

(19)



(11)

EP 2 739 794 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
23.04.2025 Bulletin 2025/17

(21) Application number: **12820445.0**

(22) Date of filing: **31.07.2012**

(51) International Patent Classification (IPC):
E03C 1/05 (2006.01)

(52) Cooperative Patent Classification (CPC):
E03C 1/055; E03C 1/04

(86) International application number:
PCT/US2012/000337

(87) International publication number:
WO 2013/019272 (07.02.2013 Gazette 2013/06)

(54) **AUTOMATIC FAUCETS**

AUTOMATISCHE WASSERHÄHNE

ROBINETS AUTOMATIQUES

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **31.07.2011 US 201161574345 P**
15.03.2012 PCT/US2012/000150

(43) Date of publication of application:
11.06.2014 Bulletin 2014/24

(73) Proprietor: **Sloan Valve Company**
Franklin Park, IL 60131 (US)

(72) Inventors:
• **HERBERT, Kay**
Winthrop, MA 02152 (US)
• **MO, Xiaoxiong**
Lexington, MA 02420 (US)
• **KRULL, Jeff**
Naperville, IL 60556 (US)
• **DAHER, Jean F.**
Auburn, MA 01501 (US)
• **CHEN, Qiaohong**
Lexington, MA 02420 (US)

• **VISH, Ronald J.**
West Roxbury, MA 02132 (US)
• **GULER, Fatih**
Winchester, MA 01890 (US)
• **WANG, Xu**
Hoffman Estates, IL 60061 (US)

(74) Representative: **Schmidbauer, Andreas Konrad**
Wagner & Geyer Partnerschaft mbB
Patent- und Rechtsanwälte
Gewürzmühlstrasse 5
80538 München (DE)

(56) References cited:
DE-A1- 102010 009 215 DE-A1- 102011 110 092
DE-B3- 10 320 636 JP-A- 2008 248 474
US-A- 4 894 874 US-A- 5 199 639
US-A- 5 823 229 US-A- 6 082 407
US-A1- 2009 106 891 US-A1- 2009 188 995
US-A1- 2010 044 604 US-A1- 2010 071 126
US-A1- 2010 269 923 US-A1- 2010 275 359
US-A1- 2010 327 197 US-A1- 2013 167 953
US-B2- 7 608 936 US-B2- 7 650 653
US-B2- 7 690 623 US-B2- 7 871 057
US-B2- 7 921 480

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 2 739 794 B1

Description

[0001] This application claims priority from and is a continuation-in part of PCT Application PCT/US2012/000150, filed on March 15, 2012, entitled "Automatic Faucets" and US Provisional Application 61/574,345, filed on July 31, 2011, entitled "Automatic Faucets."

[0002] This invention relates to automatic faucets and methods for operating and controlling such faucets.

BACKGROUND OF THE INVENTION

[0003] In public facilities or large private facilities, there are several different types of automatic faucets in use today. There are also metering faucets that are manually activated to turn on the water by pressing the faucet head and are hydraulically timed so that the water remains on for a set period of time after depression of the head. Some of these faucets have separate head allowing separate control over the hot and cold water. Other metering faucets mix the incoming hot and cold water streams and, when actuated, deliver a tempered output stream.

[0004] Also known is a manually activated metering faucet whose on-time is controlled electronically. Still other known faucets are activated electronically when the user positions a hand under the faucet. Automatic water dispensing systems have provided numerous advantages including improved sanitation, water conservation, and reduced maintenance cost. Since numerous infectious diseases are transmitted by contact, public-health authorities have encouraged the public and mandated to food workers the exercise of proper hygiene including washing hands effectively. Effective hand washing has been made easier by automatic faucets. Automatic faucets typically include an object sensor that detects presence of an object, and an automatic valve that turns water on and off based on a signal from the sensor. If the water temperature in an automatic faucet is not in an optimal range, individuals tend to shorten their hand washing time. To obtain an optimal water temperature,

a proper mixing ratio of hot and cold water and proper water actuation has to be achieved. Automatic faucets usually use a preset valve that controls water flow after mixing.

[0005] The hydraulically timed faucets are disadvantaged in that it is difficult to accurately control the on-time of the faucet over the long term because of mains pressure changes and foreign matter build up in the faucet which can adversely affect the hydraulic controls within the faucet. Furthermore, some faucets can not always discriminate between a user's hand and other substances and objects which may be brought into proximity to the faucet, e.g., a reflective object disposed opposite the faucet's infrared transceiver, soap build up on the faucet's proximity sensor, etc. Resultantly, those prior faucets may be turned on inadvertently and/or remain

on for too long a time resulting in wastage of water

[0006] There is still a need for reliable automatic faucets that do not waste water and have energetically efficient operation.

[0007] JP2008248474 discloses an automatic faucet with a generator located in a spout and designed for a stable operation. In the automatic faucet, inside of the main body portion, there is a water passage, an electromagnetic valve for opening and closing the water passage, a sensor for detecting a user, the generator for generating electric power by using a water flow running through the water passage, and a control portion for controlling the electromagnetic valve on the basis of output from the sensor. The automatic faucet is also equipped with a water ejection joint which is fixed to the main body portion and the leading end of which is provided with an spout; a leading end, which allows the water flow to run into the generator, is supported on the side of the main body portion; and a back end, which allows the water flow to run out from the generator, is supported on the side of the water ejection joint. Thus, the generator is fixed by being held in the state of being sandwiched between the side of the main body portion and that of the water ejection joint.

[0008] US Patent publication 2013/0167953 discloses a faucet device. The faucet device includes a device body; a solenoid valve; a spout port forming portion; a generator for generating electrical power by rotating an impeller; a solenoid valve-side water-passage forming member for guiding water to the generator; and a spout port-side water-passage forming member for guiding water to a spout port. The faucet device also includes a first elastic member for sealing between the solenoid valve-side water-passage forming member and the generator and allowing relative displacement therebetween; a second elastic member for sealing between the spout port-side water-passage forming member and the generator and allowing relative displacement therebetween; a third elastic member for coupling the solenoid valve-side water-passage forming member and the device body and allowing relative displacement therebetween; and a fourth elastic member for coupling the spout port-side water-passage forming member and the device body and allowing relative displacement therebetween.

[0009] DE 102010009215 discloses a flow controller for fluids. The flow controller has an energy supply by means of the flow of the fluid. The flow controller consists of a supply line for the fluid and a turbine wheel which is rotationally mounted and through which the fluid flows and which drives an electric generator which charges the energy accumulator and a consumption point for the fluid. The forwarding of the liquid can be blocked by a shut-off valve which can be electrically controlled by control electronics which use at least one sensor and which can be adapted to various types of sensors and to the characteristics of the various types of consumption points and the shut-off valve. The control electronics and the sensor can be supplied with electric energy from the accumu-

lator.

[0010] DE 102011110092 discloses a sanitary fitting. The sanitary fitting has a fitting housing and an electrical control unit for controlling the water flow through at least one water line. The electrical control unit has at least one electrically actuatable control element, in particular a throughflow valve, for closing and opening the water line. The fitting housing is provided for arranging at an installation site, in particular on a wall, on an installation platform and/or on a sanitary body such as a washbasin, bathtub or the like. The sanitary fitting can be maintained or repaired with particularly little effort, specifically even in applications in which the demands with regard to vandalism are of considerable significance. The fitting housing comprises at least one fitting main body that can be firmly fixed at the installation site and comprises an assembly cover, which can be released from the fitting main body and which covers a housing opening, for the opening of the fitting housing for maintenance and/or servicing purposes. The fitting main body includes at least one turbine, which drives an electrical generator, for utilizing the flow energy of the water flow.

[0011] US Patent publication 20090188995 discloses a faucet apparatus with a turbine. The faucet turbine includes a rotatable rotor vane which is disposed in a water supply channel, and in which an axial direction is substantially parallel to the water supply channel. The faucet turbine also includes a magnet which is rotatable integrally with the rotor vane; a coil which is disposed to be opposed to one end face in an axial direction of the magnet; and a controller which is disposed on a side of the one end face of the magnet and above the water supply channel, and which is connected to the coil through wiring.

[0012] Finally, DE103206368 discloses a faucet which can be actuated manually or touchless. This DE document is seen as the closest prior art.

SUMMARY OF THE INVENTION

[0013] The present invention is set forth in the independent claims, respectively. Preferred embodiments of the invention are described in the dependent claims. The present invention is defined and limited by the scope of the appended claims.

[0014] The present invention generally relates to automatic sensor based faucets and methods of operating such faucets.

[0015] Thus, according to the present invention, a method of controlling water flow in an automatic faucet is provided. The method comprises the features of independent claim 1.

[0016] Also according to the present invention, an automatic faucet is provided. The automatic faucet comprises the features of independent claim 2.

[0017] Further, the dependent claims describe preferred embodiments of the automatic faucet.

[0018] In the following, several aspects are discussed.

However, these aspects are not covered by independent claim 1, nor by independent claim 2:

According to one aspect, useful for the understanding of the invention, an automatic faucet includes a housing forming partially an internal barrel and a faucet head and being constructed to include at least one water inlet conduit extending into the barrel and a water outlet for delivering water from a spout. The automatic faucet also includes a faucet crown removably mounted on the faucet head. The automatic faucet also includes inside the barrel a valve module, a sensor module, and a control module. The valve module includes an electromagnetic actuator for controlling the water flow from the water outlet. The sensor module is constructed to provide sensor data influenced by a user. The control module is constructed to receive the sensor data from the sensor module. The internal barrel and the faucet head are constructed and arranged to releasably enclose and retain the valve module, the sensor module and the control module.

[0019] Preferred embodiments may include one or more of the following features: The control module is located on a circuit board removably mounted inside the faucet head. The circuit board is removable after removing the faucet crown from the faucet head.

[0020] The automatic faucet includes a turbine module constructed to generate electrical power. The turbine module is located inside the faucet head and is removable for servicing. The turbine module is constructed to generate electrical power, and the turbine module is located inside the faucet head and being removable after removing the faucet crown from the faucet head.

[0021] The valve module includes a housing comprising a mixing valve module cooperatively arranged with a shut-off cartridge. The shut-off cartridge is designed for turn shut-off upon removal of the actuator and associated actuator housing. The automatic faucet may include a mixing handle for controlling the mixing valve module. The valve module includes a housing comprising a mixing valve module cooperatively arranged with a shut-off cartridge and the turbine module is constructed to receive water flow from the shut-off cartridge.

[0022] According to another aspect, useful for the understanding of the invention, an automatic faucet includes a housing constructed to receive at least one water inlet conduit and having a spout for delivering water and a valve module including a valve controlled by an electromagnetic actuator for controlling the water flow from the spout. The faucet also includes a sensor module constructed to provide sensor data influenced by a user, and a control module constructed to control opening and closing of the valve by providing signals to the electromagnetic actuator. The control module is constructed to receive sensor data from the sensor module and execute a sensing algorithm that keeps track of a noise signal level and dynamically adapts a signal threshold, the sensing algorithm tracking signal trend to determine a presence of a user.

[0023] Preferred embodiments may include one or more of the following features: The control module is constructed and programmed to execute the sensing algorithm utilizing separate parameters for different power supply sources. There may be one or more sensor modules and the sensor module may include a capacitive sensor. The capacitive sensor includes a touch capacitive sensor, or the capacitive sensor includes a proximity capacitive sensor. Alternatively, the sensor module includes an active infra-red (IR) sensor comprising an infrared emitter and detector, or a passive infra-red sensor comprising an infrared detector. Alternatively, the sensor module includes an ultrasonic sensor detecting approach, presence, or departure of a user.

[0024] The valve module, the sensor module and the control module are located in the housing of the faucet. Alternatively, the valve module and the control module are located in a control system unit located below a top surface of a sink. The control system unit may include a quick connect fitting for connecting the water inlet conduit. The control system unit includes a water filter associated with the actuator.

The control system unit is mounted on a wall using a wall plate. The valve module is designed for auto shut off upon removal of the actuator.

[0025] The automatic faucet includes a water turbine module for providing power to the electronic control circuit. The water turbine and the control module are designed to measure a water flow rate of the faucet. The water turbine and the control module are designed to detect a fault condition of the faucet. The control module is constructed to execute a power management algorithm.

[0026] The automatic faucet may include a photovoltaic cell for providing power to the electronic control circuit. The automatic faucet includes an indicator for indicating status to a user. The indicator includes an LED diode, an acoustic indicator, or a display.

[0027] According to yet another aspect, useful for the understanding of the invention, an automatic faucet includes a housing constructed to receive at least one water inlet conduit and having a spout for delivering water. The automatic faucet includes a valve module, a sensor module, a battery module, a turbine module, and a control module. The valve module includes a valve controlled by an electromagnetic actuator for controlling the water flow from the spout. The sensor module is constructed to provide sensor data influenced by a user. The control module is constructed to control opening and closing of the valve by providing signals to the electromagnetic actuator. The control module is also constructed to receive sensor data from the sensor module and execute a sensing algorithm. The control module is also constructed to execute a power management algorithm for managing electrical power generated by the water turbine and provided to and from the battery.

[0028] Aspects useful for the understanding of the invention may include one or more of the following features:

tures:

The control module (control system unit) may include the valve module including the electromechanical actuator (a solenoid actuator) and an optional filter. The actuator housing is constructed to enable an auto shut-off by turning the actuator housing (i.e., turn shut-off) and thus there is no need to shut the water off in case of maintenance, valve changing, or filter cleaning. The combination of filter attached to removable valve module (i.e., valve cartridge) and the turn shut-off associated with the electromagnetic actuator allows for inspecting and cleaning of the filter without tools and without having to shut off the water supply.

[0029] According to yet another aspect, useful for the understanding of the invention, a sensor based faucet includes a water turbine module located in the water flow discharged from the faucet. The water turbine includes a rotor coupled to rotor blades located within the water path having a predetermined flow rate, a magnet, a stator and an electrical coil constructed and arranged to generate electrical power.

[0030] Preferably, the faucet includes the water turbine for providing power to the electronic control circuit and a rechargeable battery. The water turbine and the electronic control circuit are designed to measure a water flow rate of the faucet. The faucet may include a water turbine, a photovoltaic cell and a rechargeable battery, and the microcontroller may include a power management system for controlling input and output of electrical power and charging of the battery.

[0031] Preferably, the faucet including the water turbine are further constructed and arranged to detect a minute amount of water leaving the faucet. The faucet including the water turbine are further constructed and arranged to detect a flow rate of water leaving the faucet. The faucet is activated by an automatic sensor and is further constructed and arranged to detect a malfunction of a faucet element based on a signal from the water turbine.

[0032] Advantageously, the control system unit is designed for easy installation and removal of water conduits (e.g., water hoses) using a quick connect design. The installation requires a simple pull / push to secure the conduits to the control system unit and/or to the faucet. After shutting off the water supply, the quick connect hose fittings allow installation of hoses prior to installing the valve housing (manifold). In combination with the special wall-mounting bracket, the manifold can be easily installed and removed for repairs without tools. The present design uses a special Allen wrench, or other key for a screw securing the cover of the control module with respect to a bracket mounted below the sink.

[0033] The control module (control manifold) is designed cooperatively with a wall-mounting bracket. The manifold provides for easy installation and removal onto the wall bracket. The manifold attaches to the wall plate via a simple twist action and is secured as soon as the manifold cover is put over the manifold.

[0034] The control system unit is rigidly and totally secured by a simple screw tightening to a wall plate. Once the cover screw is secured, the manifold cannot be removed from the wall mounting bracket (wall plate).

[0035] The control system unit also includes a battery module that connects batteries inside a battery case regardless of orientation of the case with respect to the holder. The battery case can only be installed two ways (180 degree symmetry) and therefore prevents wrong polarity installation. The battery case allows for "blind" installation, i.e., if installer cannot see the location under the sink but still can install the batteries. A simple quarter turn of the battery cover ring will make the batteries slide out for easy replacement. If the battery cover ring is not locking the batteries (batteries not secured) the battery case cannot be installed onto the manifold, which alerts the installer. The battery case is sealed via an o-ring from humidity and the battery case is secured in the manifold via snaps.

[0036] The control module manifold also includes a water turbine. The turbine reduces power consumption and also allows for precise metering by reading the AC signal frequency which is proportional to the flow rate and also optimized for different flow rates with an insertable flow nozzle and integrated in the manifold and fault detection such as leaks and clogs. That is, the turbine turns for leaks or stops for clogs.

[0037] The novel faucet provides for easy installation and removing the crown assembly using one screw. Advantageously, the crown design and function can be easily changed such as adding photovoltaic cells, display screens (e.g., LCD display) and user interfaces.

[0038] The electromechanical actuator may be coupled to only one valve interposed in one conduit delivering premixed hot and cold water. The electromechanical actuator may coupled to another type of a valve for controlling flow of hot and cold water in two separate conduits, as described in PCT application PCT/US01/43277. Alternatively, the control signals may be delivered to two electromechanical actuators constructed and arranged to control separately two valves and thereby control separately water flow in two separate conduits with hot and cold water delivered to a faucet.

[0039] According to yet another aspect, useful for the understanding of the invention, the faucet may be self-contained battery operated, electronic faucet which can operate for over two, three or more years between battery replacements. The faucet which has a minimum number of moving parts, and the individual parts may be accessed quite easily for maintenance purposes. The faucets can be manufactured and maintained at relatively low cost.

[0040] According to yet another aspect, useful for the understanding of the invention, there is a novel interface for calibrating or programming a sensor-based faucet. The interface interacts with a user via an object sensor coupled to a microprocessor for controlling the water flow

in the faucet. The sensor-based faucet includes a valve interposed in a conduit and controlled by an electromechanical actuator, and a sensor for generating sensor output signals to an electronic control circuit constructed and arranged to provide the control signals for opening and closing the valve. The control circuit may direct the valve to provide a predetermined number of water bursts or light flashes at different steps of various algorithms to communicate with a user when sensing different problems such as a battery low state, an electrical problem or a mechanical problem in one of the faucet's elements.

[0041] According to yet another aspect, useful for the understanding of the invention, the faucet has a hot and cold-water inlet and an outlet. A sensor generates sensor output signals provided to an electronic control circuit constructed and arranged to provide control signals to an electromechanical actuator. The control circuit provides also signal to an optical, acoustic or other indicator starts signaling when the actuator first opens the valve. The control circuit provides signals to the indicator that continues signaling for a predetermined duration to indicate to a user that a time interval prescribed as necessary for effective hand washing has not yet expired. When the interval does expire, the user is thereby assured that he has complied with the relevant duration regulation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042]

FIG. 1 is a front perspective view showing a faucet installed on a sink with a control system unit located below the sink.

FIG. 1A is the front perspective view of the faucet with the control system unit shown in an exploded view.

FIGs. 2 and 2A are perspective views showing two embodiments of the faucet of FIG. 1.

FIG. 3 is perspective view of the faucet of FIG. 1 with a faucet crown removed.

FIG. 3A is a perspective exploded view of the faucet without the faucet crown.

FIGs. 3B and 3C are perspective exploded views of the faucet crown and a circuit board module with an attachment for the faucet shown in FIG. 3 designed for capacitive sensing and IR sensing, respectively. FIG. 4 is a perspective, exploded view of the control system unit located below the sink of the installation shown in FIG. 1.

FIGs. 4A and 4B are perspective exploded views of the control system unit shown in FIG. 4 with individual modules shown in more detail.

FIGs. 4C and 4D are perspective side views of the control system unit shown in FIG. 4 with the cover removed illustrating a valve module with a turn shut-off when removing.

FIG. 4E illustrates a quick connect for a water conduit connecting to the control system unit of Fig. 4.

FIG. 5 is a perspective view of a wall attachment plate for attaching the control system unit shown in FIG. 1 and in FIG. 1A.

FIGs. 6 and 6A are a perspective top view and a perspective bottom view, respectively, of a base holder for the control system unit shown in FIGs. 4A through 4D without the individual modules.

FIGs. 7, 7-I, 7A, and 7A-I, are top and cross-sectional views of the control system unit with the individual modules attached.

FIG. 8 shows a cover for the control system unit in several perspective and detailed views also illustrating individual attachments elements for attaching the cover to a base.

FIG. 8A is an exploded perspective view of the battery module shown in FIG. 4A.

FIG. 8B is an exploded perspective view of the actuator module shown in FIG. 4A.

FIG. 9 is a front perspective view showing another embodiment of a faucet installed on a sink with a control system unit located inside the faucet body. FIGs. 9A and 9B are a front view and a side view of the faucet shown in FIG. 9, respectively.

FIG. 10 is a cross-sectional side view of the faucet shown in FIG. 9.

FIG. 10A is a cross-sectional, detailed side view of the faucet head of the faucet shown in FIG. 10.

FIG. 10B is a cross-sectional side view of the faucet shown in FIG. 10 showing the faucet head in an exploded view for better illustration.

FIGs. 11 and 11A are top and cross-sectional views of a turbine module located in the faucet head shown in FIGs. 10A and 10B.

FIG. 11B is a perspective exploded view of the elements located inside the faucet head including the turbine module, the circuit board module and the aerator.

FIGs. 12, 12A, 12B, 12C and 12D show several views of the turbine including water flow surfaces all located inside the turbine module

FIG. 13 shows an exploded perspective view of the control system located inside the faucet shown in FIG. 10, having the faucet enclosure removed.

FIGs. 13A, 13B, 13C, 13D and 13E show several views of a mixing and shut-off valve located inside the faucet shown in FIG. 10.

FIG. 14 is a block diagram of the faucet elements and control circuitry for controlling operation of the faucet shown in FIG. 1 or FIG. 9.

FIG. 15 is a block diagram of another embodiment of the faucet elements and control circuitry for controlling operation of the faucet shown in FIG. 1 or FIG. 9. FIGs. 16A through 16G are circuit diagrams of the faucet elements shown in the block diagram in FIG. 15.

FIG. 17 illustrates the main operation and control of the faucet shown in FIG. 1 or FIG. 9.

FIG. 18 is a flow chart that illustrates power manage-

ment for the turbine module executed by a controller. FIGs. 19, 19A, 19B, 19C, and 19D show another flow chart that illustrates power management for the faucet executed by a controller.

FIG. 20 is a flow chart that illustrates a battery contact algorithm for powering up the control circuitry.

FIG. 21 includes FIGs 21A, 21B and 21C illustrating a flow chart of the algorithm for sensing a target present at the faucet spout shown in FIG. 1 or FIG. 9.

FIG. 22 is a flow chart that illustrates target sensing for turning water on in the flow chart of FIG. 21.

FIG. 22A is a flow chart that illustrates target sensing for turning water off in the flow chart of FIG. 21.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0043] Referring to FIG. 1, a water faucet 10 is shown mounted to a sink 14, wherein a faucet base 18 is in contact with a top sink surface 15. The faucet includes a housing or encasement body 17 and a faucet crown 16. Faucet 10 is electrically coupled to a control manifold (control system unit) 100 using electrical line 11 and receives water via a water line 12. FIG. 1A illustrates faucet 10 with control system unit 100 shown in an exploded view. Water line 12 is coupled to control center unit 100 using a quick connect arrangement (shown in FIG. 4E) and provides mixed hot/cold water. That is, there is a hot cold mixing unit (not shown in FIGs 1 and 1A) located below sink 14. Control system unit 100 includes a plastic manifold 12, i.e., a base designed to accept the individual modules, and a cover 105.

[0044] FIGs. 2 and 2A show two different mounting embodiments of faucet 10, shown in FIG. 1, to sink 14. These mounting embodiments are also applicable to faucet 10A, shown in FIG. 9. The mounting can be done using a quick connect assembly including a rod 24 and coupling elements 25A and 25B. The coupling assembly may include a gasket 22 or a thicker insulation element for electrically insulating the faucet from a sink made of metal. This insulation is important for proper operation of the capacitance sensor (described below) in installation with a metal sink. FIG. 2A shows another mounting embodiment of faucet 10 using the assembly of rods 28A and 28B and coupling elements 27A, 27B, 29A and 29B.

[0045] The faucet housing actually consists of a shell-like structure that forms an upright main body and the upper portion including the faucet crown having a spout extending out from the main body portion to an aerator 38. Aerator 38 includes a removable aerator body 38A and a wrench 38B. The faucet crown (Shown as faucet crown 34 in Figs. 2 and 2A) includes a removable cover plate secured to the body. The cover plate may be replaced by an LCD display or another type of display for communicating with a user or providing a message to the user for entertainment or advertising.

[0046] FIGs. 3 and 3A illustrate the faucet having a

faucet crown 34 removed. Faucet 10 includes a flexible water conduit 12 having a quick connect 12A attachable to faucet crown insert 36 providing water to aerator 38. FIG. 3B is a perspective exploded views of a faucet crown 34A, including a circuit board and a cover plate, designed for capacitive sensing of the user's hands. FIG. 3C is perspective exploded view of a faucet crown 34B, including a circuit board and a cover plate, designed for IR sensing of the user's hands (or alternatively designed for both capacitive sensing and IR sensing).

[0047] FIG. 4 is a perspective, exploded view of a control system unit 100 located below the sink. FIG. 4A is a perspective exploded view of control system manifold (control system unit) 100 having a cover 105 removed. Control system unit 100 is designed co-operatively with a wall-mounting bracket 106 (shown in FIGs. 4 and 5) for attachment to the bathroom wall below the sink.

[0048] Referring to FIGs. 4, 4A, 4B, 4C and 4D, control system unit 100 includes a valve module 150, a battery module 200, a turbine module 250, and an electronic control module 400 (shown in FIG. 14). The valve module 150 includes a valve housing 160, a lower valve body 156, an upper valve body 152, a filter 158 (or a strainer 158), and an actuator 153. Actuator housing 152 includes an alignment mark 154A and valve housing 160 includes an alignment mark 154B used for the turn shut-off by turning the actuator housing (i.e., turn shut-off operates as a bayonet connection) and thus there is no need to shut the water off in case of maintenance, valve changing, or filter cleaning. This is enabled by the combination of a turn shut-off cartridge 170 (shown in FIGs. 13C and 13D) located inside a turn shut-off base structure 180 and enclosed within turn shut-off housing 160.

