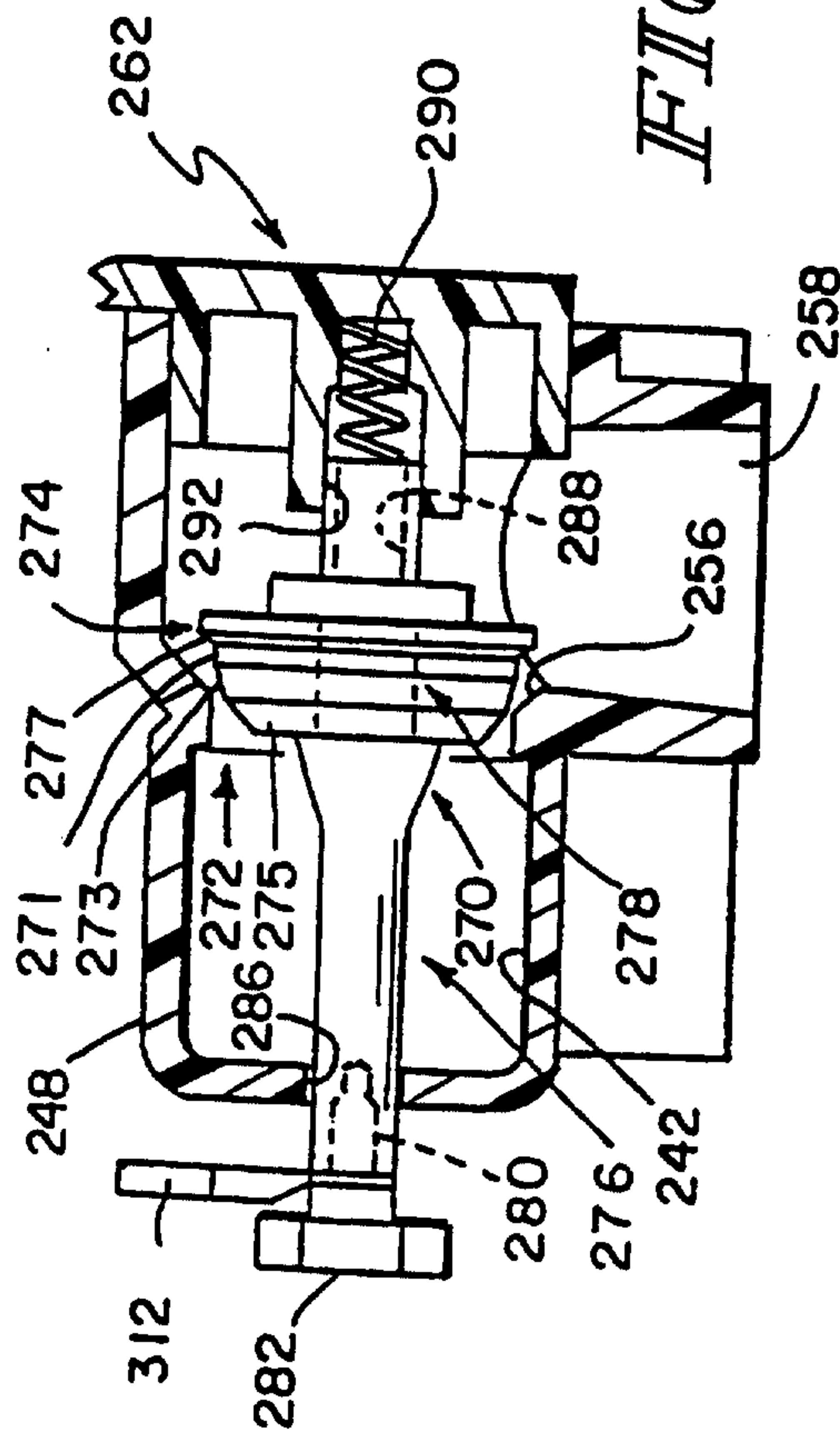


FIG. 4A

