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(54) **CLOSED-LOOP IV FLUID FLOW CONTROL**

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(52) **U.S. Cl.** ..... **604/65; 604/67; 604/118**

(58) **Field of Search** ..... **604/65, 67, 118, 604/251, 253, 254**

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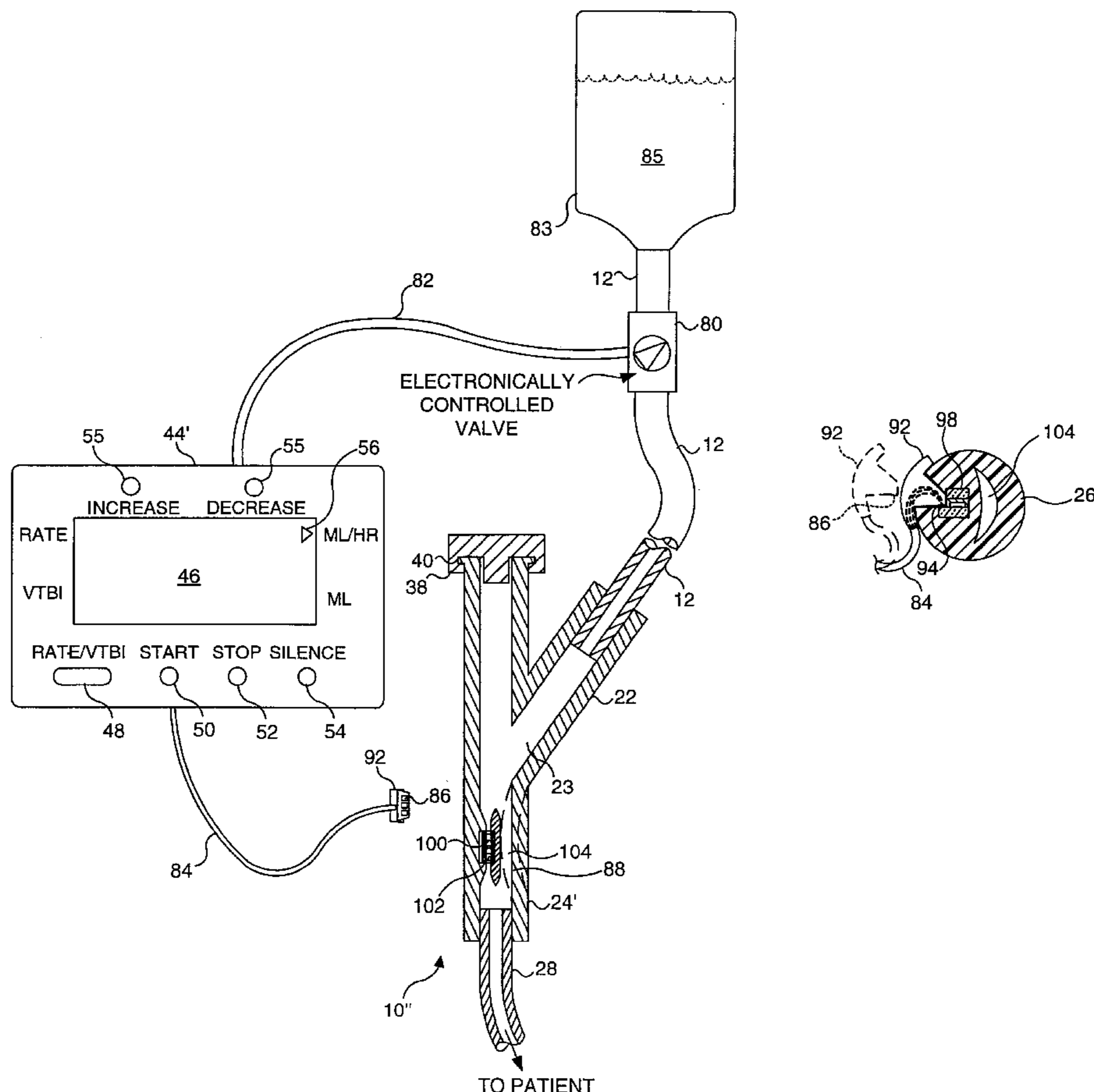
*Assistant Examiner*—Jaime Corrigan

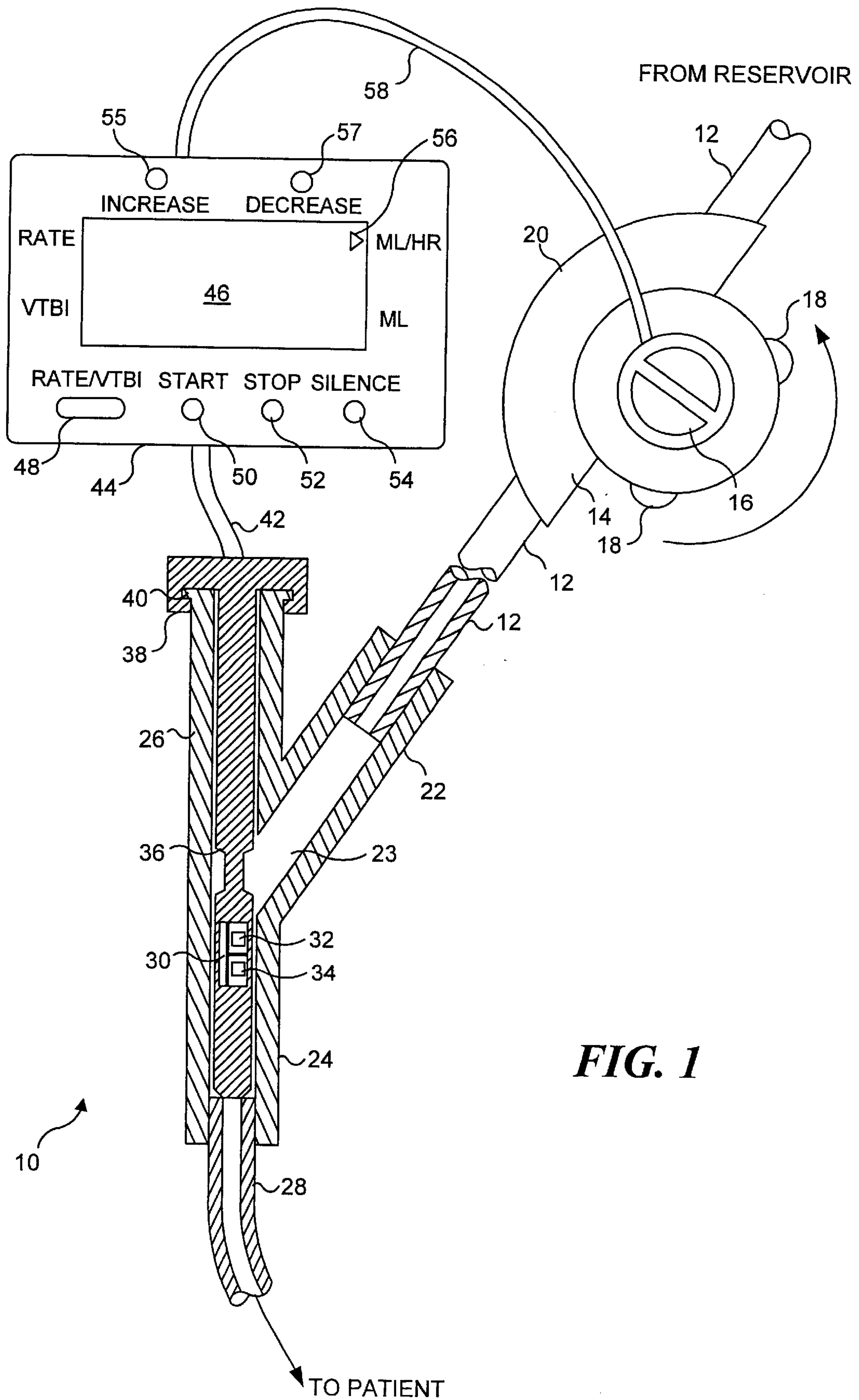
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(57) **ABSTRACT**

In a closed-loop process, a controller uses a flow sensor to monitor the flow of a medicinal fluid being infused into a patient, to achieve a desired rate of flow. A relatively inexpensive peristaltic pump or electronically controlled valve can be used to vary the flow of the medicinal fluid through a fluid line. A Y site within the fluid line includes an integral flow sensor having an orifice. The flow sensor includes proximal and distal pressure sensors disposed on opposite sides of the orifice to monitor the distal and proximal pressure, producing a signal indicative of the rate of flow of the medicinal fluid through the fluid line. A signal produced by the controller is input to a motor driving the pump or to the valve to vary the rate of flow as required to achieve the desired infusion rate of the medicinal fluid.