[0049] The valve module 150 provides a valve for controlling water flow to faucet 10 using actuator 153 and provides a shut-off valve for easy maintenance. When valve module 150 is removed from the turn shut-off housing 160 there is no water flow across control system unit 100. Also referring to FIGs. 7 and 7A, actuator module 150 is inserted into the valve housing oriented to match the arrows 154A and 154B on both elements, as shown in FIG. 4D. When actuator module 150 is turned, for example, 45 degrees as shown in Fig. 4C, water can flow across the valve module if the actuator is open. Rotating actuator module 150 about 45 degrees (from the position shown in FIG. 4C to the position shown in FIG. 4D) closes the valve for maintenance. Actuator module 150 includes an electromechanical actuator (a solenoid actuator) described below. FIG. 8B is an exploded perspective view of the actuator module and the valve including the water filter, also shown in FIG. 4A. The solenoid actuator controls the water flow delivered to the user from aerator 38. The entire faucet system includes numerous O-rings and water seals to prevent water leakage and improve water flow, as is known to a person of ordinary skill in the art.

[0050] Referring to FIGs. 4A and 4B, water turbine module 250 includes a rotor assembly 260 (shown in

detail in FIG. 12C) and a stator assembly 270 (shown in detail in FIG. 12D). Rotor assembly 260 includes a ceramic magnet 262 (or another corrosion resistant magnet) and a propeller 264 secured with a plastic pin. Stator assembly 270 includes a coil 271 located between two stator pieces 272 and 273 made from non-magnetic material.

[0051] Water turbine module 250 is located in the water path wherein the rotor is fixed integrally using the rotary shaft to couple turbine blades 264, and rotor magnet 262. The rotor magnet is opposed to stator pole elements. The stator coil is provided to be interlinked with a magnetic flux passing through the stator poles. When, the water turbine rotates by receiving the water flow, magnet 262 rotates relatively with respect to the stator pole. The flow of the magnetic flux flowing to the rotor and the stator pole is changed. As a result, an induced current flows in the stator coil in such a direction as to prevent the change in the flow of the magnetic flux. The stator - rotor arrangement has preferably 12 poles (but can also have a smaller or a larger number of poles to optimize energy output). The generator is also used as a tachometer to measure effectively the flow rate thru the faucet. This arrangement also enables fault monitoring and detection of a clogged line or a clogged filter. After the current is rectified, it is stored, for example, in the rechargeable battery using the power management algorithm described below. The corresponding signal is provided to the microcontroller, as shown in FIGs. 14 and 15.

[0052] Referring still to Fig 4B and FIGs. 12A and 12B, water turbine module 250 has a single fluid path designed to enable a range of flow rates. Turbine rotor 260 is cooperatively designed with a turbine base 282 having a specially designed focusing inlet 284, and an optional nozzle 283 located in a focusing inlet 284. For flow rates of over 0.7 GPM (gallons per minute) to 1.8 GPM, a larger cross sectional flow path is provided to reduce the internal flow resistance (that is, a pressure loss). On the other hand, for low flow rates as low as 0.35 GPM, focusing inlet 284 includes nozzle 283 that boosts the power output of the turbine generator. The nozzle may held in place by a small tab and groove molded to the nozzle. This design requires relatively small amount of space.

[0053] As shown in FIG. 4B, turn shut-off cartridge 170 includes an exit port 174 (see also FIGs. 13C and 13D), which receives water flow from the valve, which flow is confined by turn shut-off cartridge 170 and exits port 174 and has a laminar flow between turn shut-off base 180 and housing 160 flowing into focusing inlet 284. Advantageously, valve housing 160 and turbine housing 280 are made of a single piece to improve the laminar water flow.

[0054] The water turbine module reduces power consumption and also allows for precise water metering by reading the AC signal frequency, which is proportional to the flow rate and also is optimized for different flow rates with the insertable or permanent flow nozzle 283.

[0055] As described above, the magnetic flux flows

between the rotor and the stator pole in the generator. The magnetic flux acts as a resistance when the water turbine is to be rotated by the force of the flowing water. That is, a magnetic flux generated between the rotor and the stator pole acts as a detent torque to brake the operation of the water turbine during the starting and rotation of the water turbine. The turbine module of the present invention is designed to start and detect a small amount of water flow to detect the water leak in the faucet. The turbine module may be replaced by another rechargeable power source module, such as one or several photovoltaic cells. The photovoltaic cells may be installed at the top of the crown assembly.

[0056] Battery module 200 includes four batteries each providing 1.5V DC. FIG. 8A is an exploded perspective view of the battery module. The battery housing located in the control system unit is designed to receive the battery module 200 regardless of orientation of battery case 204 with respect to holder 210 in the manifold. That is, battery case 210 can only be installed two ways (180 degree symmetry) by clipping attachment clips 208 onto attachment elements 212 of holder 210. This prevents wrong polarity installation of the batteries. In other words, battery case 204 allows for "blind" installation when installer cannot see the location under the sink, but still can install the batteries. During the installation, a simple quarter turn of the battery cover ring will make the batteries slide out for easy replacement. If the battery case ring is not locking (i.e., the batteries not secured), the battery case cannot be installed onto holder 210. Battery module 200 is sealed via an or-ring from humidity and battery case is secured in the manifold via snaps.

[0057] Control system module 100 includes plastic manifold 120, which attaches to a wall plate 106. FIG. 5 illustrates wall attachment plate 106 having attachment elements 113, 114 and 115 cooperatively designed with the attachment elements located on plastic manifold 120, which are cooperatively designed for tight, mechanically robust coupling. Specifically, plastic manifold 120 includes an opening 122 and a barrier 123 designed with element 115 of plate 106. These cooperating surfaces provide mechanically robust coupling and are marked for easy servicing of control system unit 100. The entire control system unit is designed cooperatively with the wall-mounting bracket 106 for easy installation and attachment to, and removal from the wall bracket.

[0058] The manifold attaches to the wall plate 106 via a simple twist action and is secured as soon as the plastic cover 105 is put over the plastic manifold 120. The unit is rigidly and totally secured by a simple screw tightening using a screw 118. Once the cover screw (FIG. 8) is secured, the manifold cannot be removed from the wall mounting bracket (wall plate) 106. The present design uses special Allen wrench (or other key) for a screw securing a cover 105 of the control module. The individual modules within faucet 10 and control system unit 100 are removable and easily replaceable for quick servicing.

[0059] FIGs. 6 and 6A are perspective top view and

perspective bottom view of plastic manifold (base holder) 120 for control system unit 100. FIGs. 7, 7-I, 7A, and 7A-I, are cross-sectional views of control system manifold 100. FIG. 10 shows manifold cover 105 in several perspective and detailed views.

[0060] The cooperative action of the valve module and the actuator module enables auto shut off and thus there is no need to shut the water off in case of maintenance, valve changing or filter cleaning. The combination of filter attached to removable valve cartridge and auto shutoff associated with the electromagnetic actuator allows for inspecting and cleaning of the filter without tools and without having to shutoff the water.

[0061] The actuator module includes an electromagnetic actuator (electromagnetic operator). The electromagnetic actuator includes a solenoid wound around an armature housing constructed and arranged to receive an armature including a plunger partially enclosed by a membrane. The armature provides a fluid passage for displacement of armature fluid between a distal part and a proximal part of the armature thereby enabling energetically efficient movement of the armature between open and closed positions. The membrane is secured with respect to the armature housing and is arranged to seal armature fluid within an armature pocket having a fixed volume, wherein the displacement of the plunger (i.e., distal part of the armature) displaces the membrane with respect to a valve passage thereby opening or closing the passage. This enables low energy battery operation for a long time.

[0062] Preferably, the actuator may be a latching actuator (including a permanent magnet for holding the armature) or a non-latching actuator. The distal part of the armature is cooperatively arranged with different types of diaphragm membranes designed to act against a valve seat when the armature is disposed in its extended armature position. The electromagnetic actuator is connected to a control circuit constructed to apply said coil drive to said coil in response to an output from an optional armature sensor. The armature sensor can sense the armature reaching an end position (open or closed position). The control circuit can direct application of a coil drive signal to the coil in a first drive direction, and in responsive to an output from the sensor meeting a predetermined first current-termination criterion to start or stop applying coil drive to the coil in the first drive direction. The control circuit can direct or stop application of a coil drive signal to the coil responsive to an output from the sensor meeting a predetermined criterion.

[0063] The faucet may be controlled, for example, by an electromagnetic actuator constructed and arranged to release pressure in the pilot chamber and thereby initiate movement of a piston, diaphragm, or a fram assembly, from the closed valve position to the open valve position. The actuator may include a latching actuator (as described in U.S. Patent 6,293,516), a non-latching actuator (as described in U.S. Patent 6,305,662), or an isolated operator (as described in PCT Application

PCT/US01/51098). The valve module may also be controlled manually, initialing an electrical signal to the actuator driver (instead of a signal initiated by a sensor) or by manually releasing pressure in the pilot chamber as described in US Patent 6,874,535.

[0064] Referring to FIG. 4 E, the control system unit is designed for easy installation and removal of the water conduit using a quick connect for providing water to faucet 10. The installation requires a simple pull-push to secure the conduit (e.g., a hose) from the mixing valve or from the faucet into an opening 128. After placement of the water conduit a sliding plate 124 is placed within a slot assembly 132 (FIG. 4A). In combination with the special wall-mounting bracket 106, control system unit 100 can be easily installed and removed for repairs basically without tools.

[0065] FIG. 9 is a front perspective view showing another embodiment of a faucet installed on a sink with a control system unit located inside the faucet body. FIGs. 9A and 9B are a front view and a side view of the faucet shown in FIG. 9, respectively. FIG. 10 is a cross-sectional side view of the faucet shown in FIG. 9. FIG. 10A is a cross-sectional, detailed side view of the faucet head of the faucet shown in FIG. 10. and FIG. 10B is a cross-sectional side view of the faucet shown in FIG. 10 showing the faucet head in an exploded view for better illustration.

[0066] FIG. 13 shows an exploded perspective view of the interior of faucet 10A. In this embodiment the control system unit is arranged differently than in FIGs 4 - 4D, but provides similar advantages and modular design for all modules now located inside the faucet as shown in FIG. 10. Still referring to FIG. 13, the control system unit includes a valve module 150A, a battery module 200A, and a turbine module 250A. Valve module 150A includes a water mixing handle 20 cooperatively designed with a mixing valve module 180A (shown in FIGs 13A, 13B and 13E) and turn shut-off cartridge 170A (shown in FIGs 13C and 13D) all enclosed in turn shut-off housing 160A.

[0067] The valve module 150A includes a lower valve body 156A, an upper valve body 152A, a filter 158A (or a strainer 158A), and an actuator 153 located inside upper valve body 152A. The actuator housing 152 may also include an alignment mark cooperatively designed with an alignment mark located on valve housing 160A used for the turn shut-off by turning the actuator housing as described in connection with FIGs. 4C and 4D. The water output from valve module 150A flows into turbine module 250A shown in detail in FIGs. 11 through 12B.

[0068] FIGs. 11 and 11A are top and cross-sectional views of turbine module 250A located in the faucet head shown in FIGs. 10A and 10B, and FIG. 11B is a perspective exploded view of the elements located inside faucet head 16A. Turbine module 250A includes rotor 260 and stator 270 both cooperatively designed to fit into turbine base 275A, which in turn fits into a hydraulic crown assembly 280A. Turbine module 250A includes a rotor assembly 260 (shown in detail in FIG. 12C) and a stator

assembly 270 (shown in detail in FIG. 12D). Rotor assembly 260 includes rotor magnet 262 (made of ceramic or another corrosion resistant magnet) and propeller 264 secured with a plastic pin. Stator assembly 270 includes coil 271 located between two stator pieces 272 and 273 made from non-magnetic material.

[0069] Faucet head 16A includes a circuit board located above hydraulic crown assembly 280A. The circuit board includes electronics described in connection with FIGs. 14 and 15.

[0070] Similarly as described above in connection with faucet 10, water turbine module 250A has a single fluid path extending from a seal 252A into a focusing inlet 276A and exiting the turbine at port 277A. Turbine module 250A is designed to enable a range of flow rates. Turbine rotor 260 is cooperatively designed with a turbine base 282 having a specially designed focusing inlet 276A and the optional nozzle located in focusing inlet 276A.

[0071] FIG. 14 is a block diagram of control electronics 400 for controlling operation of faucet 10. The control electronics preferably uses a capacitance sensor 50, or alternatively an active IR sensor or a passive IR sensor. The active IR sensor includes an IR transmitter 420 for emitting an IR beam and an IR receiver 424 for detecting the reflected IR light. The passive IR sensor uses passive optical detector for detecting presence of a user as described as described in PCT Applications PCT/US03/38730 and PCT/US03/41303.

[0072] Referring to FIG. 14, control electronics 400 includes a controller 402 powered by a battery 200. Controller 402 is preferably a microcontroller MC9S08GT16A made by Freescale[®]. The microcontroller executes various detection and processing algorithms, which are preferably downloaded. However, the controller and algorithms may also be implemented in the form of dedicated logic circuitry, ASIC, or other. The control electronics 400 includes a power switch 405, a DC-DC converter 406, and a solenoid driver 408. Solenoid driver 408 provides a drive signal to a solenoid 150 monitored by a solenoid feedback amplifier 412, and a signal conditioner 414. Controller 402 communicates with an indicator driver 434 for driving a visible diode 436 (e.g., a blue diode or a red diode) for communications with the user.

[0073] As shown in FIG. 14, the active optical sensor includes an IR diode driver 422 providing power to an IR transmitter 420, and an IR sensor amplifier 426 receiving a signal from an IR receiver 424. The entire operation is controlled by controller 402.

[0074] The IR diode driver 422 may be designed to progressively increase and decrease the optical power output according to target and environment conditions. The same applies to the IR receiver using IR sensor amplifier 426. Usually only one of the modes is used both since one is enough to achieve the purpose. The following are examples of the conditions: If the environment is too IR bright, the system boosts the optical emission signal. If the target is too close, such as in the closet,

the system reduces the IR signal to save power. If the target is not sufficiently IR reflective, the system boosts the IR signal either from the IR transmitter 520 or using IR sensor amplifier 526.

[0075] The system 402 uses an optional voice synthesizer 440 connected to a speaker 442 for providing a user interface. An optional flow sensor conditioner 444 connected to a flow sensor 446 is used for detecting water flow through the faucet. Alternatively, a sensor may be used to detect overflow of water in the sink and provide signal to controller 402 for shutting down the automatic faucet.

[0076] The system may include an optional RF transceiver 450 connected to an antenna 452 for wireless communication with a remotely located central controller or network. The present design may be deployed with a network of wirelessly connected bathroom faucets and sanitary appliances. The remotely located network enables monitoring and gathering of information concerning the faucets and appliances. The communication between the faucets and appliances uses preferably low frequency RF signals, and the communication to the remotely located network node uses preferably a high frequency RF signals.

[0077] In general, wired or wireless data communication is used for transmitting information as it relates to the well being of the bathroom faucets and sanitary appliances. The transmitted information (together with the ID of the device) may include the battery voltage, number of flushes, the unit is on run-on condition (cannot turn off), no water condition (cannot turn on), etc. Using an RF transceiver 450 and antenna 452, the system can receive information such as command remotely initiated from somewhere else. The fixtures may talk to each other in a networked fashion. The fixtures may talk to a proximal central unit and this unit may transmit data (wired or wireless) to a wider network such as internet. In an aspect, useful for the understanding of the invention, the user initiates a location wide diagnostic mission by requesting each fixture to turn on and then off. In turn, each fixture reports successful/unsuccessful operation. The fixture may also report other variables such as battery voltage, number of flushes, etc. The user then gathers the information and schedules a maintenance routing according to results. This is particularly useful in establishments such as convention centers, etc. where the maintenance personnel currently send crews to monitor the well being of the fixtures and take notes manually prior to an event.

[0078] Another aspect, useful for the understanding of the invention, of the control electronics is described in PCT Publications WO2005/056938 and WO2004/061343.

[0079] According to another aspect, useful for the understanding of the invention, the control electronics includes a microcontroller that is an 8-bit CMOS microcontroller TMP86P807M made by Toshiba. The microcontroller has a program memory of 8 Kbytes and a data

memory of 256 bytes. Programming is done using a Toshiba adapter socket with a general-purpose PROM programmer. The microcontroller operates at 3 frequencies ($f_c = 16\text{MHz}$, $f_c = 8\text{MHz}$ and $f_s = 332.768\text{kHz}$), wherein the first two clock frequencies are used in a normal mode and the third frequency is used in a low power mode (i.e., a sleep mode). The microcontroller operates in the sleep mode between various actuations. To save battery power, microcontroller periodically samples optical sensor unit for an input signal, and then triggers power consumption controller. Power consumption controller powers up signal conditioner and other elements. Otherwise, the optical sensor unit, the voltage regulator (or the voltage boost) and the signal conditioner are not powered to save battery power. During operation, the microcontroller also provides indication data to an indicator, e.g., a visible diode or a speaker. Control electronics may receive a signal from the passive optical sensor or the active optical sensor described above. A Low battery detection unit may be the low battery detector model no. TC54VN4202EMB, available from Microchip Technology. The voltage regulator may be the voltage regulator part no. TC55RP3502EMB, also available from Microchip Technology (<http://www.microchip.com>). Microcontroller may alternatively be a microcontroller part no. MCU COP8SAB728M9, available from National Semiconductor.

[0080] The faucet may include one or several photovoltaic cells alone or in combination with the water turbine for producing voltage that is proportional to the amount of light that it receives. When system 500 powers up and starts operation, the system registers this voltage and continuously monitors the voltage thereafter. At first time power up, if there is no voltage from the photovoltaic cell, this means dark environment and therefore the unit marks the time and count for a predetermined amount of time. If the time is long enough, such as hours and days, and there is no target detected within the same period of time then the faucet system is powered up but nobody is using the bathroom (i.e., the lights are turned off) and therefore the system goes into a power saving mode. In this mode, the system scans for target at a much slower frequency to conserve battery power. The system may also shut down or slow down other functions such as scanning the override buttons, battery voltage, etc. The use of the photovoltaic cells is described in the PCT Application PCT/US2008/008242, filed on July 3, 2008.

[0081] FIG. 15 is a block diagram of another embodiment of the control circuitry for controlling operation of the faucet shown in FIG. 1.

[0082] FIGs. 16A - 16G are circuit diagrams of the control circuitry shown in the block diagram in FIG. 15.

[0083] Fig. 17 the faucet operation using a state diagram 500. The processor executes the algorithm by first performing all initialization, enabling the interrupts set to power up (state 501). Next, the power for all sources is checked in the All Power Source Check state (state 506). If there is a battery A/D error or the microcontroller is

running out of external power the algorithm enters again state 501 (transition 504). Otherwise, for normal power level and if there is no solenoid activation, the algorithm enters (by transition 512) the Big Capacitor Charge Control (state 518).

[0084] In state 506, if there is normal power level and if there is solenoid activation, the algorithm enters (508) Solenoid Open Timer Control (state 510). After the target is no longer detected or after a pre-selected time period (520) the algorithm enters the Close Solenoid state (state 524). Thereafter, the algorithm transitions (over transition 526) to Big Capacitor Charge Control (state 518). From Big Capacitor Charge Control (state 518) the algorithm transitions (over transition 528) to Capacitor Sensor Control (state 530).

[0085] In Capacitor Sensor Control (state 530) the system executes target detection and when the target is not detected and solenoid activated, the system transitions (transition 534) to Red LED Flash Control (state 550). Alternatively, when the target is detected (FIGs. 22 and 22A), the system transitions (transition 536) to the Open Solenoid state (state 540), where the solenoid is opened. Alternatively, when the target is out of detection zone when solenoid is opened, the system transitions (transition 532) back to the Close Solenoid state (state 524), where the solenoid is closed. Otherwise, when there is no sensing activity, and there is no LED Flash and second battery check needed, the system transitions from state 530 (over transition 538) to the Sleep state (state 570).

[0086] From the Red LED Flash Control state (state 550), the system transitions (transition 552) to the Sleep state (state 570) after there is LED Flash and second battery check is needed. However, if the flag is set to the second battery check, the system transitions (transition 556) to the Second Battery Check Control state (state 560). Also, after the Open Solenoid state (state 540) is there is second battery check required the system transitions (transition 546) to the Second Battery Check Control state (state 560), and then after the battery checking is completed, the system transitions (transition 554) to the Sleep state (state 570).

[0087] Upon each wakeup, the system transitions (transition 574) from the Sleep state (state 570) to the All Power Source Check state (state 506). If there is no turbine power, or no battery power (or low battery power for 10 min less than 3.7 V), or no solar power, the system transitions (transition 572) back to the Sleep state (state 570).

[0088] FIG. 18 is a flow chart that illustrates power management for the control circuitry. The system periodically checks battery power, power from the turbine and optionally power provided by a photovoltaic cell. FIGs. 19, 19A, 19B, 19C, and 19D illustrate power management for the control circuitry.

[0089] FIG. 20 is a flow chart that illustrates battery contact control for powering the control circuitry.

[0090] FIG. 21 is a flow chart that illustrates the algo-

rithm for sensing a target present at the faucet spout shown in FIG. 1 or FIG. 9.

[0091] The system performs the capacitive sensing operation in order to control the faucet operation. Starting from power-up or any kind of reset, system performs self calibration and initialization first, and then it acts as a state machine. Upon waking up from its sleep, the system scans the capacitance sensor to get the current raw data, to update the baseline, and then the system performs associated tasks based on its current status. The processor will go to sleep again after the completion of current task.

[0092] The calibration process includes several processes: "Normalize raw data", "Environment Check", and "Determine Water Effect". The Normalize Raw Data adjusts raw data in dynamic range (a range near 11500). The Environment Check makes sure the noise level is in predefined range, if not, the system blinks LED and keeps monitoring noise level until it falls in the predefined range. If the system keeps in this stage, it is the indication that the system is not suitable for this environment, as shown in Fig. 21A. The Determine Water Effect turns on water to determine water effect and determines if this is a 1.5/0.5 GPM spout / head. It is only an initial value, system will automatically update this during its regular operation. When the calibration is completed, the system turns on water second times to indicate system is ready to use.

[0093] The system uses the total of 8 statuses: TARGETCLEAR, INVERIFY, TOUCHED, TARGETSET, OUTVERIFY, PROHIBITION, PAUSE, and CLEAN. The system will be in one and only one of these statuses at any given time.

[0094] In the TARGETCLEAR status, target signal is always cleared. The system updates the signal threshold, monitoring the noise level and determines signal threshold and the number of a signal to be verified as a target. If the difference of current data and baseline is greater than the signal threshold, and the data continuously increased more than certain value, the system enters INVERIFY status and speedup the scan. In the INVERIFY status, the target signal will be set if the data is verified in this status. The system determines when it needs to set target signal. If the signal data is over Signal Threshold and continuously for predetermined times, then the system turns on target signal and enters TARGETSET status, and stores current raw data as part of reference used to determine when the target removing. If this is triggered 5 times in 30 seconds, the system enters the PAUSE status.

[0095] In the TOUCHED status, target signal will be cleared after it is been touched for 5 seconds. The system determines to clear target signal and clear target signal if it is touched for more than 5 seconds. The system determines what to do from touch to untouched. If touched more than 5 seconds, system enters in the CLEAN status. If touched less than 5 seconds, system goes back to the TARGETSET status.

[0096] In the TARGETSET status the target signal is

always set. The system calibrates the water effect during first 2 seconds, and determines the water effect value, and then sets following parameters:

- signal threshold for the water on time; and
- reference value for the water on to be used to determine if the target has been moved out. The system determine if it needs to enter the OUTVERIFY status.

The system enters OUTVERIFY status if any of the following occurs:

- Run time out
- Raw data does not change over a predefined range
- Signal data is less than signal threshold
- Raw data is fall below than the reference predefined just before the water is turned on.

[0097] In the OUTVERIFY status, the target signal will be cleared if the signal has been verified. The system tracks water run time and clears target signal if water time run out, and system enters in the PAUSE status. The system determines if the data is stable and clears the target signal when data is in predefined range continuously for 1.5 seconds, and then enters in status PROHIBITION. The system determines if the data falls below a reference value, clears target signal when data is in predefined range continuously for 1.5 seconds, and then enters in status PROHIBITION. The system determines if the data is below signal threshold, clear target signal when data is in predefined range continuously for 1 second, and then enters in status PROHIBITION.

[0098] In the PROHIBITION status, the target signal is always cleared. The system determines when to go out of this status. The system will enter in TARGETCLEARED status if it has been in this status for predefined minimum off time.

[0099] In the PAUSE status, target signal is always cleared. The system determines when to go out of this status. The system will enter in TARGETCLEARED status if it has been in this status for predefined time. In the CLEAN status, the target signal is always cleared. The system determines when to go out of this status. The system will enter in TARGETCLEARED status if it has been in this status for predefined time.

[0100] Referring to FIG. 14, the capacitance detector processor 465 communicates with microcontroller processor 402 using the Heart Beep pulse from high to low every 5 seconds to indicate it is in good condition. In the Hold down, the system stops scanning when port 2.5 is low to save the power. In the request LED power, the system sets port 1.5 low to indicate it may need power to turn on LED.

[0101] FIG. 22 is a flow chart that illustrates target sensing for turning water on and FIG. 22A is a flow chart that illustrates target sensing for turning water off in the flow chart in FIG. 21C. This algorithm is described for the proximity and touch capacitive sensor (such as made by

Cypress Semiconductor). However, this algorithm is also applicable for the active IR sensor using a light source and a light detector detecting a reflected signal from a user. The target detection algorithm (and any algorithm described herein) may be imbedded in a designated chip or may be downloaded to the corresponding processor.

[0102] Referring to FIG. 22, the target detection algorithm for turning "water on" starts in the target clear status (water is off).

- Scan sensor at 8 Hz to read sensor data
- Signal = Current raw data - baseline
- If signal > Threshold, Go to verify status
- In verify status, Threshold increase by 5
- In verify status, Threshold increase by 5
- If signal > Threshold consecutively more than "Verify" times, turn on water.
- Threshold and "Verify" times are dynamically updated as below:

For the past 5 seconds:

Noise level = Maximum raw data - minimum raw data

If noise level is low,

threshold = High sensitive level

Verify = 3

If noise level is Medium,

threshold = medium sensitive level

Verify = 4

If noise level is HIGH,

threshold = low sensitive level

Verify = 5

- In "Verify" < Verify Threshold than scan sensor to read sensor data.

[0103] Referring to FIG. 22A and 22A-I, the target detection algorithm for turning "water off" starts after water was turned on.

