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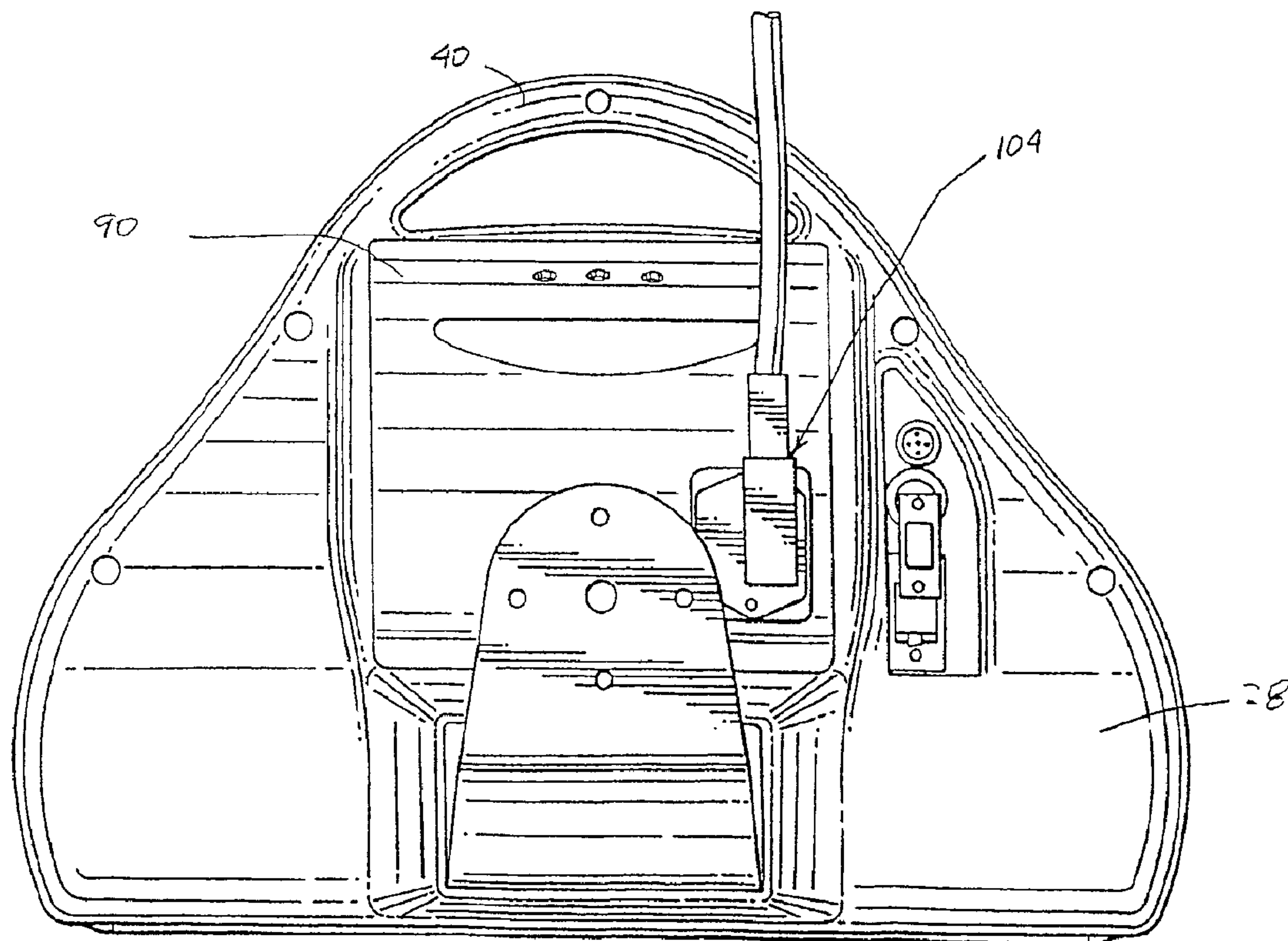
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(54) Title: INFUSION PUMP



(57) Abrégé/Abstract:

An infusion pump comprises a housing including a compartment structured to receive a syringe, the syringe including a syringe barrel and a syringe plunger moveable within the syringe barrel; a drive mechanism supported by the housing, the drive mechanism

(57) **Abrégé(suite)/Abstract(continued):**

structured and arranged to contact the syringe plunger and move the syringe plunger within the syringe barrel; and a syringe plunger position sensor including: a magnet positioned on the drive mechanism; a magnetic sensor array supported by the housing and positioned adjacent to the magnet, the magnetic sensor array configured to generate an output indicative of a magnetic field associated with the magnet; and software installed on the pump and configured to use the output to determine a linear position of the syringe plunger within the syringe barrel.

Abstract

An infusion pump comprises a housing including a compartment structured to receive a syringe, the syringe including a syringe barrel and a syringe plunger moveable within the syringe barrel; a drive mechanism supported by the housing, the drive mechanism structured and arranged to contact the syringe plunger and move the syringe plunger within the syringe barrel; and a syringe plunger position sensor including: a magnet positioned on the drive mechanism; a magnetic sensor array supported by the housing and positioned adjacent to the magnet, the magnetic sensor array configured to generate an output indicative of a magnetic field associated with the magnet; and software installed on the pump and configured to use the output to determine a linear position of the syringe plunger within the syringe barrel.

INFUSION PUMP

DESCRIPTION

Technical Field

The present invention relates to a pump and more particularly to an infusion pump for the delivery of a medication to a patient.

5 Background of the Invention

Generally, medical patients sometimes require precise delivery of either continuous medication or medication at set periodic intervals. Medical pumps have been developed to provide controlled drug infusion wherein the drug can be administered at a precise rate that keeps the drug concentration within a therapeutic margin and out of an unnecessary or possibly toxic range. Basically, the medical pumps provide appropriate drug delivery to the patient at a controllable rate which does not require frequent attention.

Medical pumps may facilitate administration of intravenous therapy to patients both in and outside of a clinical setting. Outside a clinical setting, doctors have found that in many instances patients can return to substantially normal lives, provided that they receive periodic or continuous intravenous administration of medication. Among the types of therapies requiring this kind of administration are antibiotic therapy, chemotherapy, pain control therapy, nutritional therapy, and several other types known by those skilled in the art. In many cases, patients receive multiple daily therapies. Certain medical conditions require infusions of drugs in solution over relatively short periods such as from 30 minutes to two hours. These conditions and others have combined to promote the development of increasingly lightweight, portable or ambulatory infusion pumps that can be worn by a patient and are capable of administering a continuous supply of medication at a desired rate, or provide several doses of medication at scheduled intervals.

Configurations of infusion pumps include elastomeric pumps, which squeeze solution from flexible containers, such as balloons, into IV tubing for delivery to the patient. Alternatively, spring-loaded pumps pressurize the solution containers or

reservoirs. Certain pump designs utilize cartridges containing flexible compartments that are squeezed by pressure rollers for discharging the solutions, such as in U.S. Patent No. 4,741,736. Other references which disclose portable infusion pumps include U.S. Patent Nos. 5,330,431 (showing an infusion pump in which standard pre-filled single dosage IV bags are squeezed by the use of a roller); 5,348,539 (showing an infusion pump in which prepackaged IV bags are squeezed by a bladder which is actuated by fluid pumped from a reservoir); 5,429,602 (showing a programmable portable infusion pump system for injecting one or more medicinal substances into an individual); and 5,554,123 (showing an infusion pump in which the amount of fluid required to pump a bladder sufficient to fully dispense solution from a bag is less than the volume of an IV bag.). Infusion pumps utilizing syringes are also known wherein a drive mechanism moves a plunger of the syringe to deliver fluid to a patient. Typically, these infusion pumps include a housing adapted to receive a syringe assembly, a drive mechanism adapted to move the syringe plunger, a pump control unit having a variety of operating controls, and a power source for powering the pump including the drive mechanism and controls.

While the discussed prior art and other designs have recognized the need for an infusion pump which is smaller and more compact for mobile use by ambulatory patients or other patients, each has failed to address the need for a more suitable power source. Naturally, a portable pump must be supplied with an equally portable power source as a means for powering the pump motor. Batteries are a suitable choice of power for portable units. Some prior art pumps may use disposable batteries while other pumps may use rechargeable batteries.

Disposable batteries have proven to have a longer life than the life of a rechargeable battery (with a single charge). Disposable batteries are also typically smaller than rechargeable battery units. However, there is an environmental disposal concern with such batteries, as they place a considerable burden on the environment. Disposable batteries are responsible for a major share of heavy metal pollution in domestic waste. Despite special collection efforts and consumer awareness campaigns, a high percentage of batteries sold still end up in domestic waste sites. Heavy metals eventually leak from the batteries into the ground soil, damaging the environment.

Environmental concerns are greatly alleviated if rechargeable batteries are used in place of disposable batteries. However, where such batteries or battery packs are rechargeable, an AC outlet is usually necessary. A separate charger, as is well-known in the art, is also required for the recharging effort. Unfortunately, these facilities are not always readily available or accessible to the patient and, with respect to the usual adapters and extension cords, they add to the bulk and weight of the infusion pump system. Furthermore, in certain pumps utilizing rechargeable batteries, the pump itself must be used in the recharging effort as it typically houses the transformer used in the recharging process.

Batteries and battery packs that are large and bulky significantly add to the weight of the portable infusion pump. Weight and size of the infusion pump is an important consideration because it may be carried about by nurses or other hospital personnel. The pump must also be sized to be attached to an I.V. pole. The I.V. pole, with attached pump, may be moved about in a hospital setting. In addition, where interrupted operation of the pump may have negative consequences, extra batteries or an extra battery pack may be added to the carrying necessities of the infusion pump. In some instances, the carrying of a second set of batteries or a back-up battery pack may double the weight of the power source.

Thus, there is seen in the prior art advantages and disadvantages to both disposable and rechargeable battery powered pumps. It should be understood that under certain circumstances, a pump that uses disposable batteries may be preferable or the only option available (if no outlet is available). Under other circumstances, the benefits of lower cost and environmental concerns may dictate that rechargeable batteries are preferred.

In addition to the above, customs and/or regulations of different sovereigns may dictate the use of one type of power source for a pump over another. For example, in the U.S., pumps powered by disposable batteries have long been preferred due to their convenience and ability to provide power for extended periods of time. On the other hand, in Europe, rechargeable battery powered pumps are preferred, due to environmental concerns with the disposal of battery waste.

In light of the advantages and disadvantages that both disposable and rechargeable batteries provide, it may be desirable for some to alternate use of both battery types.

However, it can be easily recognized that it would prove burdensome and a waste of space and resources to supply or have on hand two separate pumps, each utilizing a different battery type.

It may also be desirable for manufacturers of pumps to satisfy the needs of users of rechargeable battery powered pumps as well as disposable battery powered pumps. However, it is costly for manufacturers of pumps to manage entirely separate lines of pump types or forego supplying one pump type over another. Thus, it is recognized that several advantages exists for a pump that can utilize both disposable and rechargeable batteries. There exists a need in the art for a pump that may utilize both disposable and rechargeable batteries. There also remains a need for a pump that utilizes rechargeable batteries that can be re-charged without the use of the pump.

Additional problems have also been experienced with infusion pumps. For example, certain sensing systems that detect whether an occlusion is present in an infusion line have proven to be unreliable or too complex in construction. Certain syringe plunger position detectors and syringe barrel size detectors have also proven to be unreliable. In addition, drive mechanisms for syringe plungers have also proven to be unreliable as certain components become stripped or jammed adversely affecting the mechanism.

The present invention is provided to solve these and other problems.

Summary of the Invention

The present invention is generally directed to an infusion pump for delivering a flowable material, such as a fluid medication, to a patient through an infusion line.

Accordingly, in one aspect, there is provided an infusion pump comprising:
a housing including a compartment structured to receive a syringe, the syringe including a syringe barrel and a syringe plunger moveable within the syringe barrel;

a drive mechanism supported by the housing, the drive mechanism structured and arranged to contact the syringe plunger and move the syringe plunger within the syringe barrel;

and

a syringe plunger position sensor including:

a magnet positioned on the drive mechanism;

a magnetic sensor array supported by the housing and positioned adjacent to the magnet, the magnetic sensor array configured to generate an output indicative of a magnetic field associated with the magnet; and

software installed on the pump and configured to use the output to determine a linear position of the syringe plunger within the syringe barrel.

4a

According to another aspect there is provided an infusion pump operable with a syringe having a syringe barrel and a syringe plunger moveable within the syringe barrel, the infusion pump comprising:

a housing including;

5 a compartment structured to receive the syringe and defining a wall; and

a syringe clamp moveable towards and away from the wall, the syringe contacting the syringe barrel when the syringe clamp is moved towards the wall;

a drive mechanism supported by the housing, the drive mechanism structured and arranged to contact an end of the syringe plunger so as to be able to move the syringe plunger
10 within the syringe barrel; and

a syringe barrel size sensor including:

a magnet operably coupled to the syringe clamp; and

a sensing member supported by the housing and configured to generate an output indicative of a magnetic field associated with the magnet; and

15 software installed on the pump and configured to use the output to determine a size of the syringe barrel received by the compartment.

According to another aspect there is provided an infusion pump method comprising:

sensing a magnetic field associated with a first magnet coupled to a syringe clamp to determine a size of a syringe barrel received in a housing of an infusion pump; and

20 sensing a magnetic field associated with a second magnet to determine a linear position of a syringe plunger moveable inside the syringe barrel.

Other features and advantages of the invention will be apparent from the following specification taken in conjunction with the following drawings.

25

Brief Description of the Drawings

To understand the present invention, it will be described by way of example, with reference to the accompanying drawings in which:

FIG. 1 is a front perspective view of one embodiment of an infusion pump which may be
30 configured in accord with and embody the present invention;

FIG. 2 is another factor perspective view of the infusion pump of the present invention with an access door removed;

FIG. 3a is a front elevation view of the infusion pump of the present invention;

4b

FIG. 3b is another front elevation view of the infusion pump of the present invention mounted in an alternative configuration;

FIG. 4A is a rear perspective view of the infusion pump of the present invention, showing
5 a rechargeable battery unit associated therewith;

FIG. 4B is a rear perspective view of the infusion pump of the present invention, showing a disposable battery unit associated therewith;

FIG. 5 is another rear perspective view of the infusion pump of the present invention with the battery unit removed.

10 FIG. 6 is a rear elevation view of the infusion pump of the present invention;

FIG. 7 is a side elevation view of the infusion pump of the present invention;

FIG. 8 is an opposite side elevation view of the infusion pump of the present invention;

FIG. 9 is a perspective view of the rechargeable battery unit shown in FIG. 4A;

5 FIG. 10 is a side elevation view of the rechargeable battery unit shown in FIG. 9;

FIG. 11 is an end elevation view of the rechargeable battery unit shown in FIG. 9;

FIG. 12 is a electrical schematic view of the rechargeable battery unit;

FIG. 13 is a perspective view of the disposable battery unit shown in FIG. 4B;

10 FIG. 14 is a schematic view of a syringe drive mechanism and occlusion sensor for the infusion pump of the present invention;

FIG. 15 is partial perspective view of the syringe drive mechanism and further showing a syringe plunger position indicator;

FIG. 16 is a partial plan view of the syringe drive mechanism and further showing the syringe plunger position indicator;

15 FIG. 17 is a partial plan view of the syringe plunger position indicator;

FIG. 18 is a perspective underside view of the syringe drive mechanism and further showing a syringe barrel size indicator;

FIG. 19 is an enlarged partial perspective view of a syringe barrel clamp of the infusion pump of the present invention;

20 FIG. 20 is partial perspective view of a video display and pad associated with a user interface of the infusion pump of the present invention;

FIG. 21 is a partial cross-sectional view of the video display mounted in a housing of the infusion pump;

FIG. 22 is a partial perspective view of the syringe drive mechanism;

25 FIG. 23 is a partial cross-sectional view of the syringe drive mechanism;

FIG. 24 is a partial perspective view of a slide assembly of the syringe drive mechanism having a rotary nut in a disengaged position;

FIG. 25 is a cross-sectional view of the slide assembly of FIG. 24 in a disengaged position;

30 FIG. 26 is a partial perspective view of the slide assembly wherein the rotary nut is in an engaged position;

FIG. 27 is a cross-sectional view of the slide assembly of FIG. 26 in an engaged position;

FIG. 28 is a perspective view of the rotary nut;

FIG. 29 is an elevation view of the rotary nut;

5 FIG. 30 is an underside perspective view of the rotary nut;

FIG. 31 is a schematic wiring diagram of a patient controlled analgesia button associated with the pump of the present invention, the button being in an at rest position;

10 FIG. 32 is another schematic wiring diagram of the patient controlled analgesia button associated with the pump of the present invention, the button being in an actuated position;

FIG. 33 is a table summarizing information revealed by the circuits associated with the button of FIGS. 31 and 32.

Detailed Description

15 While the present invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detail preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiments illustrated.

20 Referring to FIG. 1, therein is shown one embodiment of an infusion pump of the present invention generally referred to with the reference numeral 10. The infusion pump 10 generally includes a housing 12 that supports a syringe assembly 14, a user interface 16, a power supply 18, a drive mechanism 20 having an occlusion sensor 22 (FIG. 14), and a syringe sensor system 24 (FIGS. 15-18).

25 While the present invention discloses a portable infusion pump, such as, for example, a syringe-based infusion pump, and their progeny, designed and manufactured by Baxter International, Inc. of Deerfield, Illinois, it is understood that individual aspects of the invention that can be incorporated into other types of pumps or other electrical or medical devices.

30 As shown in FIGS. 1 and 2, the housing 12 of the pump 10 has a generally contoured shape. The housing 12 includes a first member 26 and a second member 28 that are connected together to form a central cavity 30. The central cavity 30 houses

various components of the pump 10 including the user interface 16. The first member 26 of the housing has an opening 32 that accommodates a display screen of the user interface 16. As shown in FIG. 5, a rear portion of the housing 12 has a receptacle or recess 33 that is adapted to receive the power supply 18 to be described in greater detail below. At a bottom, front portion of the housing 12, a container compartment or syringe compartment 34 is defined that accommodates the syringe assembly 14, a portion of the drive mechanism 20 and other components. The first member 26 of the housing 12 has a hinged access door 36 that encloses the syringe assembly 14 in the compartment 34. The access door 36 is preferably transparent in order for medical personnel to view the contents in the syringe assembly 14. A lock 38 is provided with the door 36 to prevent unauthorized access to the syringe assembly 14. The lock 38 is required because oftentimes drugs such as morphine are infused by the pump 10 and can be unfortunately subject to theft. An upper portion of the housing 12 is provided with a handle 40. The housing 12 can be made from a variety of materials including various types of plastics and metals. As shown in FIGS. 4-8, the housing 12 has a pole clamp 42 attached to the second member 28 of the housing 12. The pole clamp 42 can have various designs and is adapted to mount the pump 10 on a pole assembly such as used in a hospital setting. In a preferred embodiment, the pole clamp 42 is adapted to be able to mount the pump 10 in various positions. For example, the pump 10 can be mounted in a generally horizontal position shown in FIG. 3a or a generally vertical position shown in FIG. 3b.

FIG. 2 discloses the syringe compartment 34 in greater detail. Generally, the syringe compartment 34 is dimensioned to receive and support the syringe assembly 14 as well as receive a portion of the drive mechanism 20. Briefly, the syringe assembly 14 generally includes a syringe barrel 46 and a syringe plunger 48. The syringe barrel 46 contains medication and slidably receives the syringe plunger 48. The syringe plunger 48 is driven by the drive mechanism to force medication from the syringe barrel 46 through a tube (not shown) and to a patient. The tube would have one end connected to an end of the syringe barrel 46 and another end adapted to be connected to a patient.

The syringe compartment 34 has a rear wall 44 that is generally concave to receive the syringe barrel 46 of the syringe assembly 14. The syringe barrel 46 of the syringe assembly 14 and rear wall 44 are generally in confronting relation. The housing 12 further has a curved lip 50 that in a preferred embodiment is integral with the rear wall

44. The lip 50 aids in loading a syringe 18 in the compartment 34 to be described in greater detail below. As shown in FIGS. 2 and 19, a syringe clamp 52 is movably mounted in the compartment 34. The clamp 52 has a concave inner surface that faces the rear wall 44 and that fits over the syringe barrel 46. As shown in FIG. 18, the clamp 52 is
5 slidable along a rod assembly 54 to move the clamp 52 towards and away from the rear wall 44. The clamp 52 can slide along the rod assembly 54 to accommodate different sized syringe barrels. As shown in FIG. 19, a base portion of the clamp 52 has a pair of rollers 56,58 that help reduce friction when the clamp 52 slides along the housing 12. Due to tolerances, the clamp 52 may also pivot slightly. The clamp 52 is resiliently
10 biased towards the rear wall 44. The housing 12 and syringe compartment 34 are sized such that an entire syringe assembly, with plunger fully extended from the syringe barrel, is contained within the housing and can be enclosed by the access door 36. No part of a syringe barrel or syringe plunger protrudes from the housing 12. A portion of the drive mechanism 20 extends into the syringe compartment 34 to engage the plunger 48. The
15 access door 36 has an opening to accommodate the tube (not shown) that is attached to the syringe barrel 46 to deliver medication to the patient.

As shown in FIGS. 1-3, the pump has a user interface 16. Portions of the user interface 16 are described in greater detail in commonly-owned U.S. Patent Application Publication No. 2004/0225252 entitled "System And Method For Operating An Infusion
20 Pump," published on November 11, 2004. The user interface 16 generally includes a display screen 60, a first control panel 62 and a second control panel 64, and associated electrical components and computer software contained with the housing 12 to operate the pump 10. The display screen 60 displays all of the general operating parameters of the pump 10 and fits within the opening 32 in the housing 12. The display screen 60
25 also acts as a touch screen for data to be inputted into the pump 10 by a user. As discussed, the pump 10 can be mounted in either a generally horizontal position (FIG. 3a) or a generally vertical position (FIG. 3b). The software associated with the user interface 16 has the ability to display information on the screen 60 in either a landscape orientation or a portrait orientation. When the pump is mounted in the horizontal
30 configuration as shown in FIG. 3a, information is displayed on the display screen 52 in a landscape configuration. Conversely, when the pump 10 is mounted in the vertical configuration as shown in FIG. 3b, information is displayed on the display screen

52 in a portrait configuration. Thus, depending on how the pump 10 is mounted, the information can be read by users without the need to tilt one's head. This feature is described in greater detail in commonly-owned U.S. Patent Application Publication No. 2003/0233071 entitled "Dual-Orientation Display For Medical Devices," published on
5 December 18, 2003. The first control panel 62 generally has a start button 66, a stop button 68 and an alarm/alert button 70. The second control panel 64 generally has a settings panel 72, a history button 74 and a data port 76. These controls will be described in greater detail below.