**30 Claims, 5 Drawing Sheets**





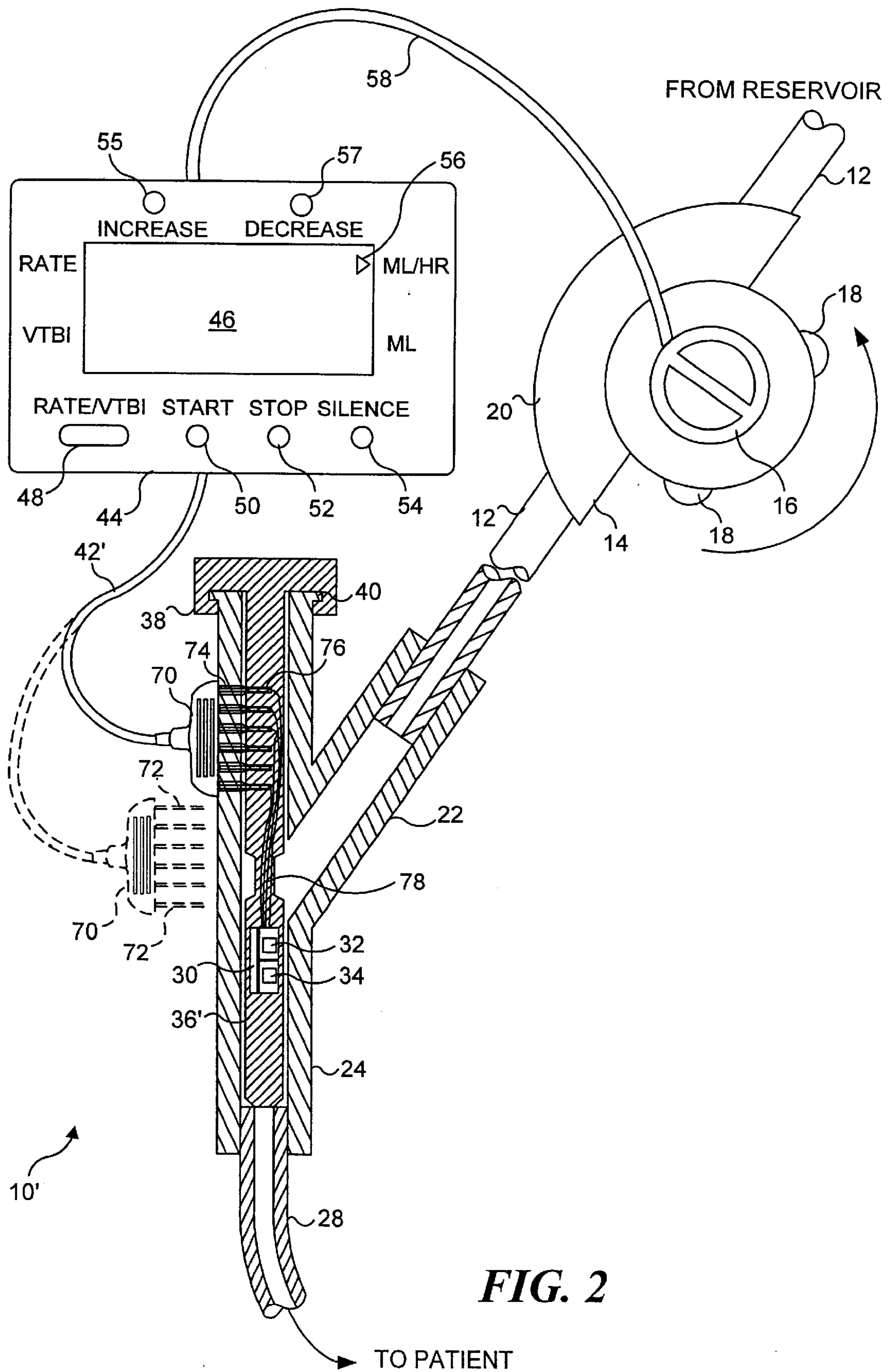
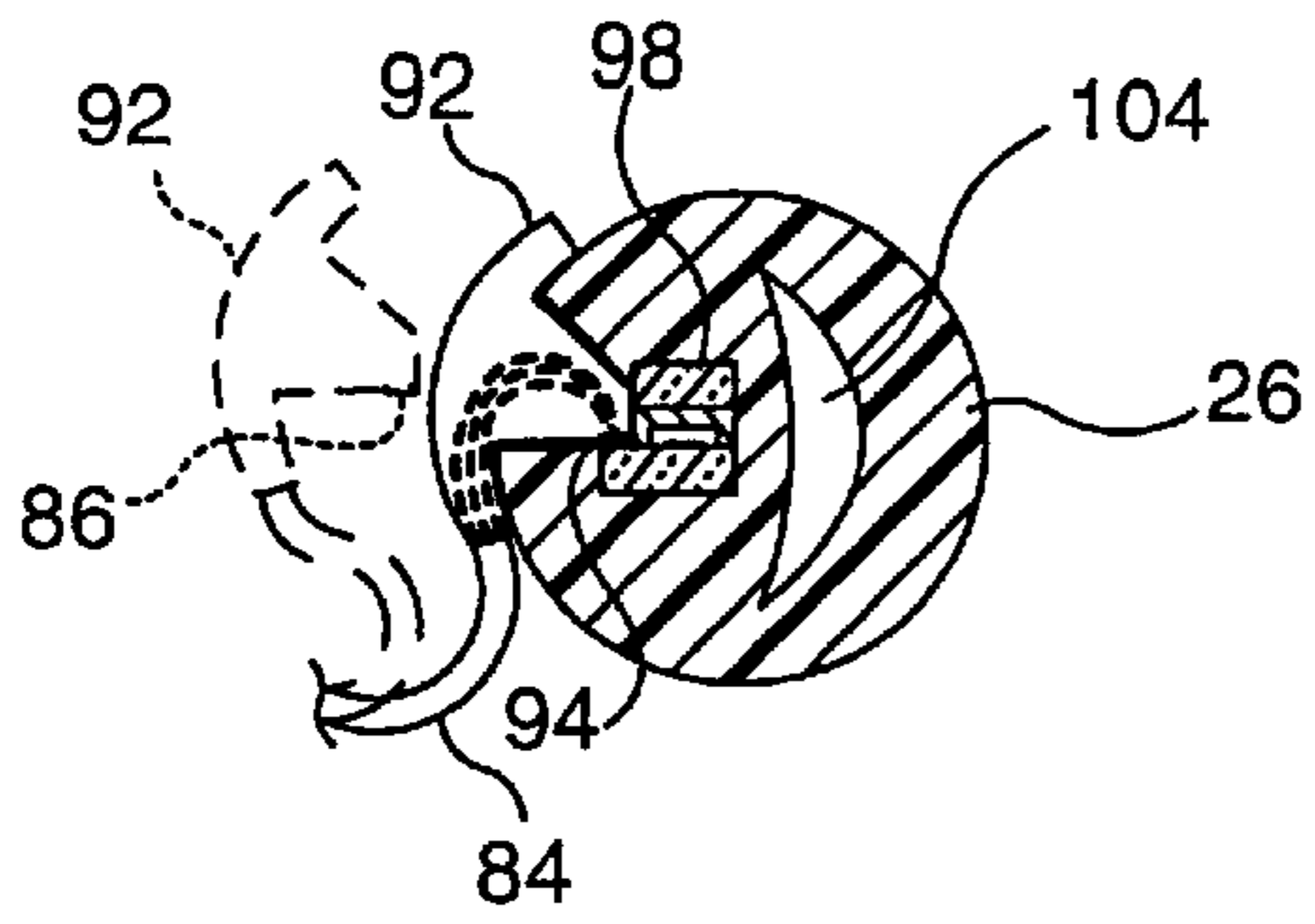
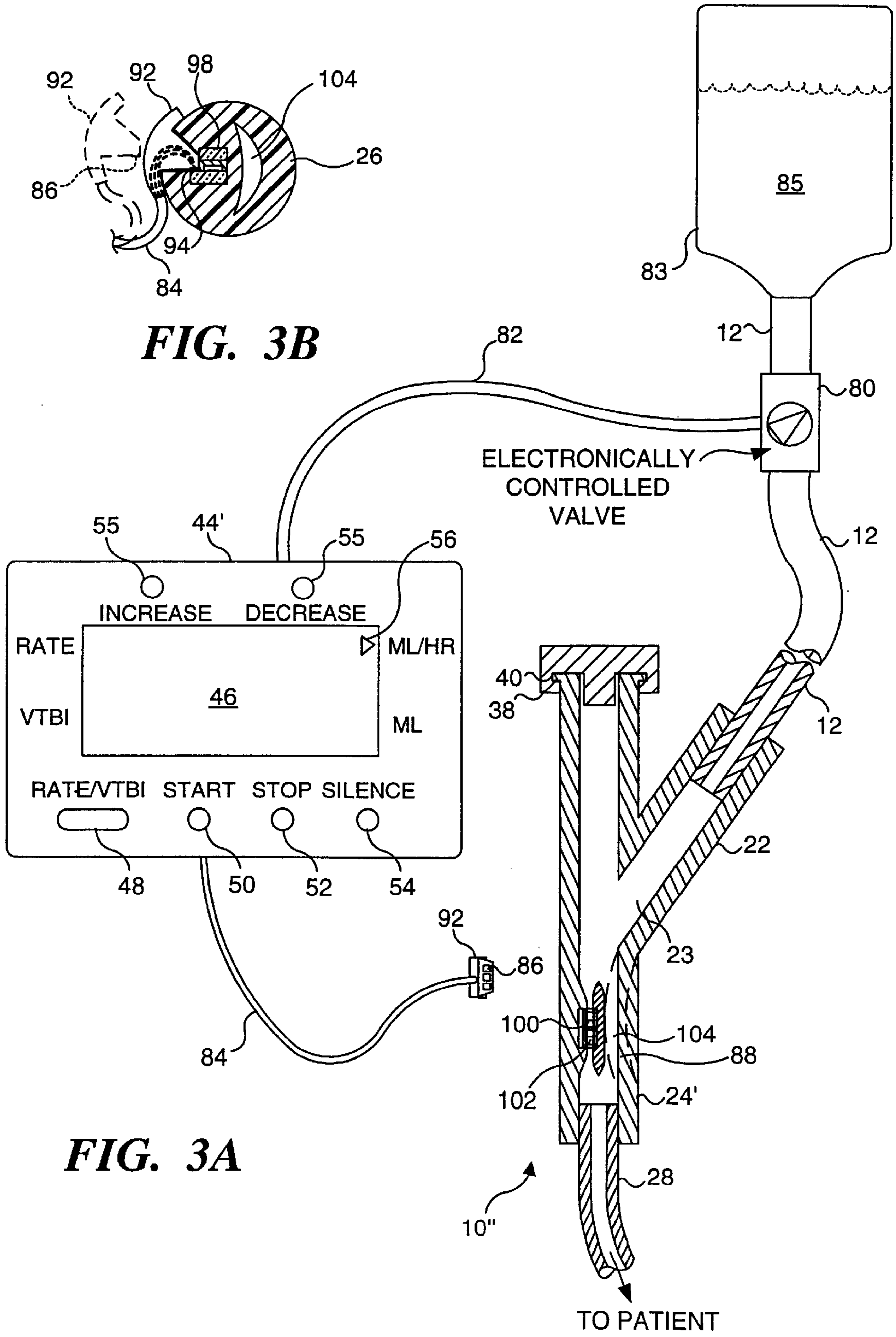