- Once water is turned on, it will stay on for at least one second even target left right away.
- Target threshold will be set as:
Threshold = Target signal at the time of trigger + water effect - 15
- Three counters are used for determining the target leaving,

Counter1 is to count the number of signal less than threshold

Counter2 is to count the number of signal not

change

Counter3 is to count the number of signal decrease

- If current signal is less than threshold, Counter1 increases by 1, otherwise Counter2 reset to 0. 5
- Stable reference initialized to the first signal data. If the difference between current signal and stable reference is less than predefined range, Counter2 increases by 1, otherwise Counter2 reset to 0, and the stable reference reset to current signal. 10
- If current signal is less than previous signal, Counter3 increase by 1, and the decreased value add to total signal decreased, otherwise, counter3 reset to 0, and total decreased reset to 0. 15
- If Counter1 greater than 8, or counter2 greater than 16, or counter3 is greater than 8 and total signal decreased is greater than 45, or counter3 is greater than 12. Turn off water, as shown in FIG. 22A-I 20
- Threshold reset to 15 after water turning off. 25

[0104] The above-described sensing algorithm overcomes several problems associated with the capacitive proximity sensing. In the capacitance signal, the sensing area is uncertain, especially when water is flowing and the human hands are only part of capacitance source. The signal/ noise ratio is not sufficiently big, and noise may cause false detections. The signal strength varies for different power supply sources (e.g., battery or power adaptor). To overcome these problems, the sensing algorithm automatically calibrates the baseline based on real application environments. The sensing algorithm keeps track of the noise signal level and adapts signal threshold accordingly. The sensing algorithm tracks signal trend not only strength to determine the presence of human hands. Furthermore, the sensing algorithm uses separate parameters for different power supply sources. 30

[0105] The faucet may use an alternative optical transceiver is described in U.S. Patent 5,979,500 or U.S. Patent 5,984,262, and is also described in copending US Applications 10/012,252 and 10/012,226. The microcontroller may be microcontroller COP8SAB and COP8-SAC made by National Semiconductor, or microcontroller TMP86c807M made by Toshiba. To save power and significantly extend battery operation, the wake-up period is much shorted than the sleep period. Depending on the controller's mode, the sleep time may be 100 msec, 300 msec, or 1 sec. 35

[0106] The electronic faucet also communicate with a user by a novel "burst interface" that provides signals to a user in form of water bursts emitted from the faucet. Alternatively, the electronic faucet may include novel an optical or acoustic interface. The electronic faucet is designed to prevent wasting of water when for example 40

an object permanently located in a sink.

Claims

1. A method of controlling water flow in an automatic faucet, comprising:

providing a faucet including

a housing forming partially an internal barrel (17, 17A) and a faucet head (16, 16A), the faucet including at least one water inlet conduit extending into said internal barrel, a spout and a water outlet for delivering water from the spout;
a faucet crown (34, 34A) removably mounted on said faucet head;
a valve module (150, 150A) including an electromagnetic actuator for controlling the water flow from the water outlet;
a sensor module constructed to provide sensor data influenced by a user;
a control module (400) constructed to receive said sensor data from said sensor module; and
said internal barrel and said faucet head being constructed and arranged to releasably enclose and retain said valve module, said sensor module and said control module; wherein the control module (400) executes a sensing algorithm that keeps track of noise signal level and dynamically adapts a signal threshold, said sensing algorithm tracking signal trend to determine presence of a user; and

controls opening and closing of said valve by providing signals to said electromagnetic actuator.

2. An automatic faucet (10, 10A), comprising:

a housing forming partially an internal barrel (17, 17A) and a faucet head (16, 16A), the faucet including at least one water inlet conduit extending into said internal barrel, a spout and a water outlet for delivering water from the spout;
a faucet crown (34, 34A) removably mounted on said faucet head;
a valve module (150, 150A) including an electromagnetic actuator for controlling the water flow from the water outlet;
a sensor module constructed to provide sensor data influenced by a user;
a control module (400) constructed to receive said sensor data from said sensor module; and
said internal barrel and said faucet head being

constructed and arranged to releasably enclose and retain said valve module, said sensor module and said control module; and **characterized in that**

- said control module further constructed for executing a sensing algorithm that keeps track of noise signal level and dynamically adapts a signal threshold, said sensing algorithm tracking signal trend to determine presence of a user in order to control opening and closing of said valve by providing signals to said electromagnetic actuator.
3. The automatic faucet of claim 2, wherein said control module is located on a circuit board removably mounted inside said faucet head.
 4. The automatic faucet of claim 3, wherein said circuit board is removable after removing said faucet crown from said faucet head.
 5. The automatic faucet of claim 2, 3 or 4 including a turbine module (250, 250A) constructed to generate electrical power.
 6. The automatic faucet of claim 5, wherein said turbine module is located inside said faucet head and being removable for servicing.
 7. The automatic faucet of claim 4, including a turbine module constructed to generate electrical power, said turbine module being located inside said faucet head and being removable after removing said faucet crown from said faucet head.
 8. The automatic faucet of claim 2, 3 or 4, wherein said valve module includes a housing comprising a mixing valve module (180; 180A) cooperatively arranged with a shut-off cartridge (170, 170A).
 9. The automatic faucet of claim 8 including a mixing handle for controlling said mixing valve module.
 10. The automatic faucet of claim 5, wherein said valve module includes a housing comprising a mixing valve module (180; 180A) cooperatively arranged with a shut-off cartridge (170, 170A) and wherein said turbine module is constructed to receive water flow from said shut-off cartridge.
 11. The automatic faucet of claim 5, wherein said turbine module and said control module are designed to measure a water flow rate of said faucet.
 12. The automatic faucet of claim 10, wherein said turbine module and said control module are designed to detect a fault condition of said faucet.

13. The automatic faucet of claim 10, wherein said control module is constructed to execute a power management algorithm.
14. The automatic faucet of claim 2, 3, 4 or 5, wherein said sensor module includes a capacitive sensor.
15. The automatic faucet of claim 14, wherein said control module is constructed to control opening and closing of said valve by providing signals to said electromagnetic actuator, and said control module is constructed to execute said sensing algorithm utilizing separate parameters for different power supply sources.
16. The automatic faucet of claim 14, wherein said capacitive sensor includes a touch capacitive sensor.
17. The automatic faucet of claim 14, wherein said capacitive sensor includes a proximity capacitive sensor.
18. The automatic faucet of claim 2, wherein said sensor module includes an active infra-red sensor comprising and infrared emitter and detector.
19. The automatic faucet of claim 2 including a quick connect fitting for connecting and disconnecting said water inlet conduit.
20. The automatic faucet of claim 2 including an indicator for indicating status to a user.
21. The automatic faucet of claim 20, wherein said indicator includes an LED diode.
22. The automatic faucet of claim 2, wherein said faucet crown includes a display.

Patentansprüche

1. Ein Verfahren zur Steuerung des Wasserflusses in einem automatischen Wasserhahn, das Folgendes aufweist:
Bereitstellen eines Wasserhahns, der Folgendes aufweist:

ein Gehäuse, das teilweise einen inneren Zylinder (17, 17A) bildet, und einen Wasserhahnkopf (16, 16A), wobei der Wasserhahn mindestens eine Wassereinlassleitung, die sich in den inneren Zylinder erstreckt, einen Auslauf und einen Wasserauslass zum Abgeben von Wasser aus dem Auslauf aufweist;
eine Wasserhahnkrone (34, 34A), die abnehmbar auf dem Wasserhahnkopf angebracht ist;
ein Ventilmodul (150, 150A), das einen elektro-

magnetischen Aktuator zum Steuern des Wasserflusses aus dem Wasserauslass aufweist; ein Sensormodul, das so konstruiert ist, dass es Sensordaten bereitstellt, die von einem Benutzer beeinflusst werden; ein Steuermodul (400), das so konstruiert ist, dass es die Sensordaten von dem Sensormodul empfängt; und der innere Zylinder und der Wasserhahnkopf so konstruiert und angeordnet sind, dass sie das Ventilmodul, das Sensormodul und das Steuermodul lösbar umschließen und halten; wobei das Steuermodul (400) einen Erfassungsalgorithmus ausführt, der den Rauschsignalpegel verfolgt und einen Schwellenwert dynamisch anpasst, wobei der Erfassungsalgorithmus den Signaltrend verfolgt, um die Anwesenheit eines Benutzers zu bestimmen; und das Öffnen und Schließen des Ventils durch Bereitstellung von Signalen an den elektromagnetischen Aktuator steuert.

2. Ein automatischer Wasserhahn (10, 10A), der Folgendes aufweist:

ein Gehäuse, das teilweise einen inneren Zylinder (17, 17A) und einen Wasserhahnkopf (16, 16A) bildet, wobei der Wasserhahn mindestens eine Wasserzulaufleitung, die sich in den inneren Zylinder erstreckt, einen Auslauf und einen Wasserauslass zum Abgeben von Wasser aus dem Auslauf aufweist; einen Wasserhahnaufsatz (34, 34A), der abnehmbar auf dem Wasserhahnkopf angebracht ist; ein Ventilmodul (150, 150A) mit einem elektromagnetischen Aktuator zum Steuern des Wasserflusses aus dem Wasserauslass; ein Sensormodul, das so konstruiert ist, dass es Sensordaten bereitstellt, die von einem Benutzer beeinflusst werden; ein Steuermodul (400), das so konstruiert ist, dass es die Sensordaten von dem Sensormodul empfängt; wobei der innere Zylinder und der Wasserhahnkopf so konstruiert und angeordnet sind, dass sie das Ventilmodul, das Sensormodul und das Steuermodul lösbar umschließen und halten; und **dadurch gekennzeichnet, dass** das Steuermodul ferner so konstruiert ist, dass es einen Erfassungsalgorithmus ausführt, der einen Rauschsignalpegel verfolgt und einen Schwellenwert dynamisch anpasst, wobei der Erfassungsalgorithmus den Signaltrend verfolgt, um die Anwesenheit eines Benutzers zu bestimmen, um das Öffnen und Schließen des Ventils durch Bereitstellen von Signalen an den elektromagnetischen Aktuator zu steuern.

3. Automatischer Wasserhahn nach Anspruch 2, wobei das Steuermodul auf einer Leiterplatte angeordnet ist, die abnehmbar im Wasserhahnkopf montiert ist.

5 4. Automatischer Wasserhahn nach Anspruch 3, wobei die Leiterplatte nach Entfernen des Wasserhahnaufsatzes vom Wasserhahnkopf abnehmbar ist.

10 5. Automatischer Wasserhahn nach Anspruch 2, 3 oder 4, der ein Turbinenmodul (250, 250A) aufweist, das so konstruiert ist, dass es elektrische Energie erzeugt.

15 6. Automatischer Wasserhahn nach Anspruch 5, wobei das Turbinenmodul im Wasserhahnkopf angeordnet und zu Wartungszwecken entfernbar ist.

20 7. Automatischer Wasserhahn nach Anspruch 4, mit einem Turbinenmodul, das zur Erzeugung von elektrischem Strom konstruiert ist, wobei das Turbinenmodul im Wasserhahnkopf angeordnet und nach Entfernen der Wasserhahnkrone vom Wasserhahnkopf entfernbar ist.

25 8. Automatischer Wasserhahn nach Anspruch 2, 3 oder 4, wobei das Ventilmodul ein Gehäuse mit einem Mischventilmodul (180; 180A) aufweist, das zusammenwirkend mit einer Absperrpatrone (170, 170A) angeordnet ist.

30 9. Automatischer Wasserhahn nach Anspruch 8, der einen Mischgriff zum Steuern des Mischventilmoduls aufweist.

35 10. Automatischer Wasserhahn nach Anspruch 5, wobei das Ventilmodul ein Gehäuse mit einem Mischventilmodul (180; 180A) aufweist, das zusammenwirkend mit einer Absperrpatrone (170, 170A) angeordnet ist, und wobei das Turbinenmodul so konstruiert ist, dass es einen Wasserstrom von der Absperrpatrone aufnimmt.

40 11. Automatischer Wasserhahn nach Anspruch 5, wobei das Turbinenmodul und das Steuermodul so konstruiert sind, dass sie eine Wasserdurchflussrate des Wasserhahns messen.

45 12. Automatischer Wasserhahn nach Anspruch 10, wobei das Turbinenmodul und das Steuermodul so konstruiert sind, dass sie einen Fehlerzustand des Wasserhahns erkennen.

50 13. Automatischer Wasserhahn nach Anspruch 10, wobei das Steuermodul so konstruiert ist, dass es einen Energieverwaltungsalgorithmus ausführt.

55 14. Automatischer Wasserhahn nach Anspruch 2, 3, 4 oder 5, wobei das Sensormodul einen kapazitiven

Sensor aufweist.

15. Automatischer Wasserhahn nach Anspruch 14, wobei das Steuermodul so aufgebaut ist, dass es das Öffnen und Schließen des Ventils durch Bereitstellung von Signalen an den elektromagnetischen Aktuator steuert, und das Steuermodul so aufgebaut ist, dass es den Erfassungsalgorithmus unter Verwendung separater Parameter für verschiedene Stromversorgungsquellen ausführt. 5 10
16. Automatischer Wasserhahn nach Anspruch 14, wobei der kapazitive Sensor einen kapazitiven Berührungssensor aufweist. 15
17. Automatischer Wasserhahn nach Anspruch 14, wobei der kapazitive Sensor einen kapazitiven Näherungssensor aufweist.
18. Automatischer Wasserhahn nach Anspruch 2, wobei das Sensormodul einen aktiven Infrarotsensor aufweist, der einen Infrarotstrahler und einen Detektor aufweist. 20
19. Automatischer Wasserhahn nach Anspruch 2, der eine Schnellkupplung zum Anschließen und Trennen der Wasserzulaufleitung aufweist. 25
20. Automatischer Wasserhahn nach Anspruch 2, der eine Anzeige zum Anzeigen des Status für einen Benutzer aufweist. 30
21. Automatischer Wasserhahn nach Anspruch 20, wobei die Anzeige eine LED-Diode aufweist. 35
22. Automatischer Wasserhahn nach Anspruch 2, wobei der Wasserhahnaufsatz eine Anzeige aufweist.

Revendications 40

1. Procédé de contrôle du débit d'eau dans un robinet automatique, comprenant : 45
 - la fourniture d'un robinet comprenant un boîtier formant partiellement un cylindre interne (17, 17A) et une tête de robinet (16, 16A), le robinet comprenant au moins un conduit d'entrée d'eau s'étendant dans ledit cylindre interne, un bec et une sortie d'eau pour délivrer l'eau du bec ; 50
 - une couronne de robinet (34, 34A) montée de manière amovible sur ladite tête de robinet ;
 - un module de valve (150, 150A) comprenant un actionneur électromagnétique pour contrôler le débit d'eau provenant de la sortie d'eau ; 55
 - un module de capteur conçu pour fournir des données de capteur influencées par un utilisate-

teur ;

un module de commande (400) conçu pour recevoir lesdites données de capteur provenant dudit module de capteur ; et

ledit corps interne et ladite tête de robinet étant construits et agencés pour enfermer et retenir de manière amovible ledit module de valve, ledit module de capteur et ledit module de commande ; dans lequel le module de commande (400) exécute un algorithme de détection qui suit le niveau du signal de bruit et adapte dynamiquement un seuil de signal, ledit algorithme de détection suivant la tendance du signal pour déterminer la présence d'un utilisateur ; et

contrôle l'ouverture et la fermeture de ladite valve en fournissant des signaux audit actionneur électromagnétique.

2. Un robinet automatique (10, 10A), comprenant :

un boîtier formant partiellement un cylindre interne (17, 17A) et une tête de robinet (16, 16A), le robinet comprenant au moins un conduit d'entrée d'eau s'étendant dans ledit cylindre interne, un bec et une sortie d'eau pour délivrer l'eau depuis le bec ;

une couronne de robinet (34, 34A) montée de manière amovible sur ladite tête de robinet ;

un module de vanne (150, 150A) comprenant un actionneur électromagnétique pour contrôler le débit d'eau provenant de la sortie d'eau ;

un module de capteur conçu pour fournir des données de capteur influencées par un utilisateur ;

un module de commande (400) conçu pour recevoir lesdites données de capteur provenant dudit module de capteur ;

ledit corps interne et ladite tête de robinet étant construits et agencés pour enfermer et retenir de manière amovible ledit module de vanne, ledit module de capteur et ledit module de commande ; et **caractérisé en ce que**

ledit module de commande est en outre construit pour exécuter un algorithme de détection qui suit le niveau du signal de bruit et adapte dynamiquement un seuil de signal, ledit algorithme de détection suivant la tendance du signal pour déterminer la présence d'un utilisateur afin de contrôler l'ouverture et la fermeture de ladite vanne en fournissant des signaux audit actionneur électromagnétique.

3. Le robinet automatique selon la revendication 2, dans lequel ledit module de commande est situé sur une carte de circuit imprimé montée de manière amovible à l'intérieur de ladite tête de robinet.

4. Le robinet automatique selon la revendication 3, dans lequel ladite carte de circuit imprimé est amovible après avoir retiré ladite couronne de robinet de ladite tête de robinet.
5. Le robinet automatique selon la revendication 2, 3 ou 4 comprenant un module de turbine (250, 250A) conçu pour générer de l'énergie électrique.
6. Le robinet automatique selon la revendication 5, dans lequel ledit module de turbine est situé à l'intérieur de ladite tête de robinet et est amovible pour l'entretien.
7. Le robinet automatique selon la revendication 4, comprenant un module de turbine construit pour générer de l'énergie électrique, ledit module de turbine étant situé à l'intérieur de ladite tête de robinet et étant amovible après avoir retiré ladite couronne de robinet de ladite tête de robinet.
8. Le robinet automatique selon la revendication 2, 3 ou 4, dans lequel ledit module de vanne comprend un boîtier comprenant un module de vanne de mélange (180 ; 180A) disposé de manière coopérative avec une cartouche d'arrêt (170, 170A).
9. Le robinet automatique selon la revendication 8 comprenant une poignée de mélange pour commander ledit module de vanne de mélange.
10. Le robinet automatique selon la revendication 5, dans lequel ledit module de vanne comprend un boîtier comprenant un module de vanne mélangeuse (180 ; 180A) disposé de manière coopérative avec une cartouche d'arrêt (170, 170A) et dans lequel ledit module de turbine est construit pour recevoir un débit d'eau provenant de ladite cartouche d'arrêt.
11. Le robinet automatique selon la revendication 5, dans lequel ledit module de turbine et ledit module de commande sont conçus pour mesurer le débit d'eau dudit robinet.
12. Le robinet automatique selon la revendication 10, dans lequel ledit module de turbine et ledit module de commande sont conçus pour détecter un état de défaut dudit robinet.
13. Le robinet automatique selon la revendication 10, dans lequel ledit module de commande est construit pour exécuter un algorithme de gestion de l'énergie.
14. Le robinet automatique selon l'une quelconque des revendications 2, 3, 4 ou 5, dans lequel ledit module de détection comprend un capteur capacitif.
15. Le robinet automatique selon la revendication 14, dans lequel ledit module de commande est conçu pour commander l'ouverture et la fermeture de ladite vanne en fournissant des signaux audit actionneur électromagnétique, et ledit module de commande est conçu pour exécuter ledit algorithme de détection en utilisant des paramètres distincts pour différentes sources d'alimentation électrique.
16. Le robinet automatique selon la revendication 14, dans lequel ledit capteur capacitif comprend un capteur capacitif tactile.
17. Le robinet automatique selon la revendication 14, dans lequel ledit capteur capacitif comprend un capteur capacitif de proximité.
18. Le robinet automatique selon la revendication 2, dans lequel ledit module de capteur comprend un capteur infrarouge actif comprenant un émetteur et un détecteur infrarouge.
19. Le robinet automatique selon la revendication 2 comprenant un raccord rapide pour connecter et déconnecter ledit conduit d'arrivée d'eau.
20. Le robinet automatique selon la revendication 2, comprenant un indicateur pour indiquer l'état à un utilisateur.
21. Le robinet automatique selon la revendication 20, dans lequel ledit indicateur comprend une diode LED.
22. Le robinet automatique selon la revendication 2, dans lequel ladite tête de robinet comprend un écran d'affichage.