10 The pump 10 and user interface 16 may utilize additional identification features regarding the medication delivered by the pump 10. For example, and as shown in FIG. 2, the pump 10 may be equipped with an RFID (radio frequency identification) reader 86 that cooperates with an RFID tag 88 attached to the syringe barrel 46. The RFID tag 86 has a transponder circuit and an antenna circuit. The RFID tag 86 can store significant information including, but not limited to, the type of medication, amount, concentration,
15 as well as pumping parameters and instructions for the medication. The RFID reader 86 has energizer, demodulator and decoder circuits. The energizer circuit emits a low-frequency radio wave field that is used to power up the RFID tag 88. This allows the tag 88 to send its stored information to the reader 86. The information is demodulated and decoded where it then can be used by the computer associated with the user interface 16.
20 While several different configurations are possible, the RFID reader 86 can be mounted in pump housing adjacent the syringe compartment 34. The RFID tag 88 is affixed generally to the syringe barrel 46. When the syringe assembly 14 is properly inserted into the pump 10, the RFID reader 86 automatically reads the information from the RFID tag 88, which can be used to aid in properly operating the pump 10 for a particular
25 patient. It is understood that other types of data reader/data carrier systems can also be used.

As shown in FIGS. 20 and 21, the display screen 60 is equipped with a pad 78 about the outer periphery of the screen 60. The pad 78 is a shock absorbent member made preferably of an elastomeric material. In one preferred embodiment, the pad 78 is
30 made from polyurethane. The pad 78 has a face 80 that is positioned between the display screen 60 and an inner surface 82 of the first member 26 of the housing 12. The pad 78 also has a sidewall 84 preferably integral with the face 80. The pad 78 absorbs forces

generated if the pump 10 is jostled, bumped or dropped, and minimizes the effect such occurrences have on the display screen 60. The pad 78 also resists fluid infiltration into the housing 12.

The pump 10 of the present invention includes the power supply 18 that can take many different forms. In one preferred embodiment, the power supply 18 may be in the form of a rechargeable battery unit 90 or a disposable battery unit 92. The rechargeable battery unit 90 is generally shown in FIG. 4a and the disposable battery unit 92 is generally shown in FIG. 4b. The pump 10 will operate with either unit 90,92 depending on the needs and desires of the user. As shown in FIG. 5, the pump 10 has an electrical contact 94 positioned in the recess 33 that is in electrical communication with the user interface components of the pump 10 as is known. The contact 94 will cooperate with a corresponding electrical contact on either of the rechargeable battery unit 90 or the disposable battery unit 92 as will be described.

FIGS. 4a and 6-12 generally disclose the rechargeable battery unit 90. FIGS. 9-11 show the rechargeable battery unit 90 removed from the pump 10. As shown in FIG. 4a and 11, the rechargeable battery unit 90 generally includes a battery housing 96 having an electrical contact 98 to cooperate with the pump housing electrical contact 94, a rechargeable battery 100, associated electrical components 102, and an AC power supply assembly 104.

As shown in FIGS. 9-11, the rechargeable battery unit housing 96 generally has a base member 106 and a cover member 108. The base member 106 and cover member 108 are contoured wherein the housing 90 has a shallow first end 110 and a deeper second end 112. The contour of the housing 90 is generally similar to the outer contour of the backside of the pump housing 12. FIGS. 4a, 6-8 show the unit 90 installed in the pump housing 12 illustrating the corresponding contours. As shown in FIG. 11, a bottom portion of the base member 106 supports the electrical contact 98, and contacts the housing electrical contact 94 when the unit 90 is installed. As further shown, the battery unit housing 96 has a pair of posts 114 that laterally protrude from the housing 96. The posts 114 cooperate with retainers in the pump housing 12 to retain the unit 90 within the housing 12. A push button 116 is included on the housing cover 108 to retract the posts 114 when removing the unit 90 from the pump housing 12.

As further shown in FIGS. 9 and 10, the AC power supply assembly 104 has a power cord 118 and an associated terminal 120 that plugs into the housing 60. The AC power supply assembly 104 has a plug that can be inserted into a standard electrical outlet to recharge the rechargeable battery 100 when necessary. AC power can also be supplied through the assembly 104 to power the pump 10.

FIG. 12 schematically shows the electrical components 102 that are associated with the rechargeable battery unit 90. The electrical components 102 generally include a power supply 122 and a recharger assembly 124 that includes a recharger 126 and a diode mechanism in the form of a first diode 128 and a second diode 130. The power supply 122, in one preferred embodiment, is an off-line switching power supply. The power supply 122 generally includes a field-effect transistor (FET) 132, connected to a transformer 134, which in turn is connected to a power supply diode 136. The power supply 122 has one connection to the AC power supply assembly 104. The power supply 122 is also connected to the recharger 126. The diodes 128,130 are generally connected to the recharger 126, the power supply 122, the rechargeable battery 100 and the terminal 98 so as to provide the desired power through the unit 90. For example, when the plug of the AC power supply assembly 104 is not plugged into a wall outlet as shown in FIG. 12, the first and second diodes 128,130 are biased and configured such that power is being supplied by the rechargeable battery 100. If the plug of the assembly 104 is plugged into a wall outlet, the power supply 122 provides 12 volts. When the 12 volts are sensed, the diodes 128, 130 are configured such that the rechargeable battery 100 is being recharged by the power supply 122 and the unit 90 is supplying power through the power supply 122 via the plugged in AC power supply assembly 104. Accordingly, power can be switched from being supplied from the rechargeable battery 100 or from the wall outlet. It is further noted that because the rechargeable battery unit 90 houses the power supply 122, the recharger 126 and the rechargeable battery 100 within the unit 90, the battery 100 can be recharged without the use of the pump 10. The battery 100 can be charged simply by plugging the cord of the power assembly 104, connected to the unit 90, into a wall outlet. The unit 90 need not be installed into the pump 10. In prior art pumps, the pump itself is needed to recharge the battery. It is also understood that the rechargeable battery unit 90 can be defined without the AC power cord assembly 104 wherein the assembly 104 is considered a separate component removably attachable to

the unit 90. The battery units 90,92 may also be equipped with a microchip that is capable of transmitting data to the user interface 16 of the pump 10 such as the amount of charge left in the batteries being utilized.

FIGS. 4b and 14 generally disclose the disposable battery unit 92. The general structure of the disposable battery unit 92 is similar to the rechargeable battery unit 90. The disposable battery unit has a housing 142 having an electrical contact 144 that will cooperate with the housing electrical contact 94 in the housing recess 33 (*See* FIGS. 4b and 5). The housing 142 has a base member 146 and a cover member 148. The base member 146 receives a plurality of disposable batteries 150, and in a preferred embodiment, four D-cell batteries are utilized. It is understood, however, that other battery configurations are possible. The batteries are supported such that the batteries will supply electrical power through the contact 144 as is known. As shown in FIG. 4b, the disposable battery unit 92 is received by the recess 33 of the pump 10 in the same fashion as the rechargeable battery unit 90 shown in FIG. 4a.

Thus, depending on the desires of the user, the pump 10 may be powered by the rechargeable battery unit 90 or the disposable battery unit 92. The pump 10 may be provided with multiple units 90,92 wherein the pump 10 can remain in use by replacing the unit 90,92 requiring either recharging, or new disposable batteries.

FIGS. 14, 15 and 22-30 disclose the syringe drive mechanism 20. FIG. 14 represents a simplified schematic view. The syringe drive mechanism 20 is accommodated by the pump housing 12 and generally includes a motor 152, a lead screw 154, a connecting linkage 156 and a slide assembly 158. Briefly, the connecting linkage 156 is connected to the slide assembly 158, which is associated with the lead screw 154. The slide assembly 158 which moves linearly in response to rotation of the lead screw 154 by the motor 152. Linear movement of the connecting linkage 156 moves the syringe plunger 48 within the syringe barrel 46 to expel fluid from the syringe assembly 14.

As shown in FIG. 14, the motor 152 is operably connected to the lead screw 154 to rotate the lead screw 154 when the motor 152 is energized. The lead screw 154 has threads 160 that cooperate with a threaded member of the slide assembly 158 as will be described in greater detail below.

FIGS. 14-18 and 22 generally show the connecting linkage 156. The connecting linkage 156 generally includes a tube member 162 and a plunger engagement arm 164. The tube member 162 is connected at one end to the slide assembly 158 and at another end to the plunger engagement arm 164. As shown in FIG. 22, the tube member 162 houses a rod 166 that is connected to a lever 168 pivotally mounted on the engagement member 164. As explained in greater detail below, the rod 166, when actuated by the lever 168, can disengage the slide assembly 158 from the lead screw 154. This allows the slide assembly 158 to freely slide along the lead screw 154 to linearly position the plunger engagement arm 164 against the plunger 48 extending from the syringe barrel 46.

As further shown in FIGS. 14, 15 and 22-23, the slide assembly 158 generally includes a rail member 170 and a slide member 172. The rail member 170 has a pair of legs 174 depending from a cover plate 176. The slide member 172 slides beneath the cover plate 172 as can be appreciated from FIG. 15. The legs 174 have an inwardly protruding portion 175. The rail member 170 is positioned within the housing 12 and adjacent the rear wall 44 of the syringe compartment 34.

As shown in FIG. 22-27, the slide member 172 generally has a base 178 and a cover 180 that collectively support a threaded member 182 or rotary nut 182 therein. The base 178 has a countersunk bore 184 therethrough that is in communication with a channel 186. The bore receives the rotary nut 182 and the channel 186 accommodates a portion of the rotary nut 182 and the lead screw 154. The base 178 has a pair of cantilevered beams 188 that correspond in shape to the legs 174 of the rail member 170. The beams 188 are slightly biased into frictional sliding engagement with the legs 174 and provide a smooth sliding movement of the slide member 172 along the rail member 170. As shown in FIG. 23, the cover 180 fits over the rotary nut 182. The cover 180 supports additional structure such as a pin 185 and lock arm 187 (See FIG. 24). This structure will be described in greater detail below.

FIGS. 28-30 further disclose the rotary nut 182. The rotary nut 182 is a unitary member having a generally cylindrical base 190. The base 190 has a lip 192 that engages the countersunk bore 84 in the slide member 172. The base 190 has a first finger 194 and a second finger 196 depending therefrom. The fingers 194,196 are spaced to define an opening 197. The opening 197 receives the lead screw 154. Each finger 194,196 has a set of threads 198 thereon that engage the threads 160 on the lead screw 154. The threads

198 are positioned on generally opposed sides of the rotary nut 182. The base 190 further has an over-rotation surface 200 and a rotation surface 202.

As further shown in FIGS. 22-27, the rotary nut 182 is received in the cylindrical bore 184 in the slide member 172. The tube member 162 of the connecting linkage 156 is connected to the base 178 of the slide member 172. The slide member 172 is positioned for sliding movement on the rail member 170. The lead screw 154 is routed through the channel 186 in the slide member 172. FIGS. 26 and 27 show the rotary nut 182 in an engaged position with the lead screw 154. In FIG. 26, the cover 180 of the slide member 172 is removed for clarity. The rotary nut 182 is rotationally biased into engagement with the lead screw 154 by a spring 204. The threads 198 on each finger 192, 194 of the rotary nut 182 engage generally opposed sides of the lead screw 154. The over-rotation surface 200 engages the pin 185 (carried by the cover 180) to prevent over-rotation of the nut 182 into the lead screw 154. This maximizes performance and minimizes wear of the threads 198 of the rotary nut 182. With the threads 198, 160 engaged, when the motor 152 rotates the lead screw 154, the rotary nut 182 moves along the lead screw 154 which, in turn, linearly moves the slide member 172 and connecting linkage 156. This pushes the plunger 48 into the syringe barrel 46 to displace medicament from the syringe assembly 14. The lock arm 187 engages the base 190 of the rotary nut 182 to prevent the rotary nut 182 from disengaging under load such as from back pressure from the syringe assembly 14.

The rotary nut 182 can also be easily disengaged from the lead screw 154 which allows the slide member 172 to be positioned along the lead screw 154 such as when positioning the plunger engagement arm 164 against the syringe plunger 48. As shown in FIGS. 22, 24 and 25, the lever 168 is rotated on the plunger engagement arm 164. A camming action linearly moves the rod 166 within the tube member 162. The rod 166 engages the rotation surface 202 to rotate the rotary nut 182. The rotary nut 182 is rotated such that the threads 198 become disengaged from the threads 160 on the lead screw 154. This allows the slide member 172 to slide freely along the rail member 170 to position the plunger engagement arm 164.

The rotary nut 182 provides several advantages over previous nut/lead screw arrangements using single or multiple half-nuts that engage the lead screw. Half-nuts require a high rate spring to bias the nut into engagement with the lead screw and prevent

disengagement. This requires transverse side loading of the lead screw that causes wear and mechanism inefficiency. Because the rotary nut 182 is a unitary piece, misalignment problems between two half-nuts is also eliminated. The rotary nut 182 utilizes a positive stop and lock. Therefore, side loads, moments, over engagement and disengagement during pumping are eliminated and wear is minimized.

The pump 10 is equipped with an occlusion sensor 22 to determine if an infusion line connected to the syringe barrel 46 is blocked. In one preferred embodiment of the invention, the occlusion sensor 22 is incorporated into the plunger engagement arm 164 of the drive mechanism 20. As shown schematically in FIG. 14, the occlusion sensor 22 generally includes a load cell 210 and a load beam 212. The load cell 210 is connected to a distal end of the plunger engagement arm 164. The load beam 212 is connected to generally a mid-portion of the arm 164 through a pivotal connection 214. The load beam 212 has a pusher block 216 that abuts against the end of the syringe plunger 48. The load cell 210 is positioned adjacent to and in contact with a distal end 218 of the load beam 212. Thus, one side of the load beam 212 contacts the load cell 210 and another side of the load beam 212 contacts the syringe plunger 48. A flipper 220 can extend from the arm 164 and be abutted against the plunger 48 to assure the plunger 48 always remains in contact with the pusher block 216.

In operation, the drive mechanism 20 drives the arm 164 as described above. This in turn drives the load beam 212 wherein the pusher block 216 pushes against the plunger 48. This forces and linearly moves the plunger 48 within the barrel 46. The load cell 210 measures a reactive force from the force pushing against the load beam 212. The circuitry associated with the load cell 210 converts the force to a usable signal. In a preferred embodiment, the usable signal is a voltage value. If too much force is required to move the plunger 48, it signifies that the infusion line is blocked. In such a case, the voltage detected is greater than a predetermined value, and the sensor 22 signals an occlusion in the infusion line. Thus, if the usable signal is out of a predetermined range, an occlusion is sensed. A user can then remedy the situation.

FIGS. 15-18 disclose various aspects of the syringe sensor system 24. The system 24 generally includes a syringe plunger position sensor 230 and a syringe barrel size sensor 232. FIGS. 15-17 disclose the syringe plunger position sensor 230. The sensor 230 is generally an eletromagnetic sensor that includes a magnet 234 and a plunger linear

sensor array 236. The magnet 234 is mounted generally on the arm 164 of the connecting linkage 156 of the drive mechanism 20. The magnetic sensor in the form of a linear sensor array 236 has a plurality of sensors 238 in the form of magnets that are positioned directly adjacent to the linear path of the plunger movement. The magnet 234 has a magnetic field associated therewith. As shown in FIGS. 16-17, the sensors 238 detect the orientation of the field lines in the magnetic field. The resulting signal is typically a sine wave. One sensor 238 has a specific length over which it can detect plunger movement. Then, the next sensor 238 will sense position. The sensors are initially calibrated wherein the pump software can determine the location of the plunger engagement arm 164 and, therefore, the plunger, based on the signal levels detected by each of the sensors 238. The magnet 234 is positioned substantially at a distal end of the plunger 48, or at the plunger head. The sensors 238 are directly adjacent the syringe plunger 48. With such a configuration, a direct measurement of the plunger position is possible rather than relying on indirect measurements. The sensors 238 are also configured to compensate for temperature changes as the pump 10 may be utilized in different environments.

FIG. 18 discloses the syringe barrel size sensor 232. Similar to the plunger position sensor 230, the syringe barrel size sensor 232 is generally an electromagnetic sensor that includes a magnet 240 and a barrel linear sensor array 242. The magnet 240 is mounted on the syringe barrel clamp assembly. The linear sensor array 242 is mounted generally adjacent thereto and has a sensor 244. Because the movement of the syringe barrel clamp is less than the plunger movement, a single sensor 244 can be used. Similar to the syringe plunger position sensor, based on the signal levels sensed by the sensor 244, the sensor 232 can determine what size syringe is loaded into the pump 10.

In operation, the pump 10 is mounted on a support structure such as a pole in either a horizontal or vertical configuration as shown in FIGS. 3a and 3b. The access door 36 is opened and a syringe assembly 14 is loaded into the pump 10. As shown in FIGS. 1, 2 and 19, the syringe assembly 14 can be conveniently loaded into the pump 10 with a single hand. Prior art pumps require both hands of a user to load the syringe. As shown in FIG. 2, the curved lip 50 allows the syringe 14 to slide easily into the syringe compartment 34. As shown in FIG. 19, the rollers 56, 58 associated with the syringe barrel clamp 52 allows the clamp 52 to slide upwards along the housing 12 in accepting the syringe 14 as in a snap-fit arrangement. When the syringe 14 is further inserted, the

clamp 52 is biased back onto the syringe barrel 46. The infusion line is attached to the syringe and connected intravenously to a patient. The access door 36 is locked. The operating parameters of the pump 10 are loaded into the pump software through the user interface 16. The infusion therapy can then be started.

5 The pump 10 can be equipped with several different features to enhance its operability. For example, the pump can accommodate patient-controlled analgesia (PCA). To that end and as shown in FIG. 2, the pump 10 can have a PCA button 299 wherein a user can further control the infusion therapy wherein the user can push the button to deliver additional doses of medication. The PCA button typically has a cord that
10 can be plugged into the pump 10 as is generally known. The button 299 can be specially designed to be activated by a thumb of a patient. As further shown in FIG. 2, the button 299 can also be equipped with a fingerprint reader 301 to assure only the patient can activate the PCA button 299. The fingerprint reader 301 is operably connected to the user interface 16. The patient's fingerprint or thumbprint can be pre-loaded into the
15 pump software of the user interface 16. When the PCA button 299 is pushed, and the reader 301 reads the thumbprint, the software verifies the button 299 was pushed by the patient by comparing the print that was read with the stored thumbprint. The PCA button 299 can have peripheral structure to protect inadvertent actuation. The PCA button 299 can also be lighted so as to glow in the dark to aid patients in locating the
20 button.

FIGS. 31-33 disclose additional features associated with the PCA button 299. FIGS. 31 and 32 show wiring diagrams 300 and 301 for the PCA button. Wiring diagrams 300 and 301 include a first circuit 302, a second circuit 304, a third circuit 306, a common ground 308, and a 4-pole push button 310 carried by the PCA button 299.
25 FIG. 31 shows a wiring diagram 300 having the push button 310 in an at rest position. FIG. 32 shows wiring diagram 301 having the push button 310 in an actuated position. As shown in FIGS. 31 and 32, circuits 302, 304, and 306 share a common ground 308. Though a common ground 308 is the simplest way to wire circuits 302, 304, and 306, it is not required for the invention that the circuits 302, 304, and 306 share a common ground
30 308, as long as the circuits are able to provide signals to a microprocessor associated with the pump user interface 16. Circuits 302, 304, and 306 are designed to provide a status change in signal to the microprocessor. The status change may occur due to the

installation of the PCA button 299 and associated wiring 312. The status change may also occur due to a circuit being connected to ground through push button 310 versus when the circuits are open. Wiring 312 may be enclosed in a cable.

Circuits 302, 304, and 306 are maintained at an energized state when not
 5 connected to ground 308 through button 310. Conversely, circuits 302, 304, and 306 are at a ground state when connected to ground 308 through button 310. For example, circuits 302, 304, and 306 may maintain a small positive voltage when not connected to ground 308 through button 310. The small positive voltage may be coordinated with desired input signals for the microprocessor while considering the safety requirements of
 10 the medical environment.

As circuits 302, 304, and 306 are maintained at an energized state, also known as a "HIGH" state, when not connected to ground, the circuits will all be in a HIGH state when button 310 is not installed. Installation may involve connecting the button 310 to the wiring 312. Installation may also involve connecting the PCA button 299, and
 15 therefore, pushbutton 310 and wiring 312 to infusion pump 10.

Wiring diagram 300 shows push button 310 in an at rest installed position. When button 310 is in the at rest installed position, first circuit 302 is connected to ground directly through wiring 312 and through contacts 310b and 310a and is therefore in the ground state, or "LOW" state. When button 310 is in the actuated position as shown in
 20 wiring diagram 301, first circuit 302 is still connected to ground directly through wiring 312 and through contacts 310c and 310d and is therefore in the LOW state as long as button 310 is installed.

When button 310 is in the at rest installed position, second circuit 304 is connected to ground 308 through contact 310a and is therefore in the LOW state. When
 25 button 310 is in the actuated position as shown in wiring diagram 301, second circuit 304 is not connected to ground 308 and is therefore in the HIGH state.

When button 310 is in the at rest installed position, third circuit 306 is not connected to ground 308 and is therefore in the HIGH state. When button 310 is in the actuated position as shown in wiring diagram 301, third circuit 306 is connected to
 30 ground through contacts 310c and 310d and is therefore in the LOW state.