FIG. 2



**FIG. 3B**



**FIG. 3A**

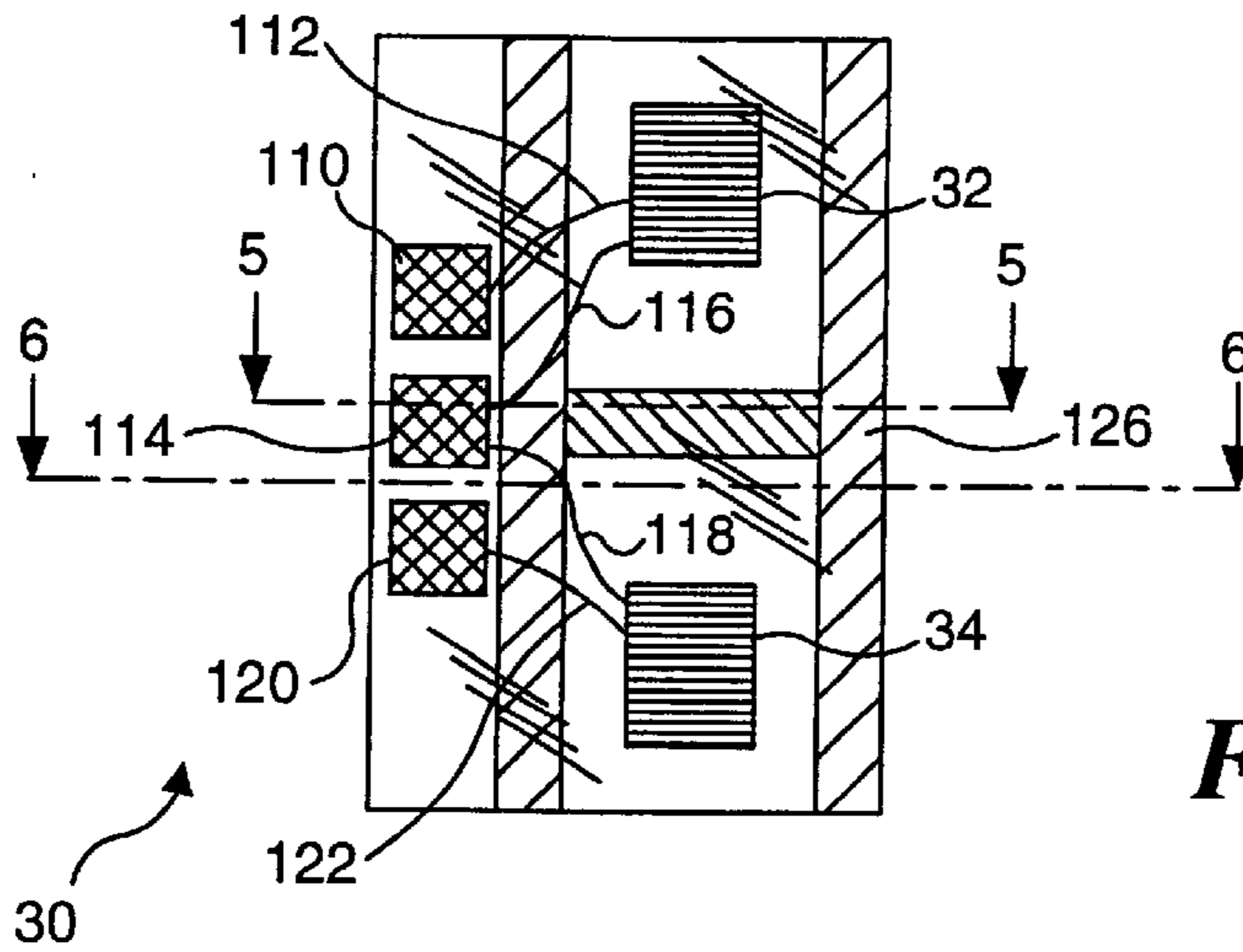


FIG. 4

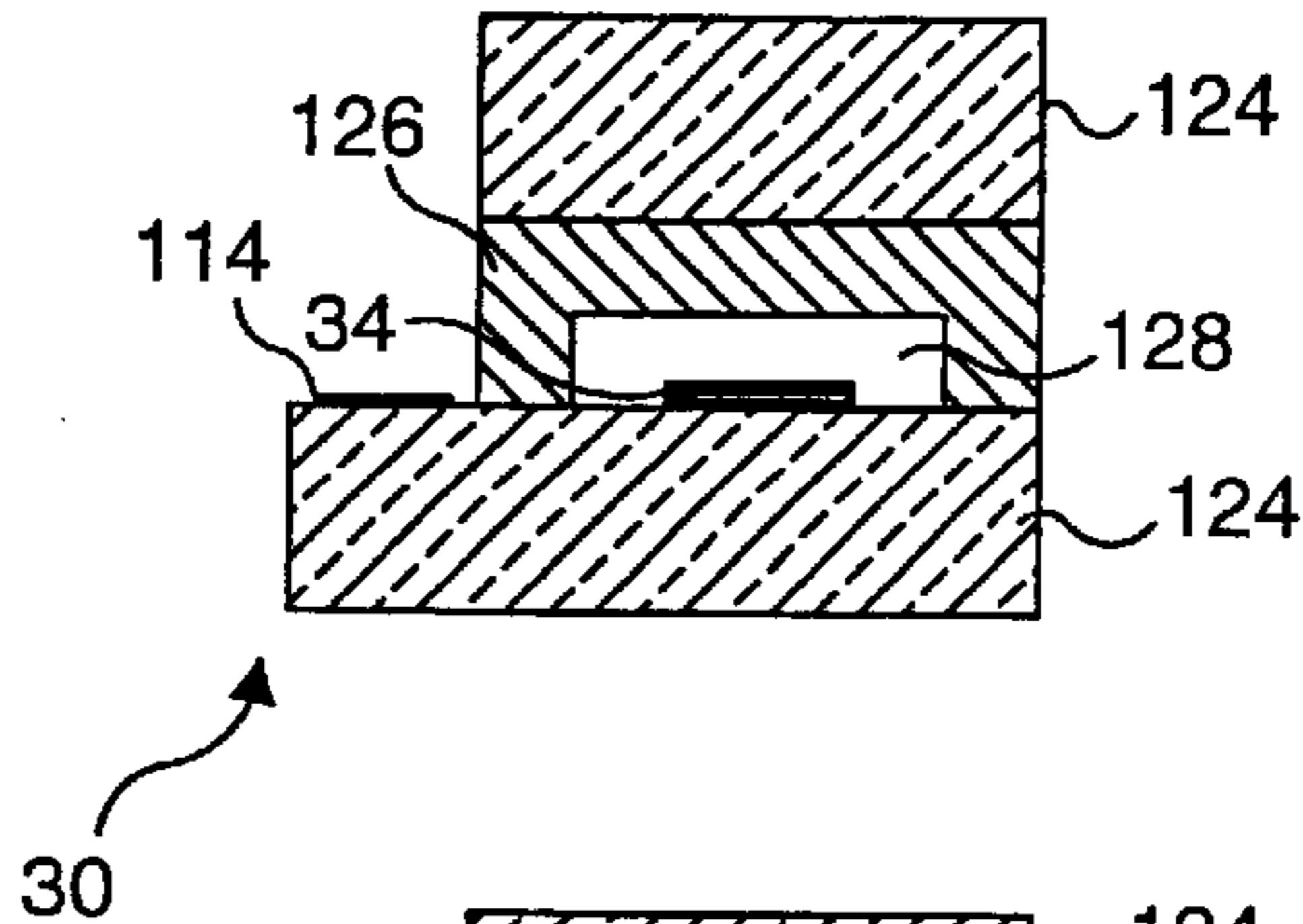


FIG. 5