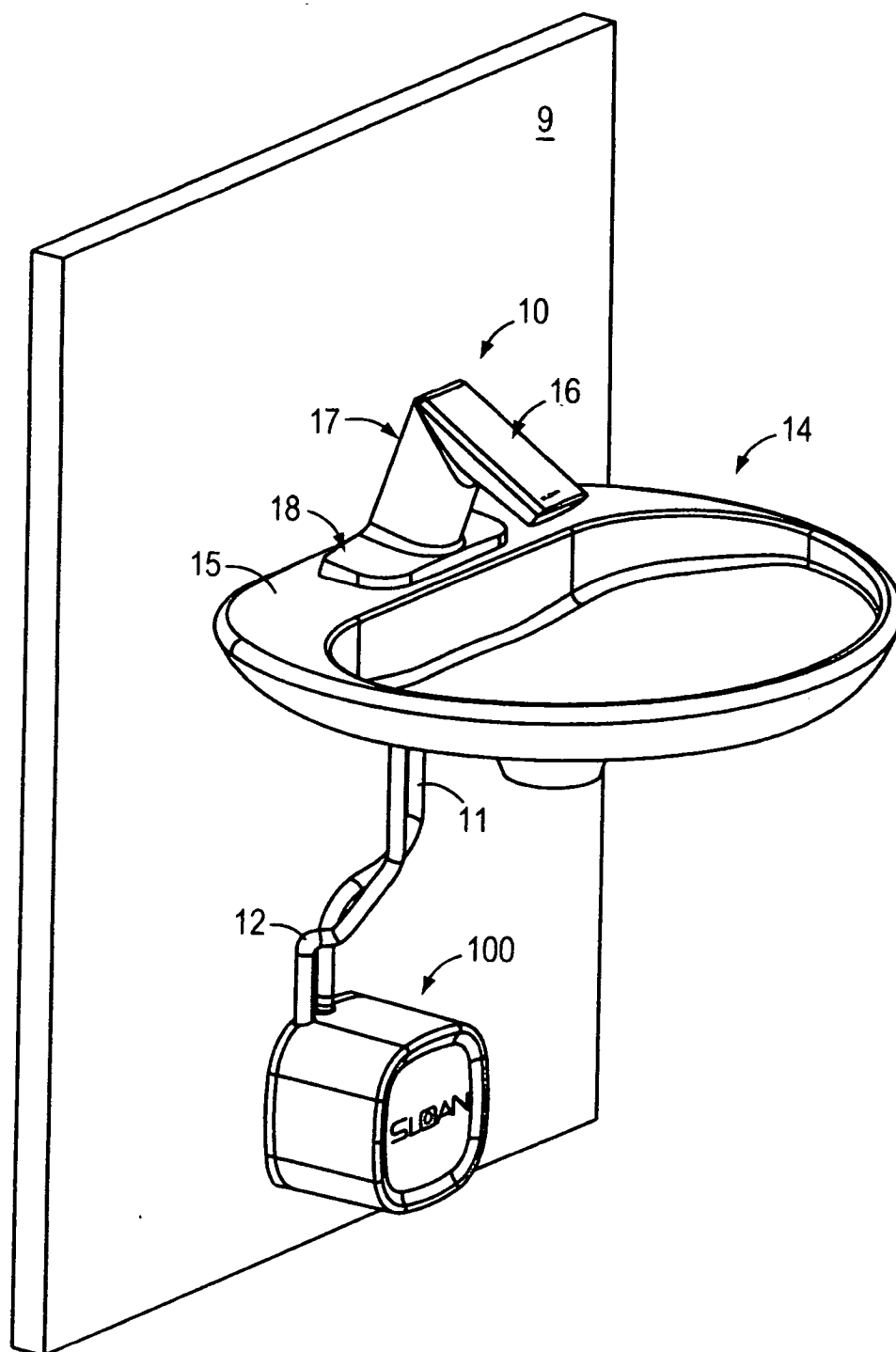


FIG. 1

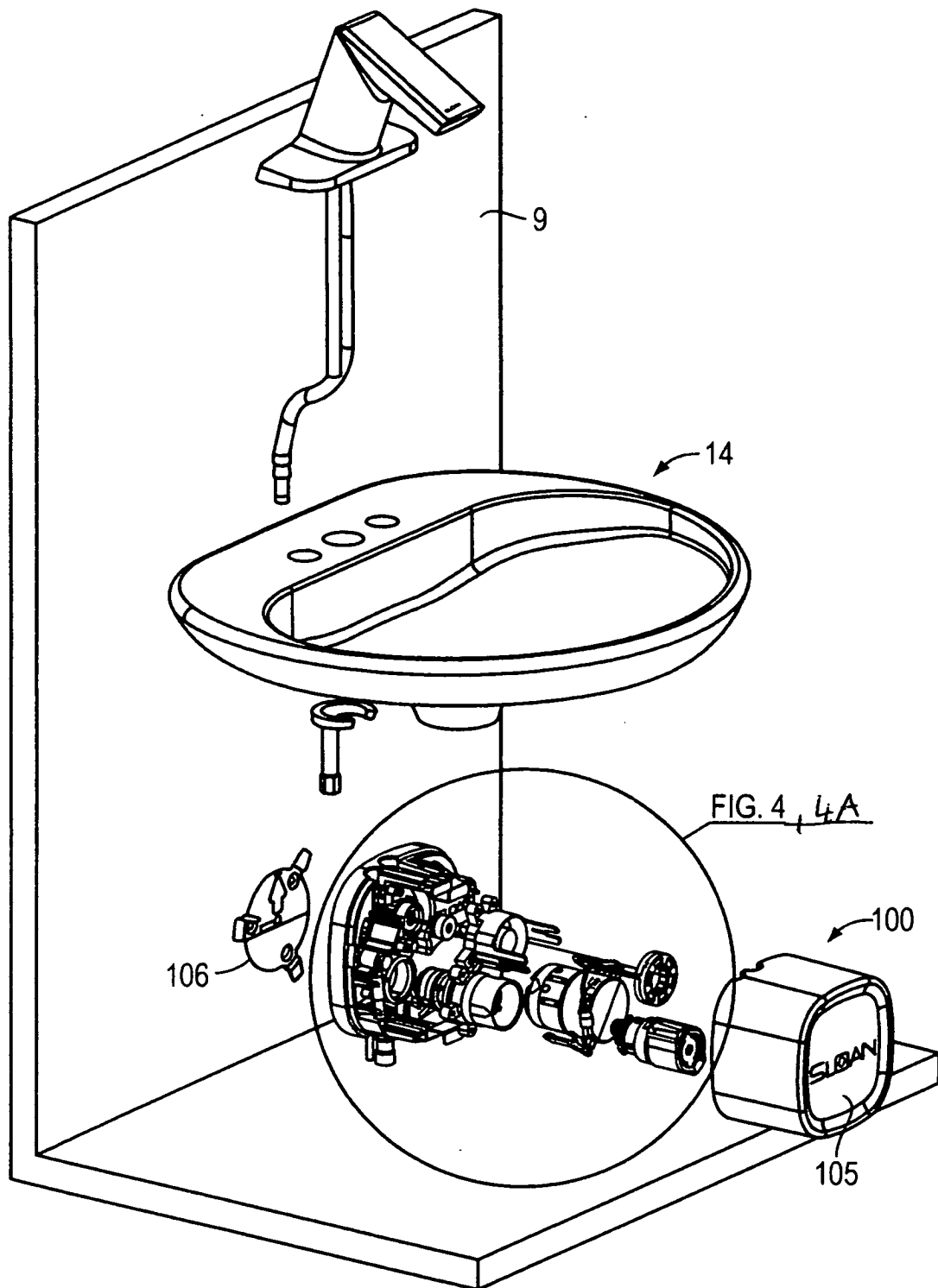


FIG. 1A

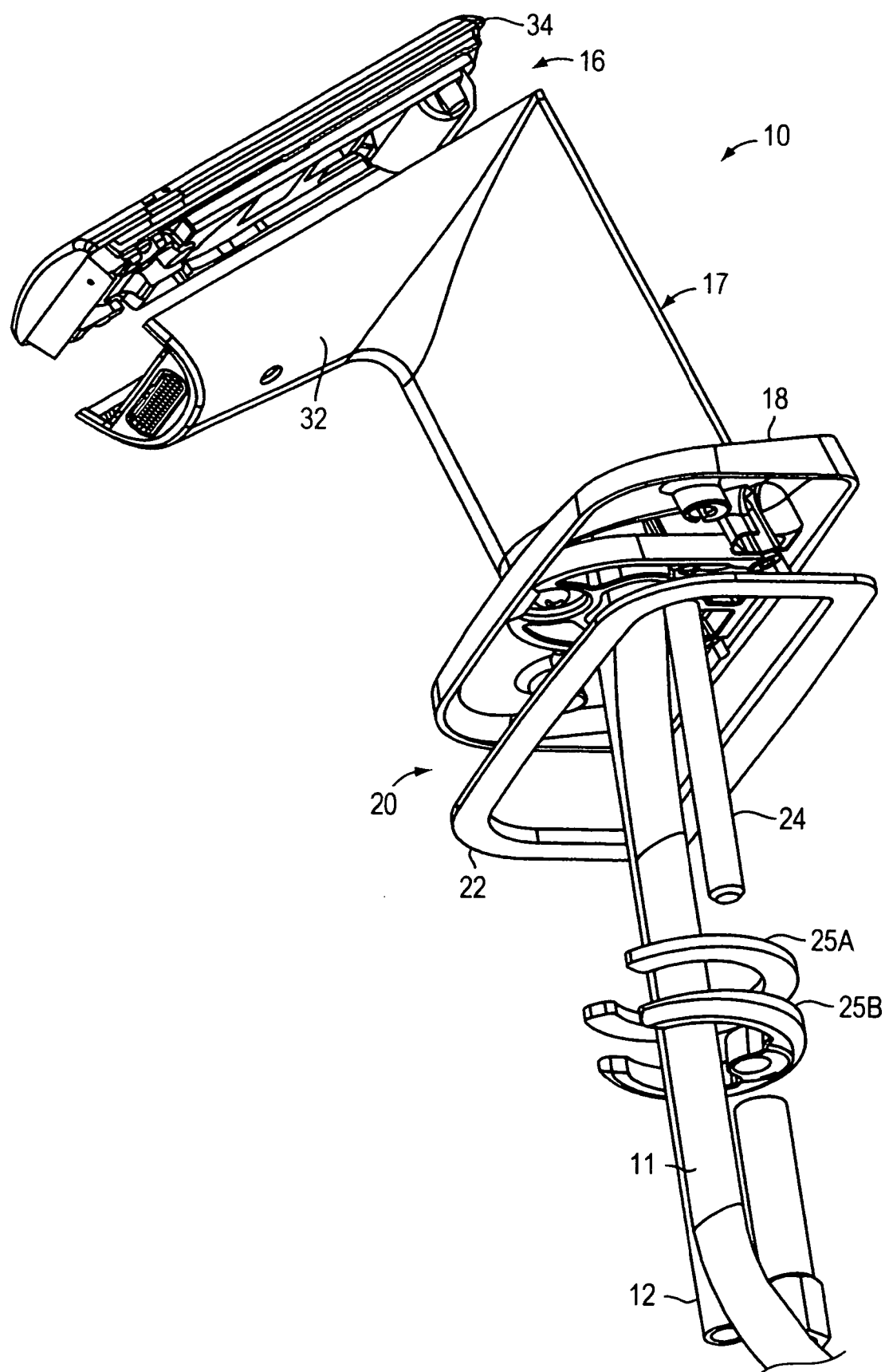


FIG. 2

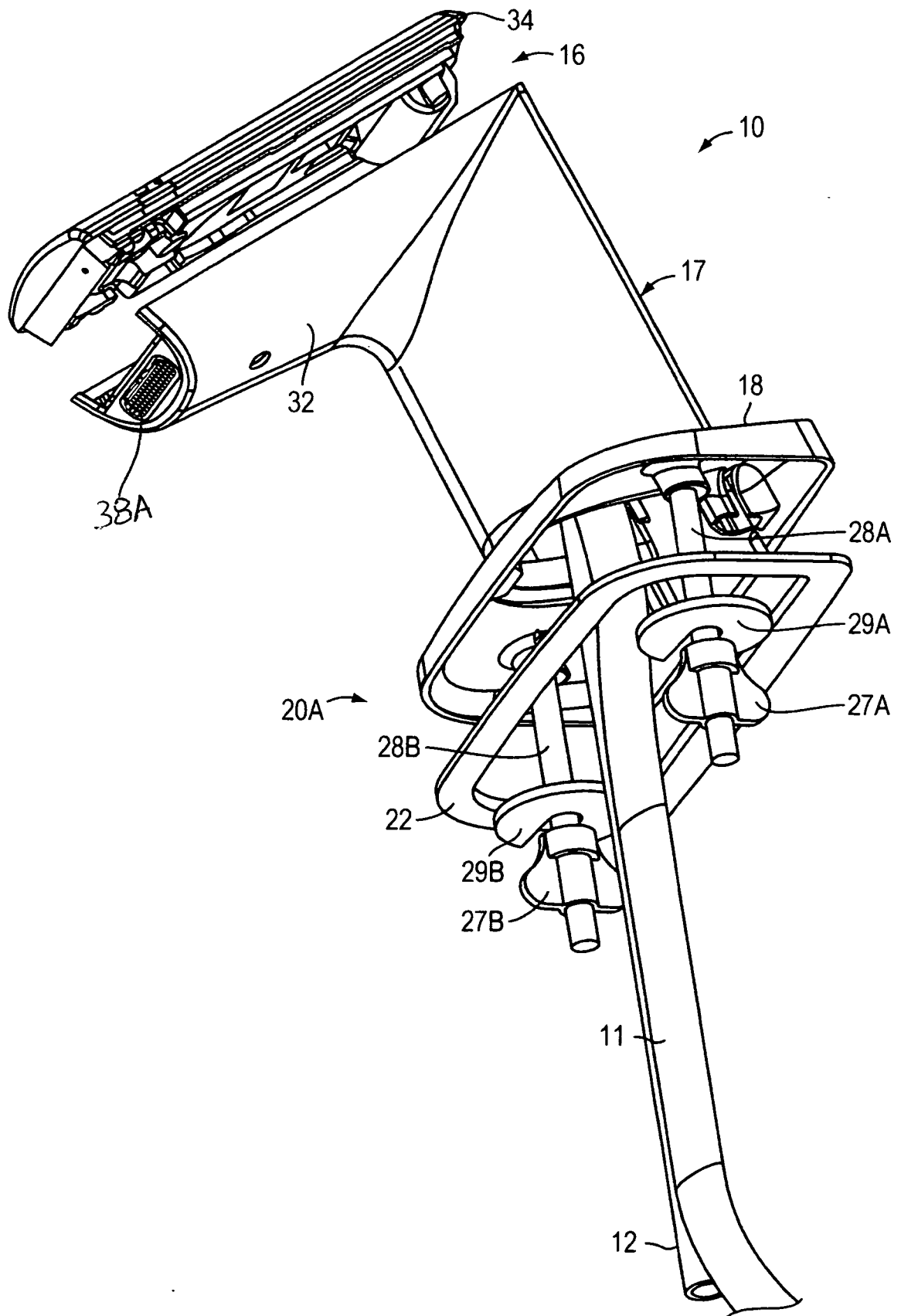


FIG. 2A

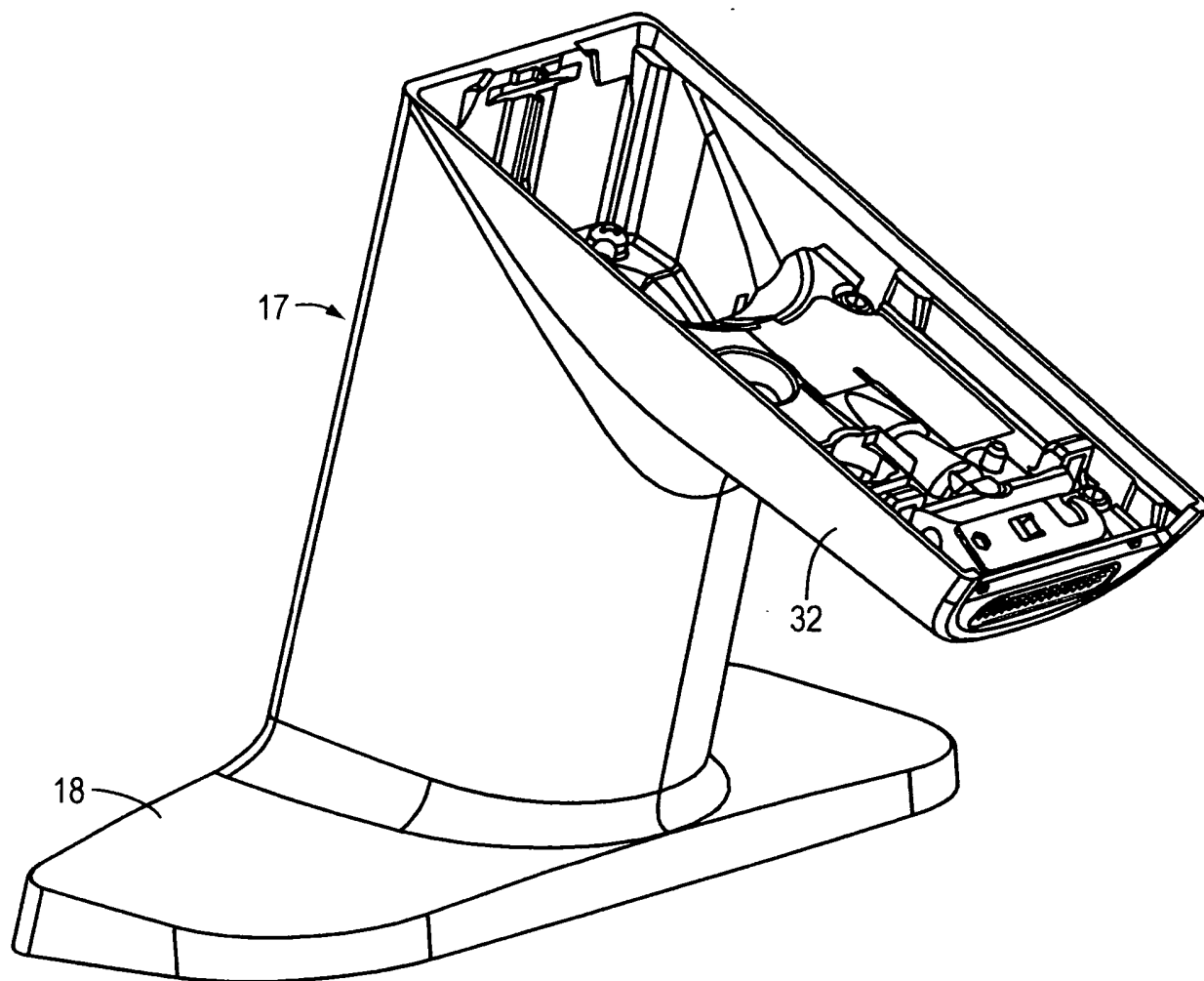


FIG. 3

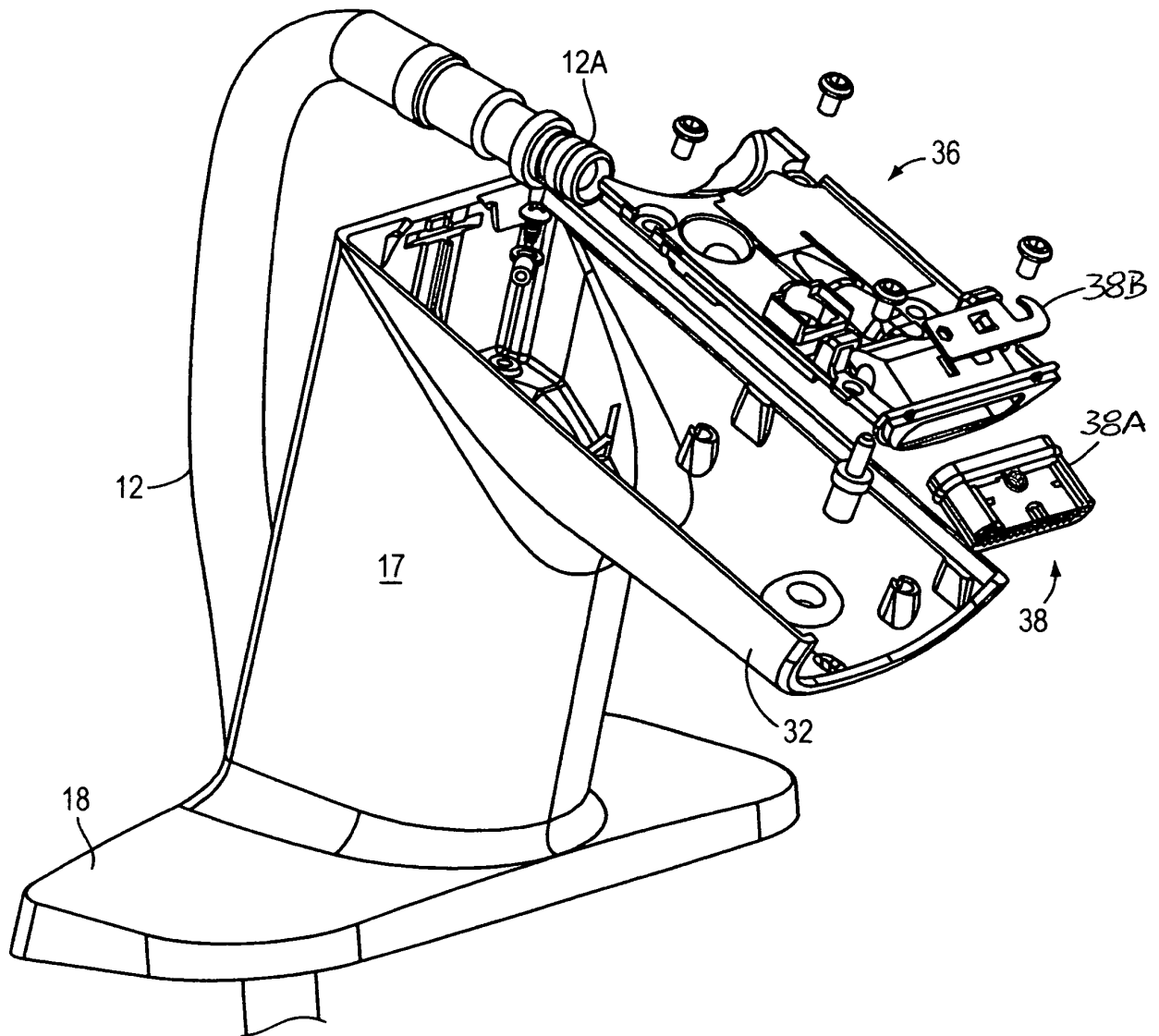


FIG. 3A