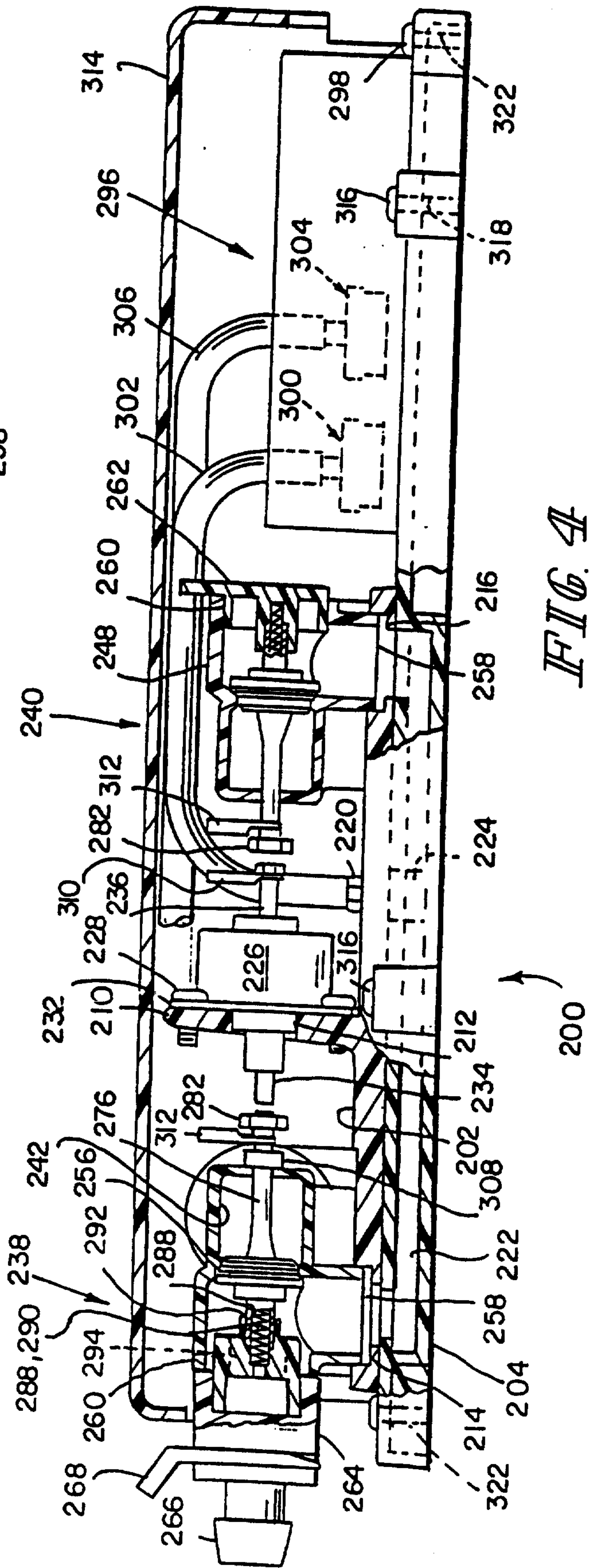
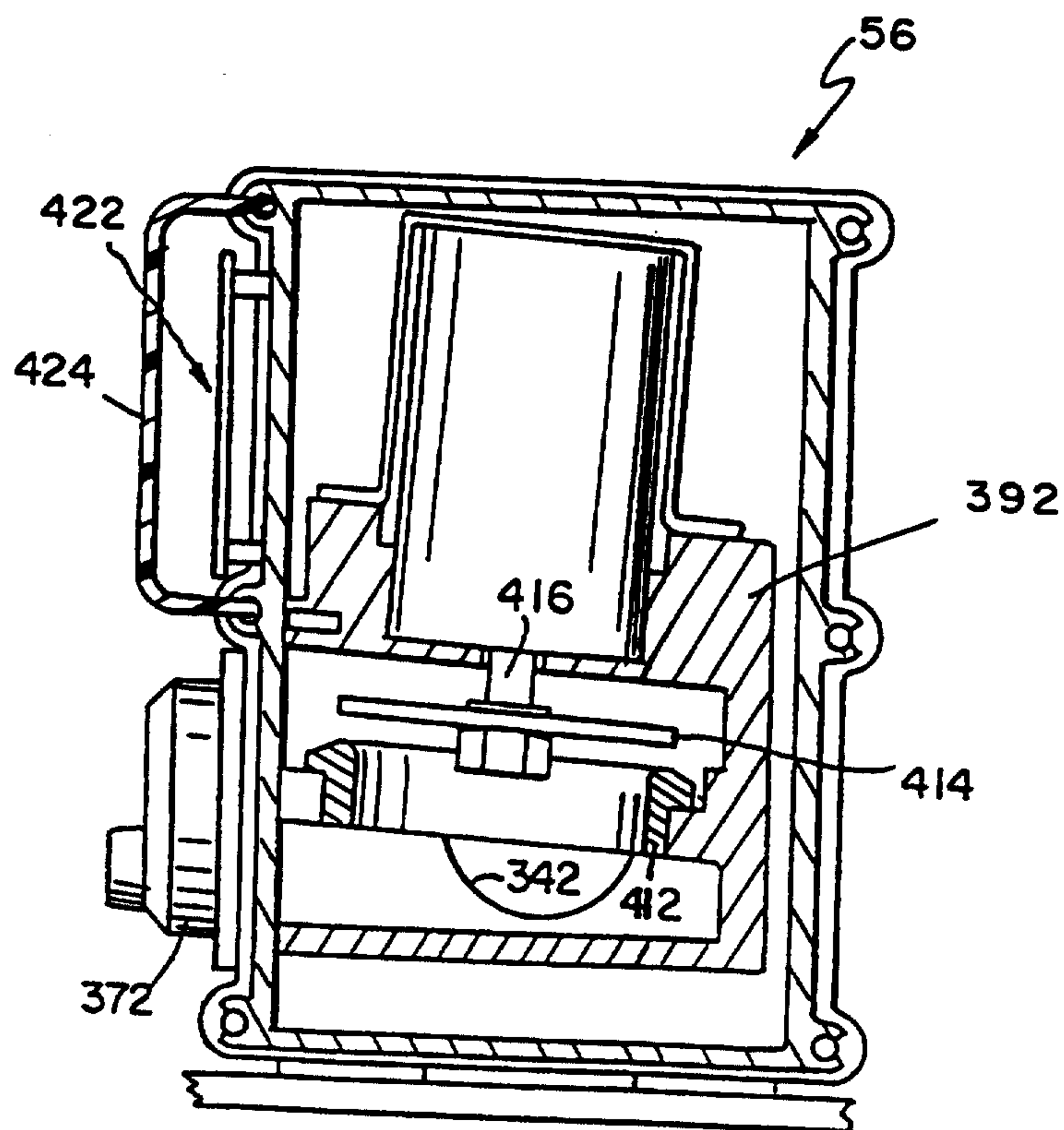