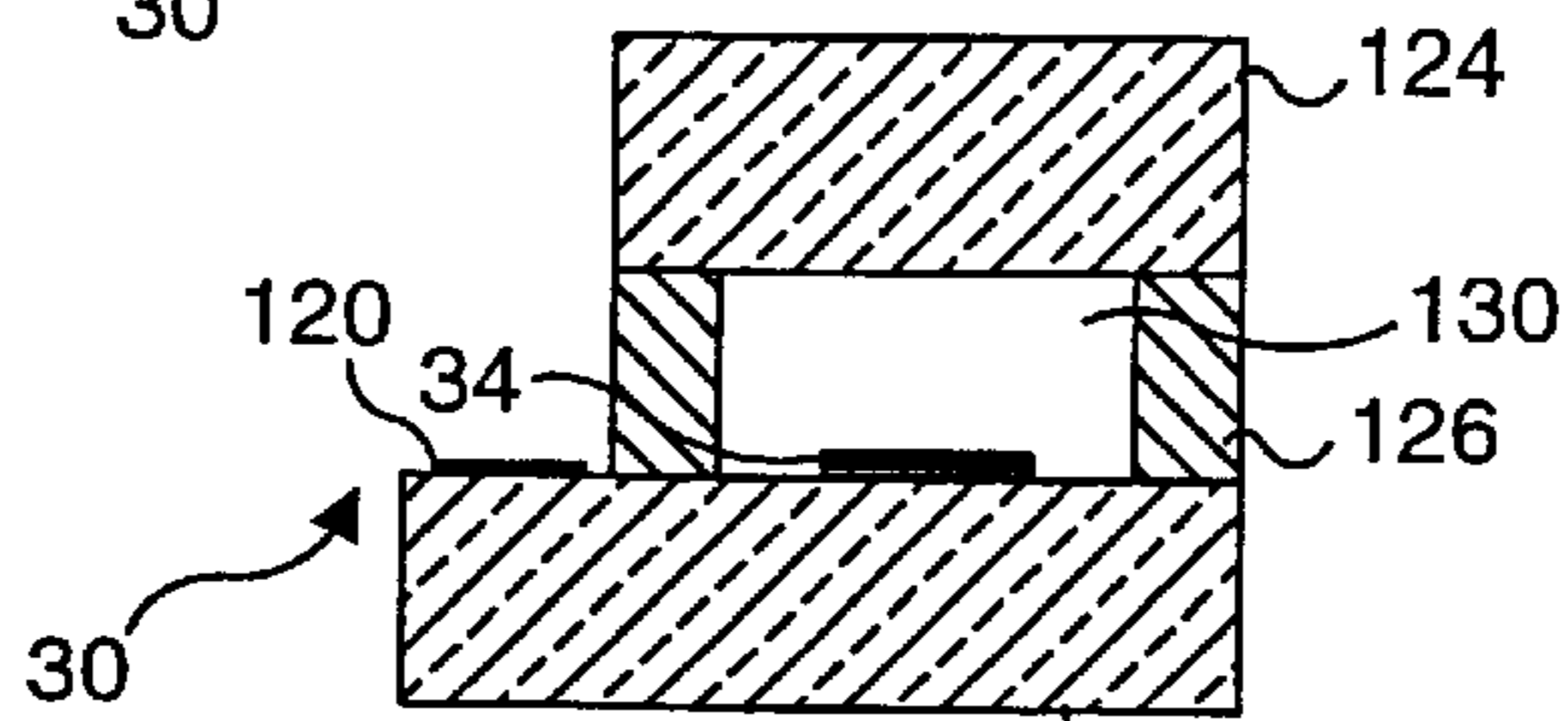


FIG. 6

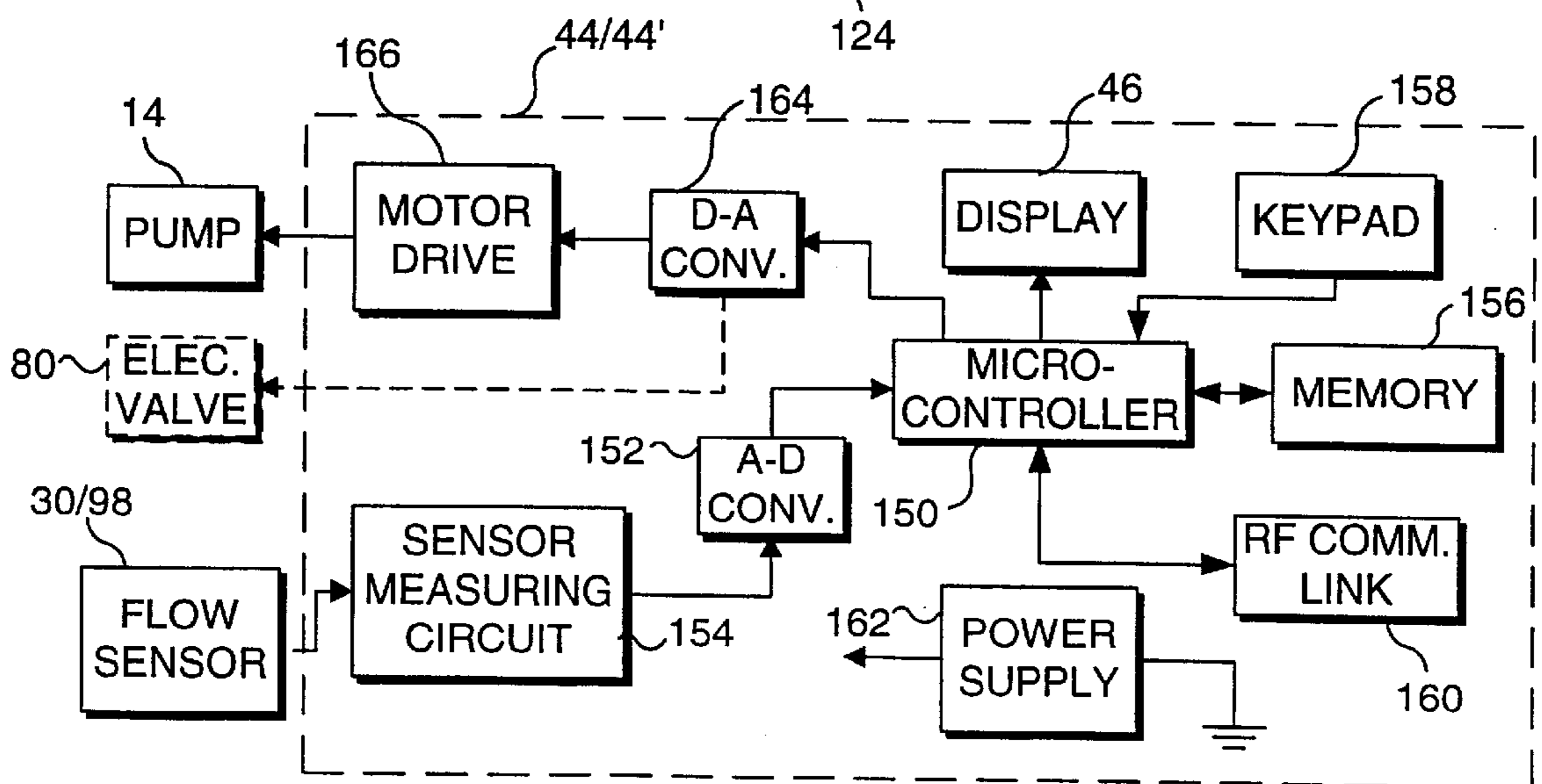
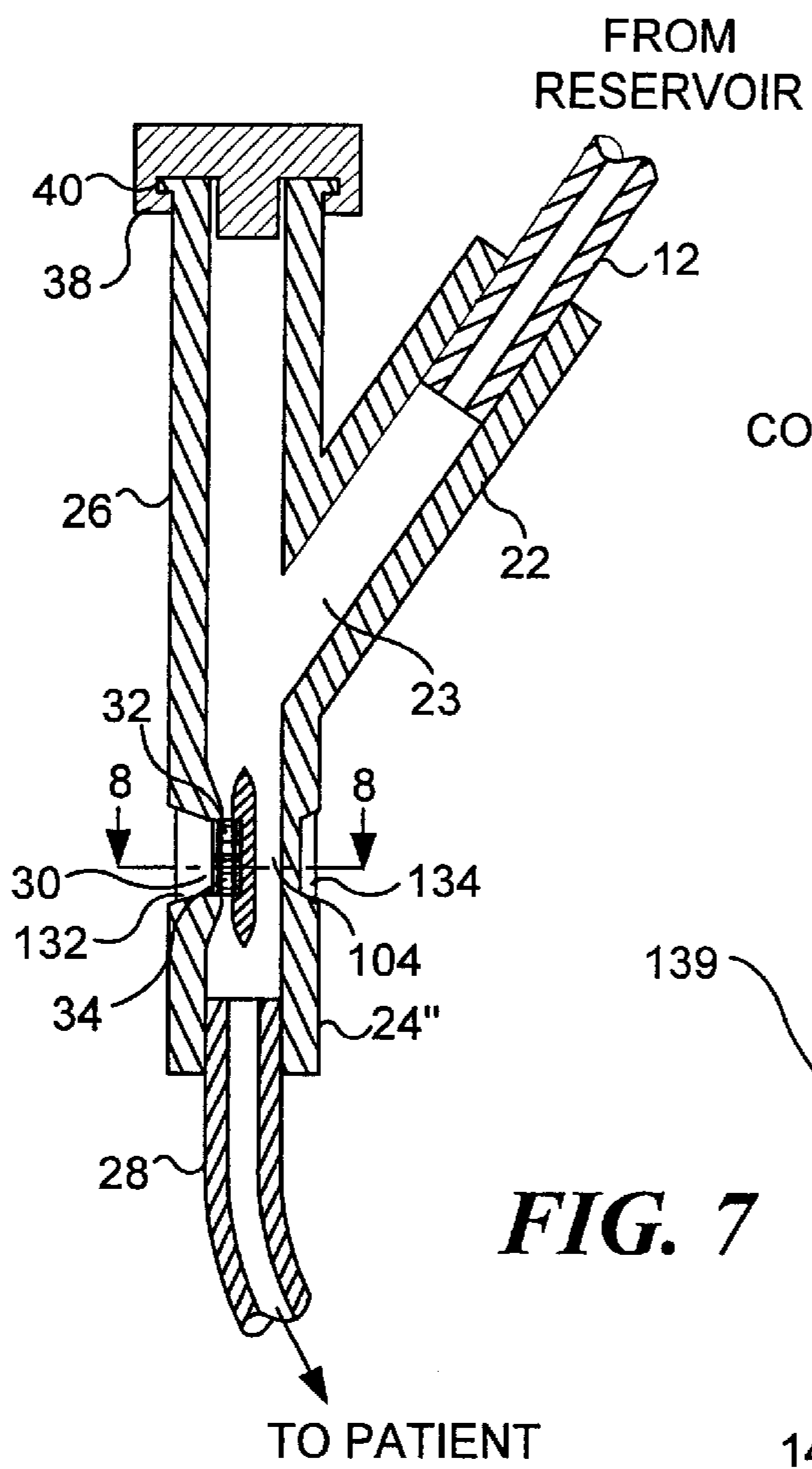
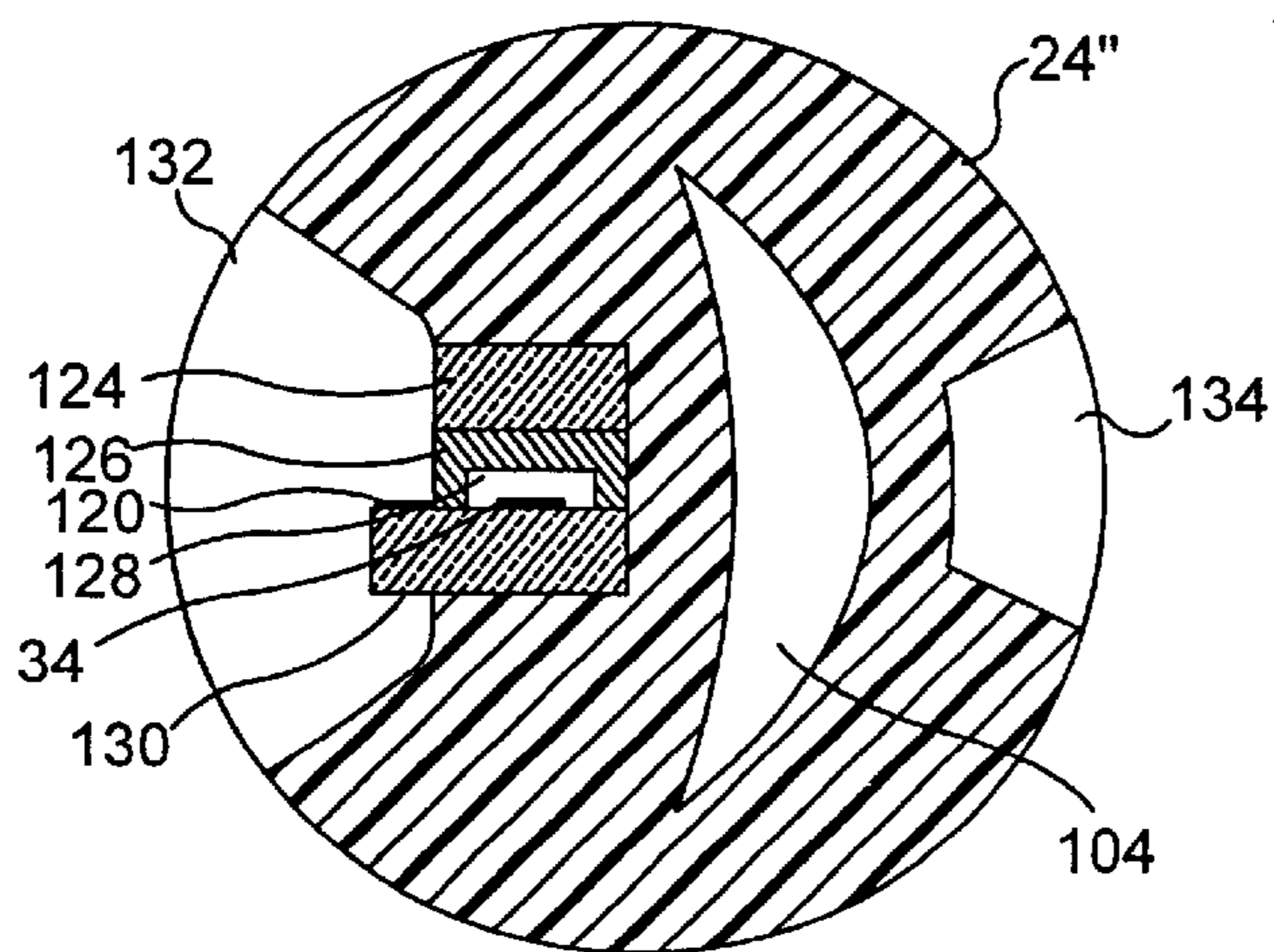