FIG. 33 shows a table 400 summarizing information provided by the status signals of the three PCA circuits 302, 304, and 306 of FIGS. 31 and 32. Table 400 shows that

the PCA button is not installed if circuits 302, 304, and 306 are all providing a HIGH status signal. If first circuit 302 and second circuit 304 are providing a LOW status signal, while circuit three is providing a HIGH status signal, the button 310 is installed and is in the rest position. If first circuit 302 and third circuit 306 are providing a LOW status signal, while second circuit 304 is providing a HIGH status signal, the button 310 is installed and is actuated. Various other combinations of status signals indicate that a fault exists. Potential faults include, but are not limited to, cable failures, switch malfunctions, and electronic circuit malfunctions. Thus, if one of the wires associated with the PCA button 299 becomes frayed and eventually breaks, a specific reading can be sensed by the user interface to indicate the PCA button 299 requires replacement.

The pump 10 can also be designed with enhanced communication capabilities. For example, the pump 10 can communicate wirelessly with other devices such as a pharmacy computer or personal digital assistants (PDA) carried by hospital personnel. The pump 10 can also be monitored remotely such as from a nurse's station. The pump 10 can be equipped with various types of readers to receive patient information such as from swipe cards or bar-coded identification bracelets. The pump 10 may also utilize RFID readers and tags as discussed above.

In one preferred embodiment of the invention, the pump 10 can communicate with a PDA 500 as shown in FIG. 2. The pump 10 has the infrared data port 76 that is operably coupled with the user interface 16 of the pump 10. The user interface 16 has memory that stores information regarding pump history such as medications delivered, dosage, time, date etc. The information stored by the user interface 16 can be electronically transferred to the PDA 500 carried, for example, by medical personnel. For example, the history button 74 can be depressed on the pump control panel indicating a desire to download pump history. The pump 10 will prompt the user for a password on the video display 60. The password may be necessary for certain regulatory requirements. The pump 10 will then prompt the user for a patient identification number so the proper pump history can be identified. The pump 10 then prompts the user to position the PDA 500 up to the data port 76. Once positioned properly, the pump 10 downloads the proper pump history to the PDA 500. The user can then view the data on the PDA 500, print the pump history or sync the data to another computer as desired. The data can be formatted to be in paginated form.

The pump 10 may also communicate directly to a printer. In one embodiment, a hand-held printer having an appropriate data port, can be held up to the data port 76 of the pump 10. Via infrared communication, data can be transferred from the pump 10 and printed by the hand-held computer.

5 As discussed, the pump 10 provides several advantages. The pump 10 can be powered by either a rechargeable battery unit or a disposable battery unit as is desired by the user. Separate pumps are not required. Because the pump 10 can be powered by battery units, the pump 10 can be used in locations where there are limited electrical outlets. Furthermore, because the transformer for recharging the batteries is contained
10 within the rechargeable battery unit rather than the pump, the rechargeable battery unit can be recharged simply by plugging the unit into a wall outlet. The pump is not required. Accordingly, the pump 10 can be equipped with a second unit and remain in use while the first unit is being recharged. Also, the transformer is better stored within the battery unit housing rather than being located at the end of the power cord. The
15 syringe loaded is improved as a syringe assembly can be easily loaded with a single hand. The syringe sensors are improved and are more reliable. The sensors provide a direct measurement of, for example, plunger position rather than an indirect measurement. The magnet and sensors are positioned directly at the syringe plunger providing a direct measurement of plunger position. The sensor system has fewer parts in general and does
20 not utilize additional moving parts that are subject to wear. This improves reliability. The rotary nut associated with the drive mechanism provides a more smooth and reliable mechanism.

While the specific embodiments have been illustrated and described, numerous
modifications can be made to the present invention, as described, by those of ordinary skill
25 in the art without significantly departing from the scope of the invention. The scope of the claims should not be limited by the specific embodiments set forth above, but should be given the broadest interpretation consistent with the description as a whole.

What is claimed is:

1. An infusion pump comprising:

a housing including a compartment structured to receive a syringe, the syringe including a syringe barrel and a syringe plunger moveable within the syringe barrel;

a drive mechanism supported by the housing, the drive mechanism structured and arranged to contact the syringe plunger and move the syringe plunger within the syringe barrel; and

a syringe plunger position sensor including:

a magnet positioned on the drive mechanism;

a magnetic sensor array supported by the housing and positioned adjacent to the magnet, the magnetic sensor array configured to generate an output indicative of a magnetic field associated with the magnet; and

software installed on the pump and configured to use the output to determine a linear position of the syringe plunger within the syringe barrel.

2. The infusion pump of Claim 1, wherein the drive mechanism includes a motor, a lead screw rotatably coupled to the motor, and a connecting linkage operably connected to the lead screw, wherein rotation of the motor causes the lead screw to rotate and move the connecting linkage to thereby move the syringe plunger within the syringe barrel, wherein the magnet is coupled to the connecting linkage.

3. The infusion pump of Claim 2, wherein the magnet is coupled to a syringe plunger engagement member of the connecting linkage.

4. The infusion pump of Claim 2, wherein the connecting linkage includes an occlusion sensor configured to determine if an infusion line connected to the syringe barrel is blocked.

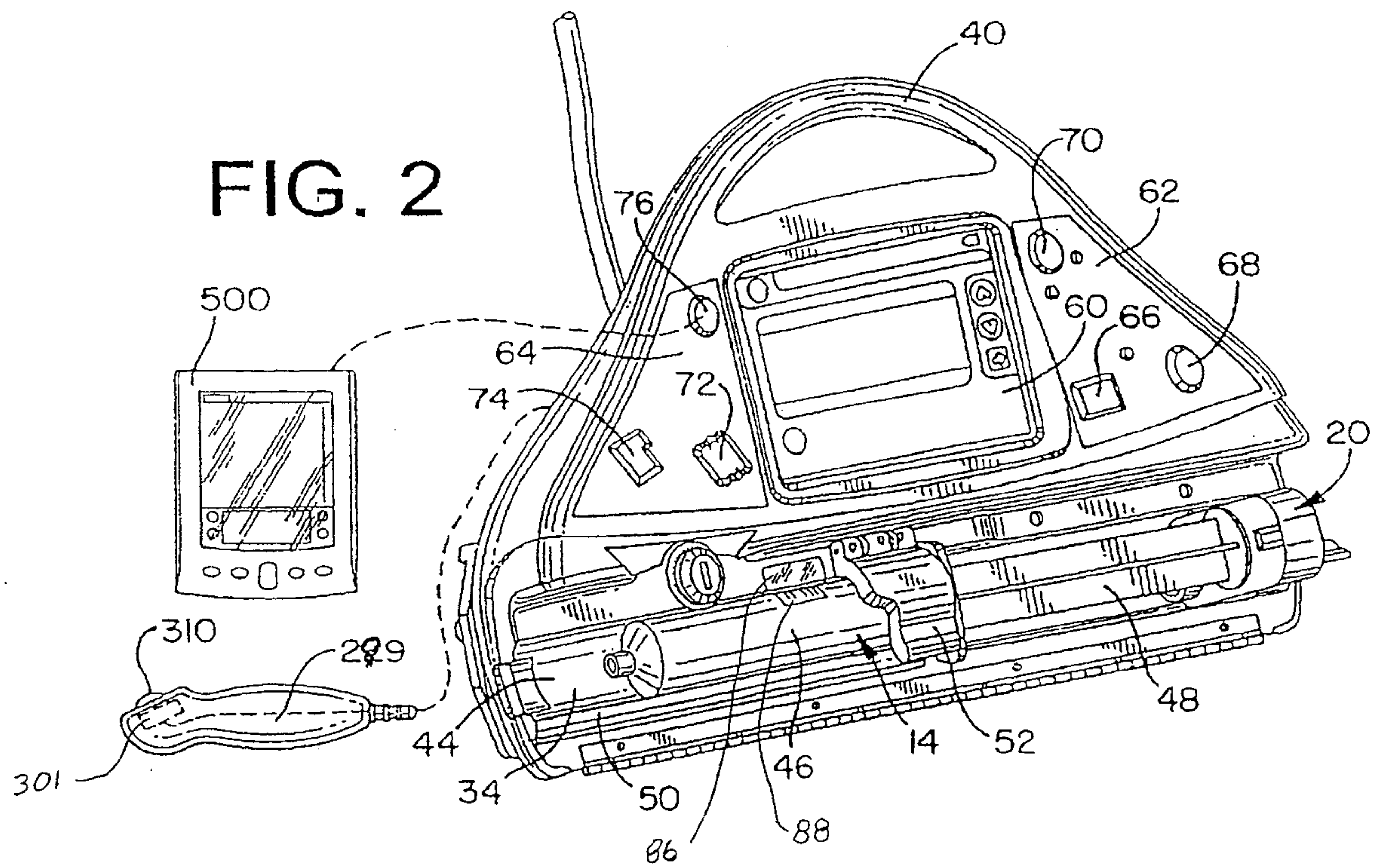
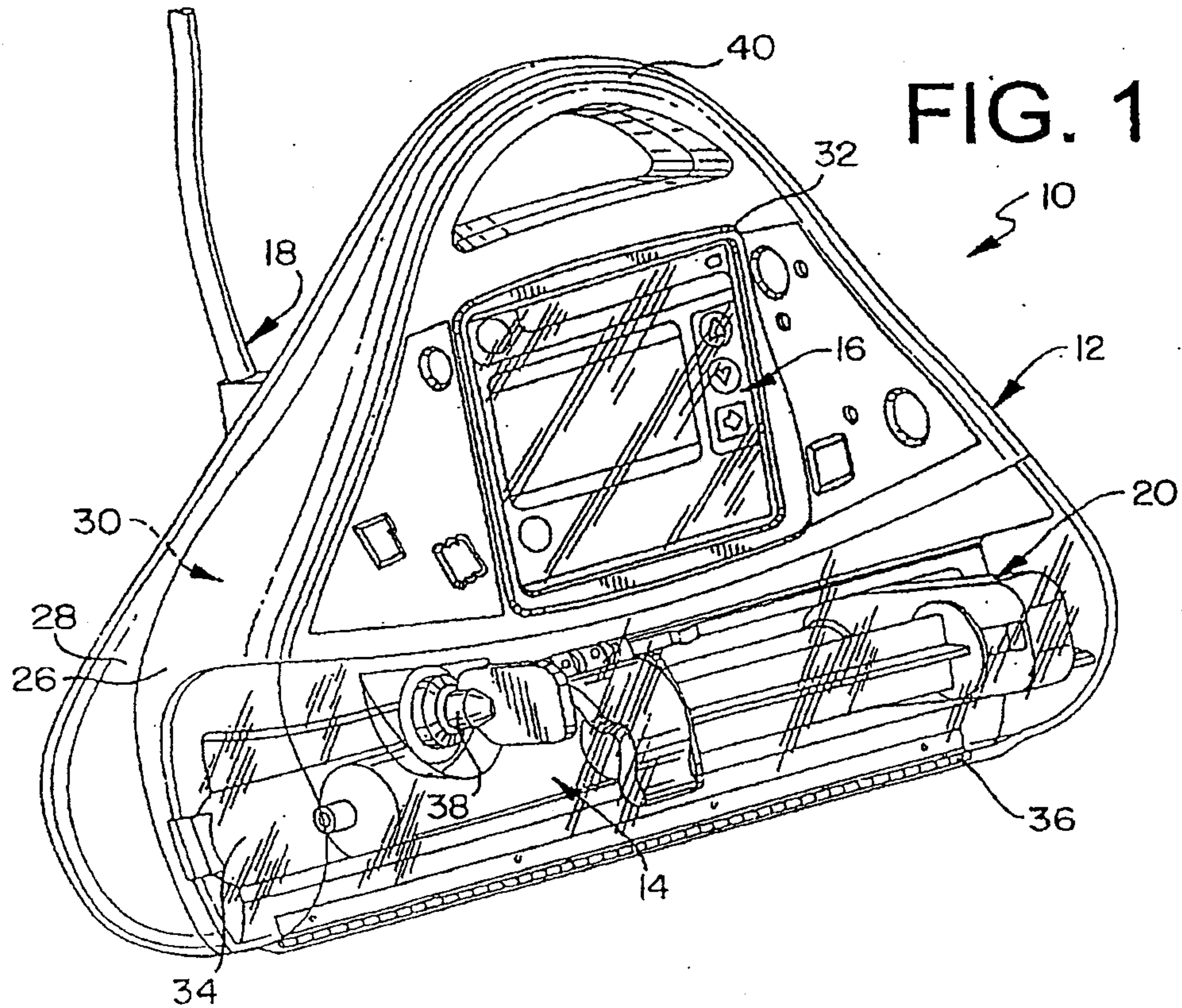
5. The infusion pump of Claim 4, wherein the connecting linkage includes a plunger engagement member configured to engage an end of the syringe barrel, the plunger engagement member including the occlusion sensor.

6. The infusion pump of Claim 1, wherein the magnetic sensor array is a linear array of magnetic sensors.

7. The infusion pump of Claim 1, wherein the magnetic sensor array is configured to compensate for temperature changes.
8. The infusion pump of Claim 1, wherein the magnetic sensor array is configured to produce a sine wave signal to determine the linear position of the plunger within the syringe barrel.
9. The infusion pump of Claim 1, the wherein the magnetic sensor array is positioned on the housing.
10. The infusion pump of Claim 1, wherein the syringe plunger position sensor includes an electromagnetic sensor.
11. An infusion pump operable with a syringe having a syringe barrel and a syringe plunger moveable within the syringe barrel, the infusion pump comprising:
 - a housing including;
 - a compartment structured to receive the syringe and defining a wall; and
 - a syringe clamp moveable towards and away from the wall, the syringe contacting the syringe barrel when the syringe clamp is moved towards the wall;
 - a drive mechanism supported by the housing, the drive mechanism structured and arranged to contact an end of the syringe plunger so as to be able to move the syringe plunger within the syringe barrel; and
 - a syringe barrel size sensor including:
 - a magnet operably coupled to the syringe clamp; and
 - a sensing member supported by the housing and configured to generate an output indicative of a magnetic field associated with the magnet; and
 - software installed on the pump and configured to use the output to determine a size of the syringe barrel received by the compartment.
12. The infusion pump of Claim 11, wherein the magnet is positioned on the syringe clamp.
13. The infusion pump of Claim 11, wherein the sensing member includes a plurality of electromagnetic sensors.

14. The infusion pump of Claim 11, wherein the sensing member includes a linear sensor array.
15. The infusion pump of Claim 11, wherein the sensing member is a single electromagnetic sensor.
16. An infusion pump method comprising:
 - sensing a magnetic field associated with a first magnet coupled to a syringe clamp to determine a size of a syringe barrel received in a housing of an infusion pump; and
 - sensing a magnetic field associated with a second magnet to determine a linear position of a syringe plunger moveable inside the syringe barrel.
17. The infusion pump method of Claim 16, which includes linearly sensing the magnetic field associated with the first magnet to determine the size of the syringe barrel.
18. The infusion pump method of Claim 16, which includes linearly sensing the magnetic field associated with the second magnet to determine the linear position of the syringe plunger moveable inside the syringe barrel.
19. The infusion pump method of Claim 16, which includes sensing an orientation of magnetic field lines associated with (i) the first magnet and (ii) the second magnet to determine (a) the size of the syringe barrel and (b) the linear position of the syringe plunger moveable within the syringe barrel, respectively.

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FIG. 3a

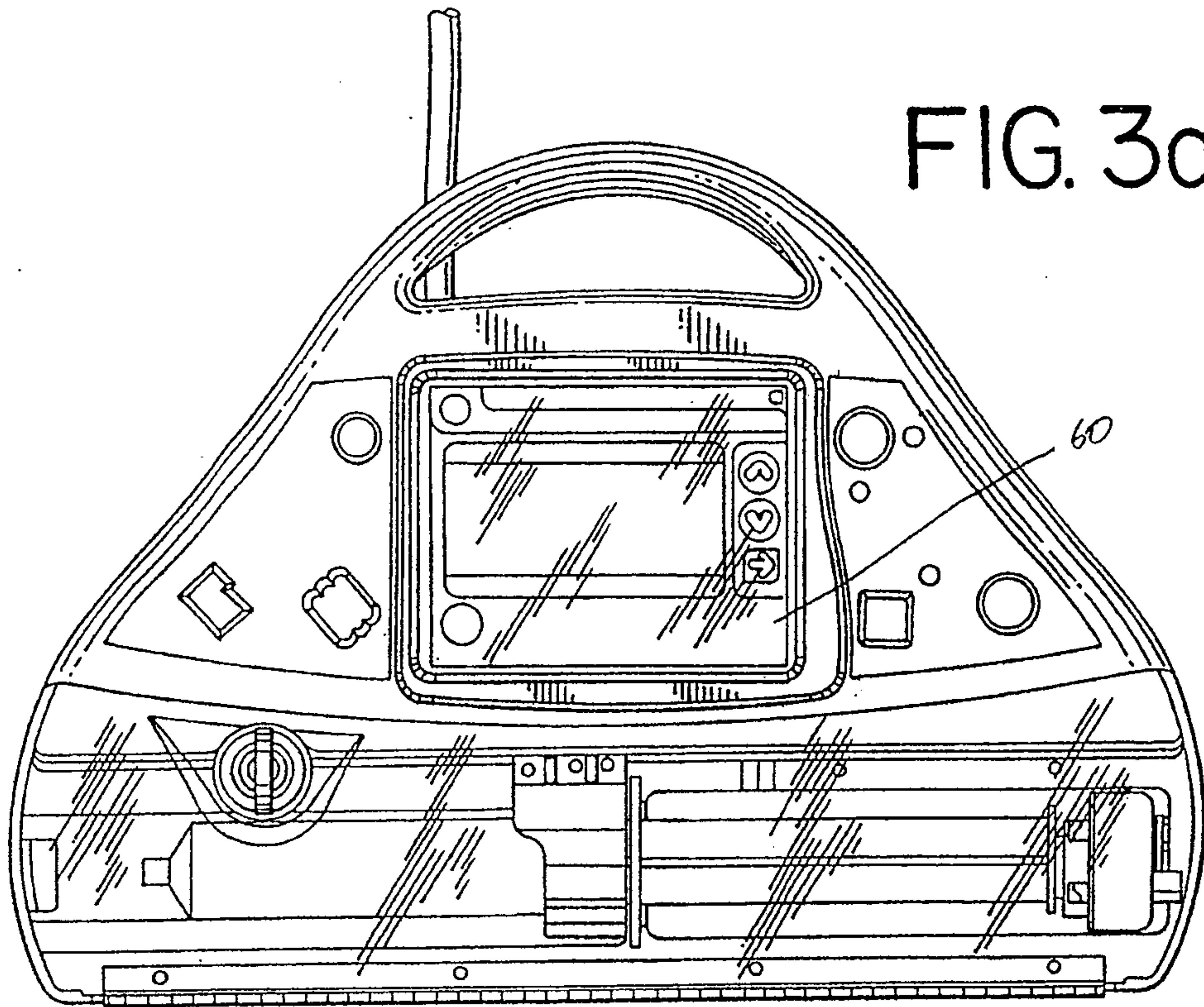
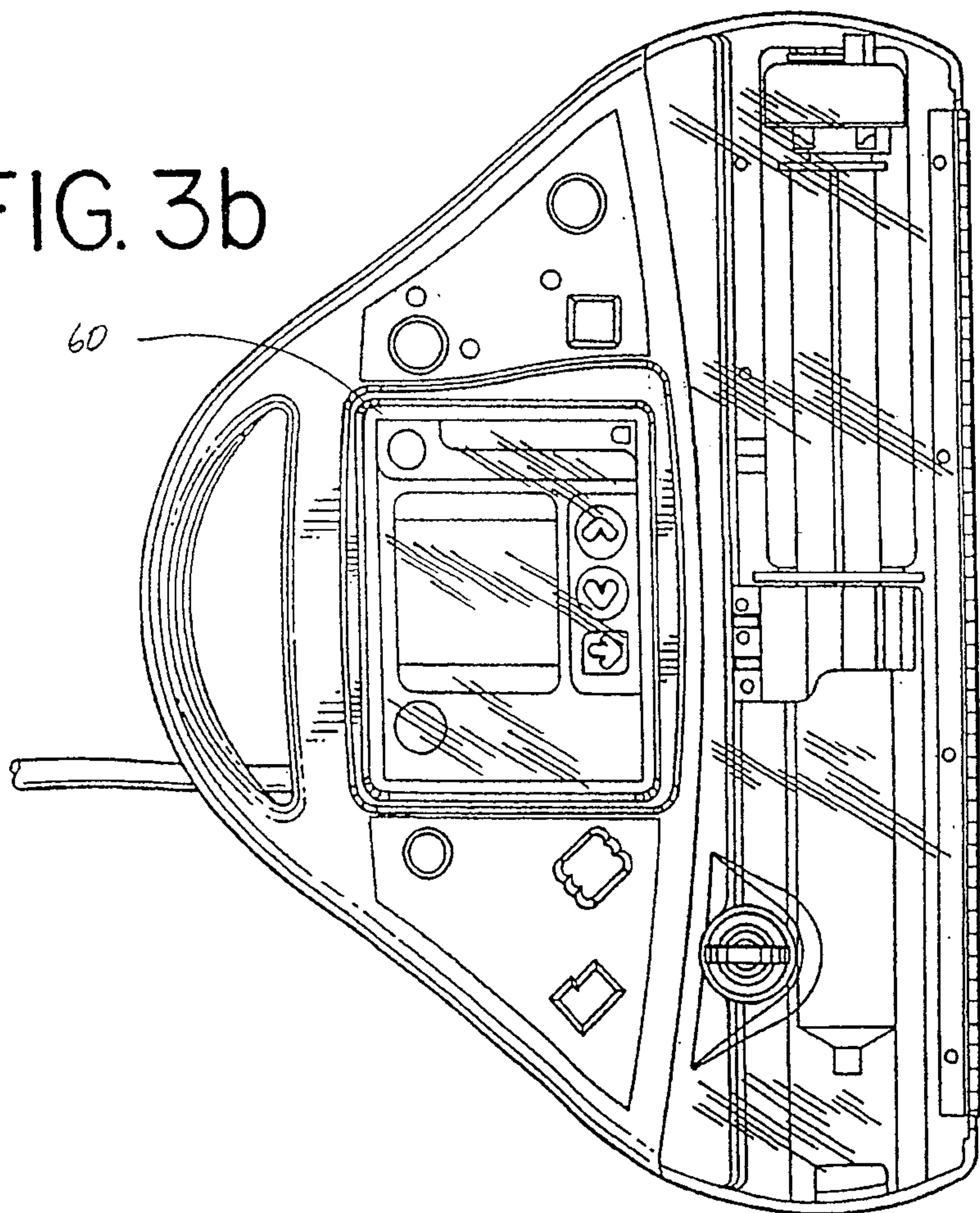