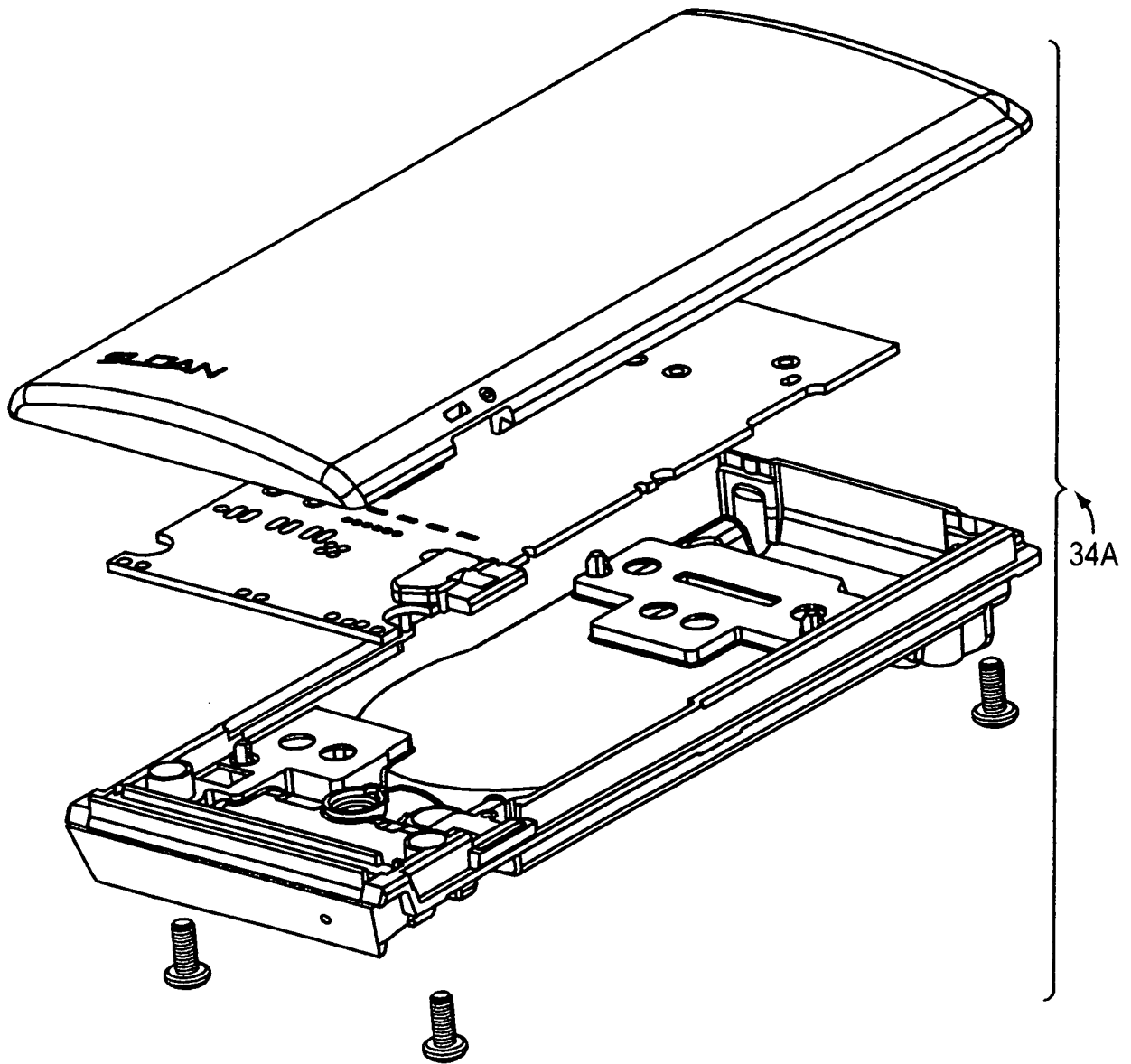


FIG. 3B

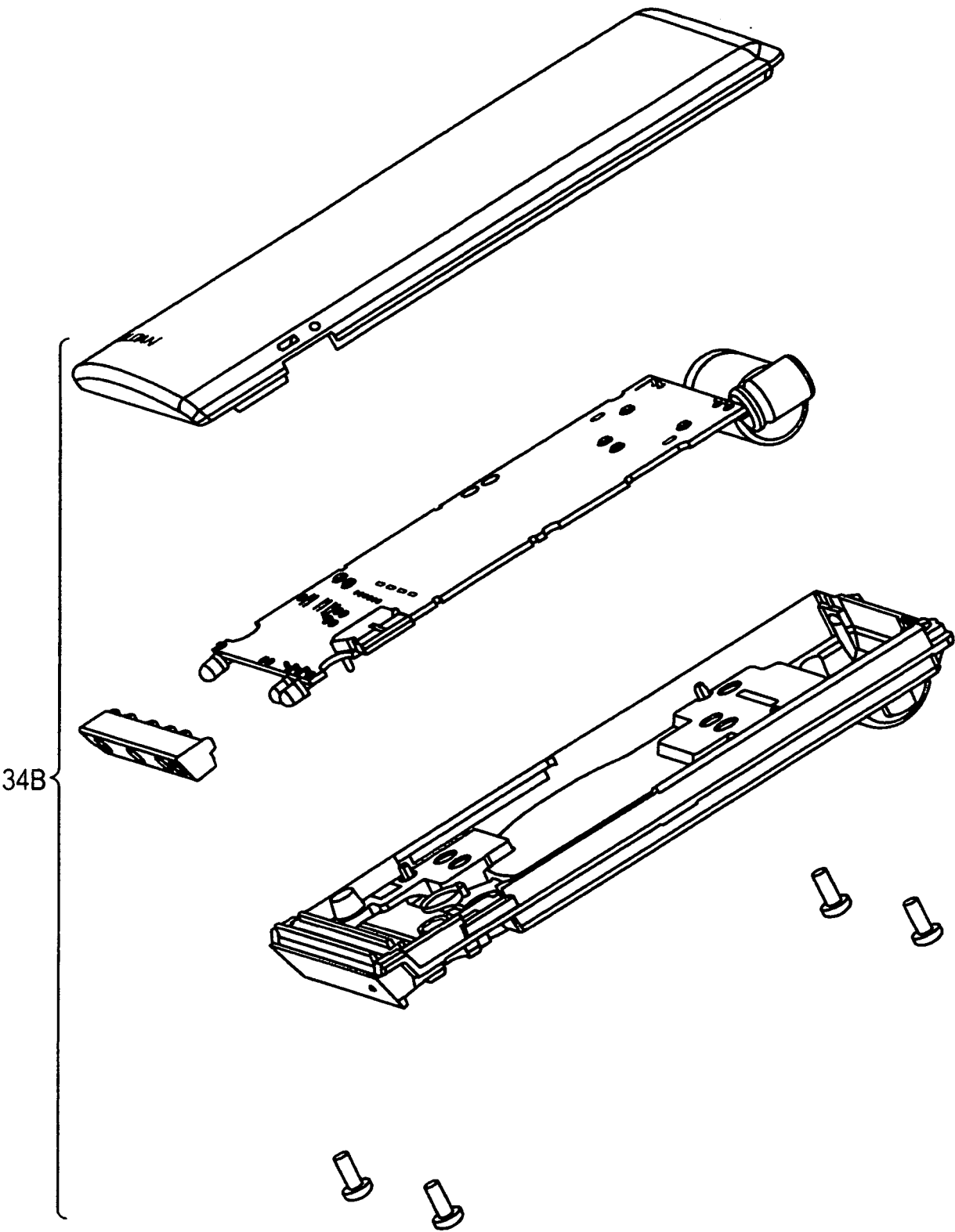


FIG. 3C

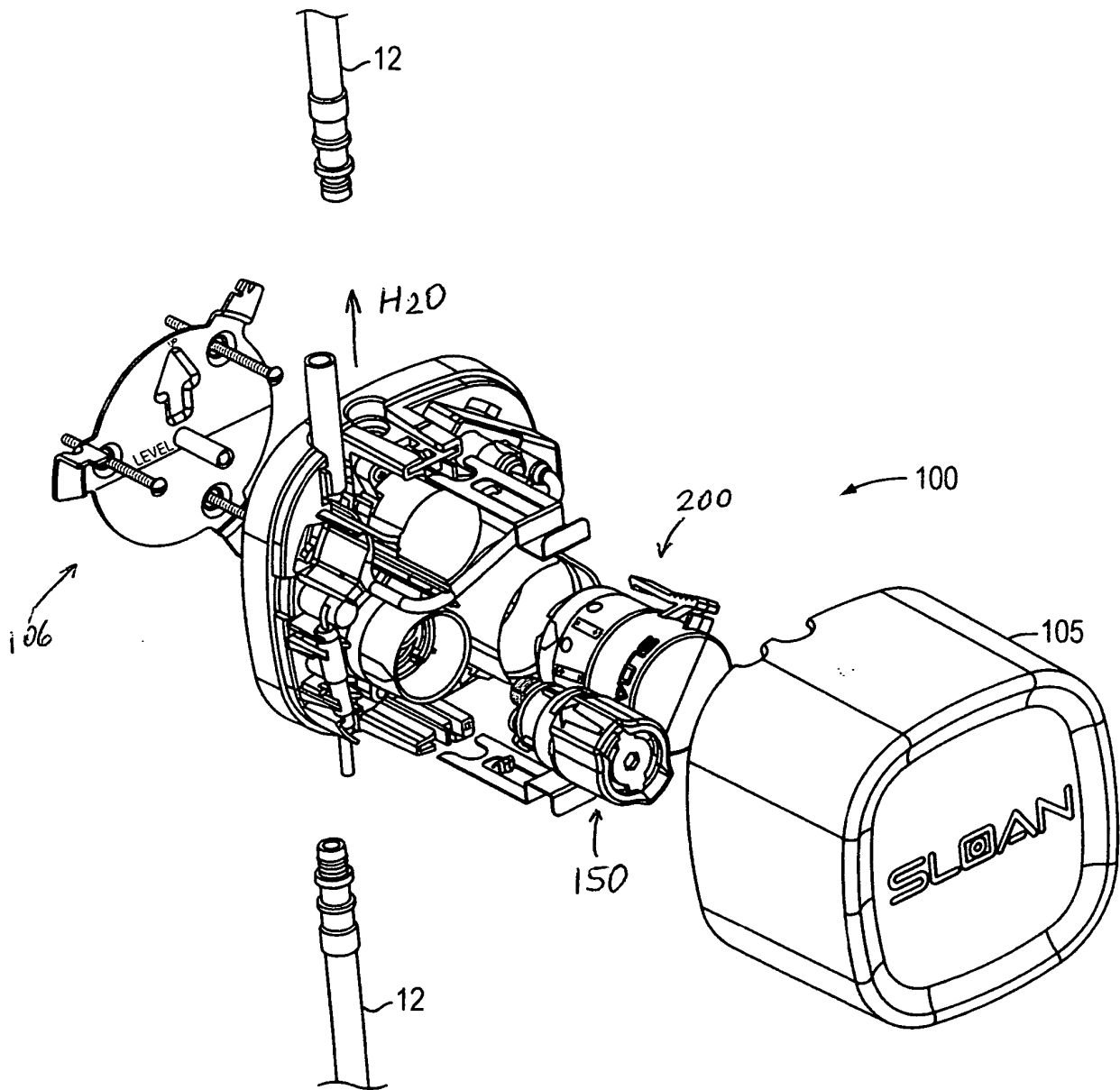


FIG. 4

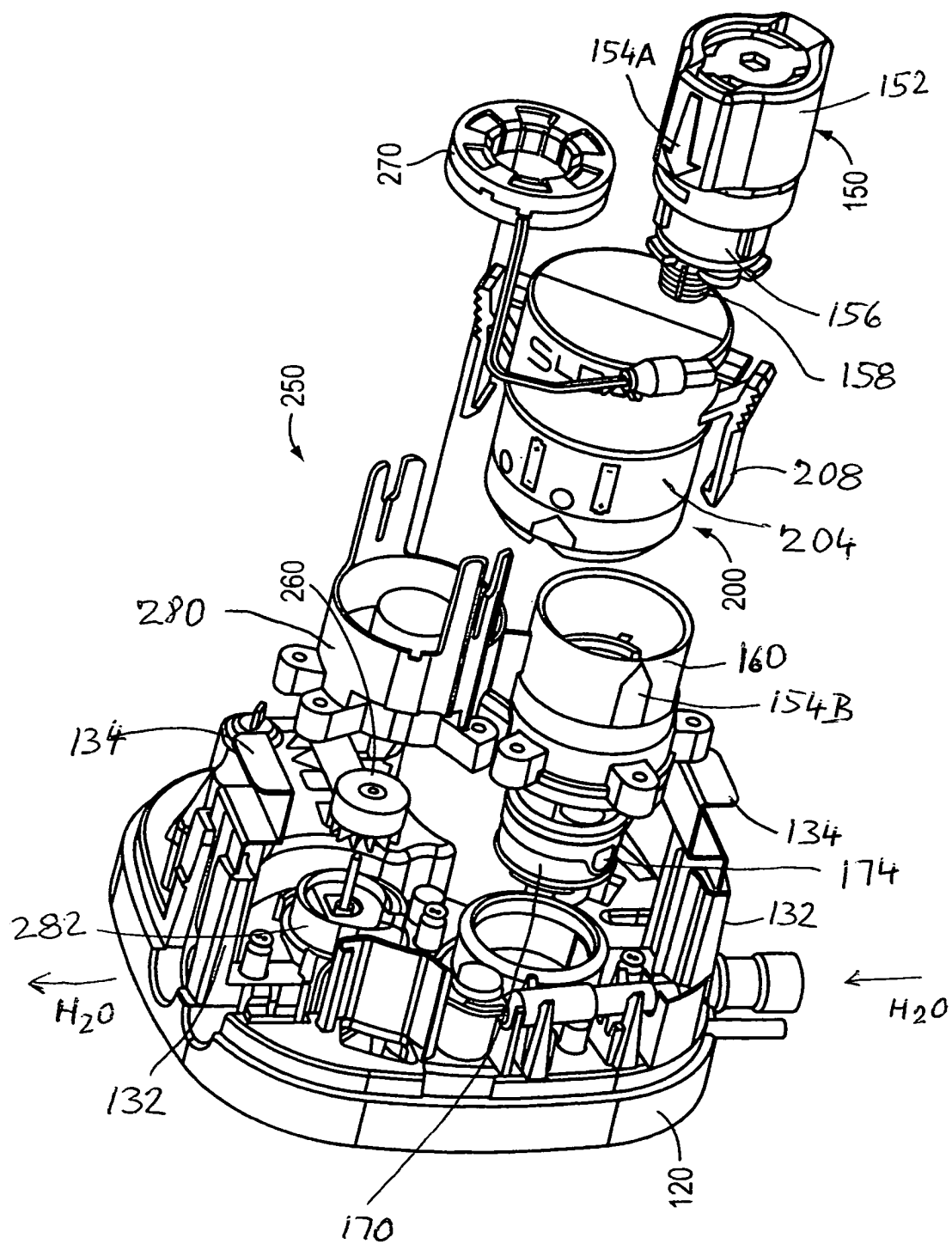


FIG. 4A

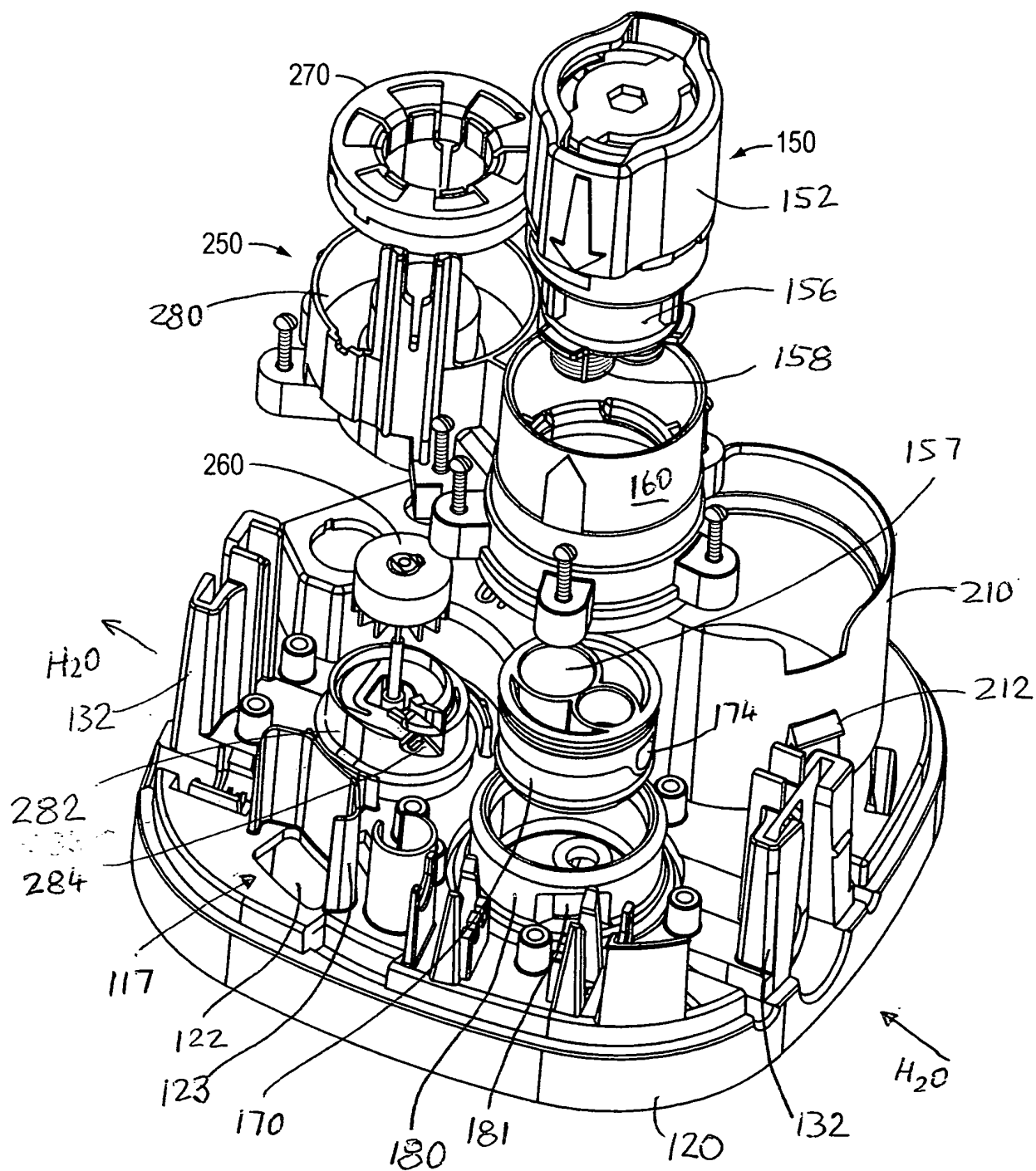


FIG. 4B

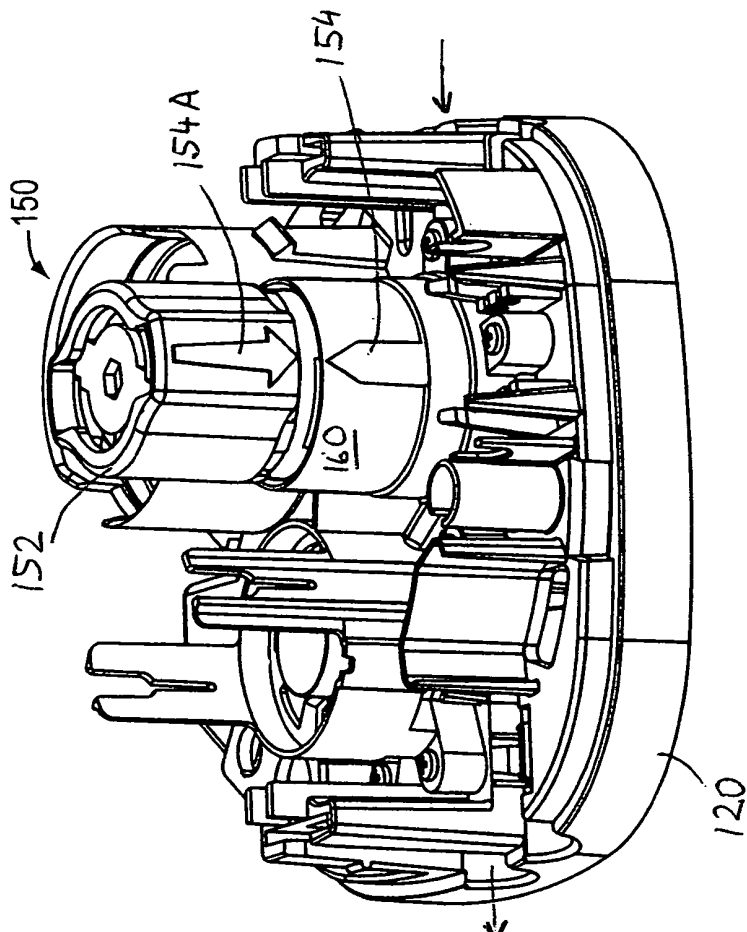


FIG. 4D