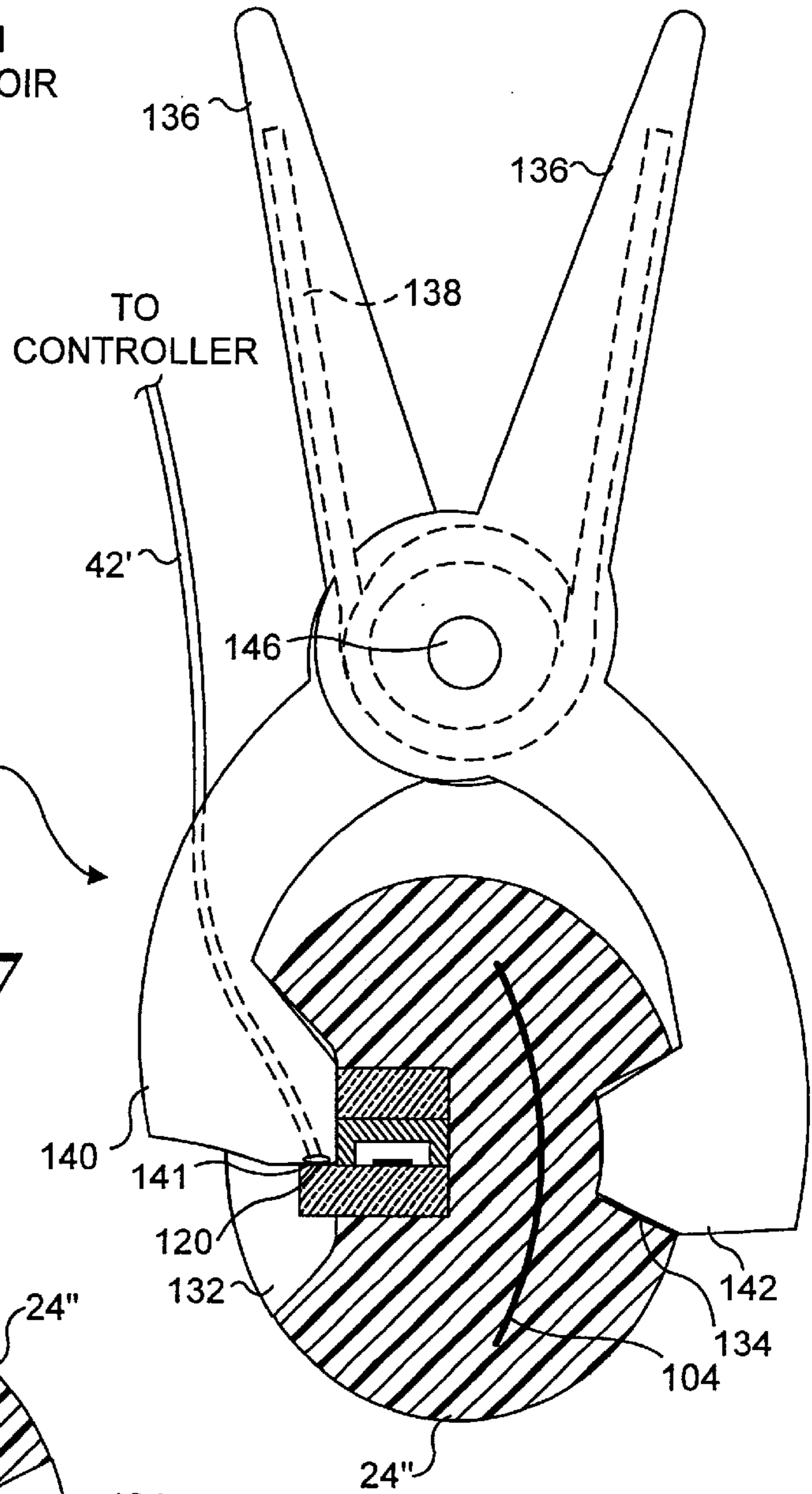
FIG. 11



**FIG. 7**

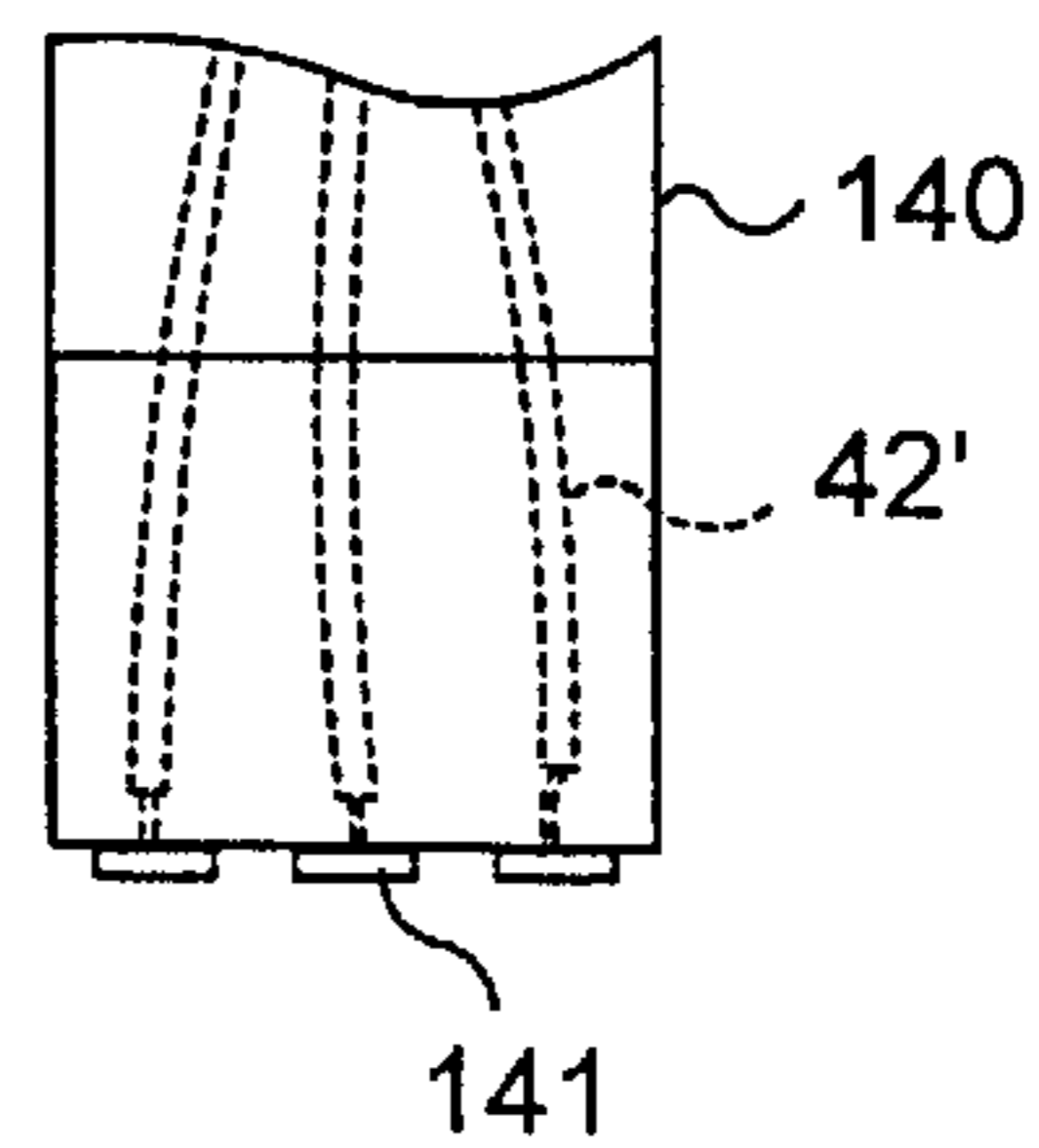


**FIG. 8**



**FIG. 9**

**FIG. 10**



**CLOSED-LOOP IV FLUID FLOW CONTROL****FIELD OF THE INVENTION**

The invention generally concerns control of fluid flow rates, and more particularly concerns the control of fluid flow rate in intravenous fluid delivery systems.

**BACKGROUND OF THE INVENTION**

Intravenous (IV) fluid delivery systems are used to deliver fluids and medicines to patients at controlled rates. To more accurately control IV fluid delivery, an open-loop control system is typically used. A processor included in the open-loop control system varies the speed of a relatively accurate fluid pump used to infuse a medicinal fluid into a patient, based on a predefined algorithm and as a function of various parameters, such as temperature, fluid type, and desired flow rate. These open-loop processor-controlled pumping systems are generally expensive and complex. Usually, compensation for variations in pump accuracy must be employed in such systems to achieve an acceptable accuracy. The rate of fluid delivery is also affected by the precision of disposable components used in the fluid path that conveys a medicinal fluid to a patient. However, variations in the internal diameter and material hardness of fluid lines and pumping component comprising the disposable components, both initially, and as a result of changes over their period of use, cannot readily be compensated in an open-loop control algorithm. As a result, higher cost disposable components that are guaranteed to meet tight tolerance specifications must be used in such systems to avoid loss of accuracy.

Accordingly, it will be apparent that it would be desirable to provide a relatively low cost, low complexity system for delivery of medicinal fluids. A closed-loop system in which a desired parameter is measured to control the system can provide the required accuracy. For example, in a closed-loop system, it would be preferable to measure flow with a low cost flow sensor and to control an inexpensive fluid delivery pump based upon the measured flow rate, so as to achieve a desired flow rate. Previously, measurement of fluid flow has generally been prohibitively expensive in medicinal fluid infusion systems. However, the development of low cost flow sensors have made it much more practical and economical to monitor fluid flow in order to control a medical infusion system.