FIG. 3b



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FIG. 4A

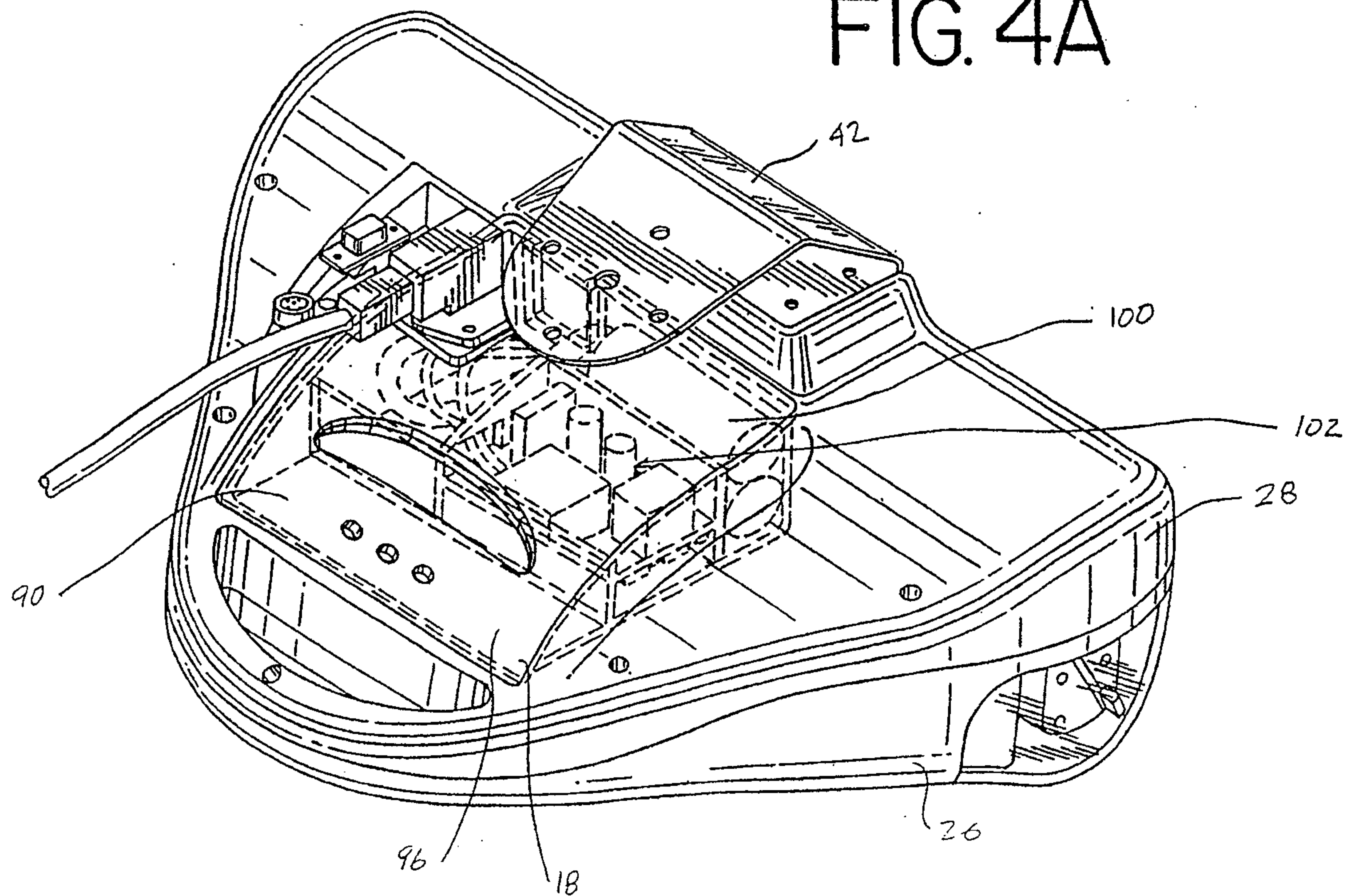
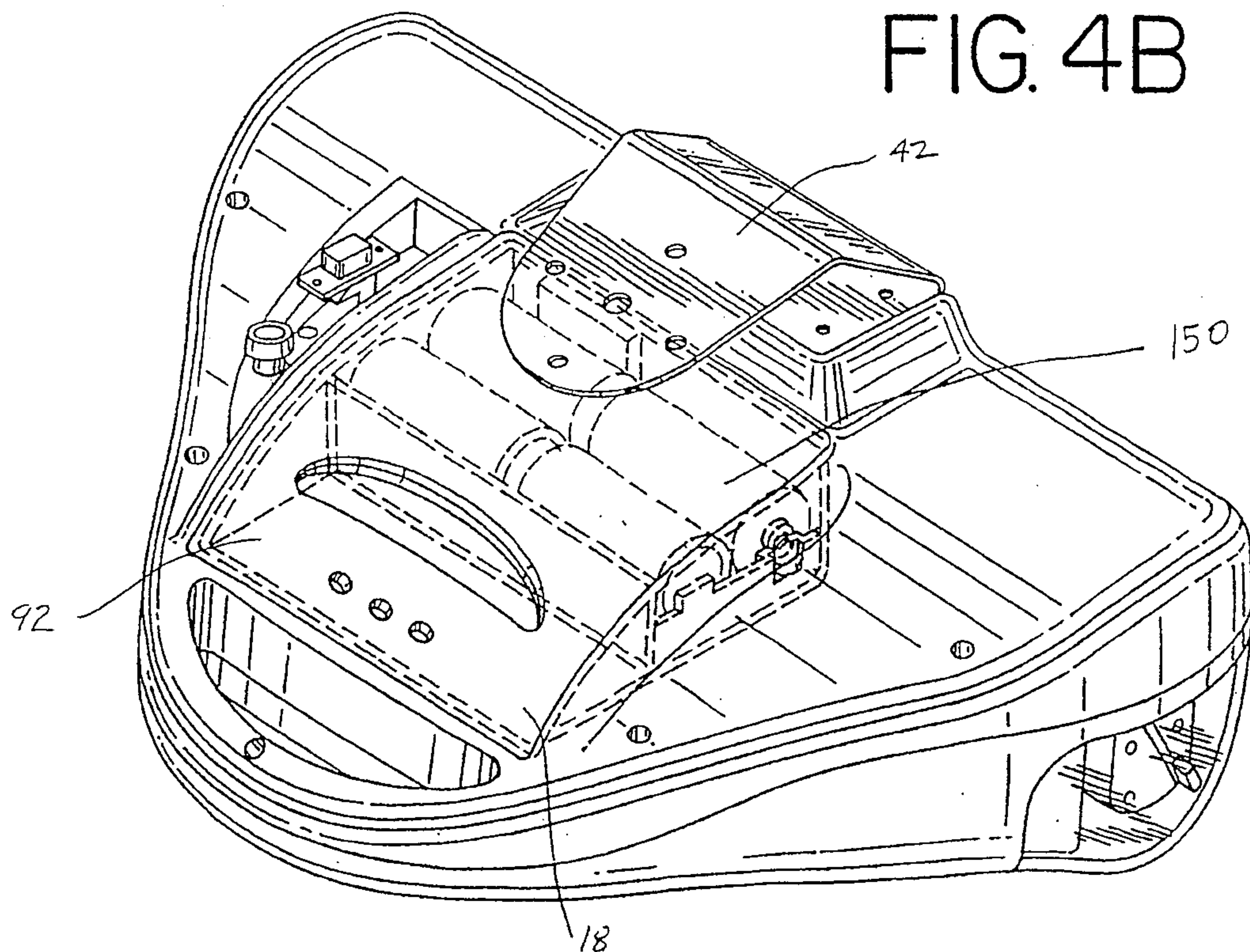
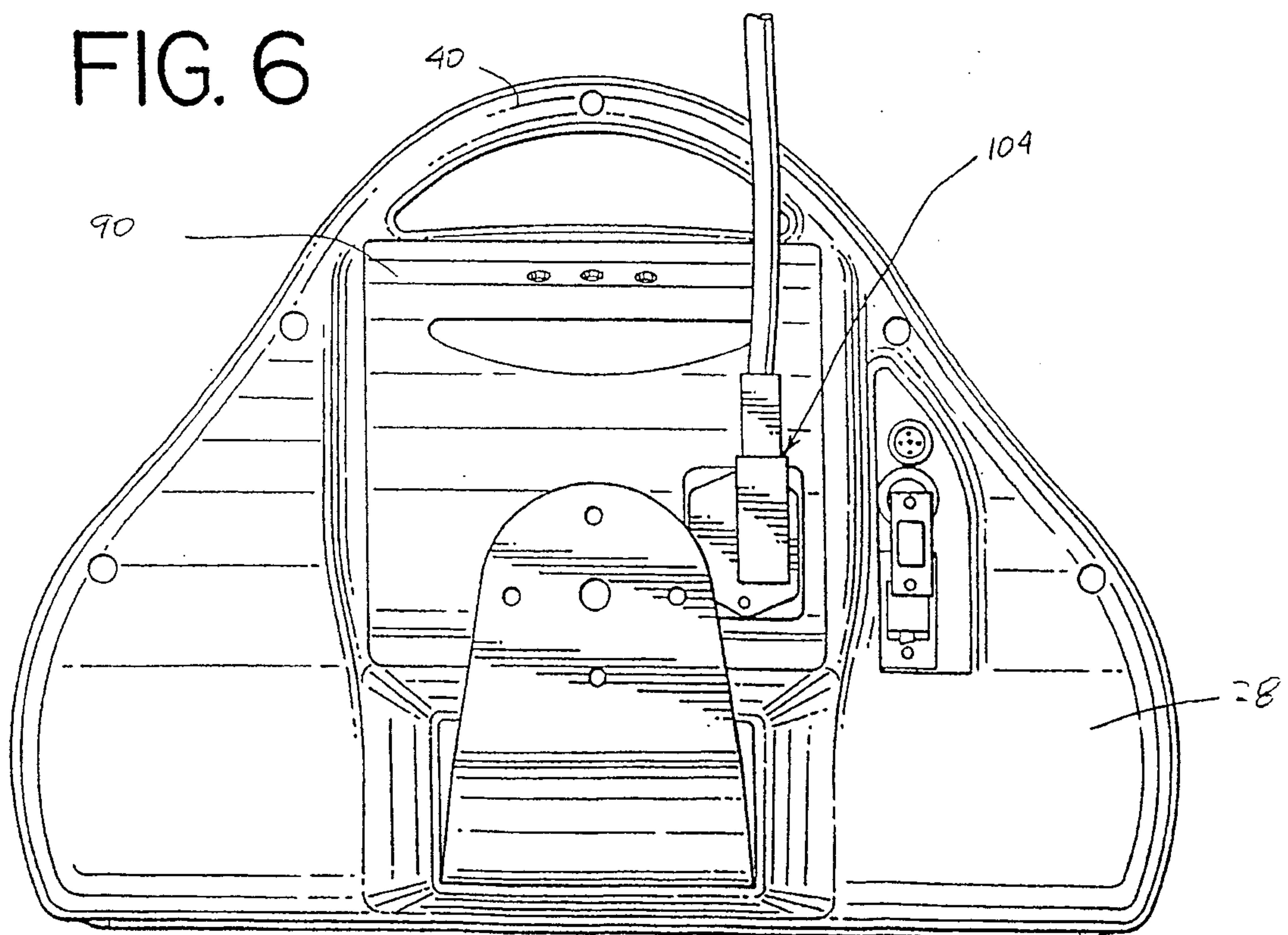
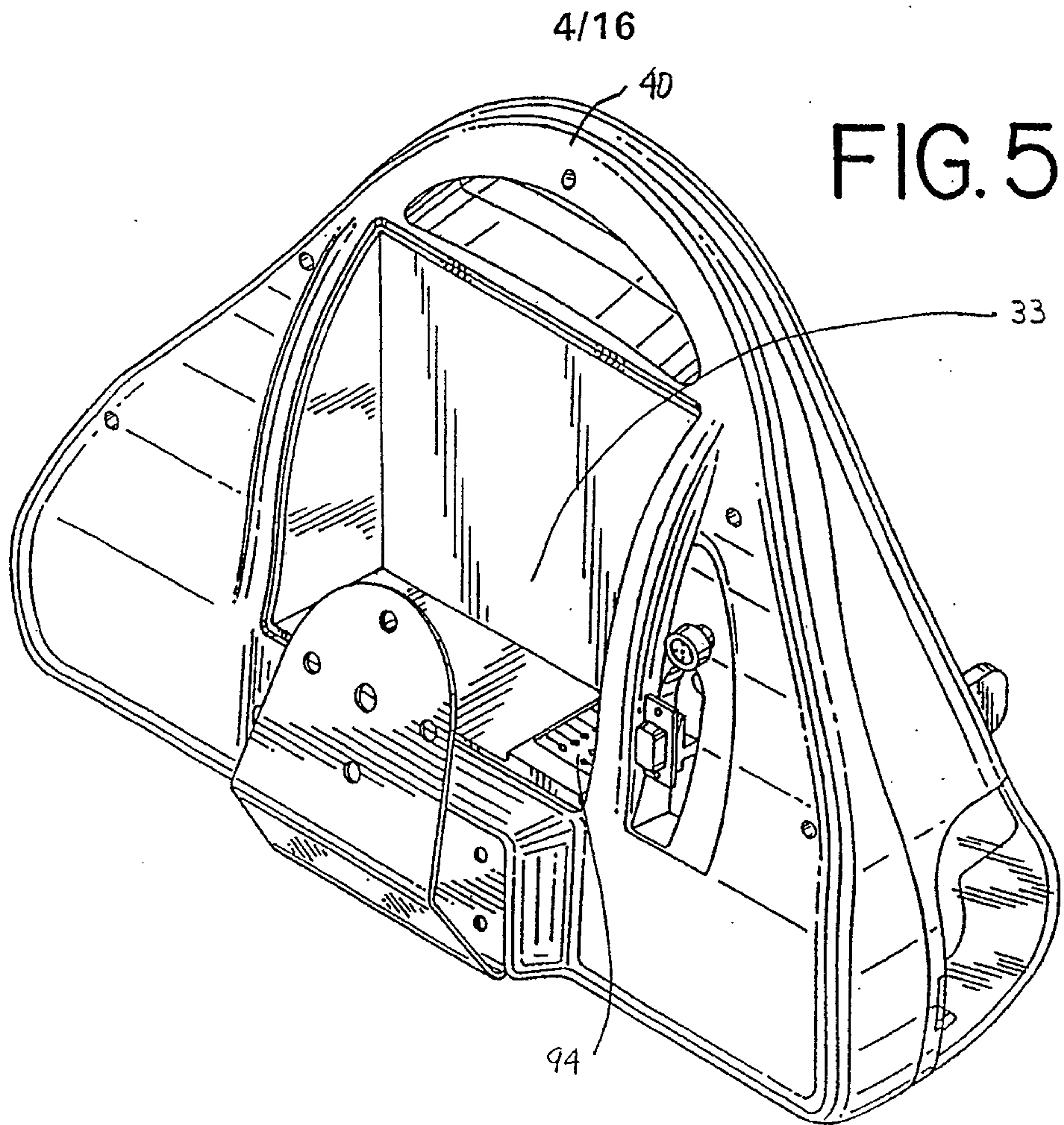


FIG. 4B





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FIG. 7

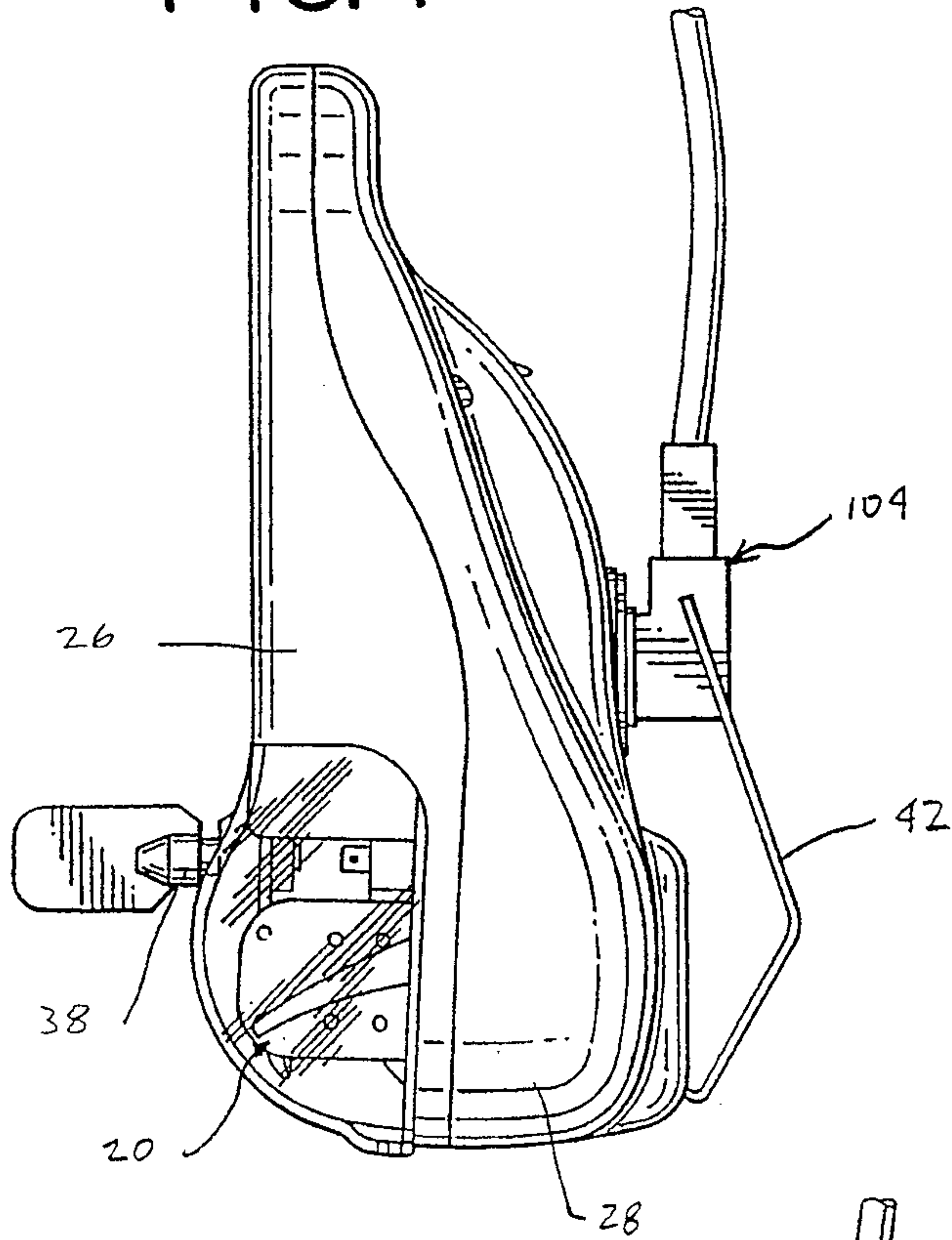
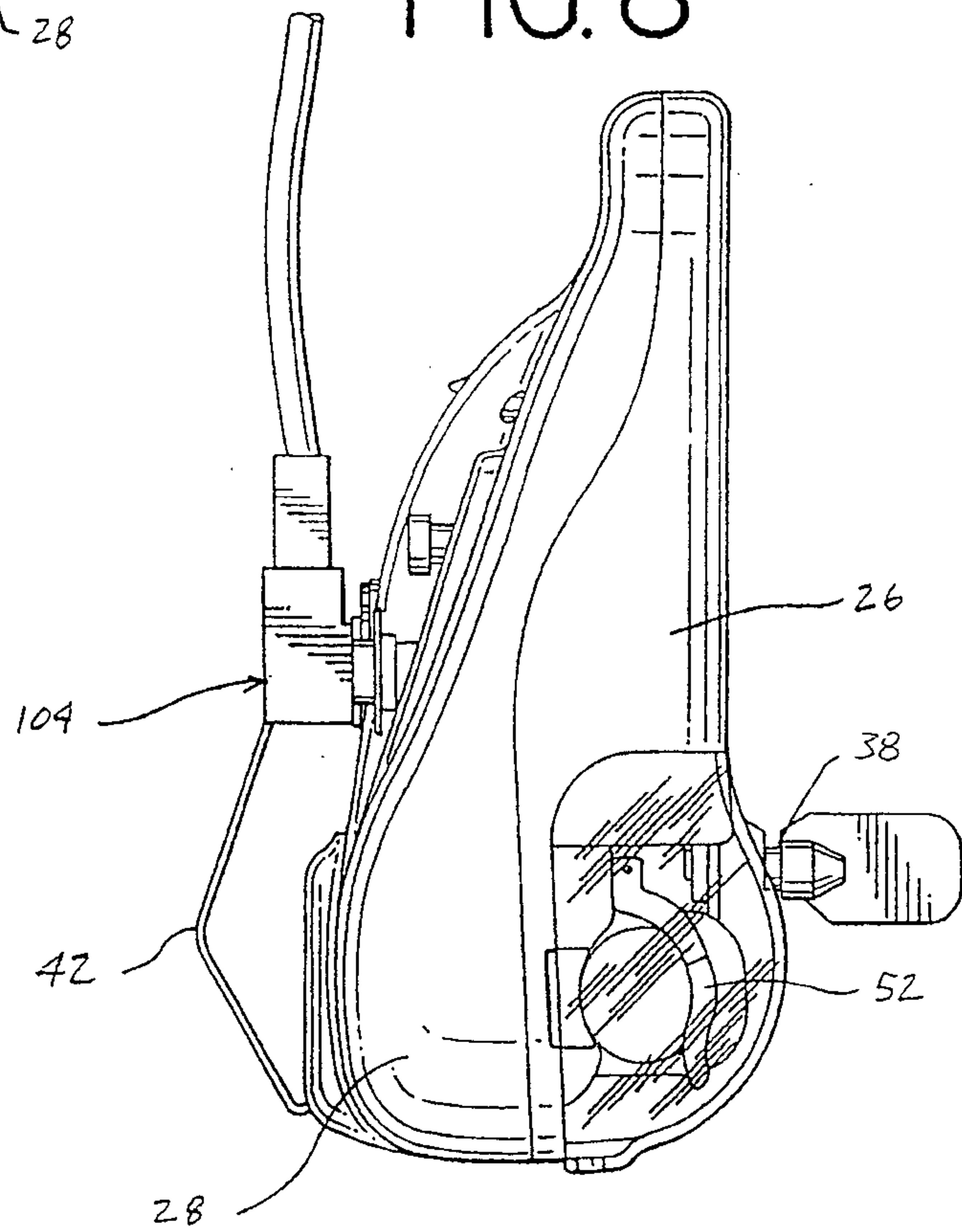