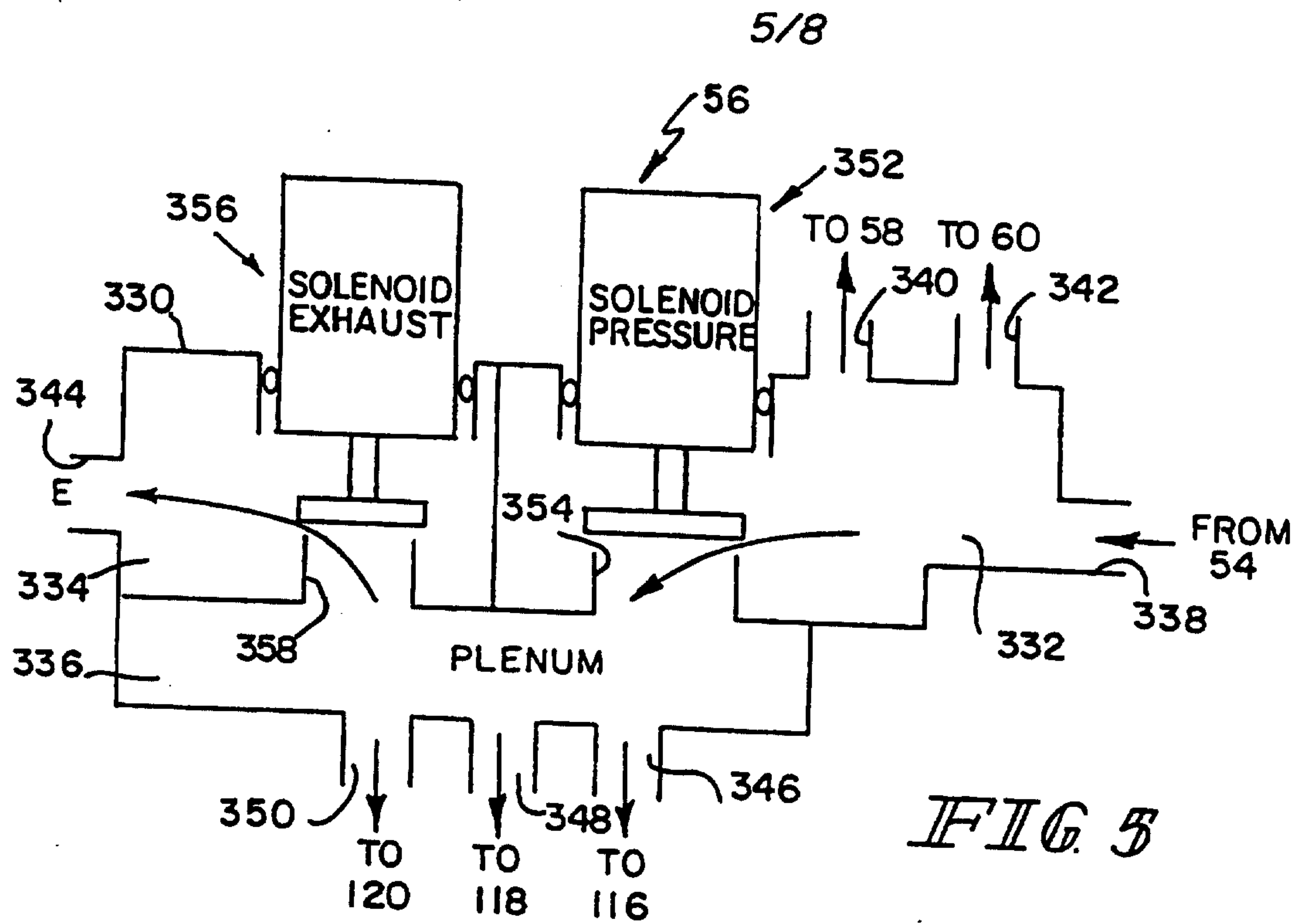
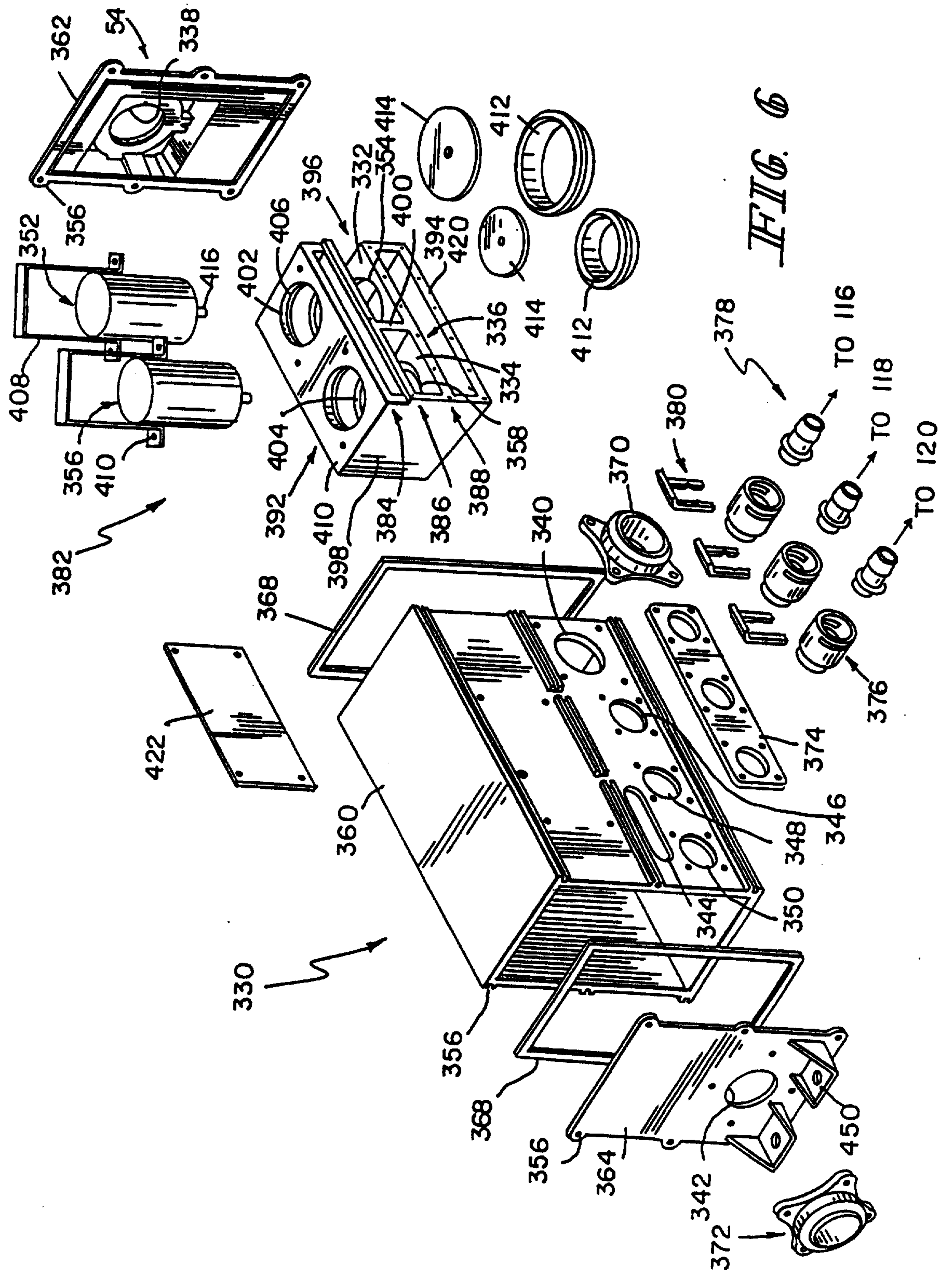