Low cost pumps can be used in a closed-loop system medicinal fluid infusion system, since the accuracy of the pump is not important in achieving a desired delivery rate. Similarly, the tolerance specifications for the disposable components used in the system can be greatly relaxed, because the precision of these components will no longer be of much concern. Also, most of the variables that must be considered in algorithms currently employed for open-loop control can be ignored in a closed-loop controlled infusion system. Consequently, the process control logic used in a closed-loop infusion system is relatively simple.

**SUMMARY OF THE INVENTION**

In accord with the present invention, a fluid delivery system is defined for infusing a medicinal fluid supplied from a reservoir into a patient at a desired rate. The fluid delivery system includes a fluid line through which the medicinal fluid is conveyed from the reservoir to a patient, and a flow controller that selectively varies a rate of flow of

the medicinal fluid through the fluid line. A processor is controllably coupled to the flow controller and to a flow sensor that monitors a rate of flow of the medicinal fluid through the fluid line, producing an output signal that is indicative thereof. The processor responds to the output signal and operates the flow controller in a closed-loop process, to achieve the desired rate of infusion of the medicinal fluid into a patient.

In one preferred form of the invention, the flow sensor includes an orifice disposed in a fluid path through which the medicinal fluid flows in the fluid line, and the orifice has a cross-sectional size that is substantially less than that of the fluid line. A pressure-sensing module in the fluid line is configured to sense a pressure drop across the orifice, producing the signal indicative of flow rate. In one embodiment, the pressure sensing module includes a distal pressure sensor and a proximal pressure sensor, the distal pressure sensor being used for monitoring a distal pressure of the medicinal fluid, downstream of the orifice, and the proximal pressure sensor being used for monitoring a proximal pressure of the medicinal fluid, upstream of the orifice. A difference between the distal pressure and the proximal pressure signals is indicative of the rate of flow of the medicinal fluid through the fluid line.

In another embodiment, the pressure sensing module includes a differential pressure sensor that monitors a differential pressure across the orifice and in response thereto, produces the signal supplied to the processor, which is indicative of the rate of flow of medicinal fluid through the fluid line.

Preferably, the flow sensor is disposed in a "Y" fitting in the fluid line. In one embodiment, the flow sensor is removably coupled to the processor through a connector. In another embodiment, the flow sensor is removably coupled to the processor.

In some cases, it will occasionally be desirable to provide a substantially greater flow of medicinal fluid that can be achieved through the orifice of the flow sensor, e.g., to prime the fluid line before connecting it to a patient. In this case, a bypass channel is provided within the fitting, generally in parallel with the orifice. The bypass channel is then selectively opened to enable the medicinal fluid to substantially bypass the orifice when a greater rate of flow of the medicinal fluid than the desired rate is required through the fluid line.

One preferred form of the invention employs a pump for the flow controller, and the pump forces the medicinal fluid through the fluid line and into a patient. Alternatively, an electronically controlled valve is employed for the flow controller, the medicinal fluid flowing through the fluid line under the force of gravity.

A user interface is preferably included to enable input by a user of the desired rate of medicinal fluid flow through the fluid line.

Another aspect of the present invention is directed to a method for controlling a rate of infusion of a medicinal fluid into a patient through a fluid path. The method includes steps that are generally consistent with the functions performed by the elements discussed above.

**BRIEF DESCRIPTION OF THE DRAWING FIGURES**

The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is an elevational view of a portion of IV tube set and a first embodiment of the present invention, showing a cross-sectional view of a Y site that is provided with a flow sensor, which produces a signal for use in controlling a pump in a closed-loop process;

FIG. 2 is an elevational view of a portion of an IV tube set much like that of FIG. 1, but showing an embodiment that includes a connector for coupling a flow sensor to a controller;

FIG. 3A is an elevational view of an embodiment that includes an electronically controlled valve for varying fluid flow rate and which includes a bypass around a flow sensor in a Y site;

FIG. 3B is a cross-sectional view of the flow sensor, showing the bypass path around the flow sensor, in the Y site shown in FIG. 3A;

FIG. 4 is an enlarged elevational view of a flow sensor having proximal and distal pressure sensors for sensing proximal and distal pressures across an orifice;

FIG. 5 is a cross-sectional view of the flow sensor of FIG. 4, taken along section line 5—5 in FIG. 4;

FIG. 6 is a cross-sectional view of the flow sensor of FIG. 4, taken along section line 6—6 in FIG. 4;

FIG. 7 is a cross-sectional view of yet another embodiment of the Y site for the present invention, which includes a bypass channel;

FIG. 8 is a cross-sectional view of the embodiment of the Y site, taken along section line 8—8 in FIG. 7, and illustrating the bypass channel in its open state;

FIG. 9 is a cross-sectional view of the Y site shown in FIGS. 7 and 8, illustrating the use of a clamp that includes electrical contact on one jaw and which is employed for closing the bypass flow channel and for electrically connecting to a pressure sensor in the Y site;

FIG. 10 is an elevational view of an end portion of one of the jaws of the clamp shown in FIG. 9, illustrating the electrical contacts and leads provided thereon; and

FIG. 11 is a functional block diagram of the controller, illustrating the components included therein.

#### DESCRIPTION OF THE PREFERRED EMBODIMENT

Several different embodiments of systems suitable for administering a medicinal fluid at a desired rate are illustrated in the Figures and are described below. A first such embodiment of a system 10 is shown in FIG. 1. System 10 includes a fluid line 12 that extends from a reservoir (not shown in this FIGURE) through a peristaltic pump 14. Peristaltic pump 14 comprises a plurality of rollers 18 that are driven along in a circular path by an electric motor 16 (or other suitable prime mover) in a rotational direction as indicated by the curved arrow. As is common in most such peristaltic pumps, rollers 18 periodically contact and compress fluid line 12, as the rollers move along the circular path, forcing successive boluses of a medicinal fluid through the fluid line for infusion into a patient (not shown). Fluid line 12 extends within the concave portion of a curved guide 20 against which rollers 18 act to compress the fluid line in pumping the medicinal fluid. However, it should be pointed out that many other types of pumps can be used in connection with the present invention.

One of the advantages of the present invention is that it enables a relatively inexpensive peristaltic pump or other type of pump, which may be of a relatively low accuracy in maintaining a desired rate of delivery, to be used, since the

pump is directly controlled in a closed-loop process to achieve the desired delivery rate of the medicinal fluid to the patient. To control the rate at which peristaltic pump 14 infuses a medicinal fluid, the speed of electric motor 16 is varied so as to achieve the desired rate for delivery of the medicinal fluid by the pump. Further details of system 10 that enable the pump (i.e., its prime mover) to be controlled in this manner to achieve the desired rate of fluid flow are described below.

Fluid line 12 connects to an upper arm 22 of a Y site 24. The outlet of the Y site is connected to a fluid line 28 that conveys the medicinal fluid flowing under the urging of peristaltic pump 14 into the body of a patient at an infusion site. It should be noted, however, that in the present invention, peristaltic pump 14 (or other low cost pump) can be disposed either proximal or distal to the Y site. The medicinal fluid flows through a cavity 23 formed within the Y site to reach fluid line 28.

A flow-sensing module 36 is disposed within an upper arm 26 of Y site 24 and extends into the lower portion of the Y site. Fluid-sensing module 36 includes a solid state flow sensor 30 that comprises a proximal pressure sensor 32 and a distal pressure sensor 34. The proximal and distal pressure sensors are disposed on opposite sides of a restriction or orifice (shown more clearly in FIG. 5). By monitoring the proximal and distal pressure at points on opposite sides of the restriction or orifice of known cross-sectional size, flow sensor 30 determines the rate of flow of medicinal fluid through Y site 24, and thus through the fluid path into the patient. Flow-sensing module 36 is retained within Y site 24 by a flange 38, which sealingly engages a lip 40 formed on the upper end of arm 26.

A cable 42 connects the signal produced by flow sensor 30 to a controller 44. Controller 44 includes a display 46 on which either the volume or the rate of medicinal fluid infusion is displayed. Details of the controller are discussed below, in connection with FIG. 11. The user interface on controller 44 includes a switch 48 that switches between a display of the rate of fluid delivery in ml/hr and the volume to be infused (VTBI) in ml. Also provided on the controller are start and stop buttons 50 and 52, a button 54 for silencing alarms such as occur when an out-of-fluid condition or air bubble is detected in the fluid line, and buttons 55 and 57 for enabling a user to respectively increase and decrease displayed values being input for the desired VTBI and the desired rate of fluid delivery.

It should be noted that the flow-sensing module can be disposed in elements of the fluid line other than a Y site. For example, a portion of the fluid line can simply include a flow monitoring module that is sufficiently low in cost to be disposed of after use with a single patient. Several different techniques are shown herein for electrically connecting the flow sensing module to controller 44 or its equivalent.

Controller 44 responds to the proximal pressure and distal pressure signals received from flow sensor 30, deriving a flow signal therefrom corresponding to their difference, and the difference in pressures sensed on opposite sides of the restriction or orifice is indicative of the rate of flow of medicinal fluid through Y site 24 and into the patient. Based upon the monitored rate of flow of the medicinal fluid, which comprises a feedback signal, controller 44 implements a closed-loop control process by varying the speed of motor 16, and thus, the speed of peristaltic pump 14 to achieve the desired rate of flow of the medicinal fluid being infused. If the monitored rate of flow exceeds the desired rate of flow of the medicinal fluid, controller 44 causes motor 16 driving



peristaltic pump **14** to slow sufficiently to the desired rate of infusion. Conversely, if the monitored rate of flow is less than the desired rate of flow of the medicinal fluid, the controller causes the motor to speed up, thereby increasing the rate at which peristaltic pump **14** is infusing the medicinal fluid sufficiently to achieve the desired rate.

In FIG. 2, a system **10** is illustrated and is similar in most respects to system **10**. However, in system **10**, a cable **42** includes a multi-pin connector **70** for electrically connecting to flow sensor **30**, which comprises a portion of a flow sensing module **36** in which the flow sensor is connected through internal leads **78** to connector **70**. Cable **42** and connector **70** are considered non-disposable and can be detached from flow sensor **30** and Y site **24**. In almost all other respects, system **10** is identical to and includes equivalent elements to the embodiment shown in FIG. 1.