FIG. 8



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FIG. 9

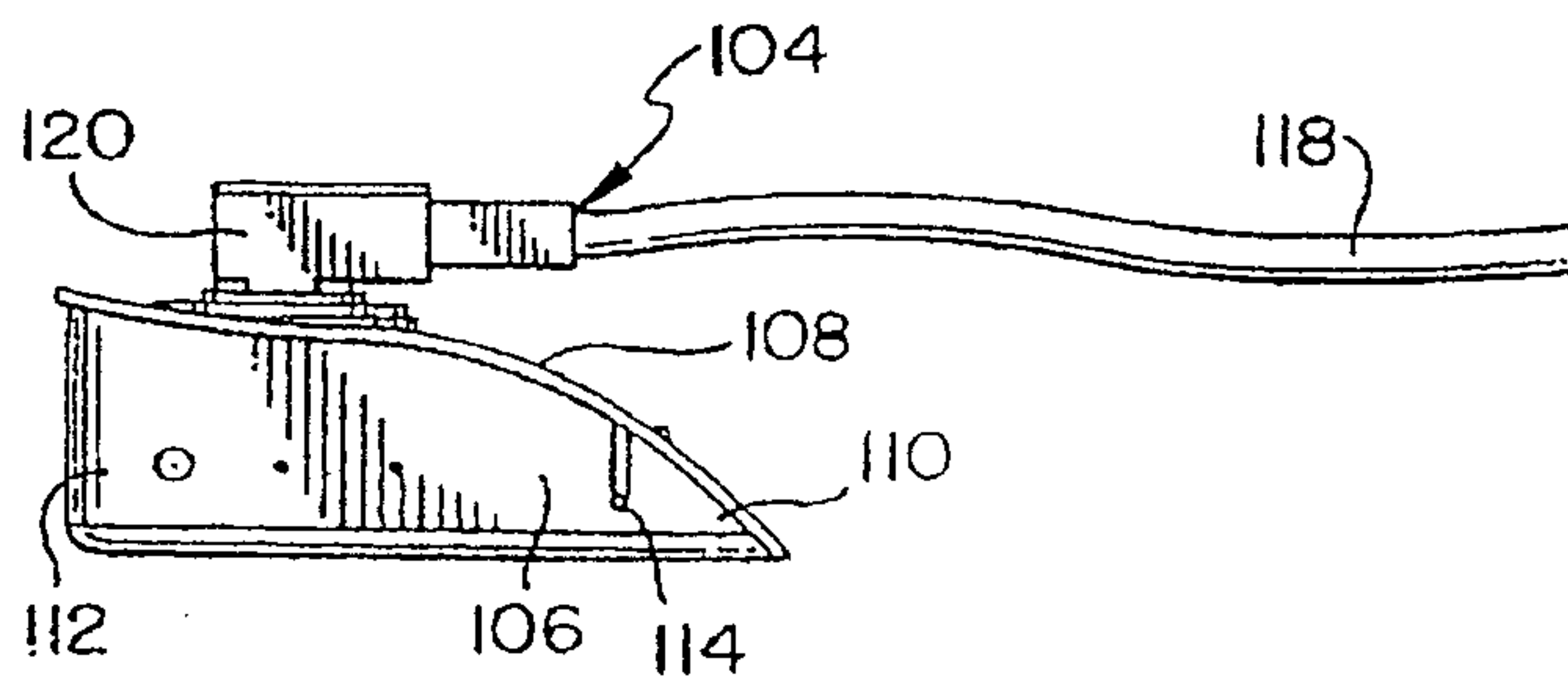
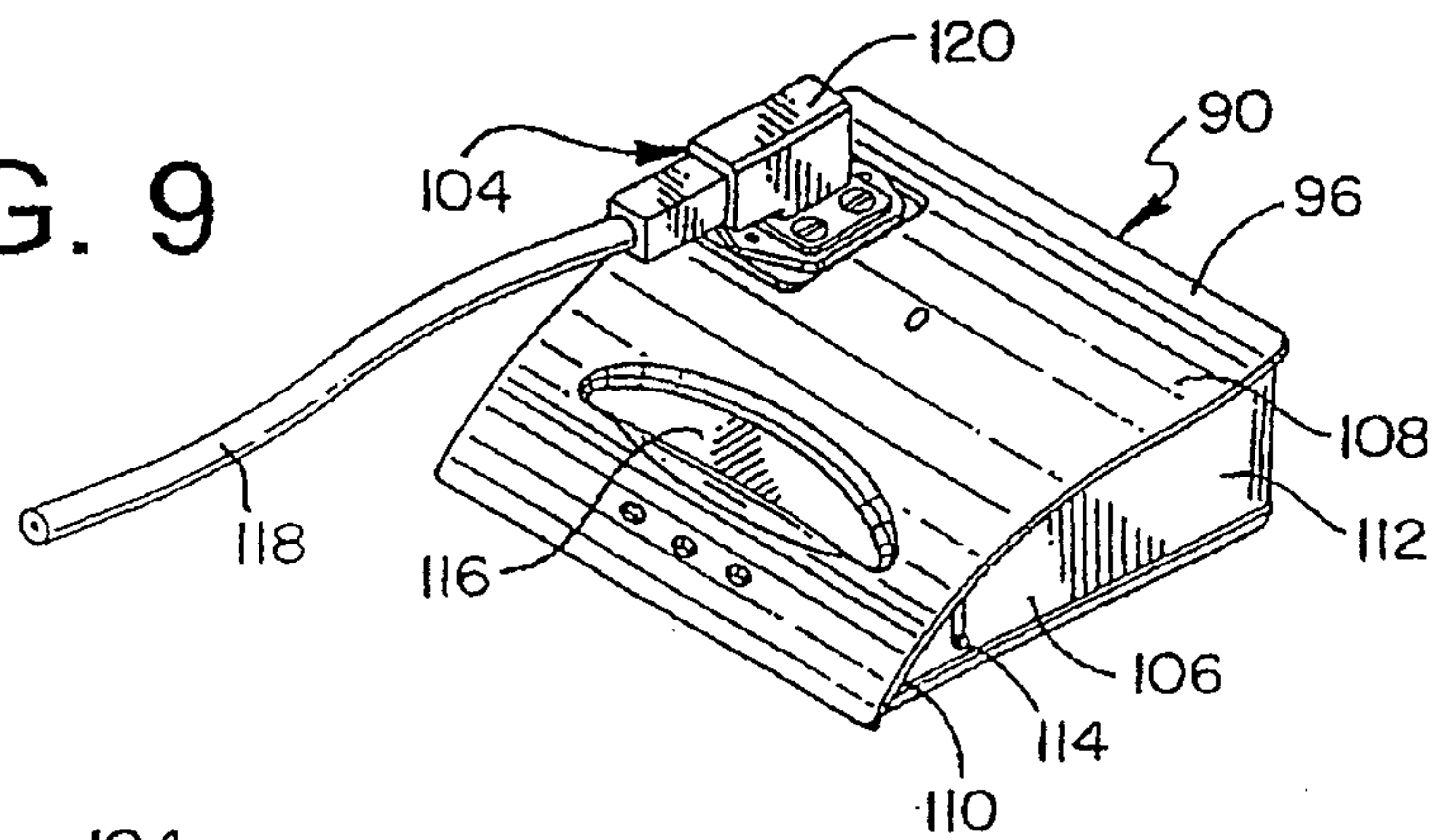


FIG. 10

FIG. 11

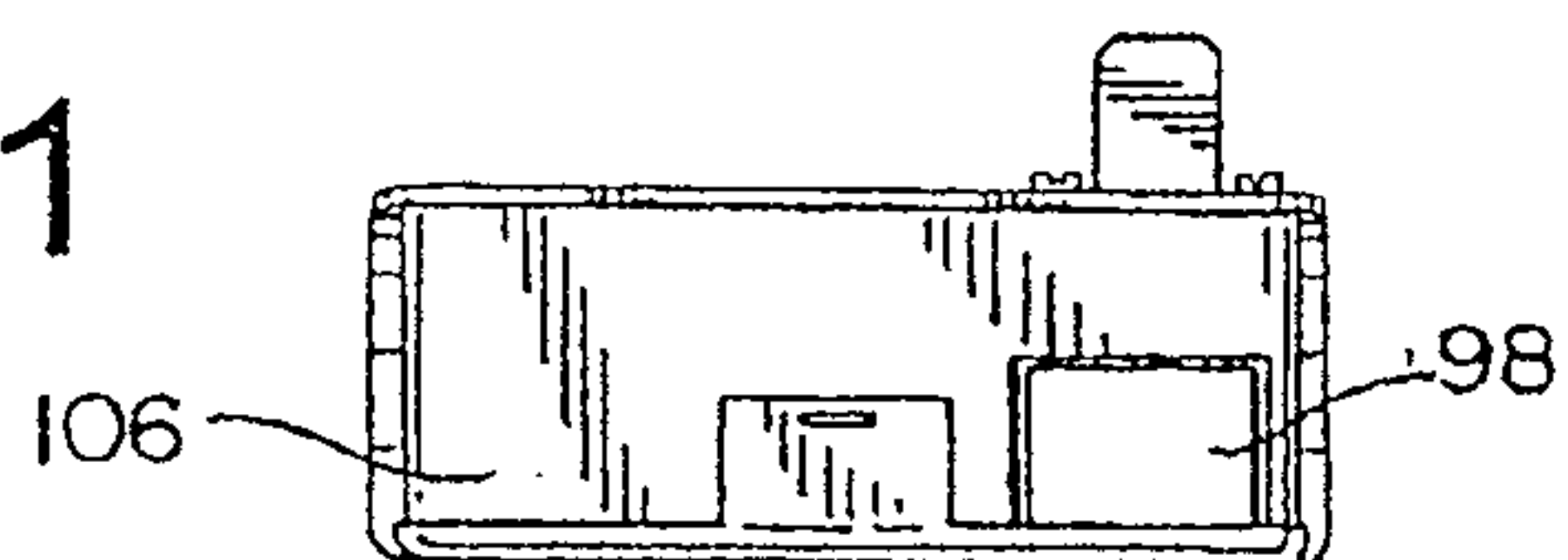
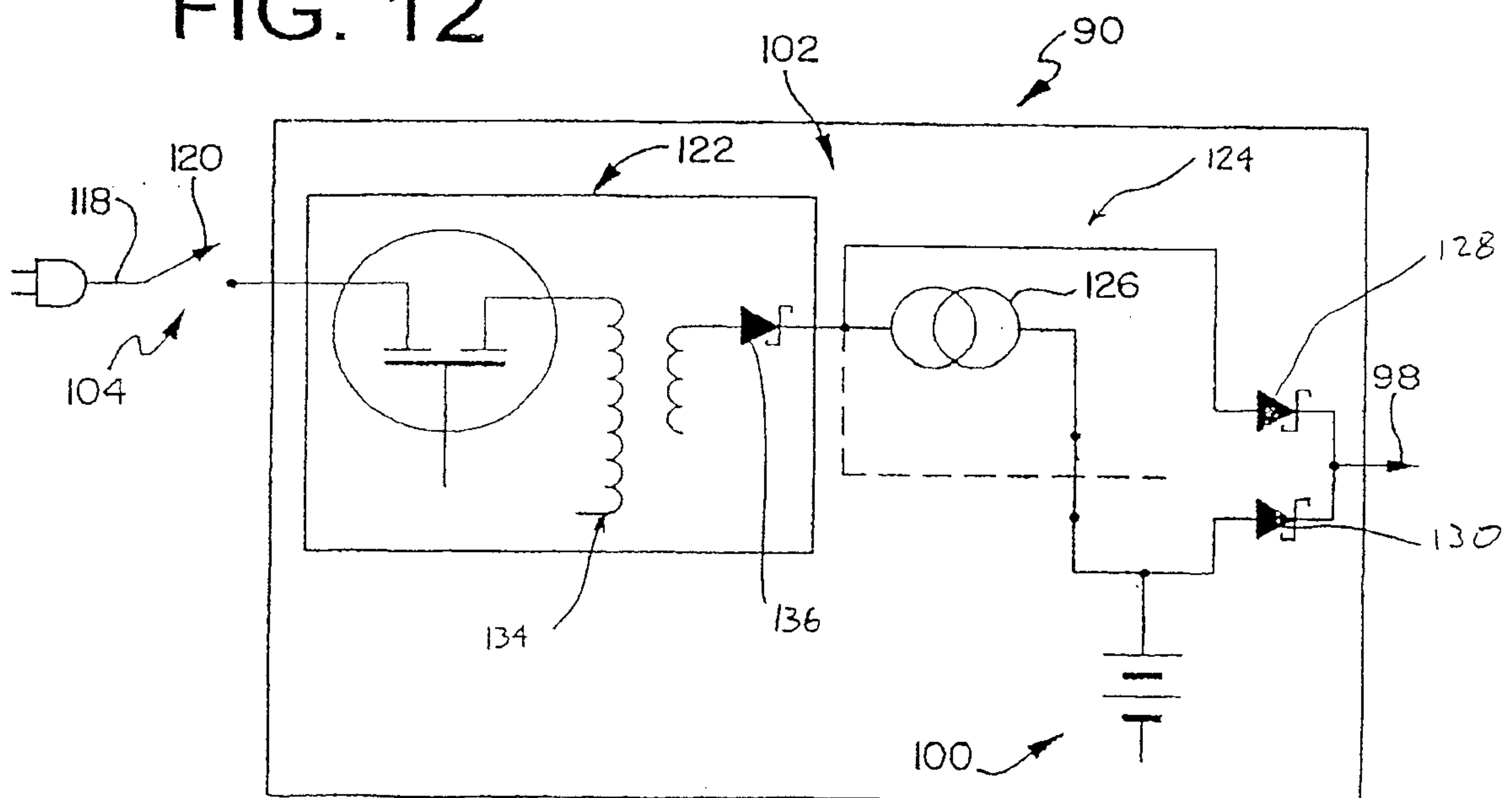
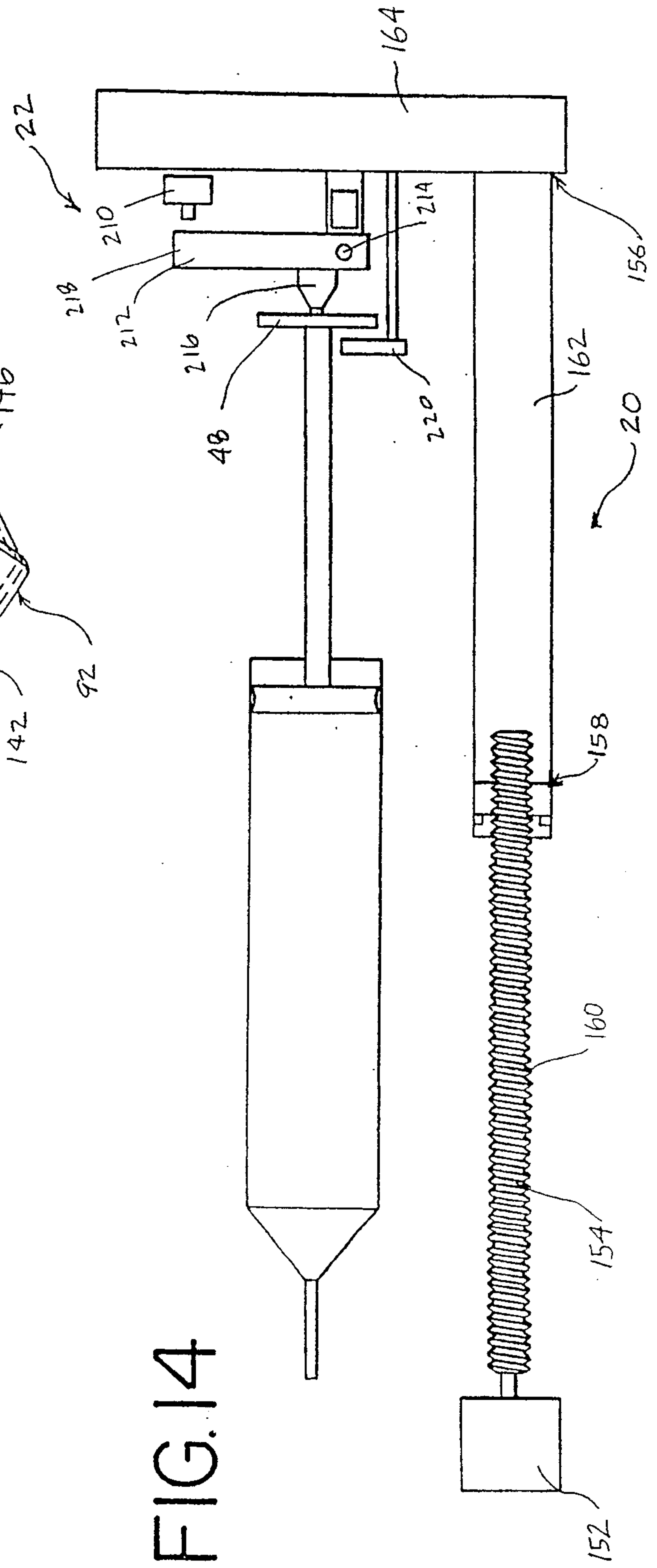
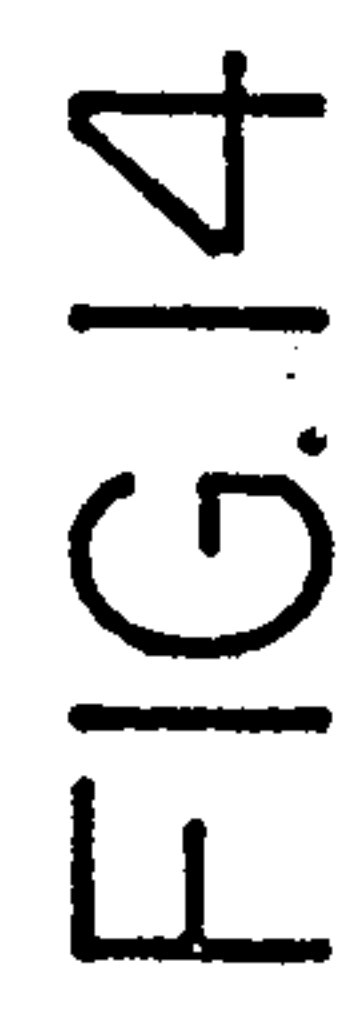
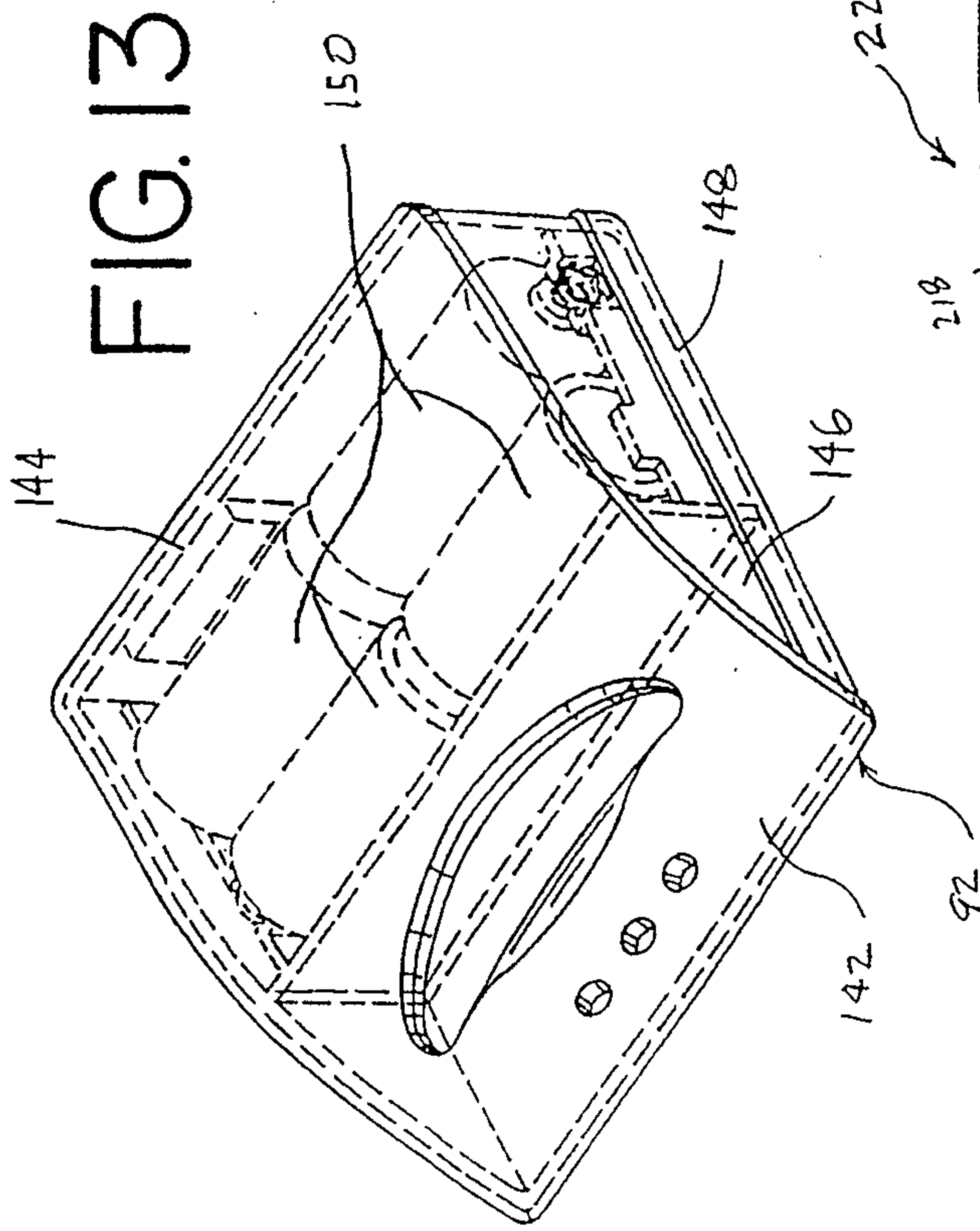