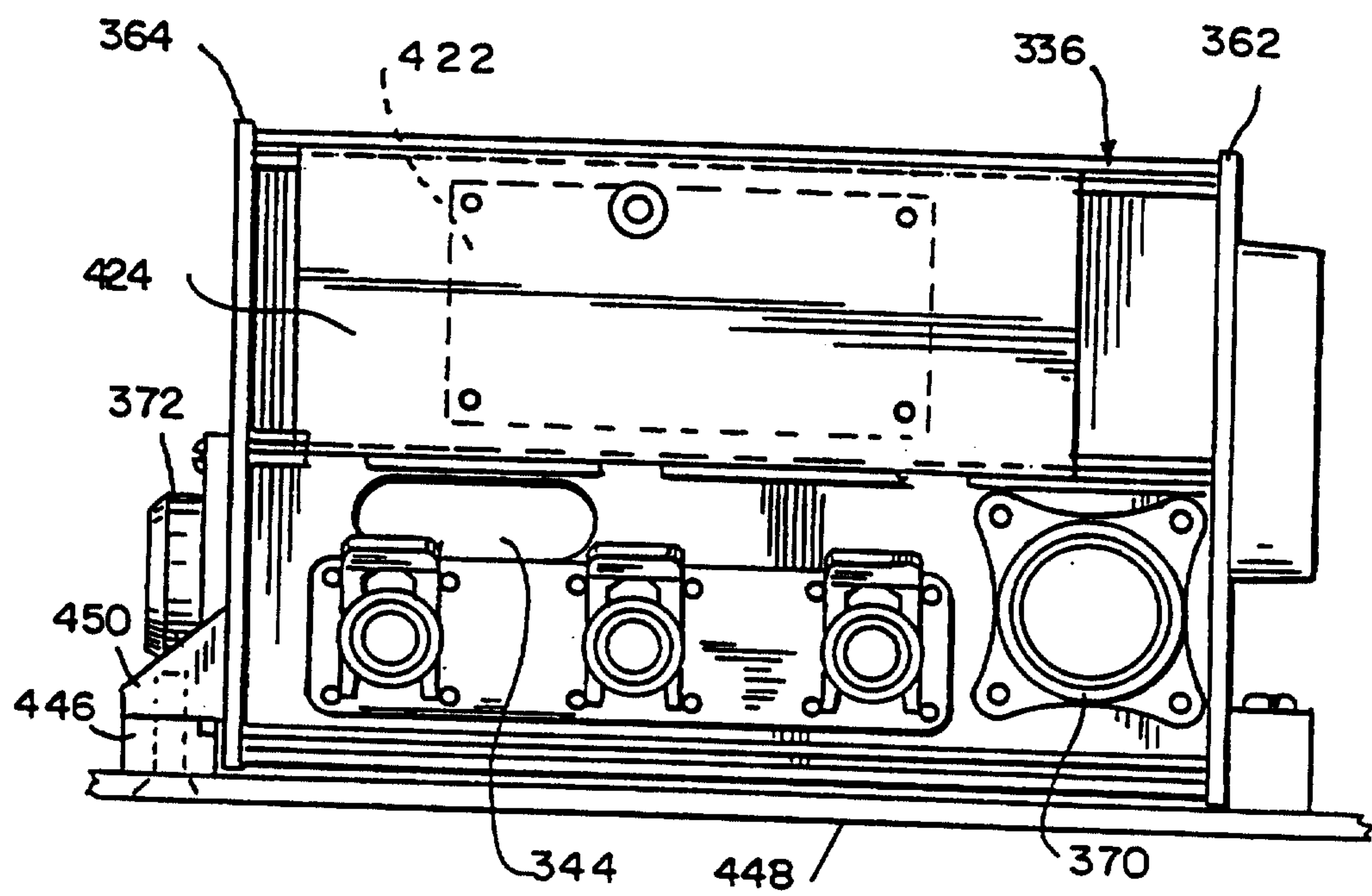
FIG. 4