Connector **70** includes a plurality of conductive pins **72** that are inserted into corresponding orifices **74** formed in the side of the upper tube of the Y site. Pins **72** make electrical contact with corresponding female receptacle **76**, which is connected to flow sensor **30** through internal leads **78** that extend through the interior of flow-sensing module **36**. The distal and proximal pressure signals determined by flow sensor **30** are conveyed through lead **78** and cable **42** to controller **44** for use in controlling peristaltic pump **14** (or other device for varying the rate of flow of the medicinal fluid, as explained herein), to achieve the desired rate of flow of the medicinal fluid into a patient.

FIGS. 3A and 3B illustrate further details of a system **10**, comprising yet another embodiment of the present invention. In system **10**, there are several differences compared to the previous two embodiments. For example, an electronically controlled valve **80** is used to vary the flow rate of a medicinal fluid **85** from a reservoir **83**, which is disposed at a substantially higher elevation than a patient's body (not shown). The pressure head thus developed is sufficient to infuse the medicinal fluid at more than the desired rate. However, electronically controlled valve **80** modulates the rate of flow of medicinal fluid **85** from reservoir **83** to achieve the desired rate. A controller **44** provides a control signal that is conveyed to electronically controlled valve **80** through a cable **82**. The control signal causes the electronically controlled valve to adjust the flow of the medicinal fluid to achieve the desired rate of infusion. The controlled flow of medicinal fluid **85** flows through fluid line **12** into a Y site **24**, which includes an embedded differential pressure sensor **98** for monitoring the rate of flow of the medicinal fluid flow through the Y site. Differential pressure sensor **98** monitors the difference between a pressure at a distal point **102** and a proximal point **100**, producing a signal for the differential pressure that is indicative of the rate of flow of the medicinal fluid flow through a restriction or orifice, which is disposed between the points at which the distal and proximal pressures are measured. Further details of the differential pressure sensor and of a probe **92** are illustrated in FIG. 3B. The power signal and the signal indicative of differential pressure are conveyed through a lead **84** that extends between controller **44** and probe **92**, which has a plurality of spaced-apart contacts **86** that are sized and configured to couple with corresponding contacts (pads) on differential pressure sensor **98** when the probe is seated in an index notch **94** formed in the side of the Y-site adjacent to differential pressure sensor **98**, so that the signal indicative of flow through the differential pressure sensor is conveyed to controller **44**.

Also shown in FIGS. 3A and 3B are details of a bypass passage **104** that extends generally parallel to the fluid path

through the restriction or orifice within differential sensor **98** and for receiving the signal that it produces corresponding to the differential pressure between the proximal and distal points. Normally, bypass passage **104** is clamped shut while Y site **24** is being used for monitoring the flow of medicinal fluid **85** to a patient and is only opened in the event that a substantially greater rate of flow is required, for example, to flush the fluid line or to initially prime the fluid line, before connecting it to the patient. FIGS. 3A and 3B show bypass passage **104** open, but FIG. 3A also illustrates a dash line showing how the elastomeric material, i.e., a polymer of other plastic material, comprising Y site **24** is compressed with a suitable clamp (not shown) that holds probe **92** in place within index notch **94**, with contacts **86** electrically mating with the corresponding contacts on the differential pressure sensor. The clamp will thus close bypass passage **104** when the Y site is being used to monitor the rate of medicinal fluid flow into a patient.

In each of the preferred embodiments, including the one shown in FIGS. 3A and 3B, the pressure sensors or differential pressure sensors can be fabricated as a capacitor, with one plate coupled to a substrate and an opposite, overlying plate supported in sealed relationship above the plate on the substrate, so that a vacuum exists between the two plates, enabling absolute pressure to be measured. In differential pressure sensor **98**, an orifice would be provided to couple the volume between the two plates to the point that is distal the orifice or restriction, while the plate overlying the plate supported by the substrate would be exposed to the pressure of the medicinal fluid proximate the orifice or restriction. Alternatively, piezoelectric type pressure sensors can be used for the two pressure sensors in flow sensor **30** and for differential pressure sensor **98**.

Further details of flow sensor **30** are illustrated in FIGS. 4-6. As will be evident particularly in FIGS. 5 and 6, flow sensor **30** includes a pair of glass slabs **124**, disposed on opposite sides of a silicon spacer **126** that defines the fluid path through the flow sensor. Furthermore, silicon spacer **126** forms a restriction or orifice **128** that separates proximal pressure sensor **32** from distal pressure sensor **34**, as shown in FIG. 4. The substantially smaller cross-sectional area of the restriction or orifice within flow sensor **30** is shown in FIG. 5, in contrast to the much greater area of a fluid passage **130** on opposite sides of the restriction. Pressure sensors **32** and **34** are fabricated on the larger of the pair of glass slabs **124** using conventional lithographic techniques, as are often used in fabricating integrated circuits. Furthermore, proximal pressure sensor **32** is connected through leads **112** and **116** to pads **110** and **114** on the larger of the glass slabs **124**, pad **114** being a common terminal for both the proximal and distal pressure transducers. Likewise, distal pressure transducer **34** is connected through leads **118** and **122** to pads **114** and **120**, which are also disposed on the exposed portion of the larger of the pair of glass slabs **124**. While leads **112**, **116**, **118**, and **122** are shown as discrete wires to simplify the drawings, it will be understood that these "wires" preferably comprise conductive traces applied to the larger one of glass slabs **124** using a conventional photolithographic technique, which is also employed to form pads **110**, **114**, **120**. It will be understood that other suitable materials can be employed in fabricating proximal, distal, or differential pressure sensors, using much the same configuration disclosed above.

In a preferred embodiment, restriction or orifice **128** within pressure sensor **30** and in differential pressure sensor **98** is substantially smaller in cross-sectional area than that of fluid paths **130** on both the distal and proximal sides of the orifice or restriction. Those of ordinary skill in the art will

appreciate that the dimensions used for the orifice and fluid paths can readily be varied, so long as the restriction provided by the orifice is substantially less than the cross-sectional areas of the proximal and distal fluid passages on opposite sides of the orifice, to ensure that a sufficiently great differential pressure is monitored as a result of the pressure drop of medicinal fluid flowing through the restriction or orifice to enable accurate control of the pump or electronically controlled valve that varies the flow rate of the medicinal fluid.

Another embodiment of a Y site **24** is illustrated in FIGS. 7–9. Y site **24** also includes bypass passage **104**, but includes flow sensor **30** with the two separate pressure sensors, instead of differential pressure sensor **98**. To connect to flow sensor **30**, a clamp **139** is provided as shown in FIG. 9. A series of three spaced-apart electrical contacts **141** are included on the end of a jaw **140** on clamp **139** and the spacing between contacts **141** and their disposition correspond to the spacing between pads **110**, **114**, and **120** on flow sensor **30**. Thus, each of electrical contacts **141** can readily make electrical connection with a different one of the pads. Connected to each of contacts **141** is a different one of a plurality of leads **42**. Leads **42** extend to controller **44** and convey the signals produced by the proximal and distal pressure sensors in flow sensor **30** to the controller.

To ensure that contacts **141** correctly meet and make contact with pads **110**, **114**, and **120** on flow sensor **30**, clamp **139** also includes a jaw **142** shaped to fit within an index groove **134** provided on the side of Y site **24**, disposed adjacent flow sensor **30**, but opposite a recess **132**. Jaw **140** is thus indexed to fit within recess **132**, bringing contacts **141** into electrically conductive connection with pads **110**, **114**, and **120**. Alternatively, the indexing function can be accomplished by providing the indexing geometry of jaw **142** and index groove **23** on jaw **140** and recess **132**. Furthermore, clamp **139** includes handles **136** and a torsion spring **138** that is enclosed therein and which extends around a pivot **146** that couples the handles together. Torsion spring **138** provides a biasing force sufficient to compress the elastomeric material comprising Y site **24** so as to close bypass passage **104** as shown in FIG. 9.

It will be understood that other techniques for providing a probe configured for making electrical contact with pads **110**, **114**, and **120** on pressure sensor **30** can alternatively be used, and that such a probe or stylus can be held in place by a separate clamp that closes bypass passage **104**. As noted above, when bypass passage **104** is closed, fluid flows through the fluid path and orifice or restriction within flow sensor **30**, enabling a signal to be produced by the flow sensor indicative of the rate of the medicinal fluid flow therethrough, which is used by the controller in determining the rate at which the medicinal fluid is being infused into the patient. This feedback signal is used by the controller to achieve a desired rate of infusion, and for monitoring the total amount of medicinal fluid infused into a patient, to achieve a desired VTBI.

FIG. 11 illustrates internal functional components of controllers **44/44**. Flow sensor **30** or differential pressure sensor **98** are connected to an appropriate sensor measuring circuit **154** having an output coupled to an analog-digital (A-D) converter **152**. A-D converter **152** converts the analog signals supplied by the sensor measuring circuit into a digital signal that is input to a microcontroller **150**. As a further alternative, microcontroller **150** may include its own internal A-D converter, in which case A-D converter **152** can be omitted.

Microcontroller **150** is connected to a memory **156** (or may alternatively include an internal memory) that com-

prises both random access memory (RAM) and read only memory (ROM)—neither separately shown. Machine instructions stored within memory **156** are used to implement control functions when executed by microcontroller **150**. A keypad **158** comprising the buttons on the user interface of controllers **44/44** enables user to control the microcontroller functions. The microcontroller drives display **46**, which indicates the values of the parameters selected by the user with keypad **158**. A radio frequency (RF) communication link **160** is optionally provided, enabling microcontroller **150** to communicate with external devices (not shown) via an RF transmission. The communication with such external devices is likely to be bi-directional, enabling input of desired parameters to alternatively be provided by an external device instead of via keypad **158**. A power supply **162** provides the appropriate voltage levels for each of the components comprising controller **44** or controller **44**.

Microcontroller **150** produces an output signal that is applied to a digital-to-analog (D-A) converter **164**. The D-A converter changes the digital signal from microcontroller **150** to a corresponding analog signal that is applied to a motor drive block **166**. It should also be noted that microcontroller **150** may include an internal D-A converter, enabling D-A converter **164** to be omitted. Also, it is contemplated that a motor drive **166** responsive to digital signals may be employed, also obviating the need for the D-A converter. As an alternative, if electrically-controlled valve **80** is used instead of peristaltic pump **14** to vary the flow of medicinal fluid through the fluid line to the patient, the digital signal from the microcontroller or the analog signal from D-A converter **164** may be used to control the electrically-controlled valve. When peristaltic pump **14** is used, motor drive **166** provides the drive signal to the electric motor that drives the pump to vary the rate at which the medicinal fluid is infused into the patient.