FIG. 12





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FIG. 15

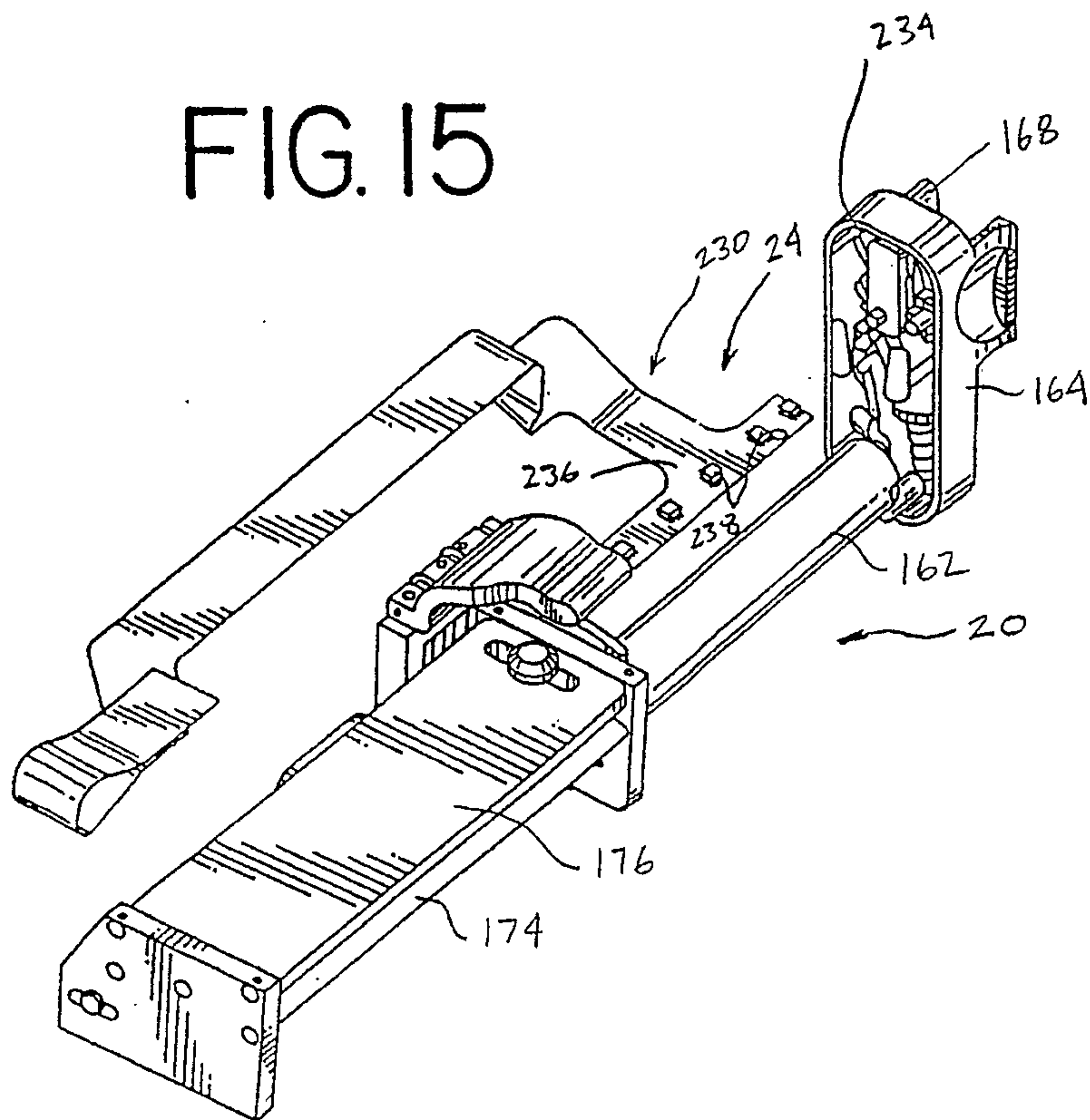
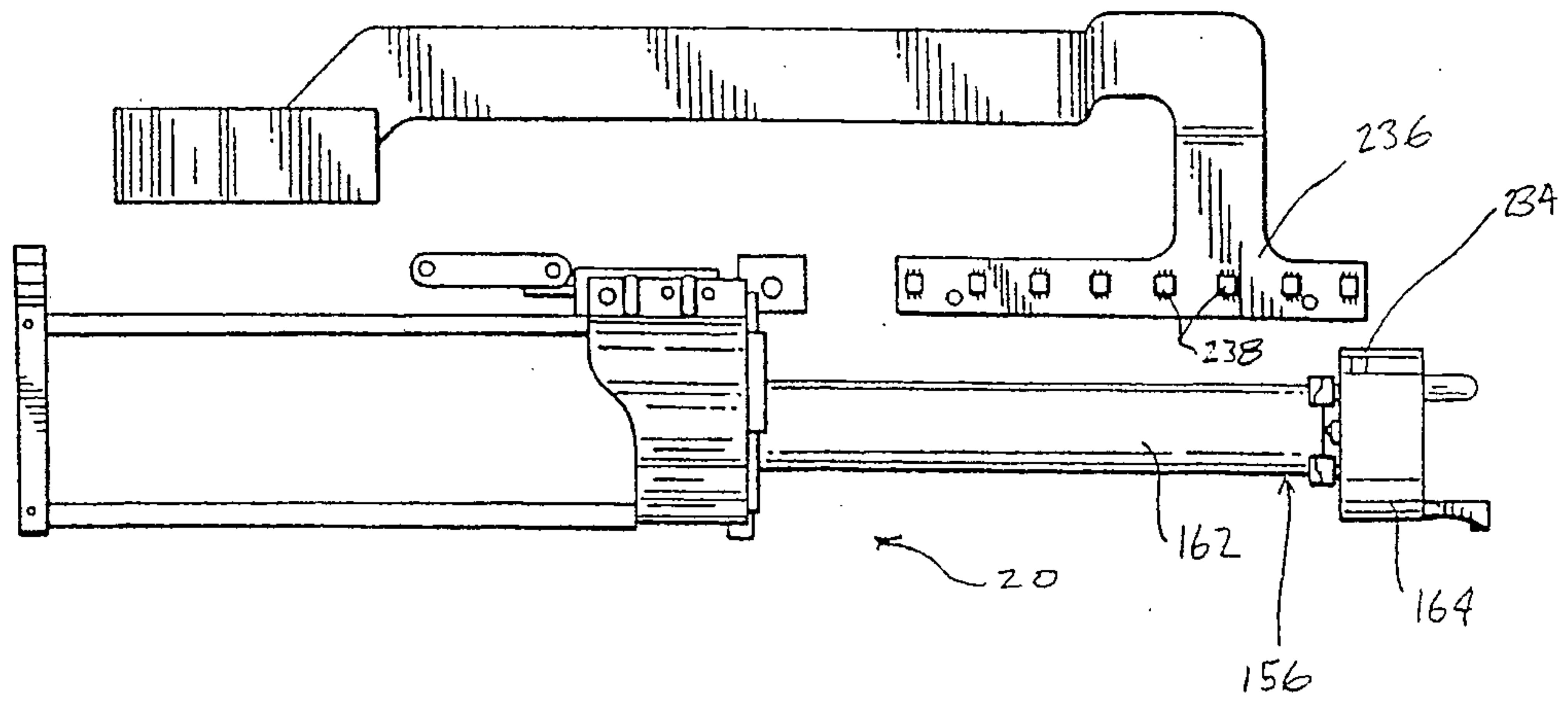
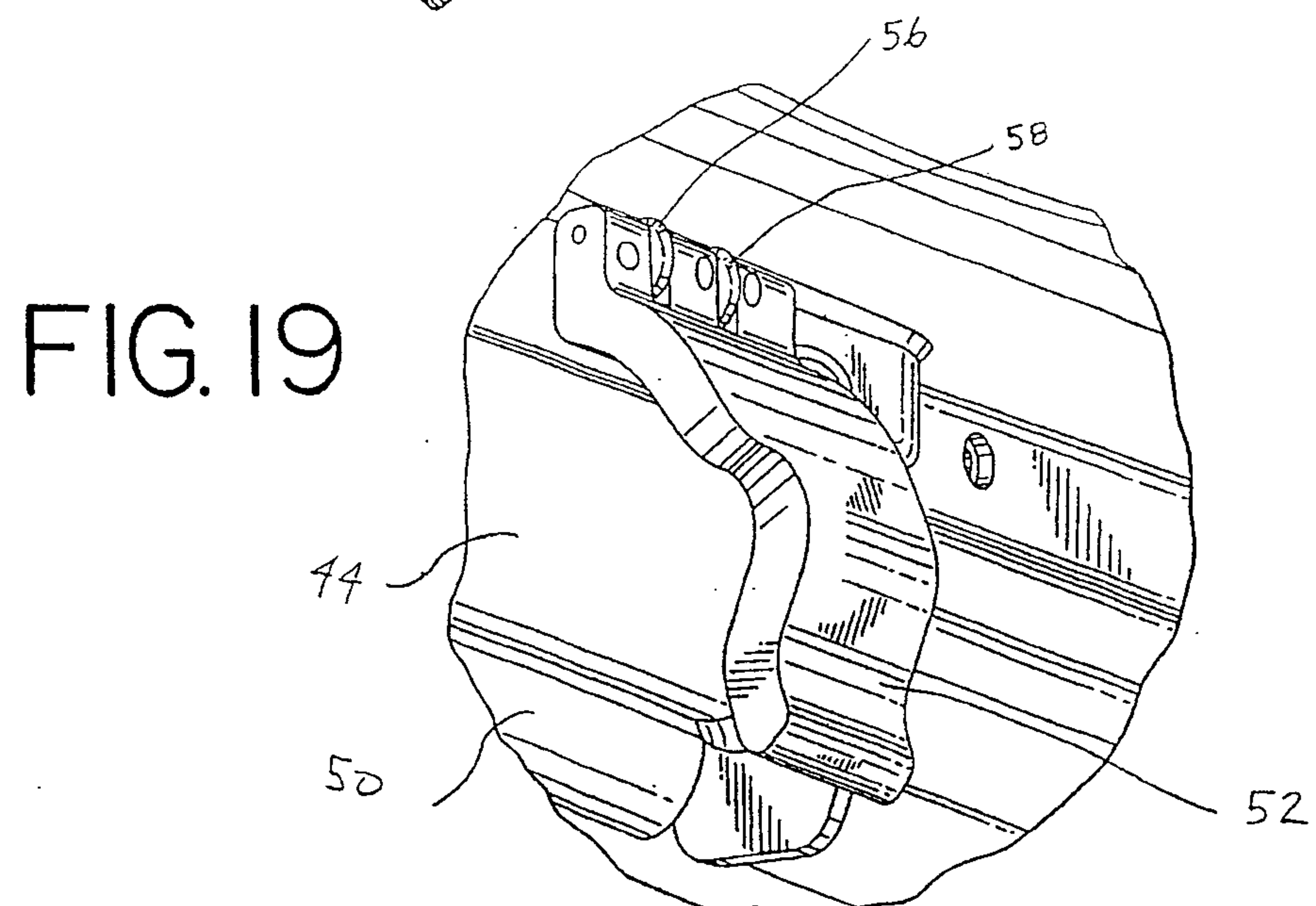
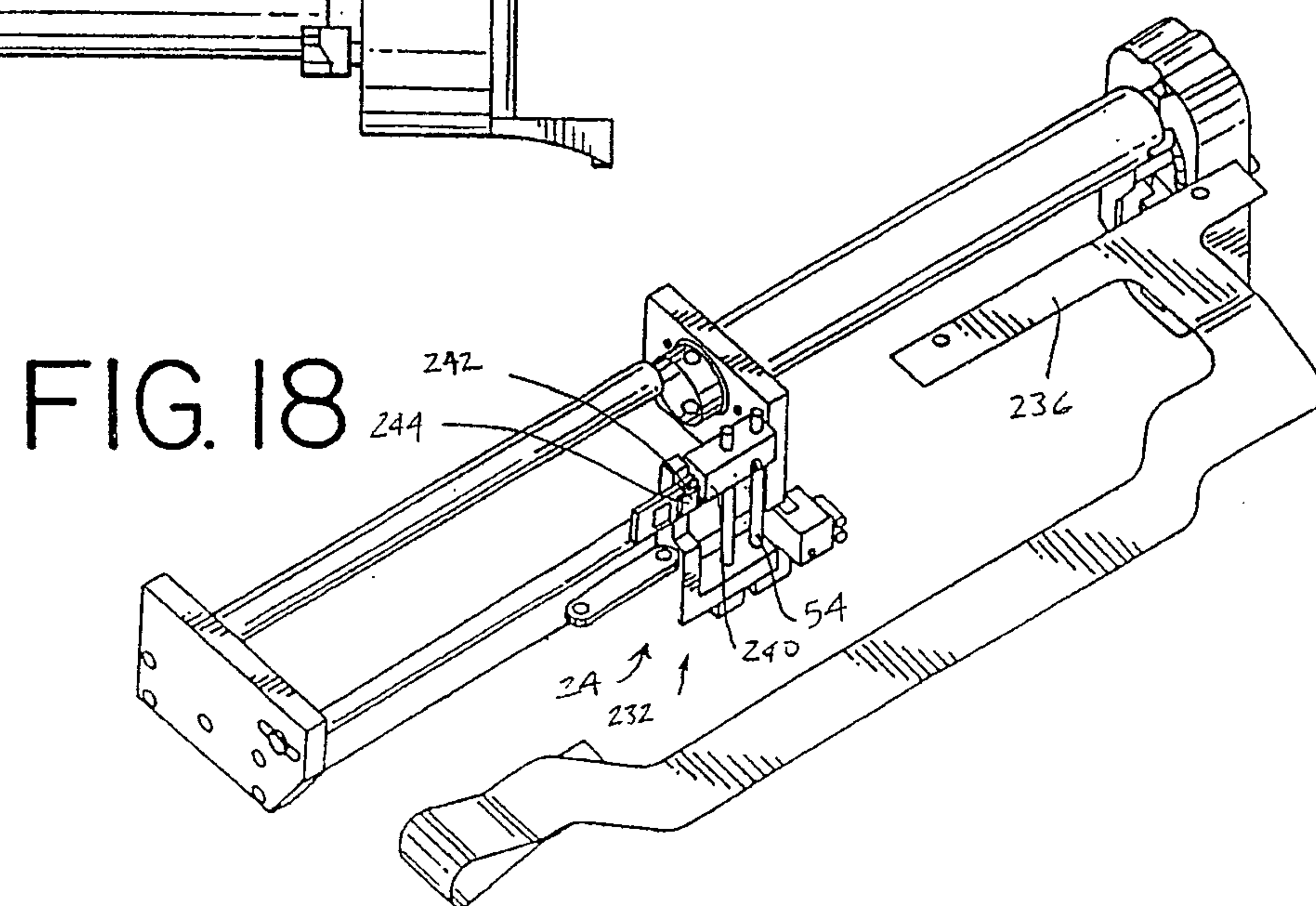
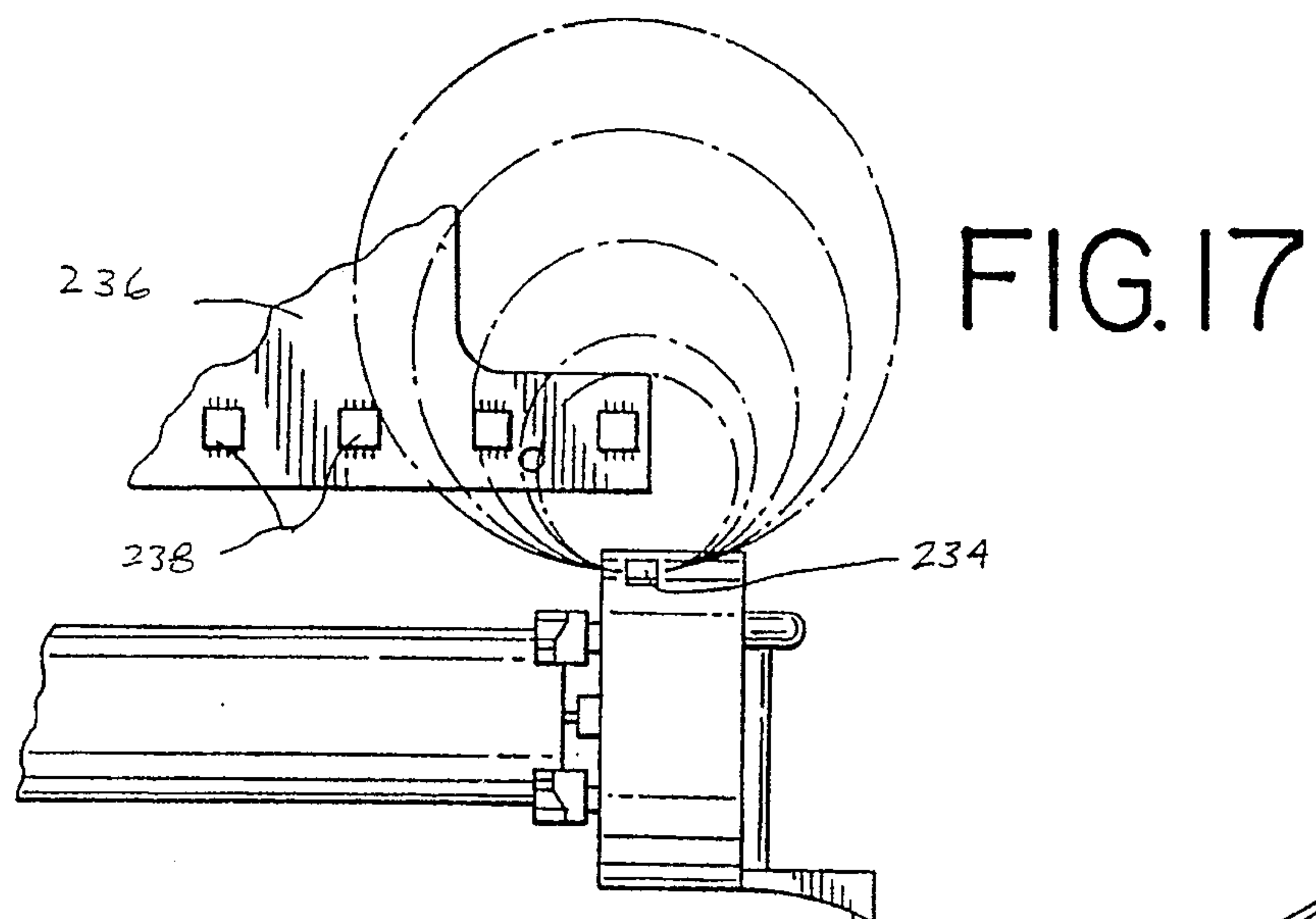