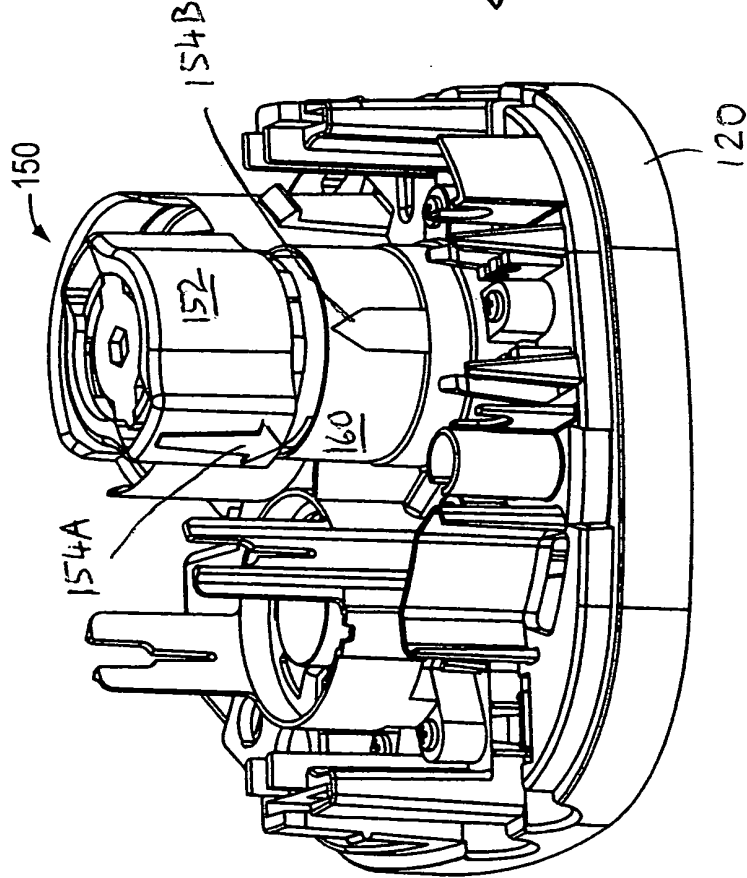


FIG. 4C

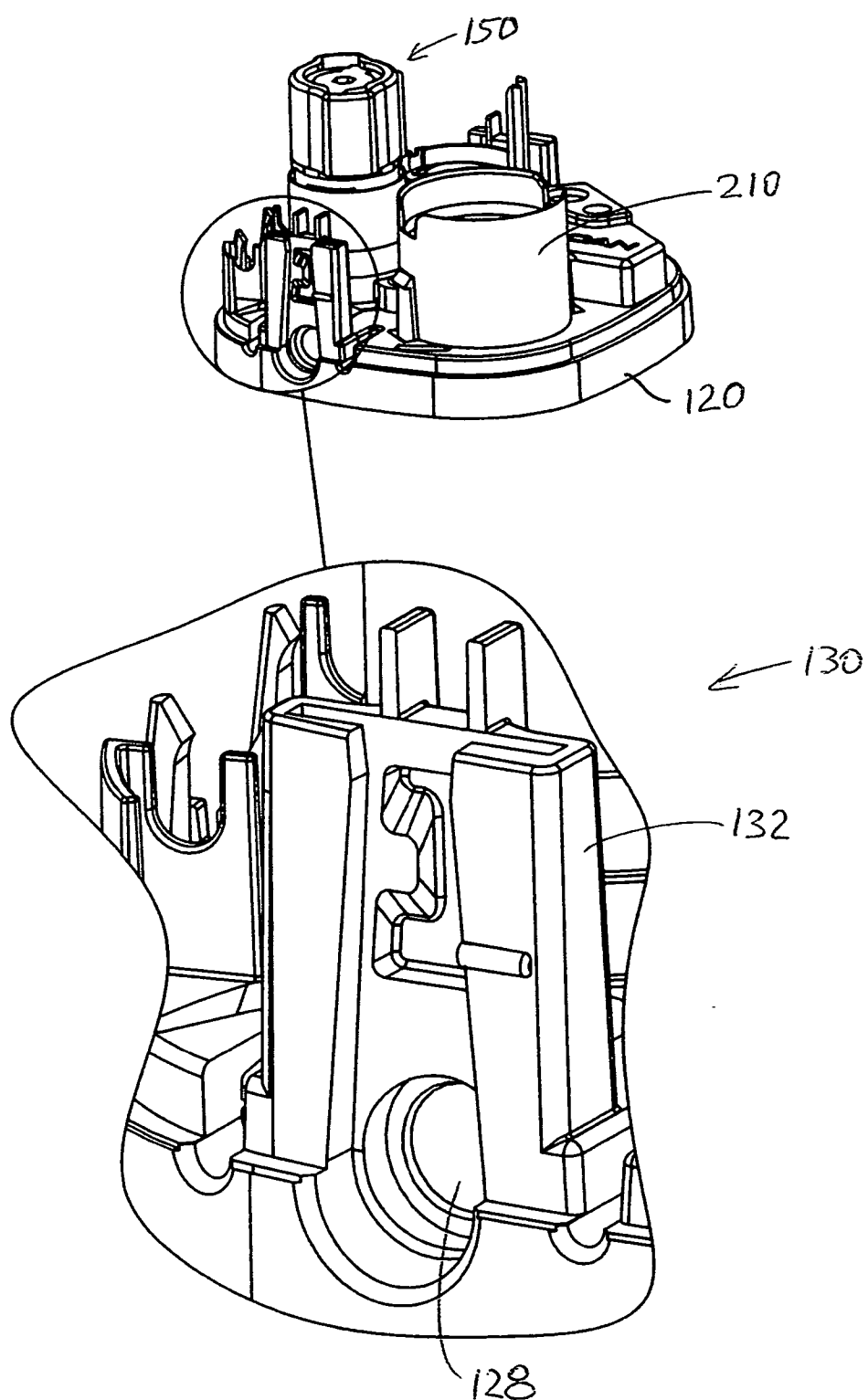


FIG. 4E

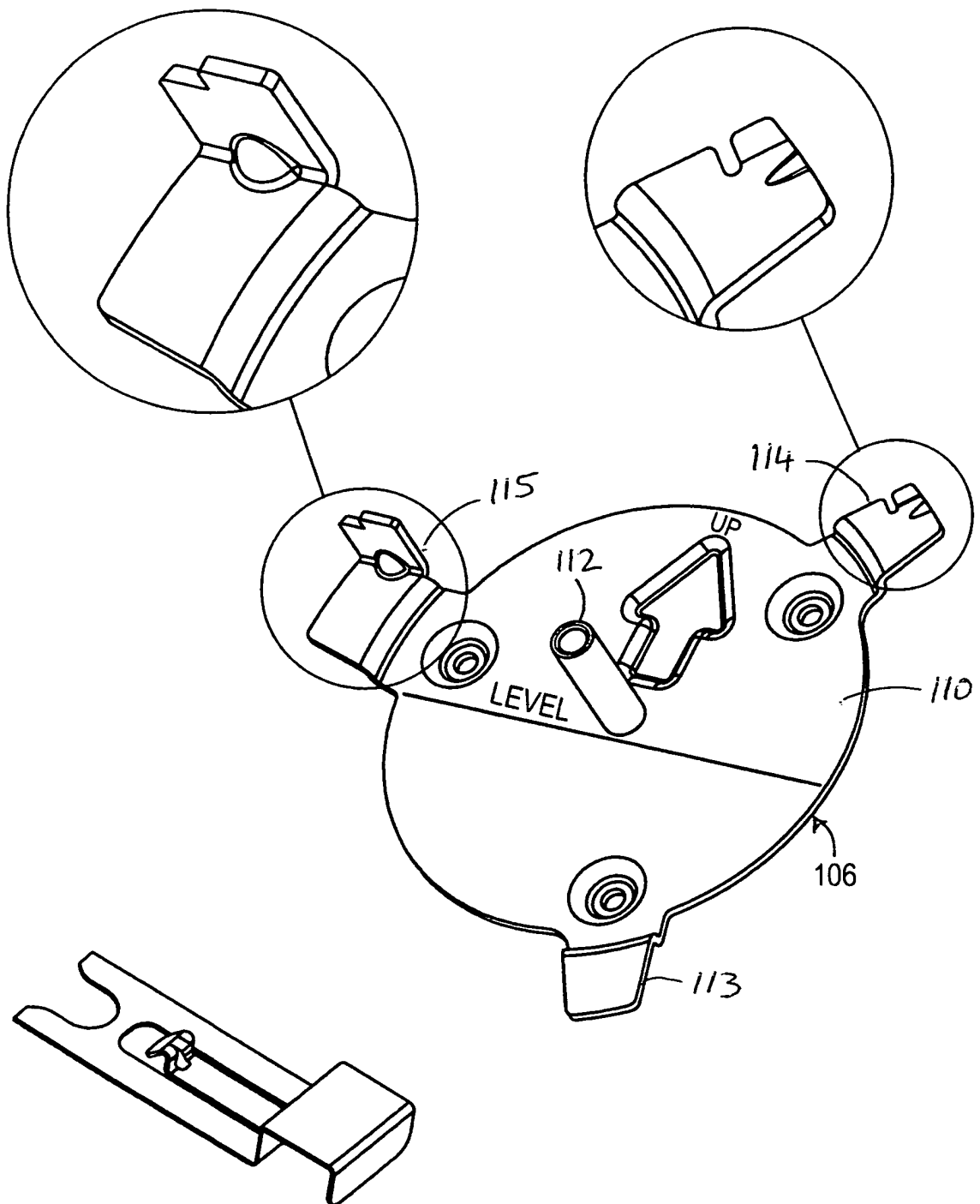


FIG. 5

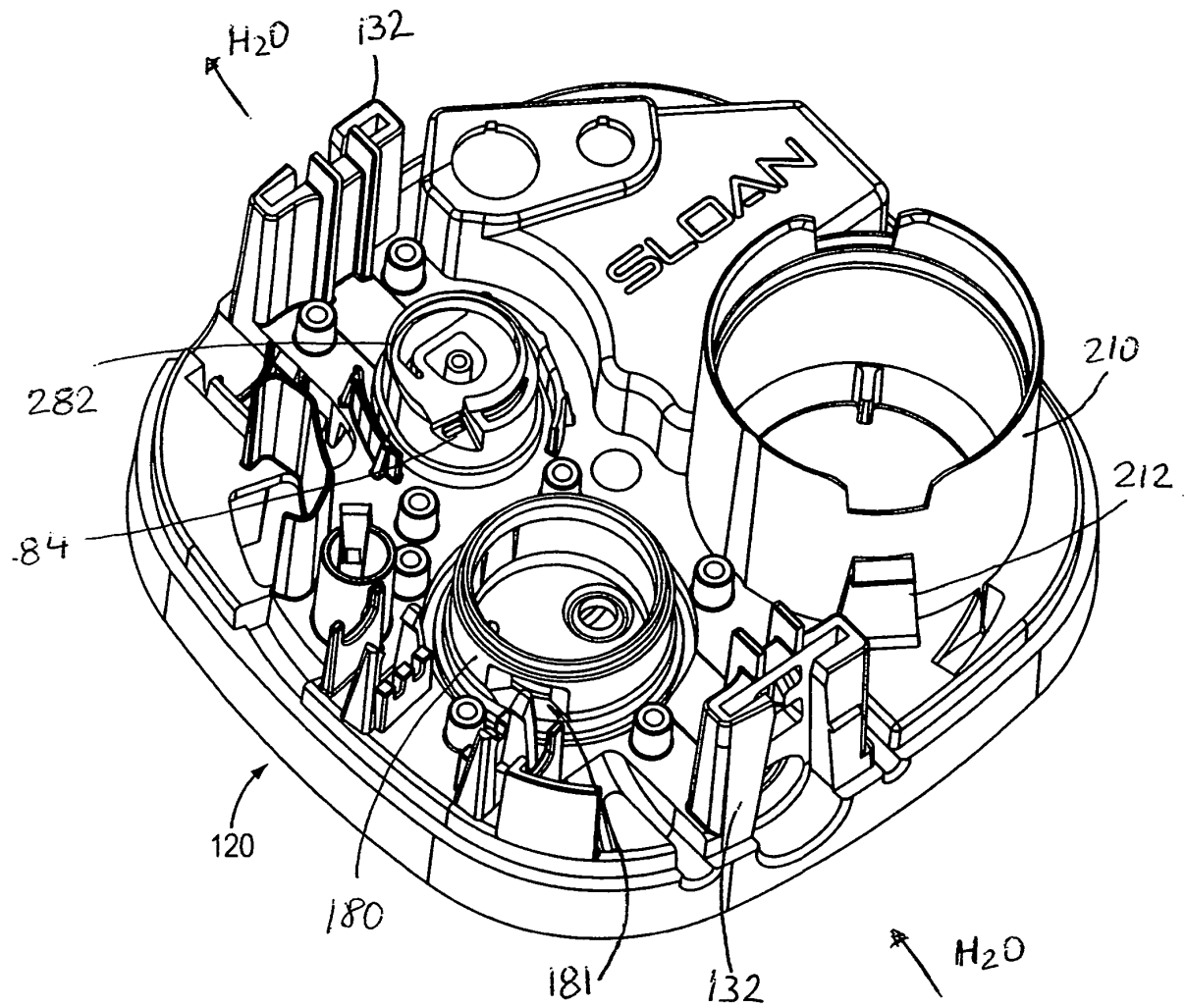


FIG. 6

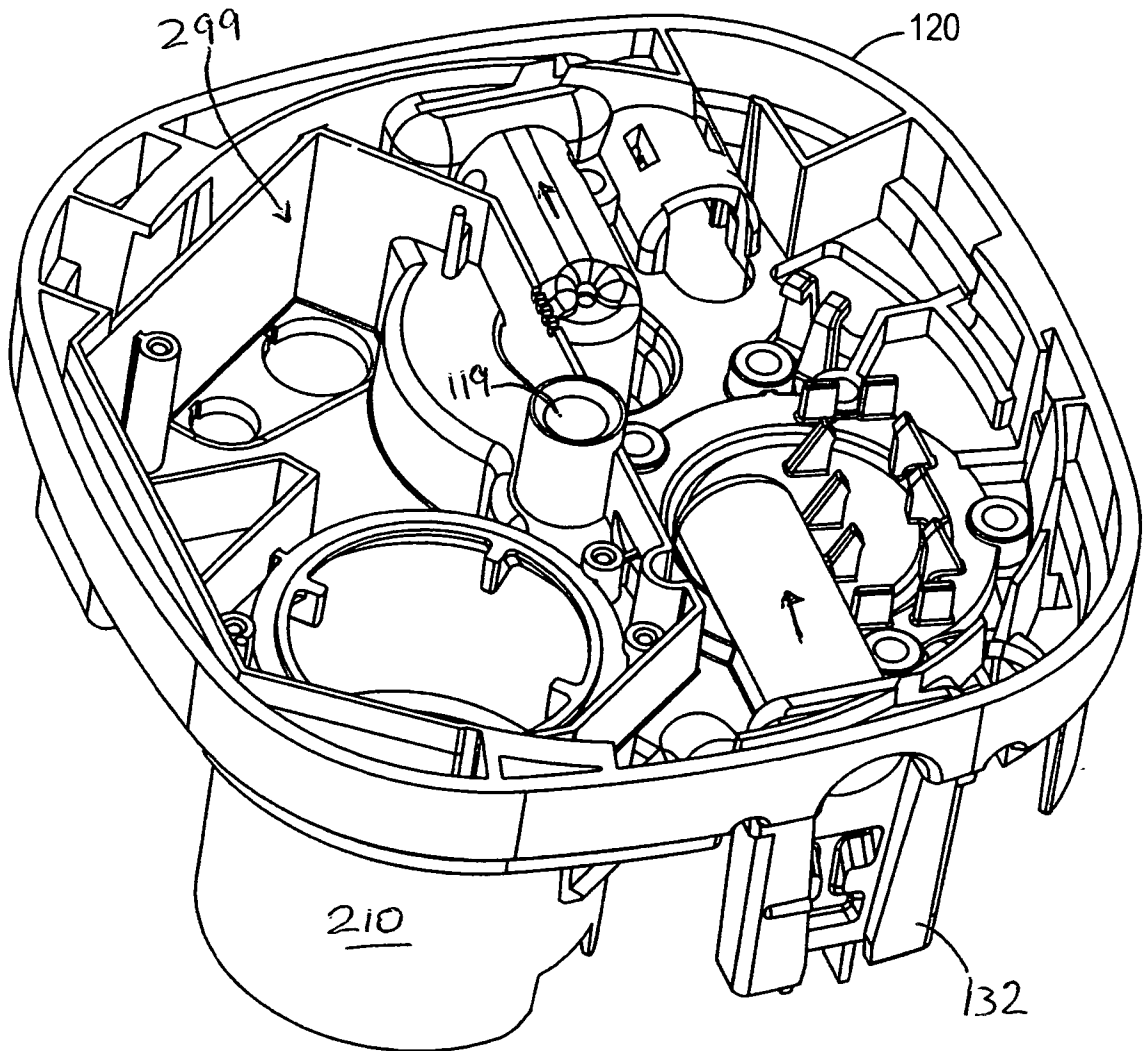
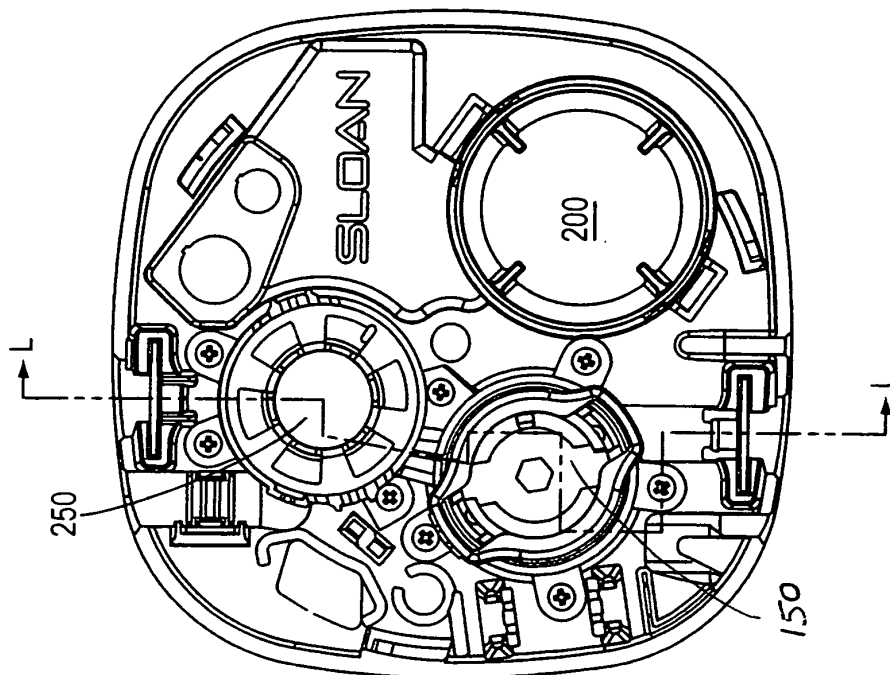
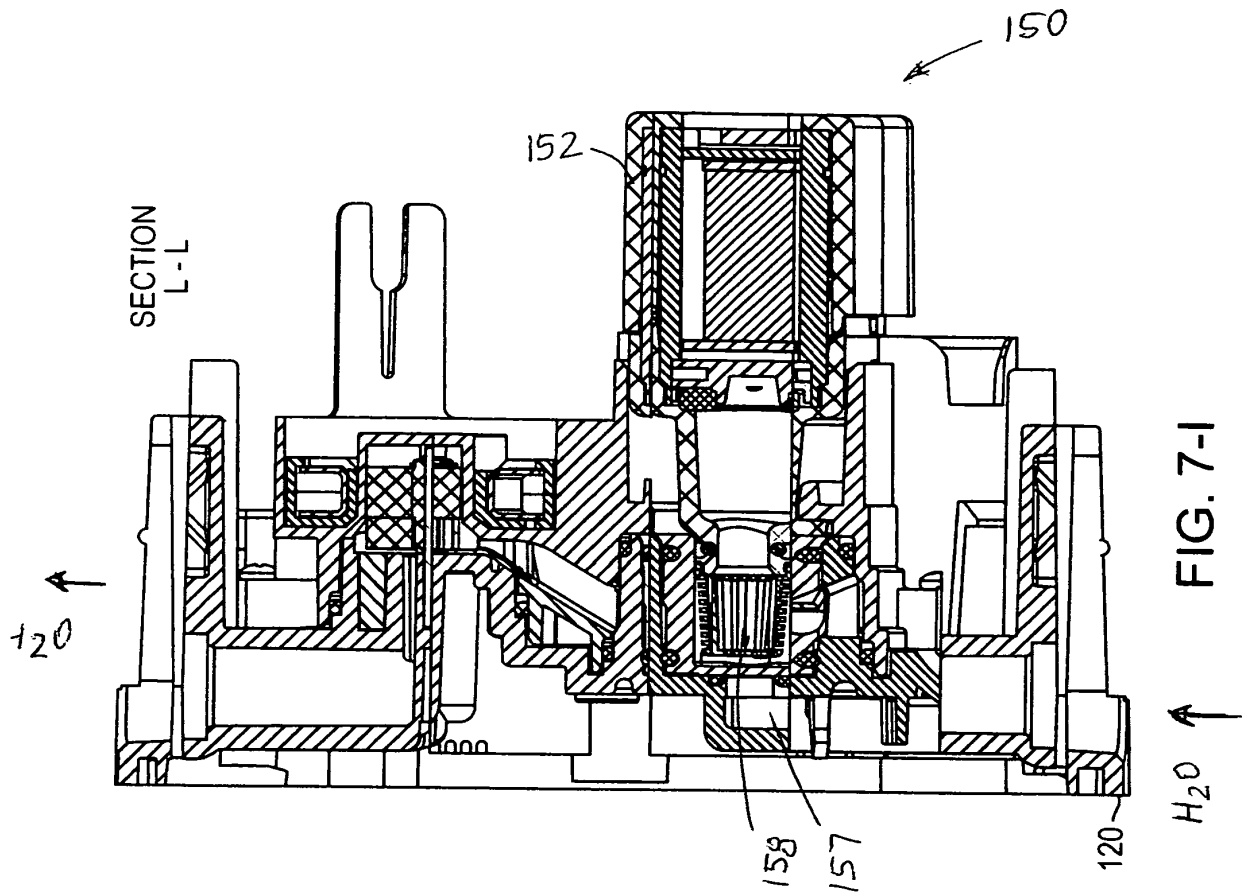