By monitoring the rate of flow of a medicinal fluid using flow sensor **30** or differential pressure sensor **98**, a feedback signal (i.e., the signal indicative of the current rate of flow of the medicinal fluid received from the Y site) is produced. Microcontroller **150** uses the feedback signal to control peristaltic pump **14** or electrically controlled valve **80** to achieve the desired rate selected by the user.

Although the present invention has been described in connection with the preferred form of practicing it and modifications thereto, those of ordinary skill in the art will understand that many other modifications can be made to the invention within the scope of the claims that follow. Accordingly, it is not intended that the scope of the invention in any way be limited by the above description, but instead be determined entirely by reference to the claims that follow.

The invention in which an exclusive right is claimed is defined by the following:

1. A fluid delivery system for infusing a medicinal fluid supplied from a reservoir into a patient at a desired rate, comprising:

- (a) a fluid line through which the medicinal fluid is conveyed from the reservoir to a patient;
- (b) a flow controller that selectively varies a rate of flow of the medicinal fluid through the fluid line;
- (c) a processor that is controllably coupled to the flow controller, said processor operating the flow controller so as to vary a rate at which the medicinal fluid flows through the fluid line; and
- (d) a flow sensor that monitors a rate of flow of the medicinal fluid through the fluid line, producing an

output signal indicative thereof, said flow sensor comprising an orifice disposed in a fluid path through which the medicinal fluid flows in the fluid line, said orifice having a cross-sectional size that is substantially less than that of the fluid line and a pressure-sensing module configured to sense a pressure drop across the orifice, said pressure sensor producing the signal in response thereto, said output signal being coupled to the processor, said processor controlling the flow controller in a closed-loop process as a function of the signal, to achieve the desired rate of infusion of the medicinal fluid into a patient.

2. The fluid delivery system of claim 1, wherein the pressure sensing module comprises a distal pressure sensor and a proximal pressure sensor, said distal pressure sensor monitoring a distal pressure of the medicinal fluid, downstream of the orifice, and said proximal pressure sensor monitoring a proximal pressure of the medicinal fluid, upstream of the orifice, a difference between the distal pressure and the proximal pressure determining the signal supplied to the processor, which is indicative of the rate of flow of medicinal fluid through the fluid line.

3. The fluid delivery system of claim 1, wherein the pressure sensing module comprises a differential pressure sensor that monitors a differential pressure across the orifice and in response thereto, produces the signal supplied to the processor, which is indicative of the rate of flow of medicinal fluid through the fluid line.

4. The fluid delivery system of claim 1, wherein the flow sensor is disposed in a Y fitting in the fluid line, said Y fitting being coupled to the processor.

5. The fluid delivery system of claim 1, wherein the flow sensor is disposable and is connected to the fluid line.

6. The fluid delivery system of claim 5, wherein the flow sensor is removably coupled to the processor through a connector.

7. The fluid delivery system of claim 5, wherein the flow sensor is removably coupled to the processor through a signal probe having an indexing structure to align a first set of contacts on the signal probe with a second set of contacts that are electrically coupled to the flow sensor.

8. The fluid delivery system of claim 1, wherein the flow controller comprises a pump that forces the medicinal fluid through the fluid line to infuse the medicinal fluid into a patient.

9. The fluid delivery system of claim 1, further comprising a user interface that enables input by a user of the desired rate of medicinal fluid flow through the fluid line.

10. A fluid delivery system for infusing a medicinal fluid supplied from a reservoir into a patient at a desired rate, comprising:

- (a) a fluid line through which the medicinal fluid is conveyed from the reservoir to a patient;
- (b) a flow controller that selectively varies a rate of flow of the medicinal fluid through the fluid line;
- (c) a processor that is controllably coupled to the flow controller, said processor operating the flow controller so as to vary a rate at which the medicinal fluid flows through the fluid line; and
- (d) a flow sensor that monitors a rate of flow of the medicinal fluid through the fluid line, producing an output signal indicative thereof, the flow sensor is disposed within a fitting in the fluid line, further comprising a bypass channel within the fitting, generally in parallel with the orifice, said bypass channel being selectively opened to enable the medicinal fluid to substantially bypass the orifice when a substantially

greater rate of flow of the medicinal fluid than the desired rate is required through the fluid line, said output signal being coupled to the processor, said processor controlling the flow controller in a closed-loop process as a function of the signal, to achieve the desired rate of infusion of the medicinal fluid into a patient.

11. A flow control for controlling a fluid flow through a fluid line to achieve a desired rate of infusion of a medicinal fluid into a patient, comprising:

- (a) a flow sensor adapted to be disposed in a fluid path of a medicinal fluid flowing through a fluid line, said flow sensor producing a signal indicative of a rate of flow of a medicinal fluid through the fluid path, said flow sensor includes an orifice disposed in the fluid path, said orifice having a cross-sectional size that is substantially less than that of the fluid path, both proximal and distal to the orifice, and a pressure-sensing module configured to sense a pressure drop across the orifice, said pressure sensor producing the signal in response thereto;
- (b) a flow regulator adapted to be disposed within the fluid path for use in varying a rate of flow of a medicinal fluid through the fluid path; and
- (c) a processor coupled to the flow sensor to receive the signal produced thereby, said processor being coupled to the flow regulator to control the rate of flow of a medicinal fluid through the flow regulator in response to the signal to achieve the desired rate of infusion.

12. The flow control of claim 11, wherein the pressure sensing module comprises a differential pressure sensor that monitors a differential pressure across the orifice and in response thereto, produces the signal supplied to the processor, which is indicative of the rate of flow of medicinal fluid through the fluid line.

13. The flow control of claim 11, wherein the pressure sensing module comprises a differential pressure sensor that monitors a differential pressure across the orifice and in response thereto, produces the signal supplied to the processor, which is indicative of the rate of flow of medicinal fluid through the fluid line.

14. The flow control of claim 11, wherein the flow regulator comprises a pump that is operatively controlled by the processor to vary a rate of the medicinal fluid flow through the fluid path.

15. The flow control of claim 11, wherein the flow regulator comprises an electrically controlled valve that is operatively controlled by the processor to vary a rate of the medicinal fluid flow through the fluid path.

16. The flow control of claim 11, wherein the flow sensor is disposed in a Y fitting in the fluid line, said Y fitting being coupled to the processor.

17. The flow control of claim 11 wherein the flow sensor is disposable and is coupled into the fluid path.

18. The flow control of claim 17, wherein the flow sensor is removably coupled to the processor through a connector.

19. The flow control of claim 17, wherein the flow sensor is coupled to the processor through a removable probe having electrical contacts.

20. The flow control of claim 11, further comprising a user interface that enables input by a user of the desired rate of medicinal fluid flow through the fluid path.

21. A flow control for controlling a fluid flow through a fluid line to achieve a desired rate of infusion of a medicinal fluid into a patient, comprising:

- (a) a flow sensor adapted to be disposed in a fluid path of a medicinal fluid flowing through a fluid line, said flow

sensor producing a signal indicative of a rate of flow of a medicinal fluid through the fluid path, wherein the flow sensor is disposed within a fitting, further comprising a bypass channel within the fitting, generally in parallel flow relationship with the orifice, said bypass channel being selectively opened to enable the medicinal fluid to substantially bypass the orifice when a substantially greater rate of flow of the medicinal fluid than the desired rate is required;

- (b) a flow regulator adapted to be disposed within the fluid path for use in varying a rate of flow of a medicinal fluid through the fluid path; and
- (c) a processor coupled to the flow sensor to receive the signal produced thereby, said processor being coupled to the flow regulator to control the rate of flow of a medicinal fluid through the flow regulator in response to the signal to achieve the desired rate of infusion.

**22.** A method for controlling a rate of infusion of a medicinal fluid into a patient through a fluid path, comprising the steps of:

- (a) providing a flow sensor within a fitting in the fluid path, said flow sensor producing a signal indicative of a rate of flow of a medicinal fluid through fluid path;
- (b) sensing the rate of flow of the medicinal fluid with the flow sensor to produce the signal;
- (c) providing an electrically controlled flow regulating device in the fluid path;
- (d) automatically controlling the flow regulating device in response to the signal produced by the flow sensor to achieve a desired rate of flow of the medicinal fluid into a patient through the fluid path;
- (e) providing a bypass within the fitting, said bypass being selectively operable by a user to enable the medicinal fluid to substantially bypass the flow sensing module if a substantially greater rate of flow of the medicinal fluid through the fluid line than the desired rate is required.

**23.** The method of claim **22**, wherein the step of providing an electrically controlled flow regulating device comprises the step of providing an electrically energized pump.

**24.** The method of claim **22**, wherein, the step of providing an electrically controlled flow regulating device comprises the step of providing an electrically controlled valve.

**25.** The method of claim **22**, wherein the step of providing a flow sensor comprises the step of providing a Y site in a fluid line through which the medicinal fluid flows and in which a flow sensing module is included.

**26.** The method of claims **25**, further comprising the step of coupling the flow-sensing module to a user interface that includes a processor used for automatically controlling the flow-regulating device.

**27.** The method of claim **26**, further comprising the step of providing an indexing structure to align electrical contacts and to facilitate the step of coupling.

**28.** The method of claim **22**, wherein the step of sensing the rate of flow comprises the step of sensing a distal pressure and a proximal pressure on a distal side and on a proximal side of an orifice through, which the medicinal fluid flows in the fluid path.

**29.** The method of claim **22**, wherein the step of sensing the rate of flow comprises the step of sensing a differential pressure between a distal side and a proximal side of an orifice through which the medicinal fluid flows in the fluid path.

**30.** The method of claim **22**, wherein the step of sensing the rate of flow comprises the step of sensing a differential pressure between a distal side and a proximal side of an orifice through which the medicinal fluid flows in the fluid path.

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UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 6,685,668 B1  
DATED : February 3, 2004  
INVENTOR(S) : Steve T. Cho and Gene E. Clark

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 12,

Line 12, after "of" delete "claims" and insert therefore -- claim --

Line 23, after "orifice" delete "through," and insert therefore -- through --

Signed and Sealed this

Twenty-first Day of June, 2005

A handwritten signature in black ink that reads "Jon W. Dudas". The signature is written in a cursive style with a large, looped initial "J".

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JON W. DUDAS  
*Director of the United States Patent and Trademark Office*