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*FIG. 7*

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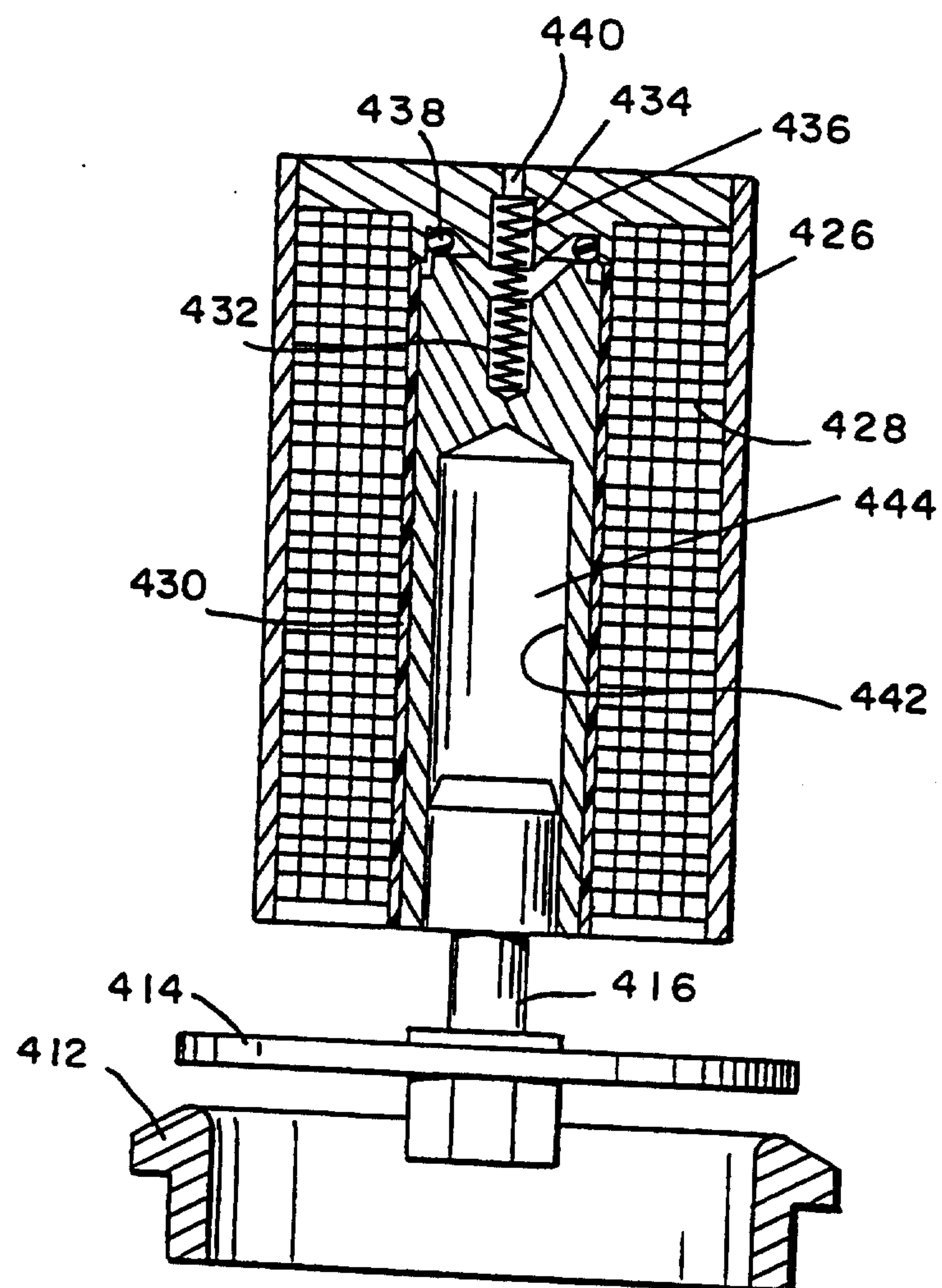


FIG. 9