FIG. 6A



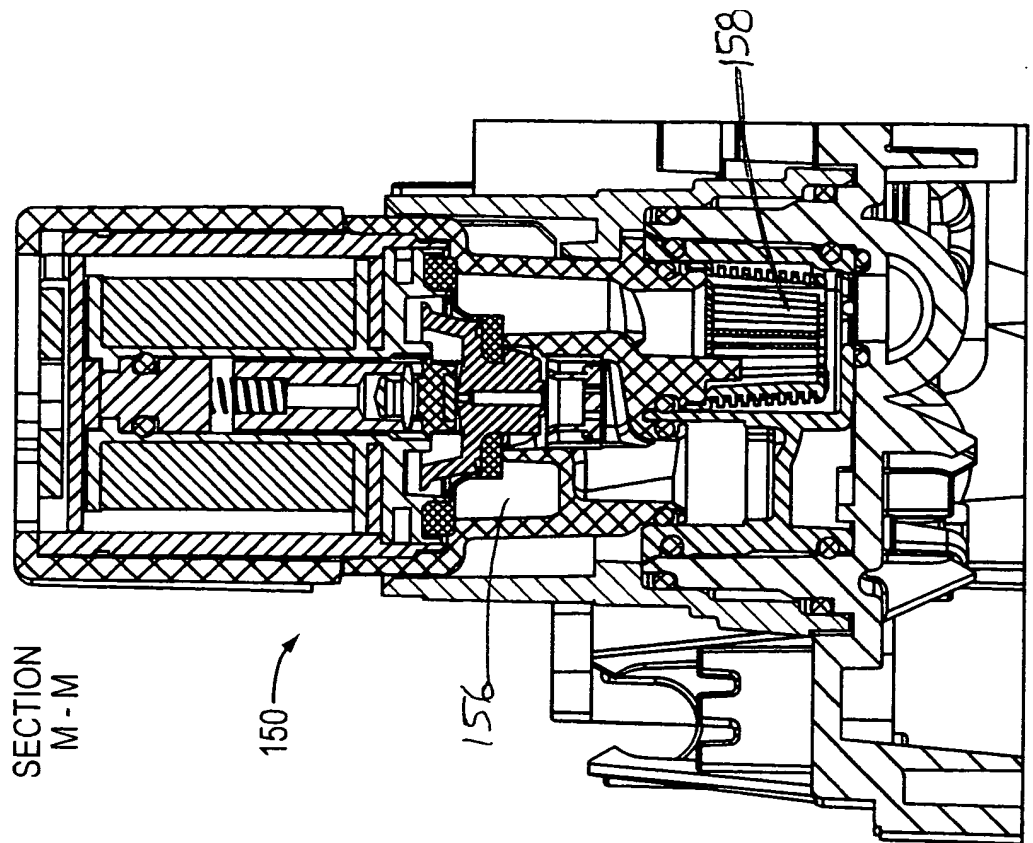


FIG. 7A-I

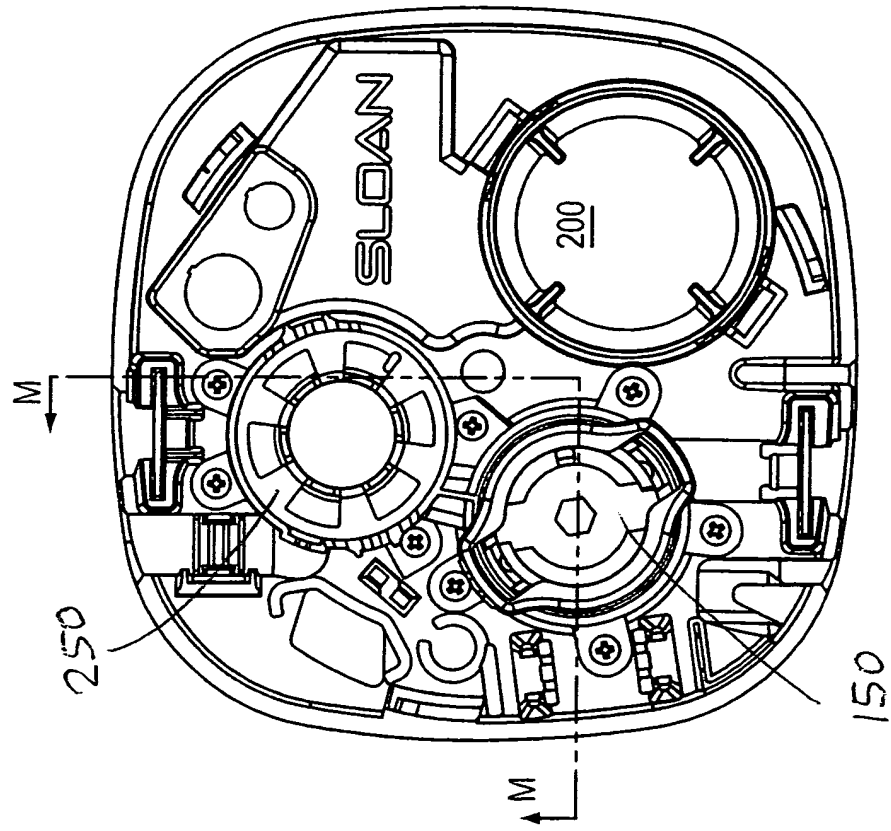


FIG. 7A

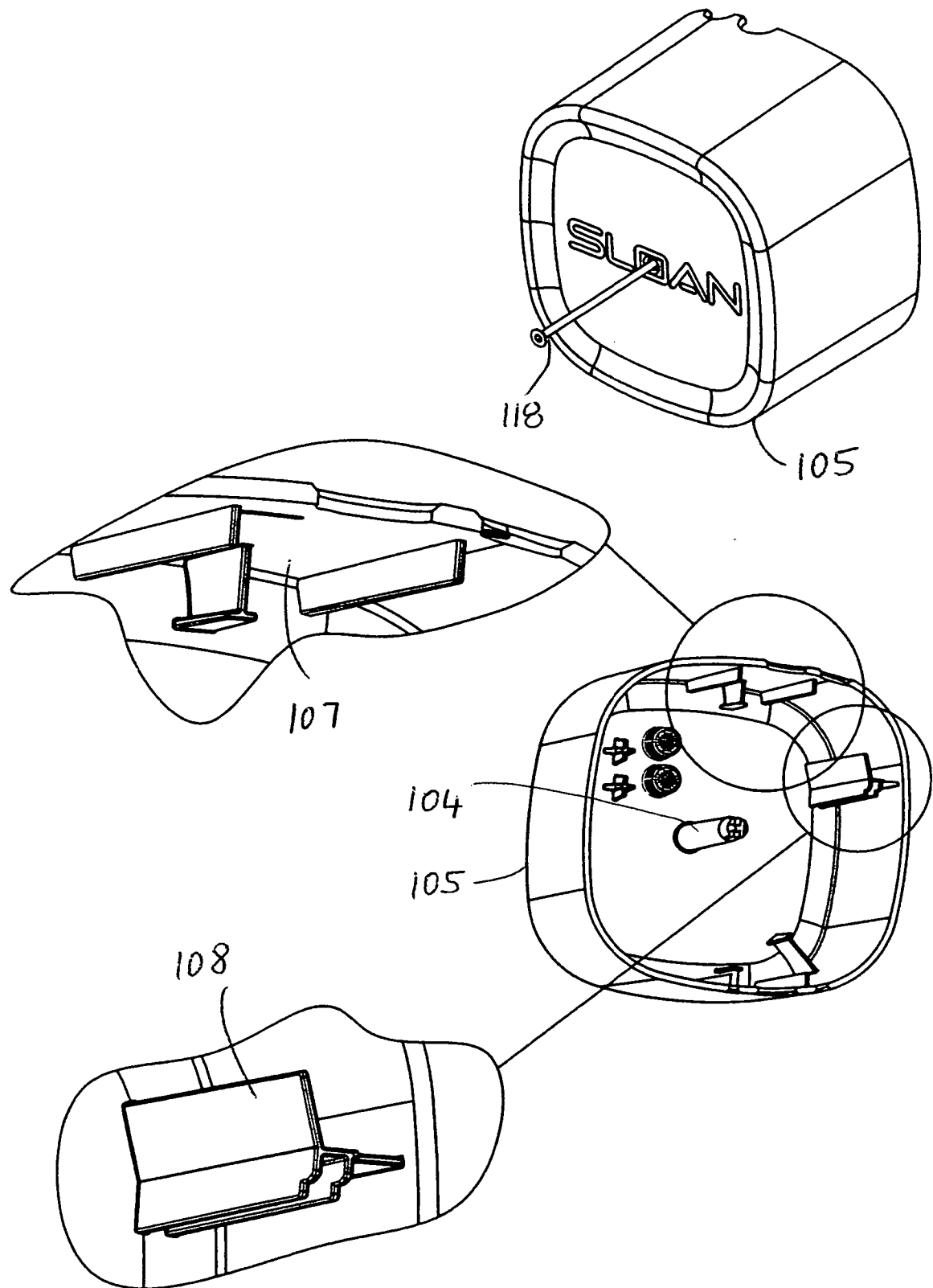


FIG. 8

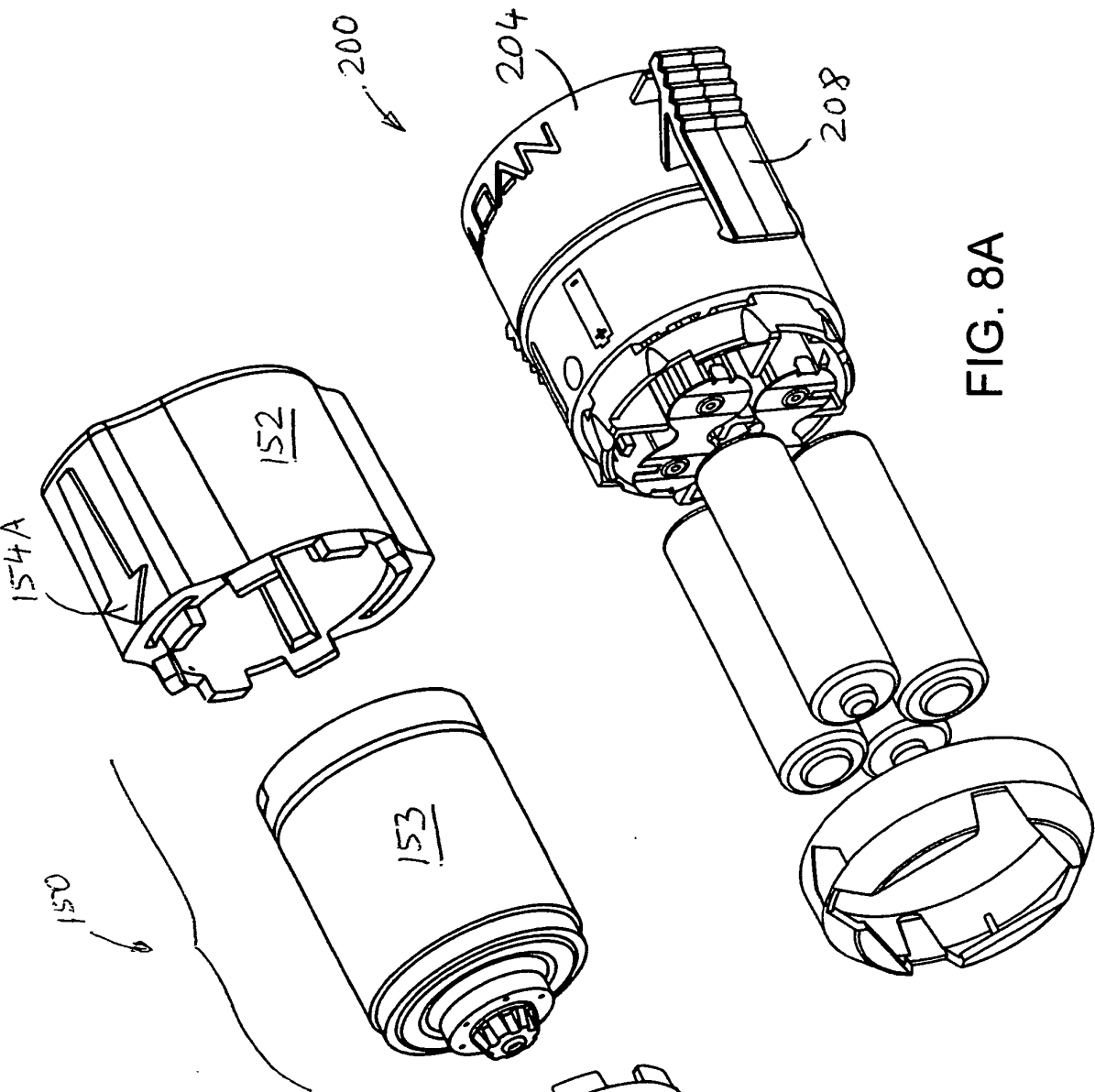


FIG. 8A

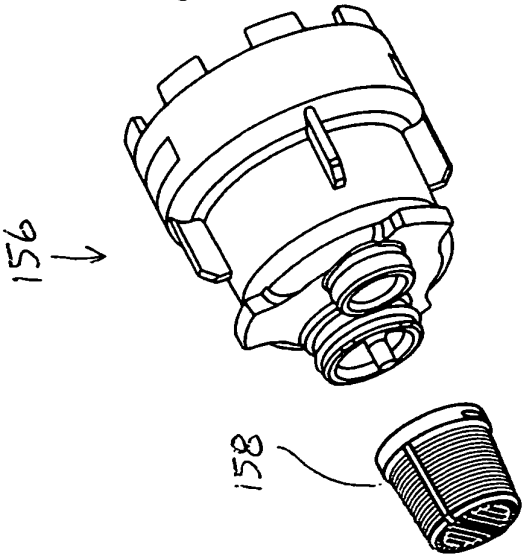


FIG. 8B

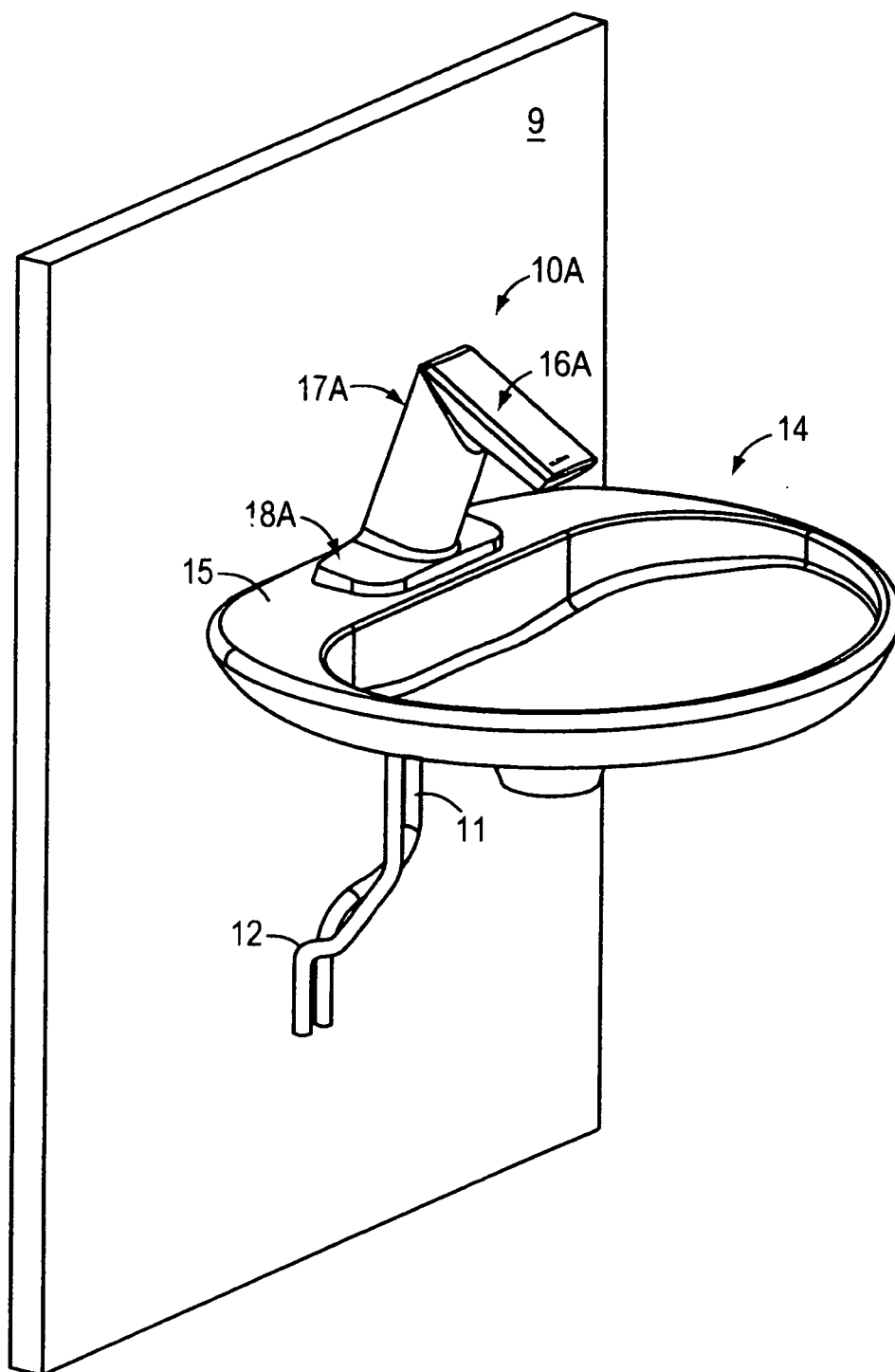


FIG. 9

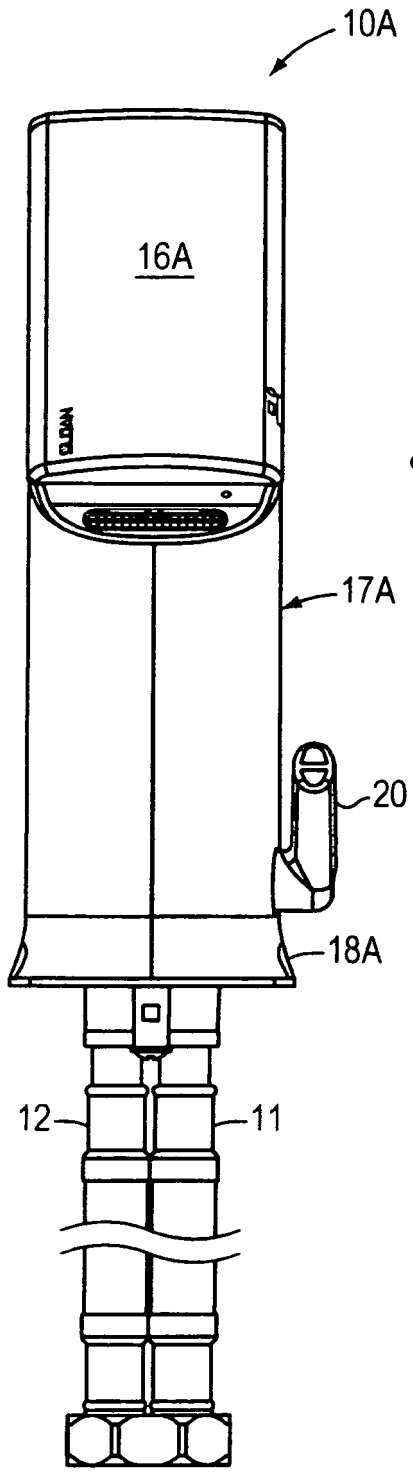


FIG. 9A

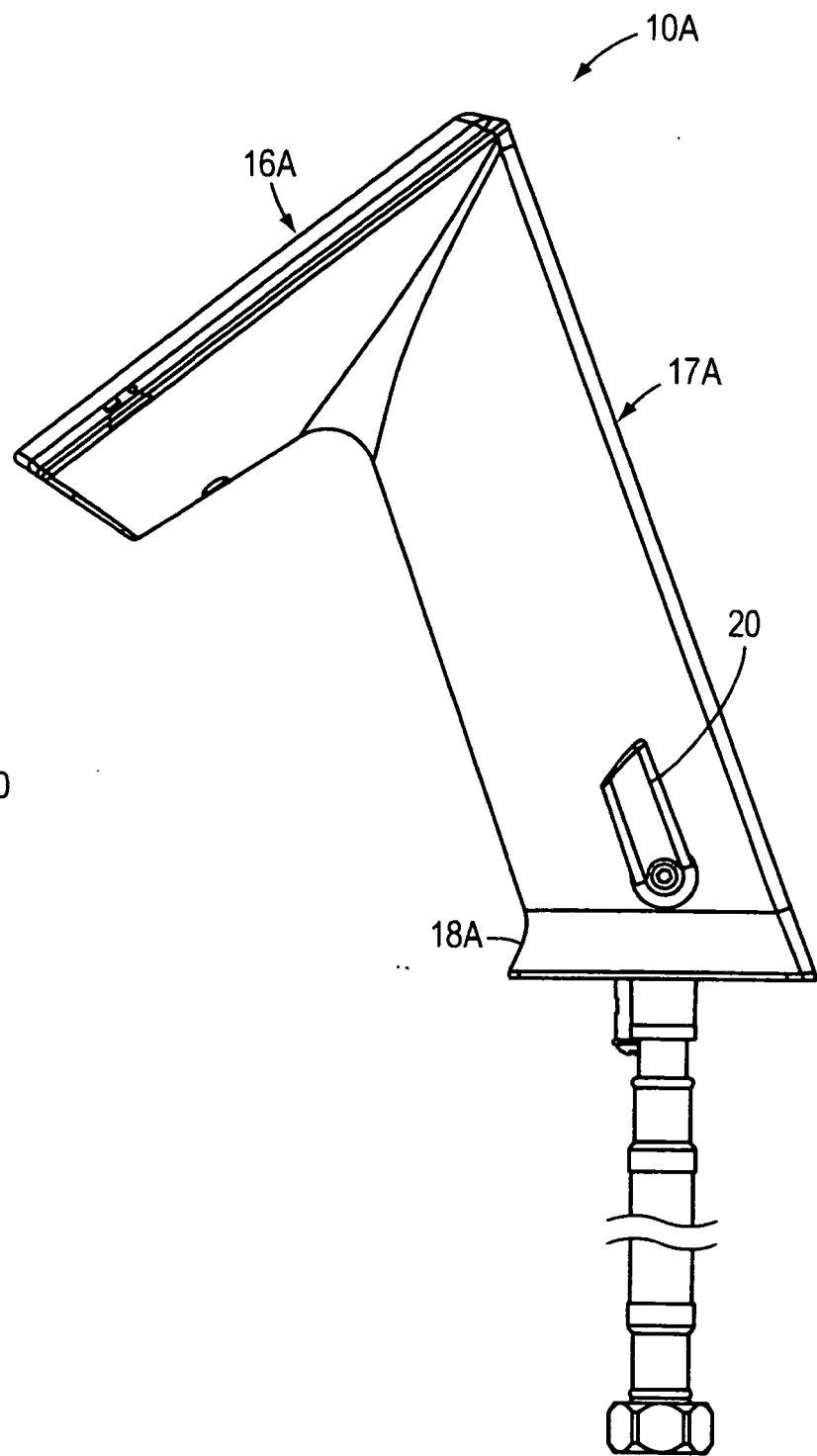
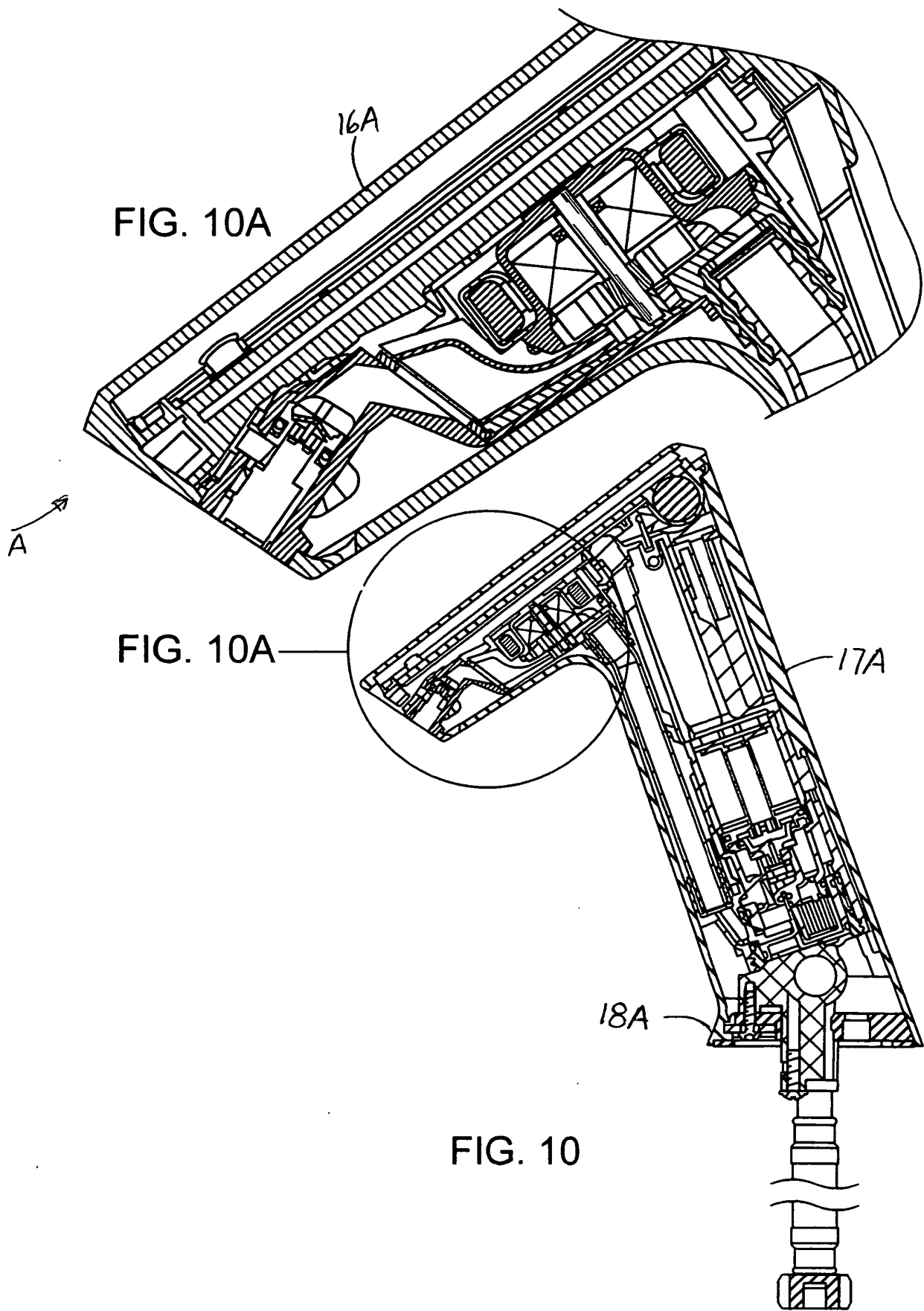


FIG. 9B



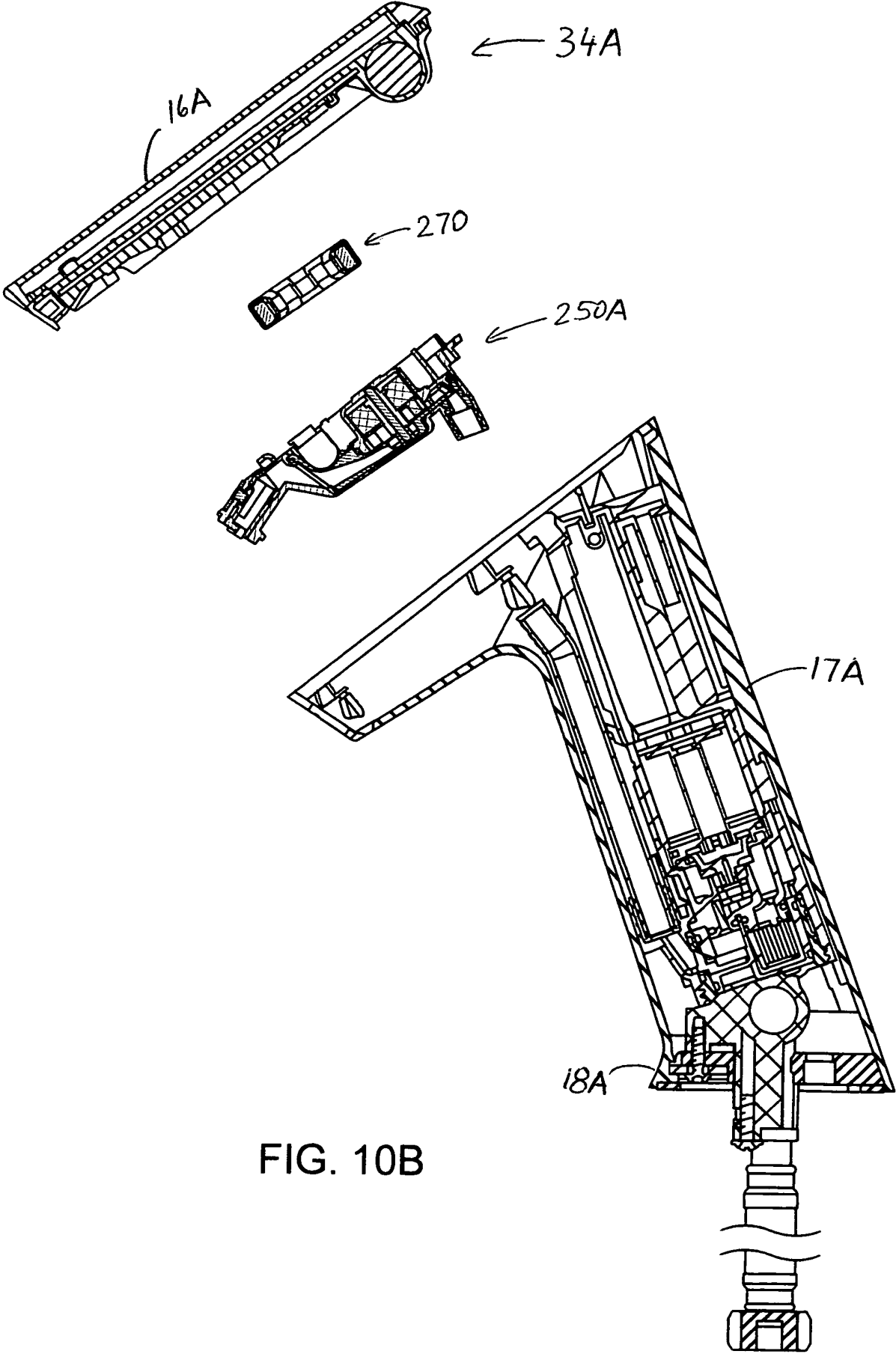
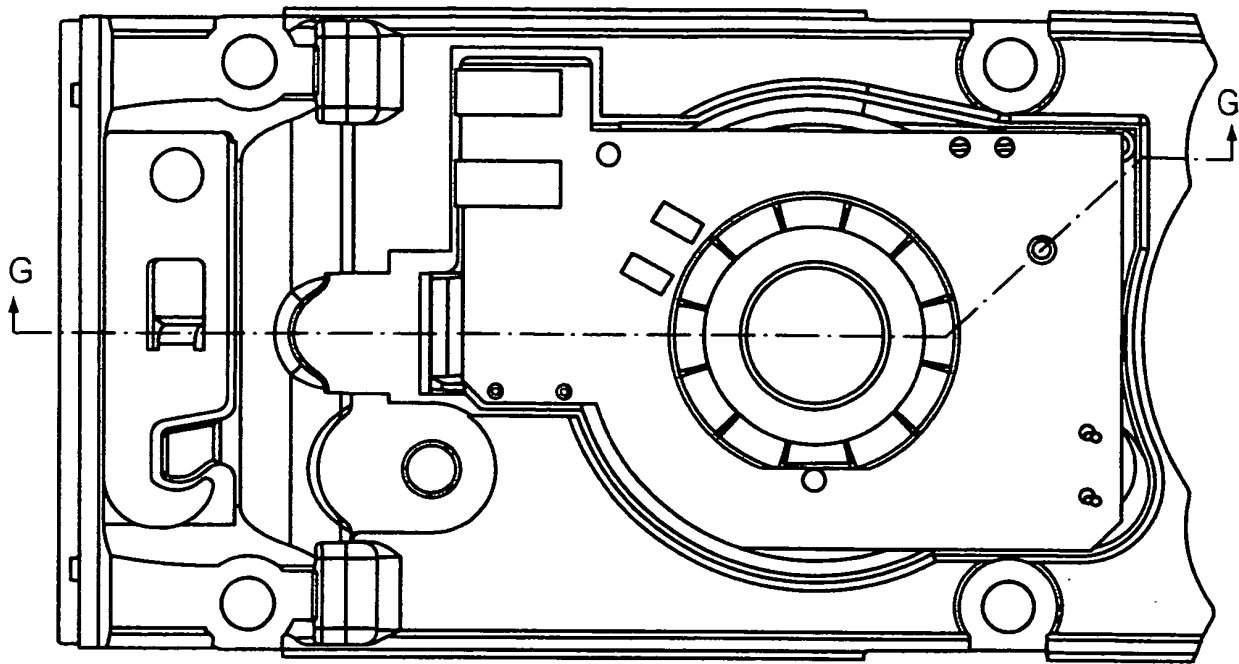