FIG. 16



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FIG. 20

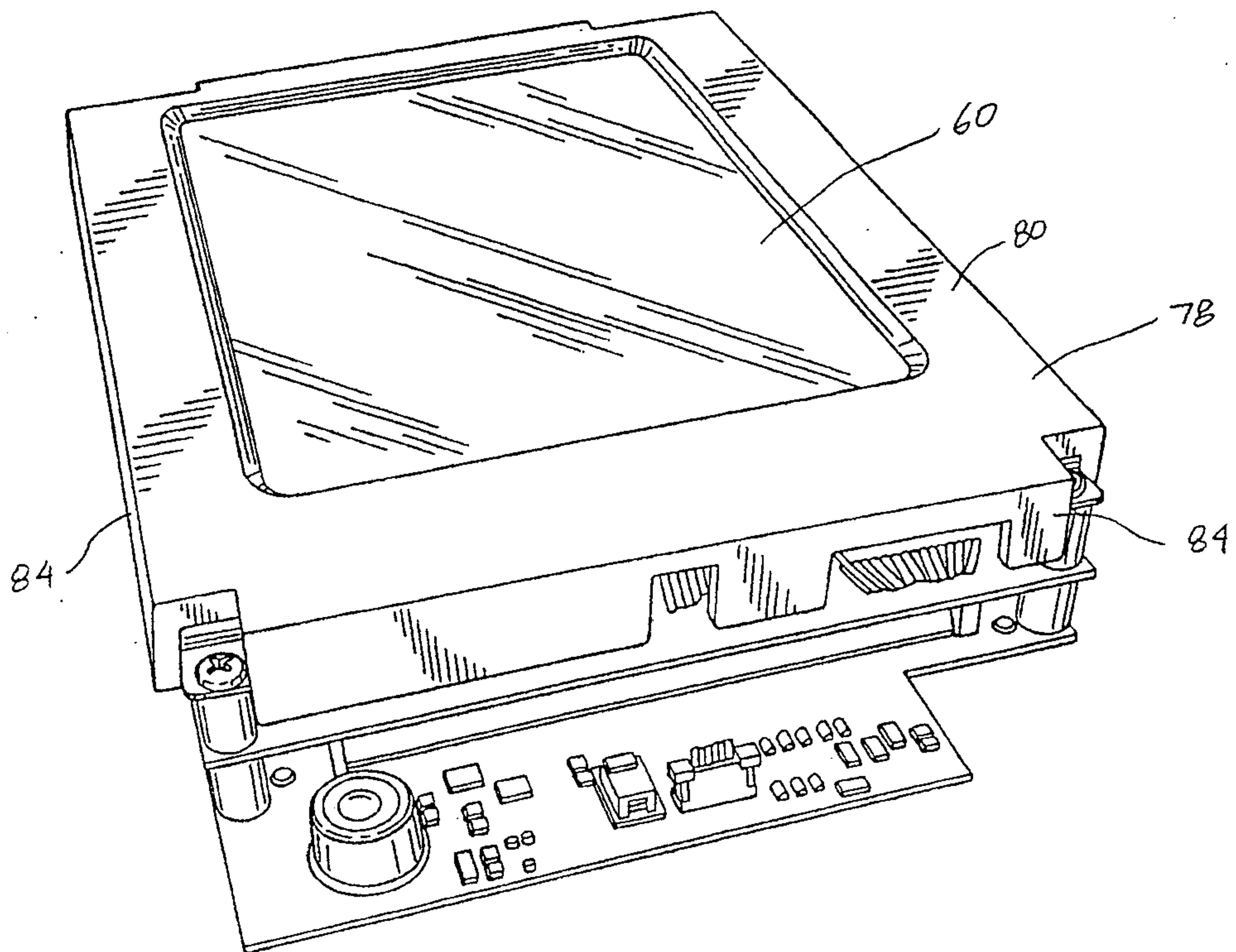
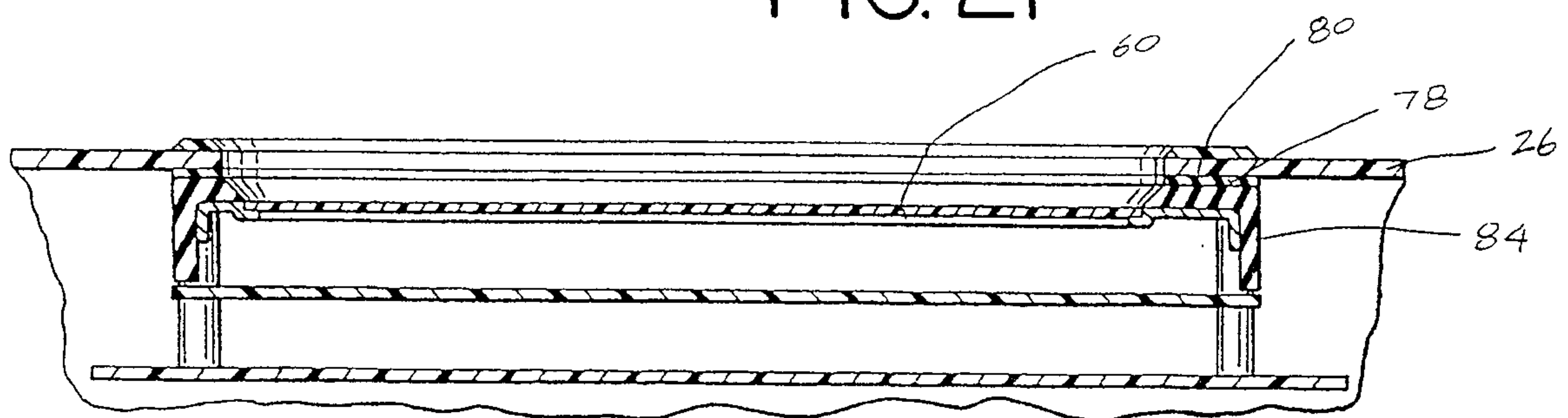
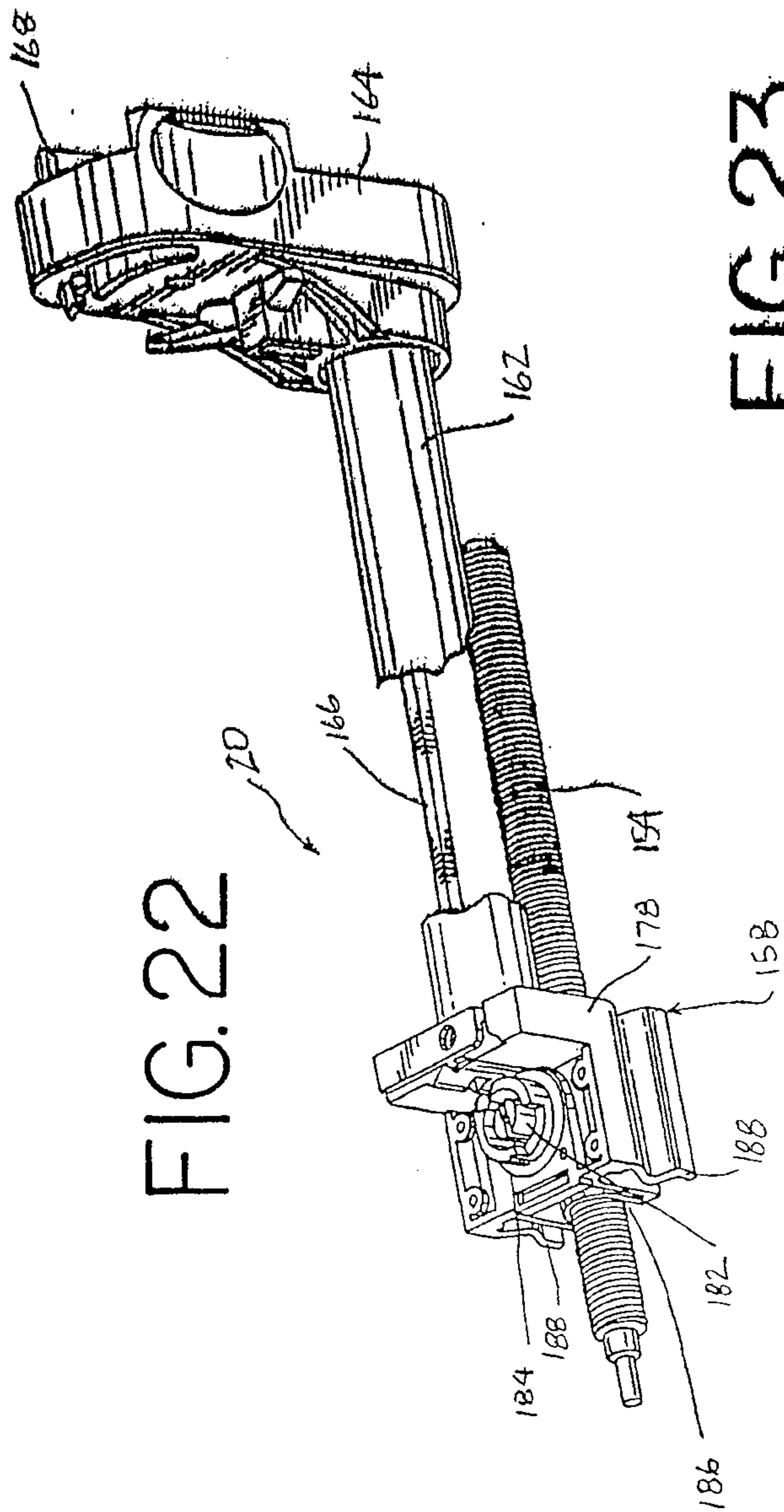
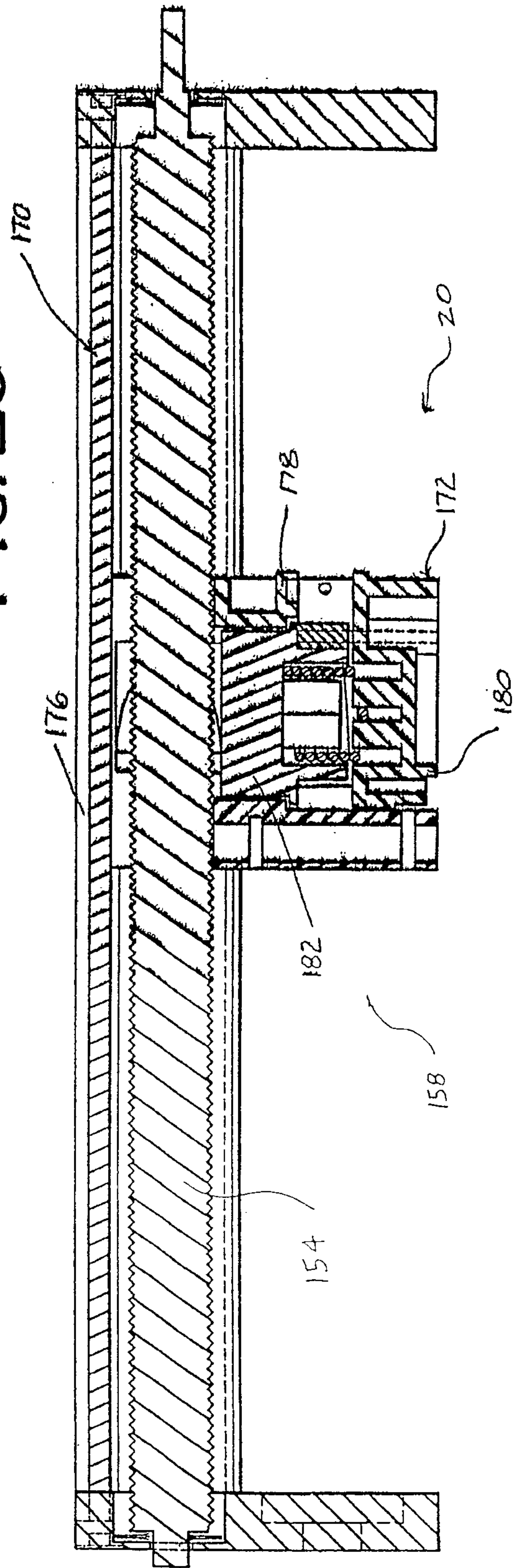


FIG. 21



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**FIG. 23**

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FIG. 24

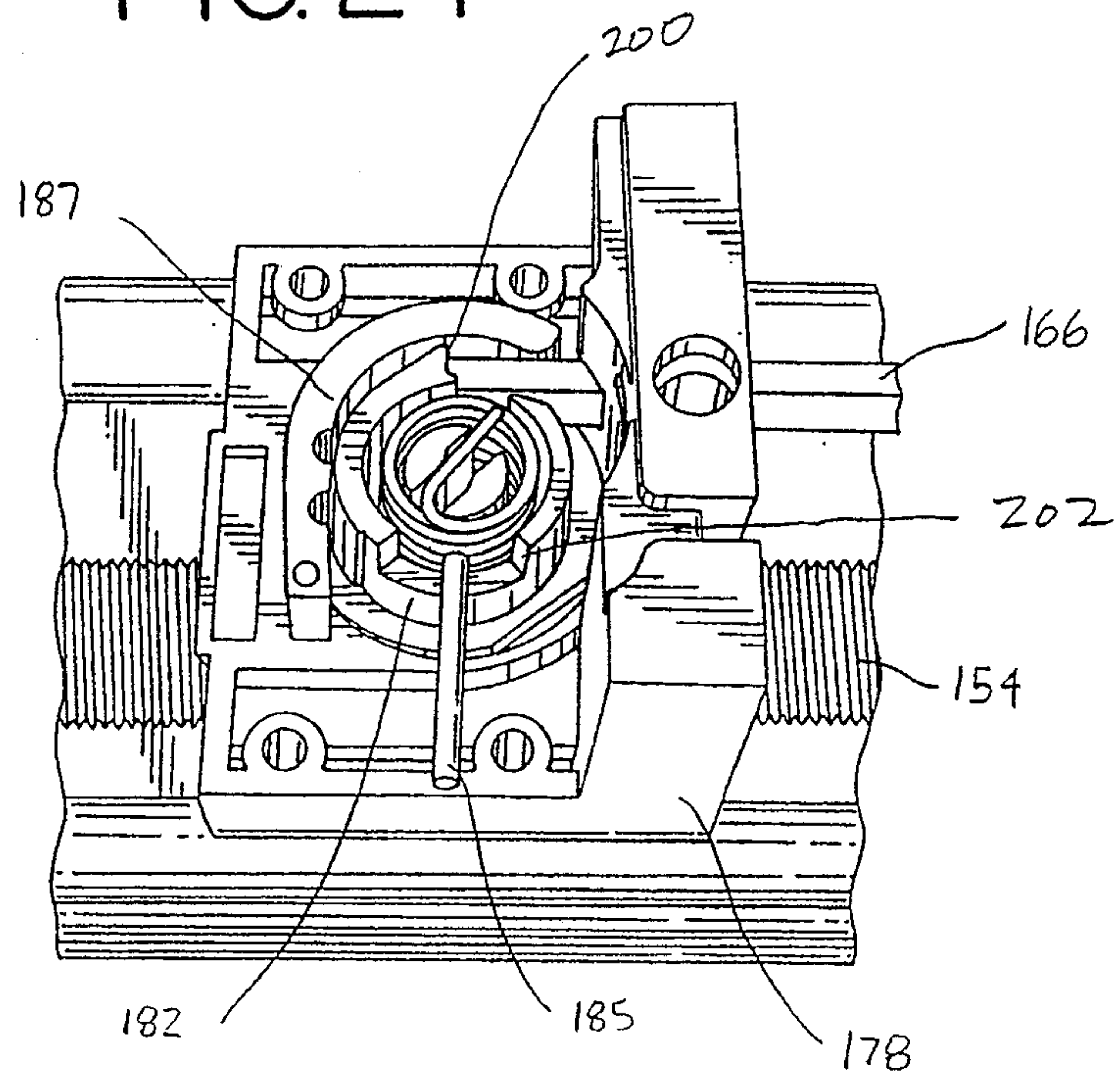
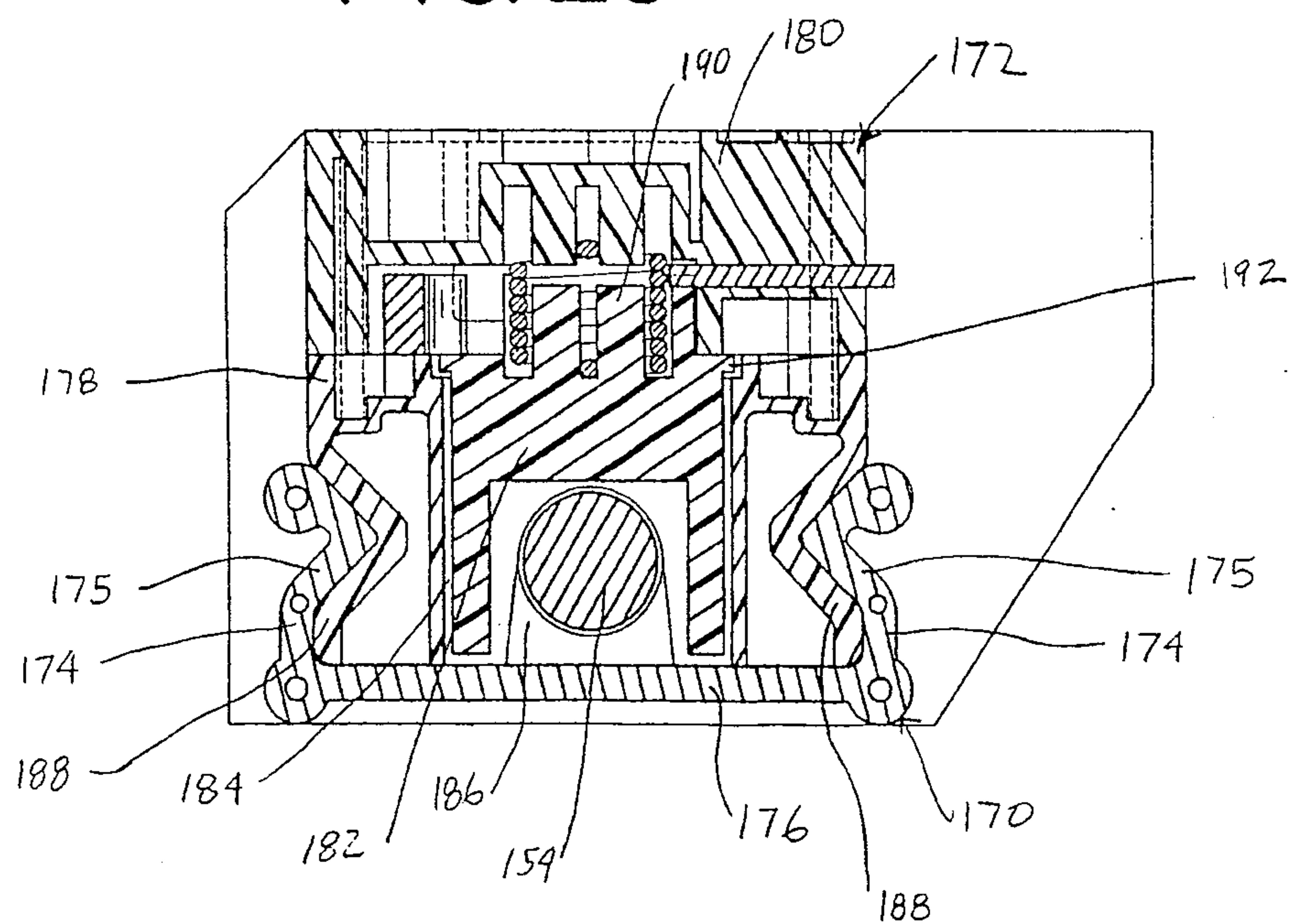


FIG. 25



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FIG. 26

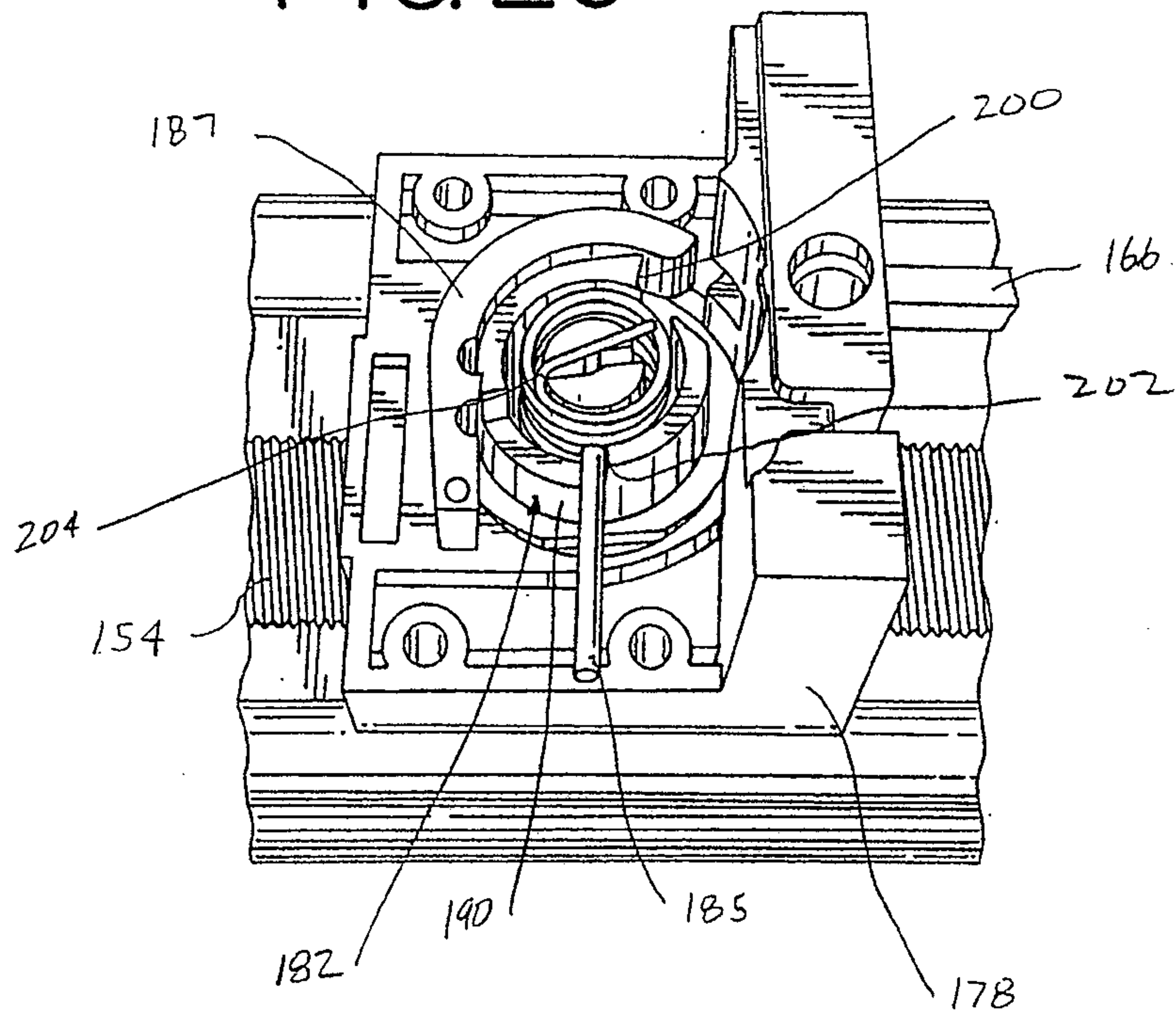
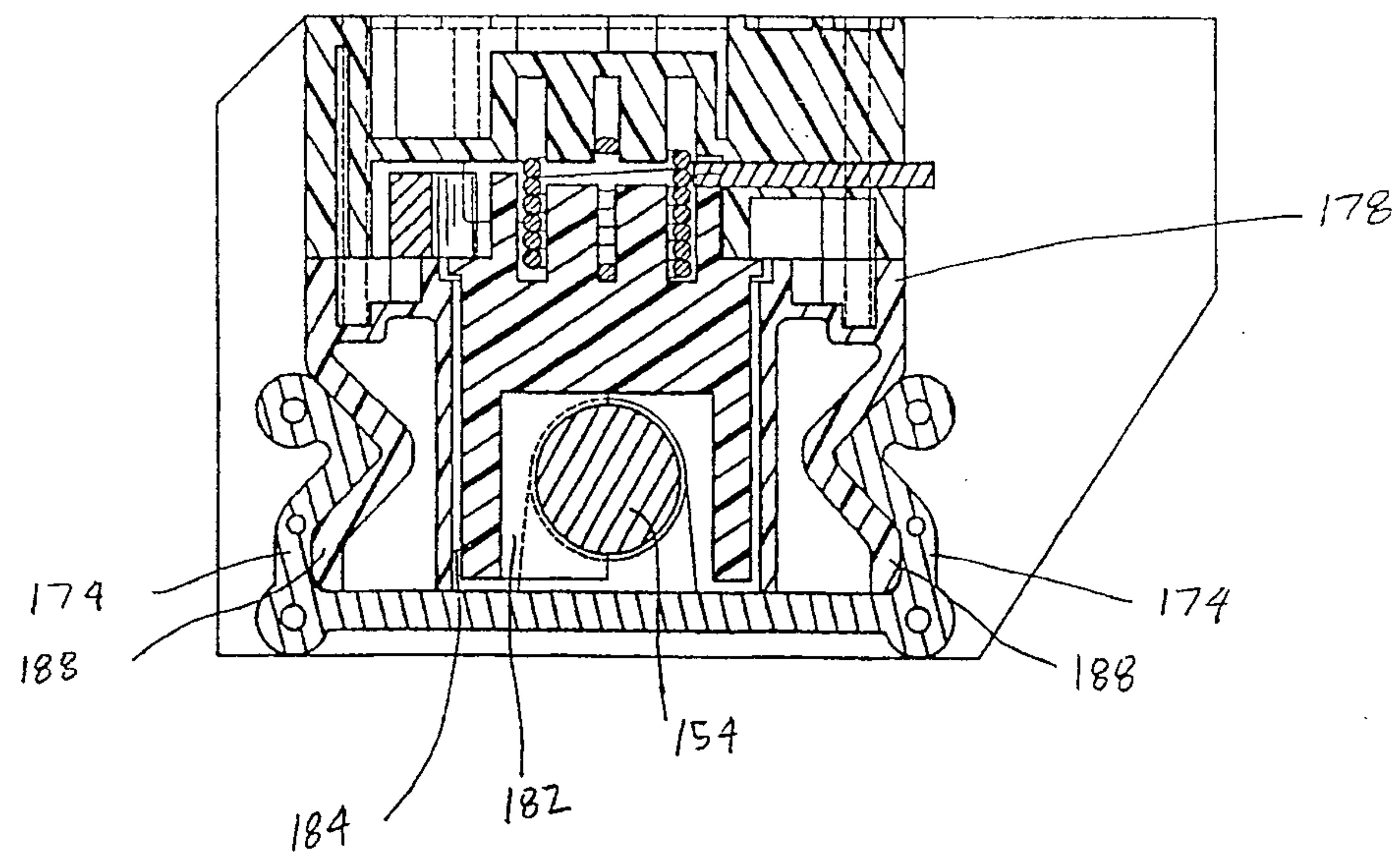


FIG. 27



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FIG. 28

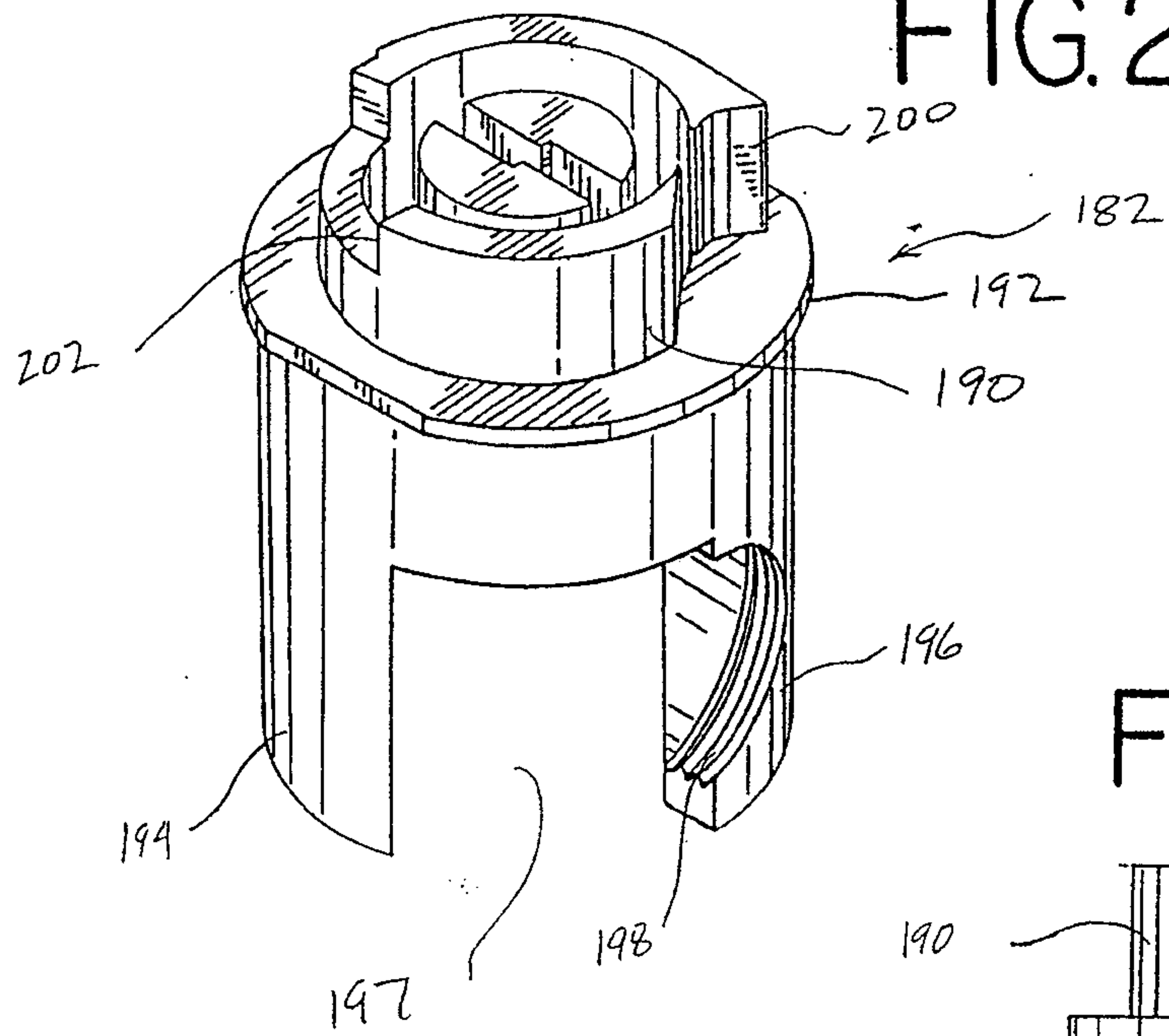


FIG. 29

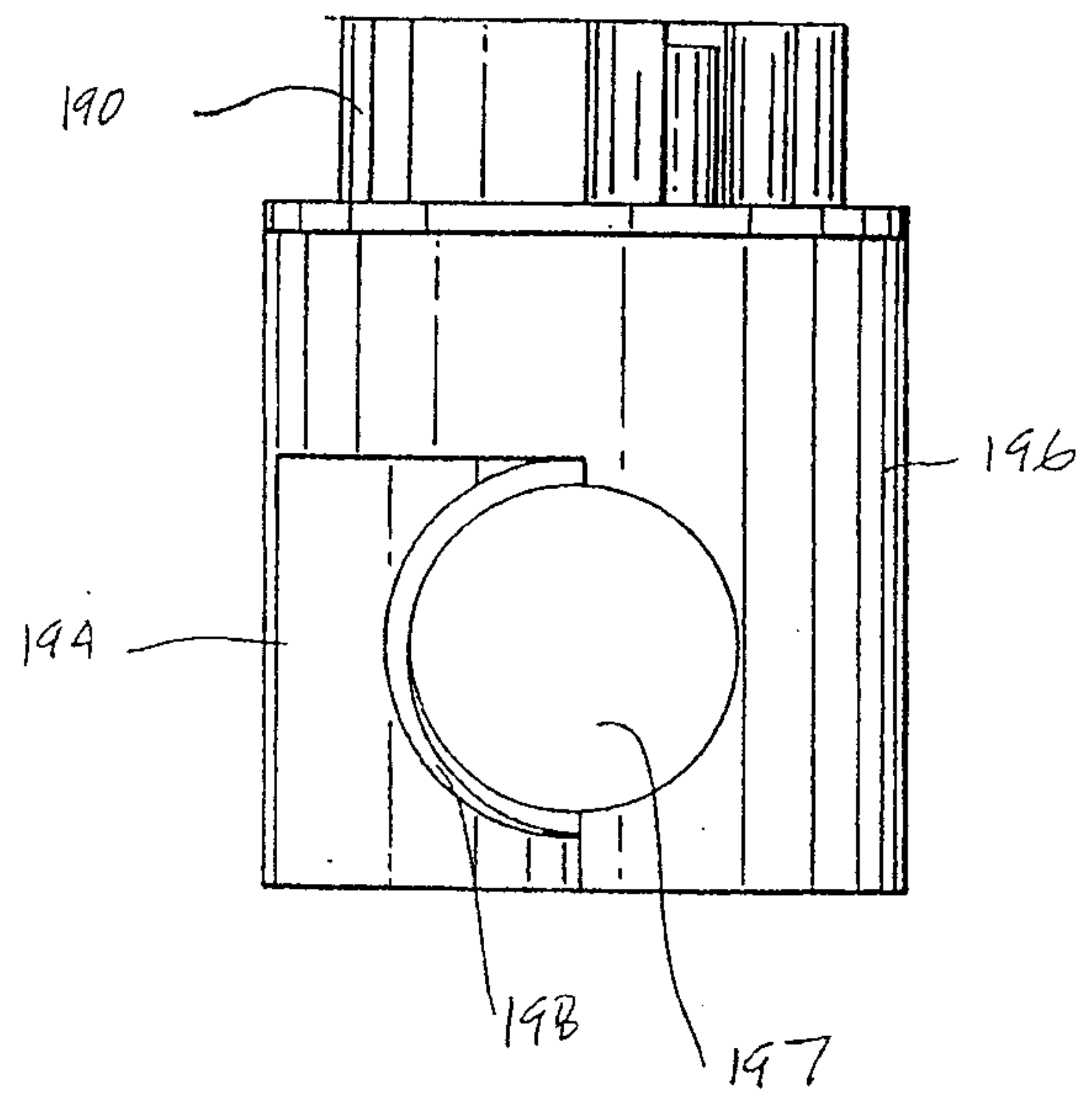
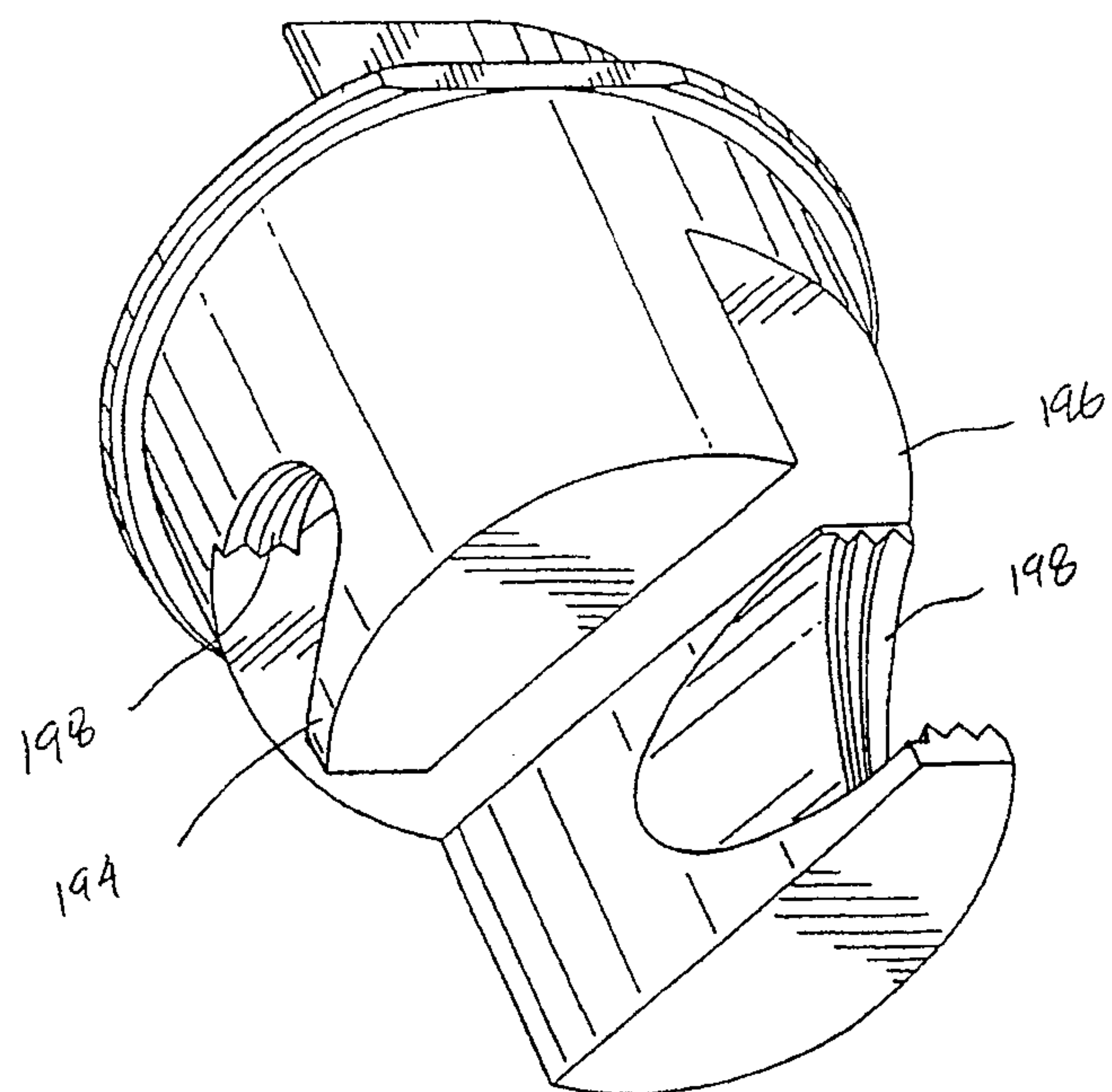


FIG. 30



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FIG. 31

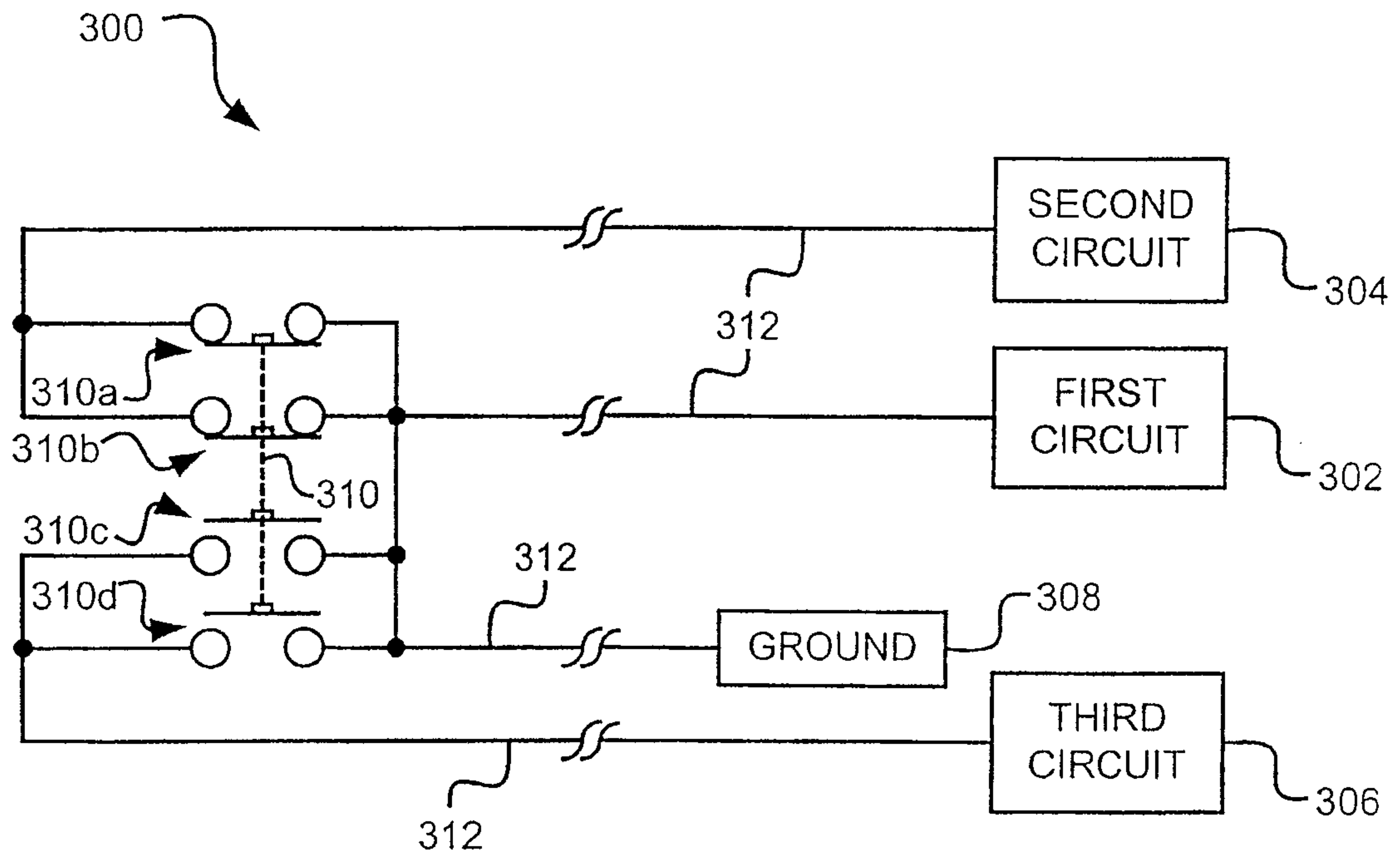


FIG. 32

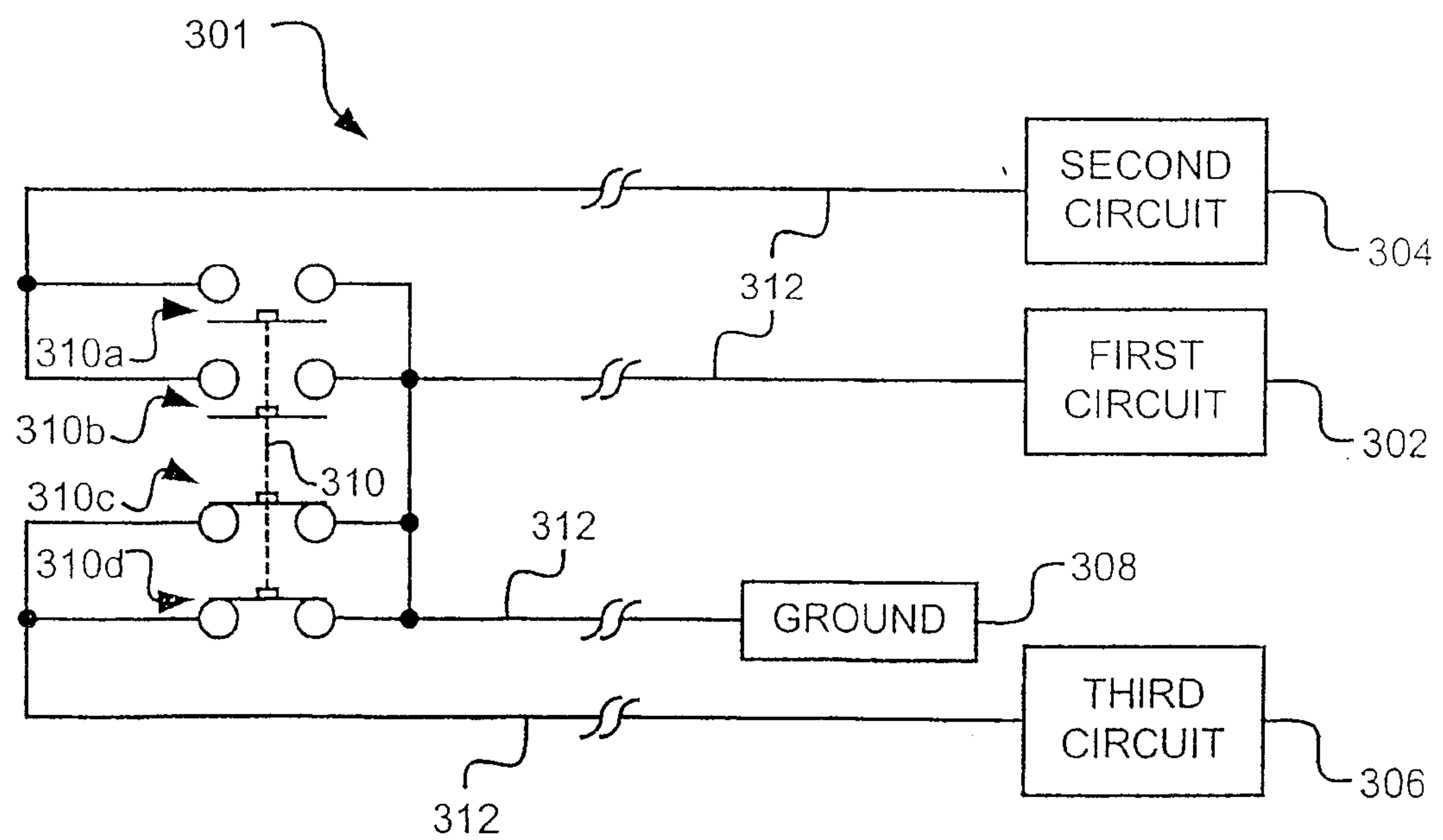


FIG. 33

400



CONDITION	FIRST CIRCUIT	SECOND CIRCUIT	THIRD CIRCUIT
PCA NOT INSTALLED	HIGH	HIGH	HIGH
PCA FAULT	HIGH	LOW	HIGH
PCA FAULT	HIGH	HIGH	LOW
PCA FAULT	HIGH	LOW	LOW
PCA FAULT	LOW	HIGH	HIGH
PCA INSTALLED	LOW	LOW	HIGH
BOLUS ACTUATED	LOW	HIGH	LOW
PCA FAULT	LOW	LOW	LOW