FIG. 10B



250A
FIG. 11

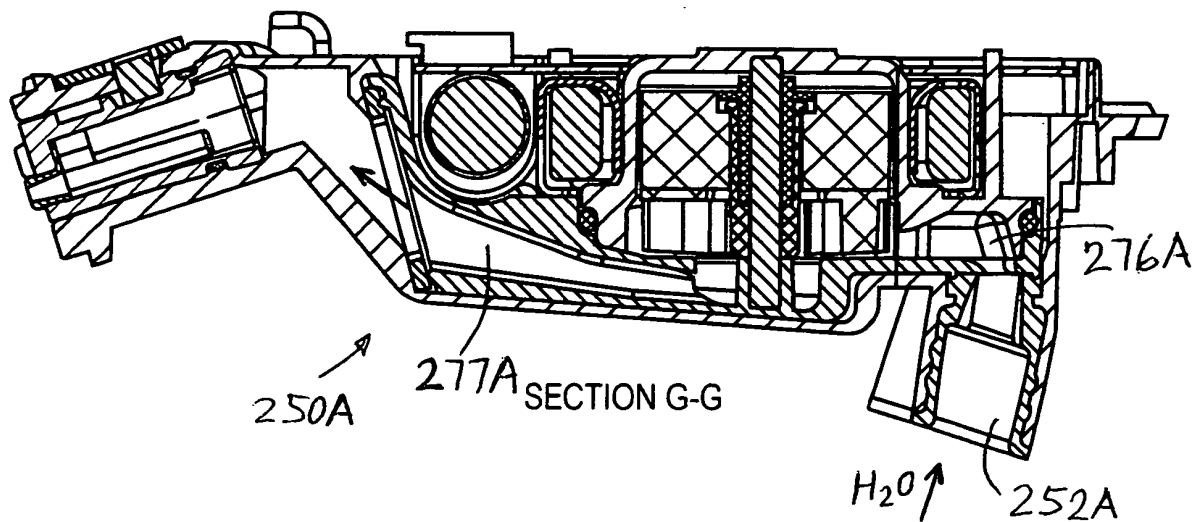


FIG. 11A

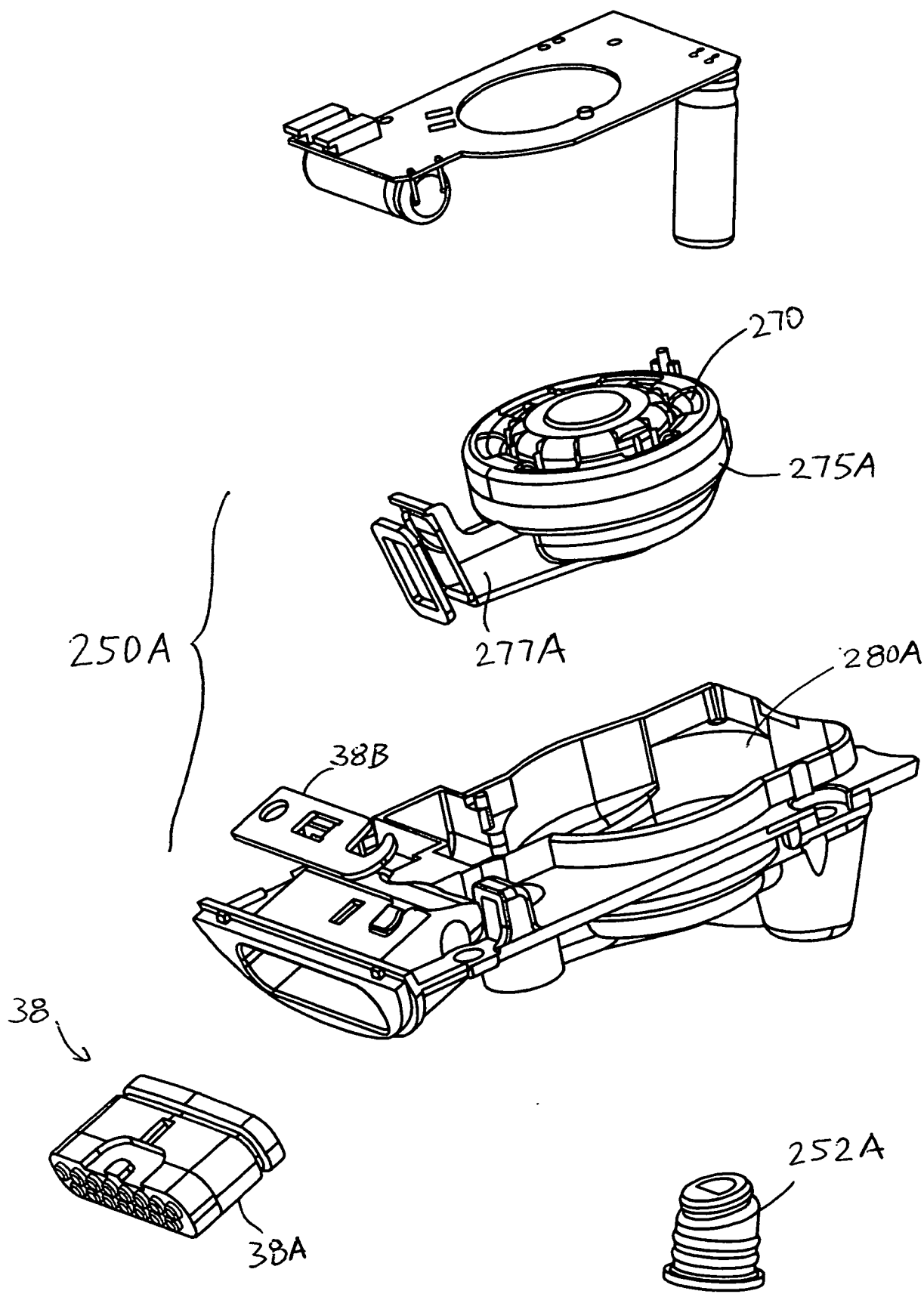


FIG. 11B

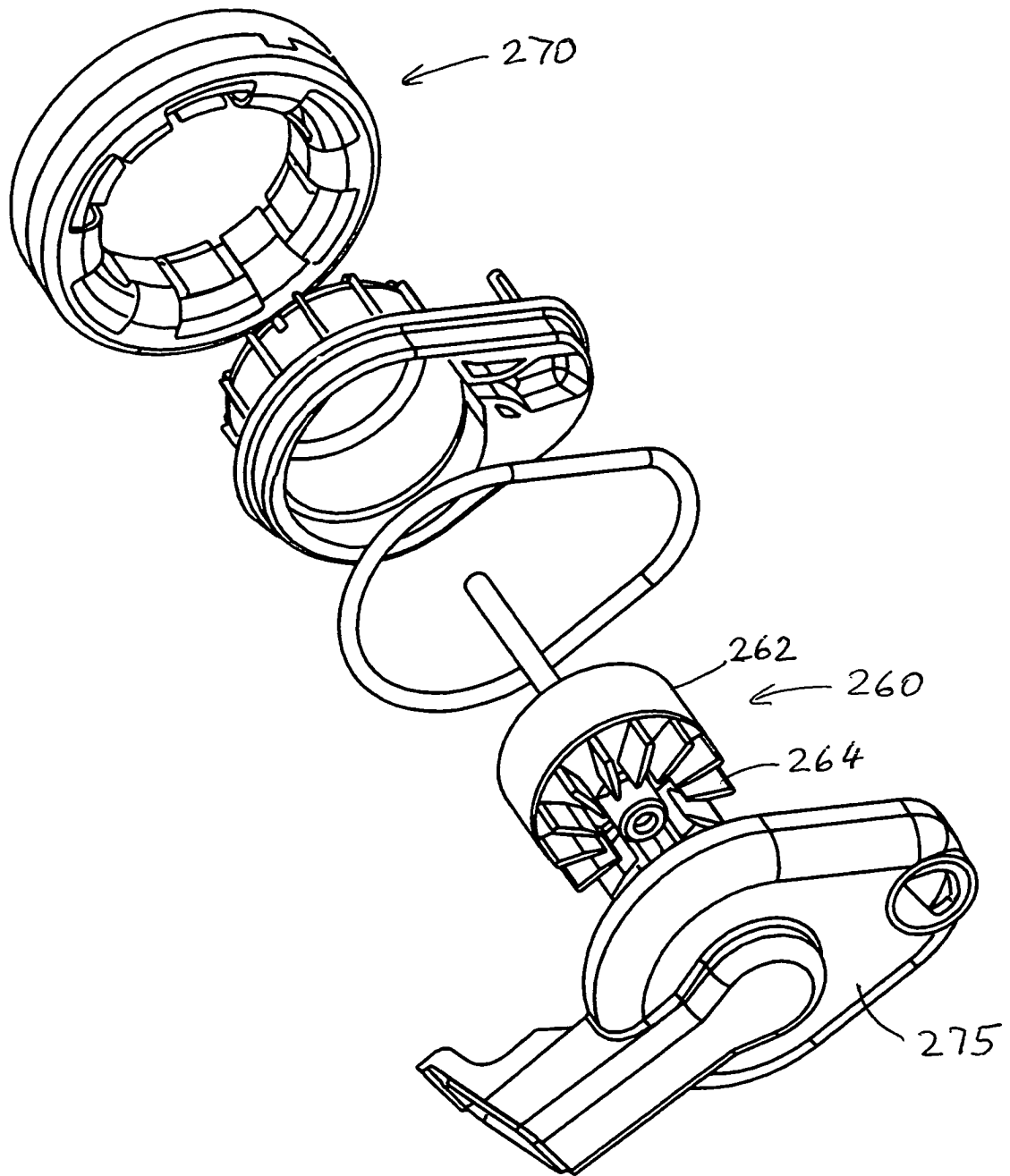


FIG. 12

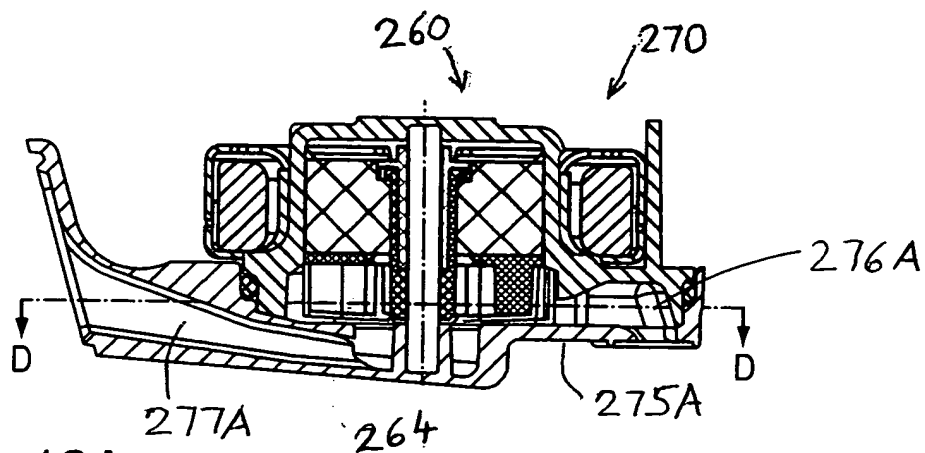


FIG. 12A

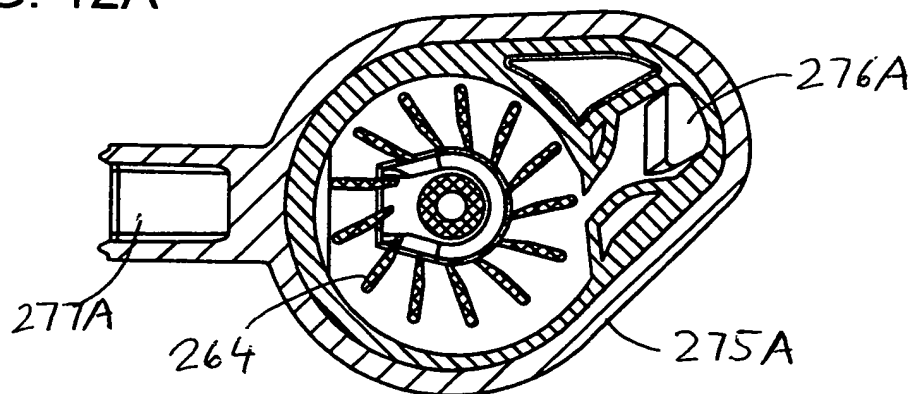


FIG. 12B

SECTION D-D

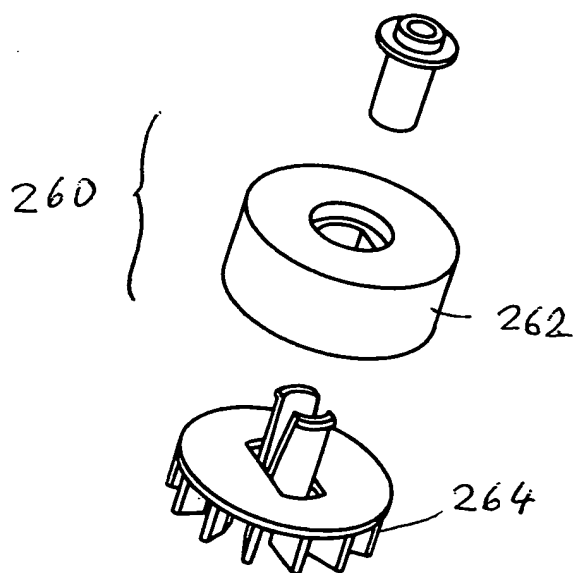


FIG. 12C

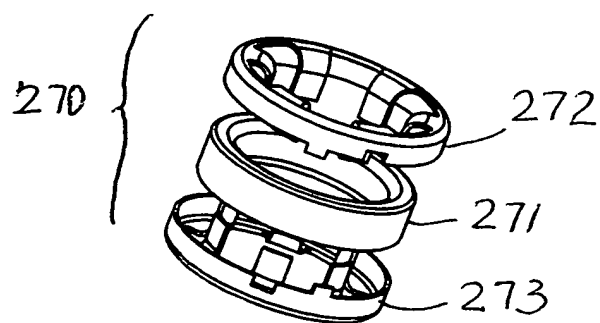


FIG. 12D

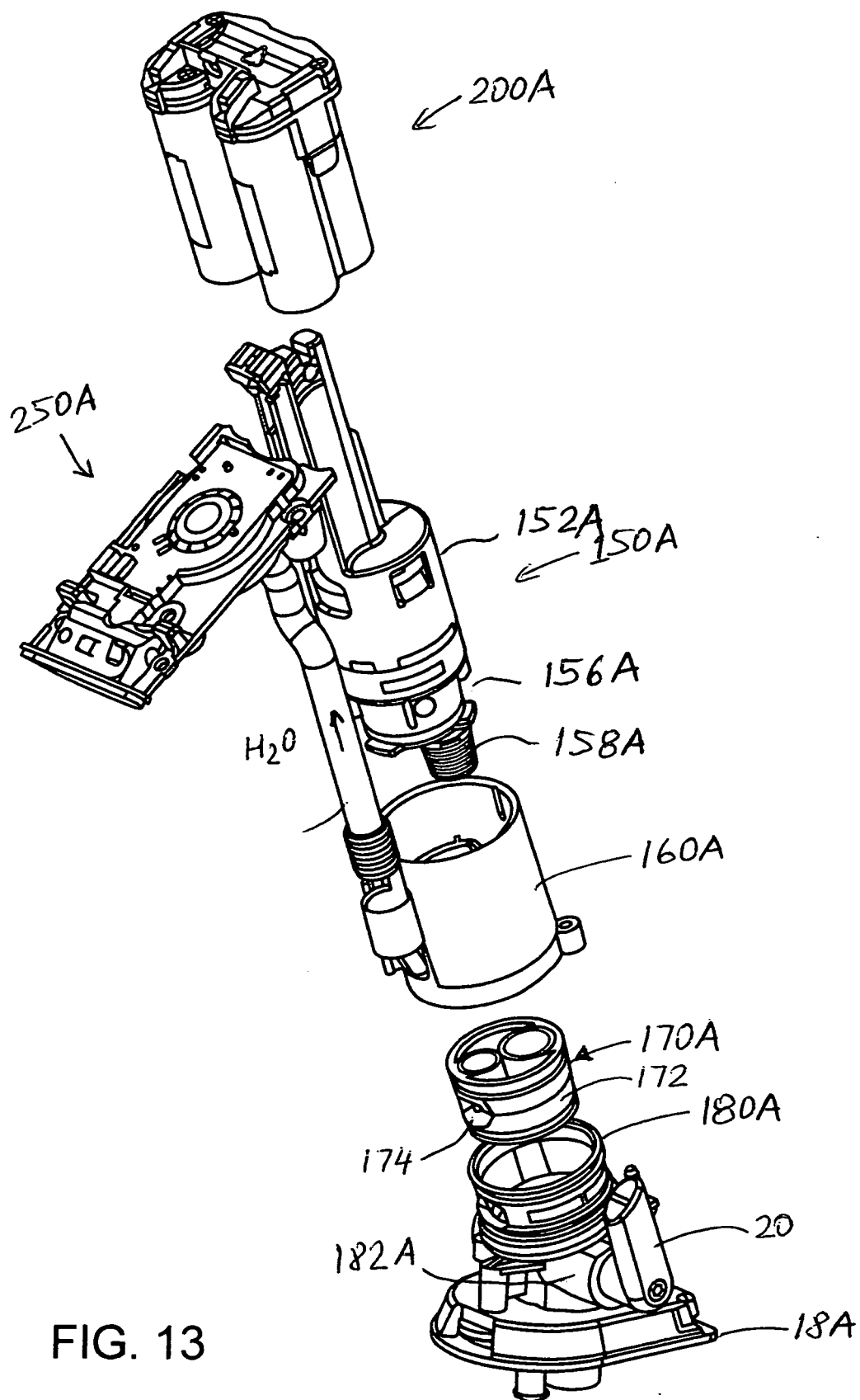
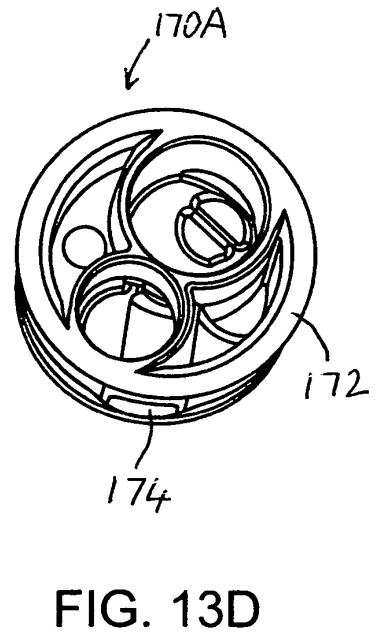
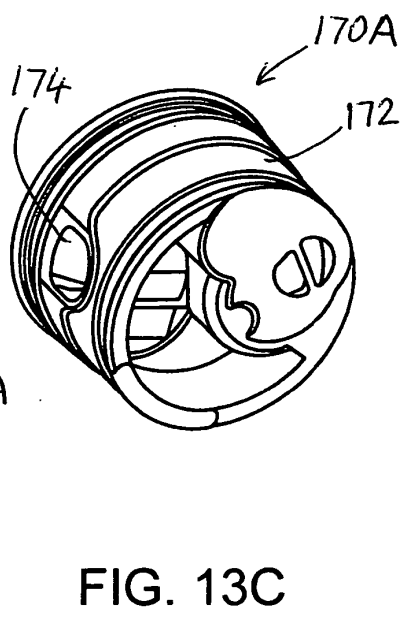
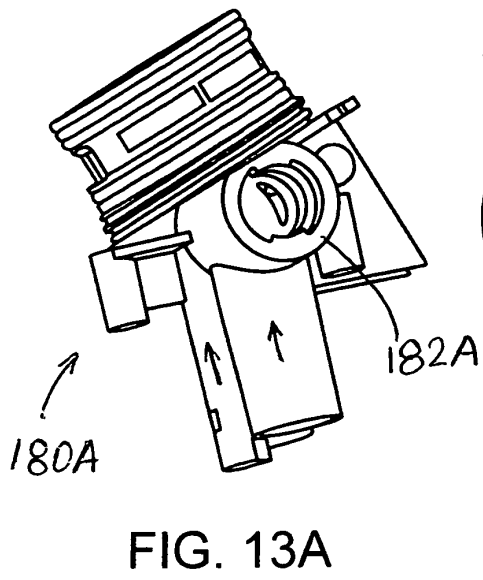
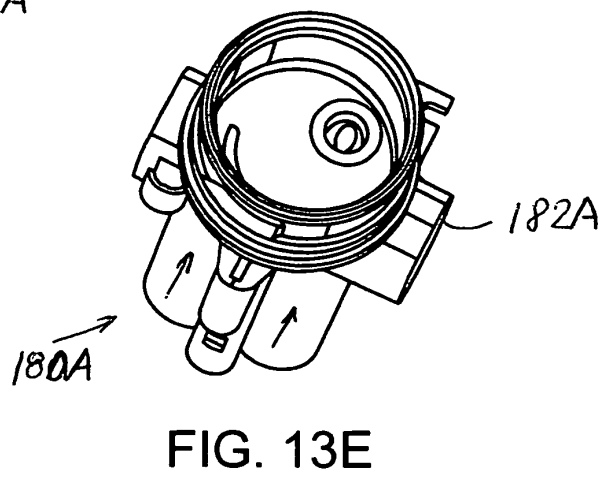
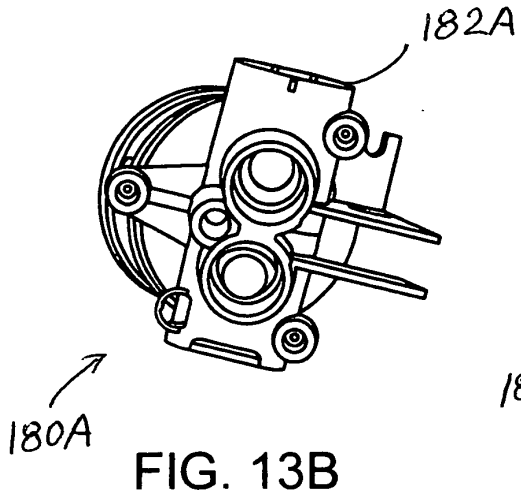


FIG. 13



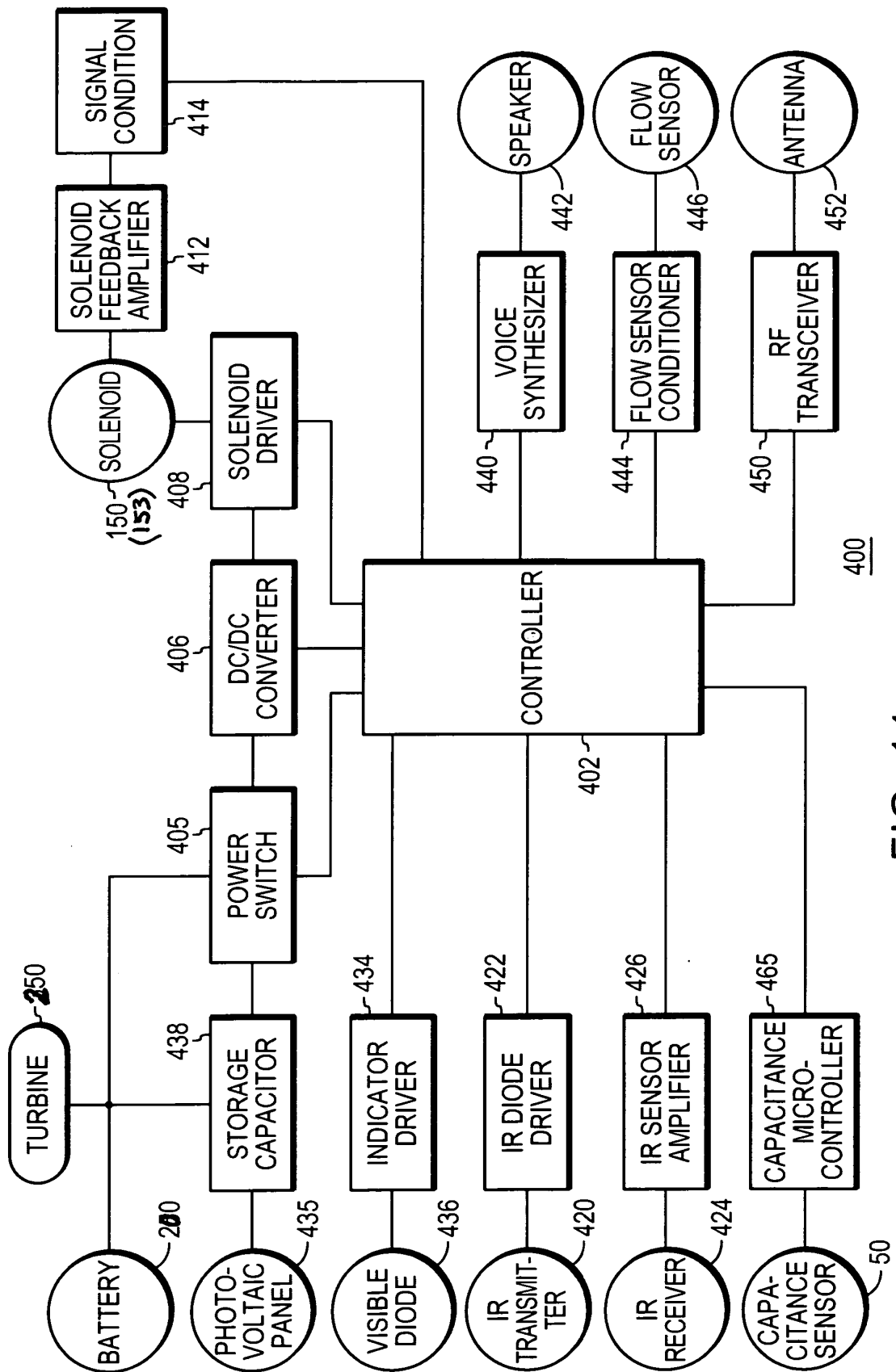


FIG. 14

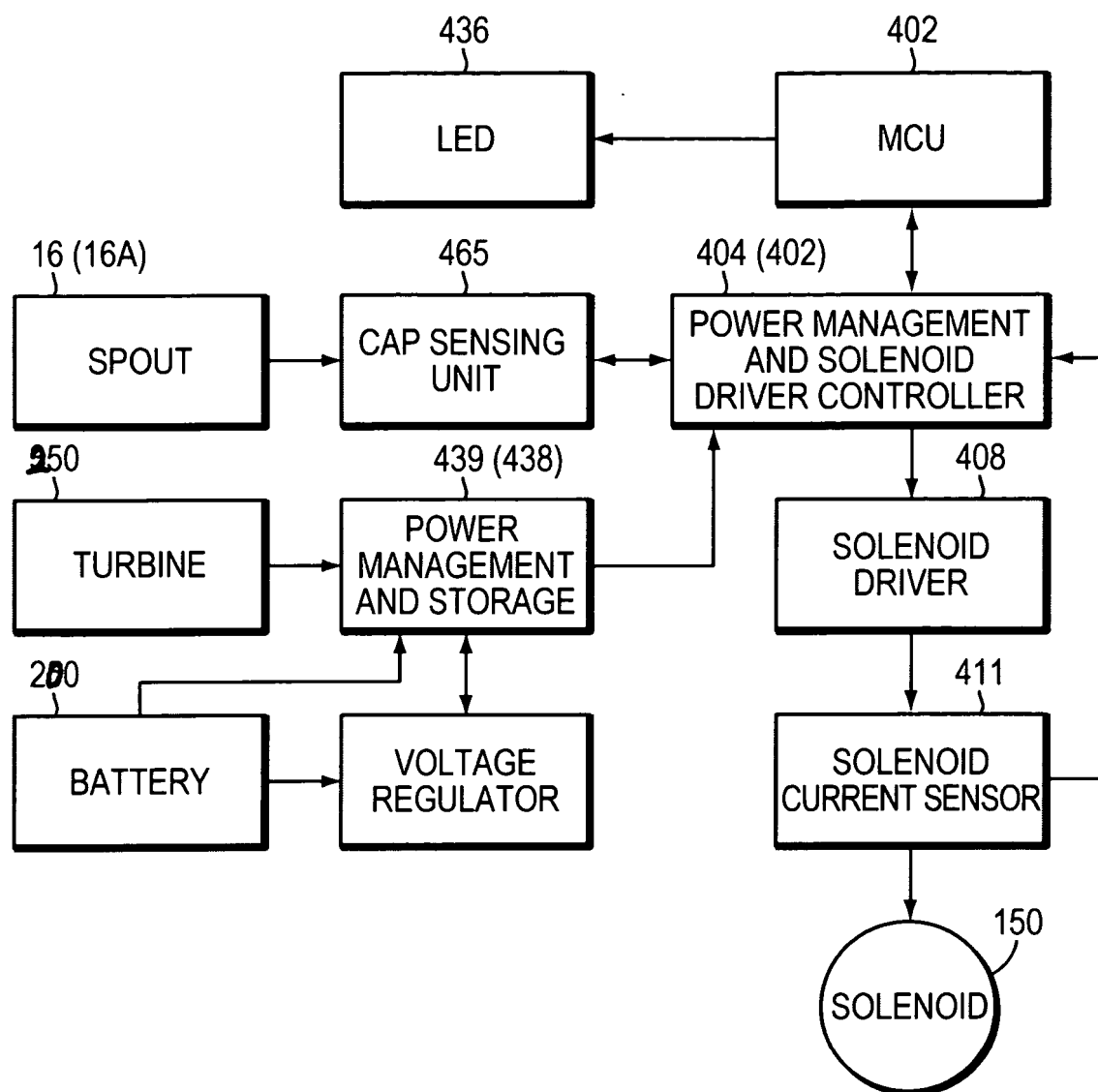


FIG. 15

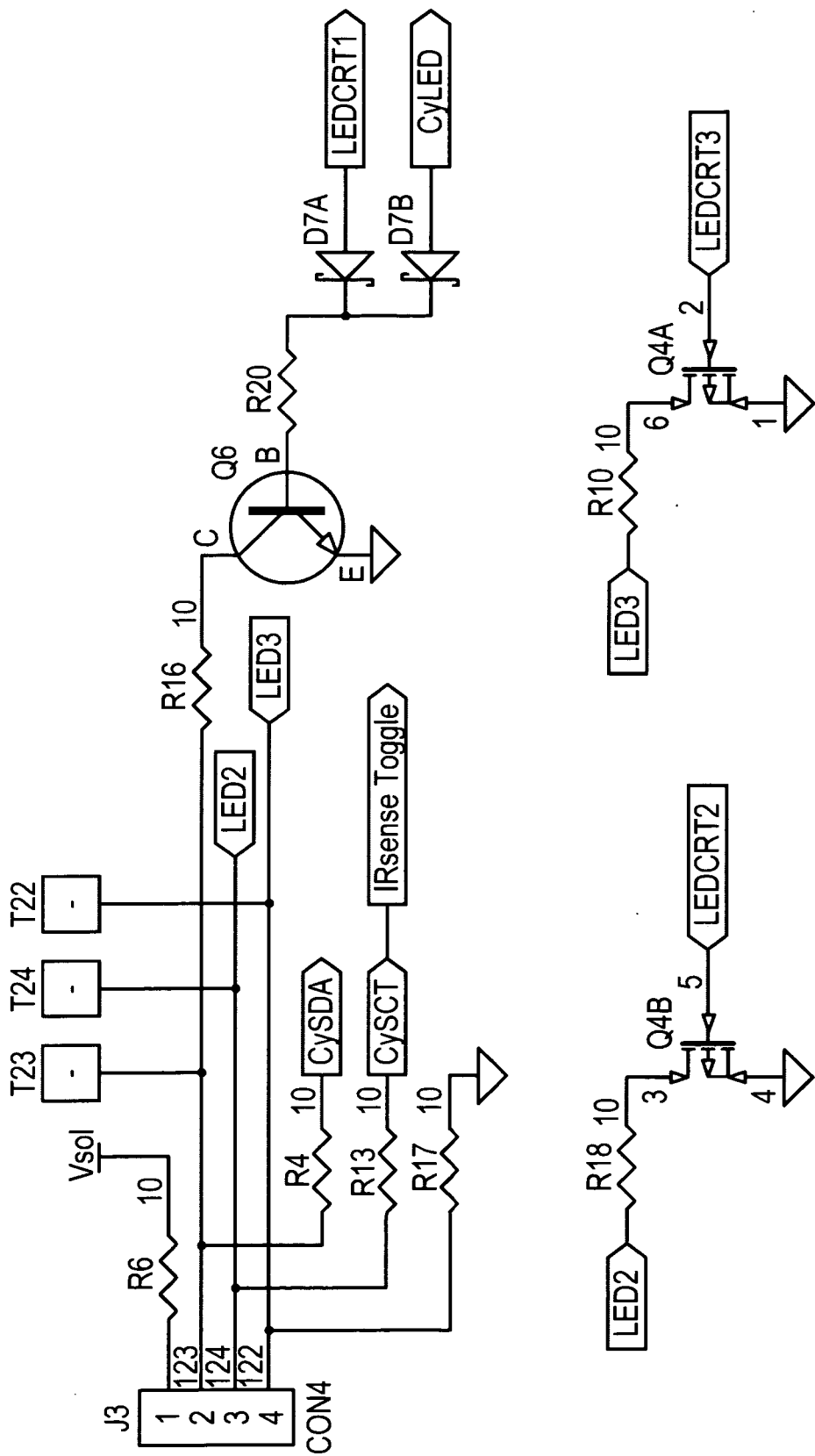
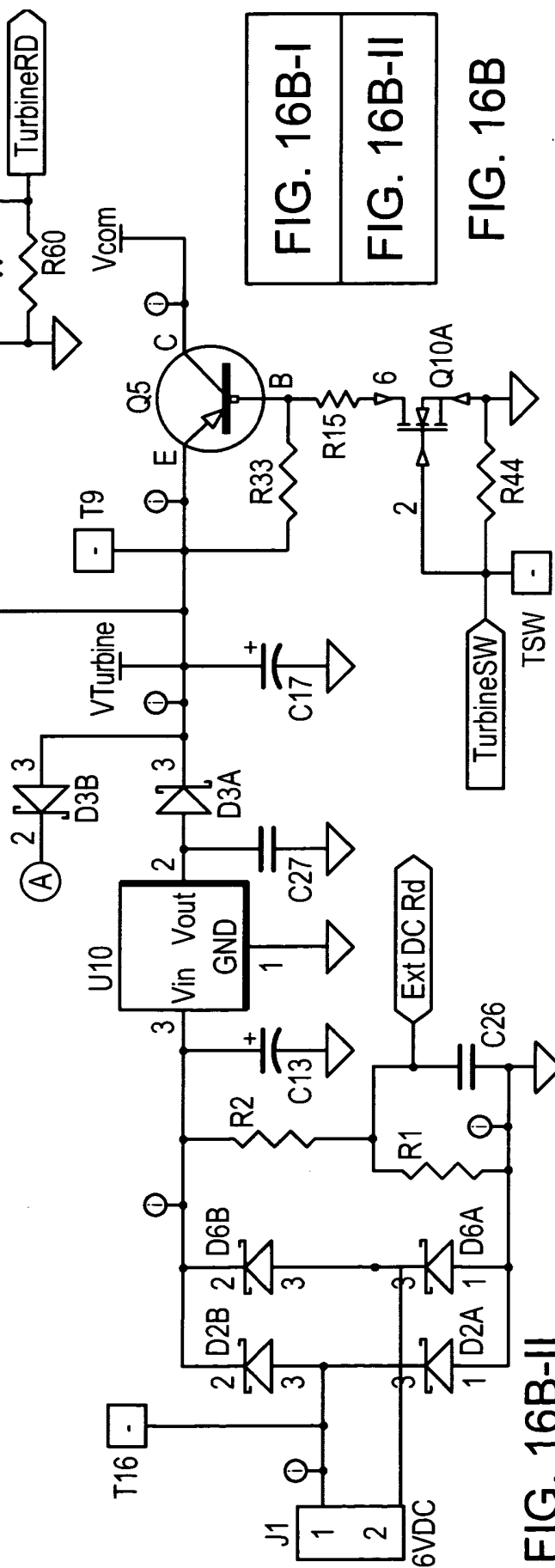
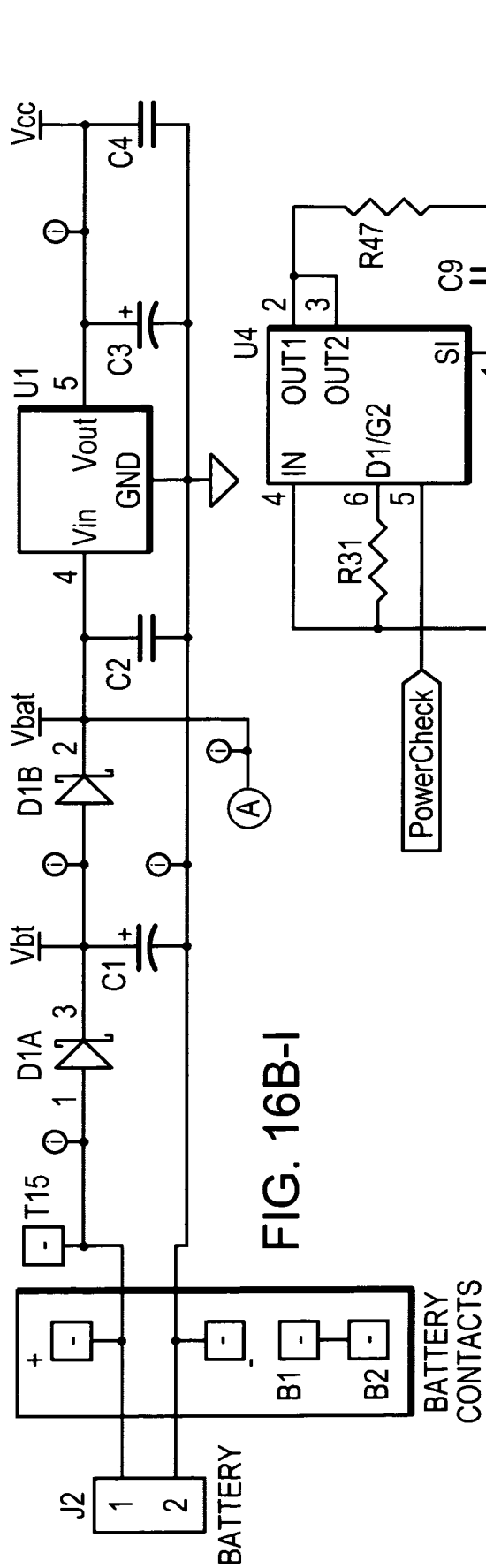


FIG. 16A



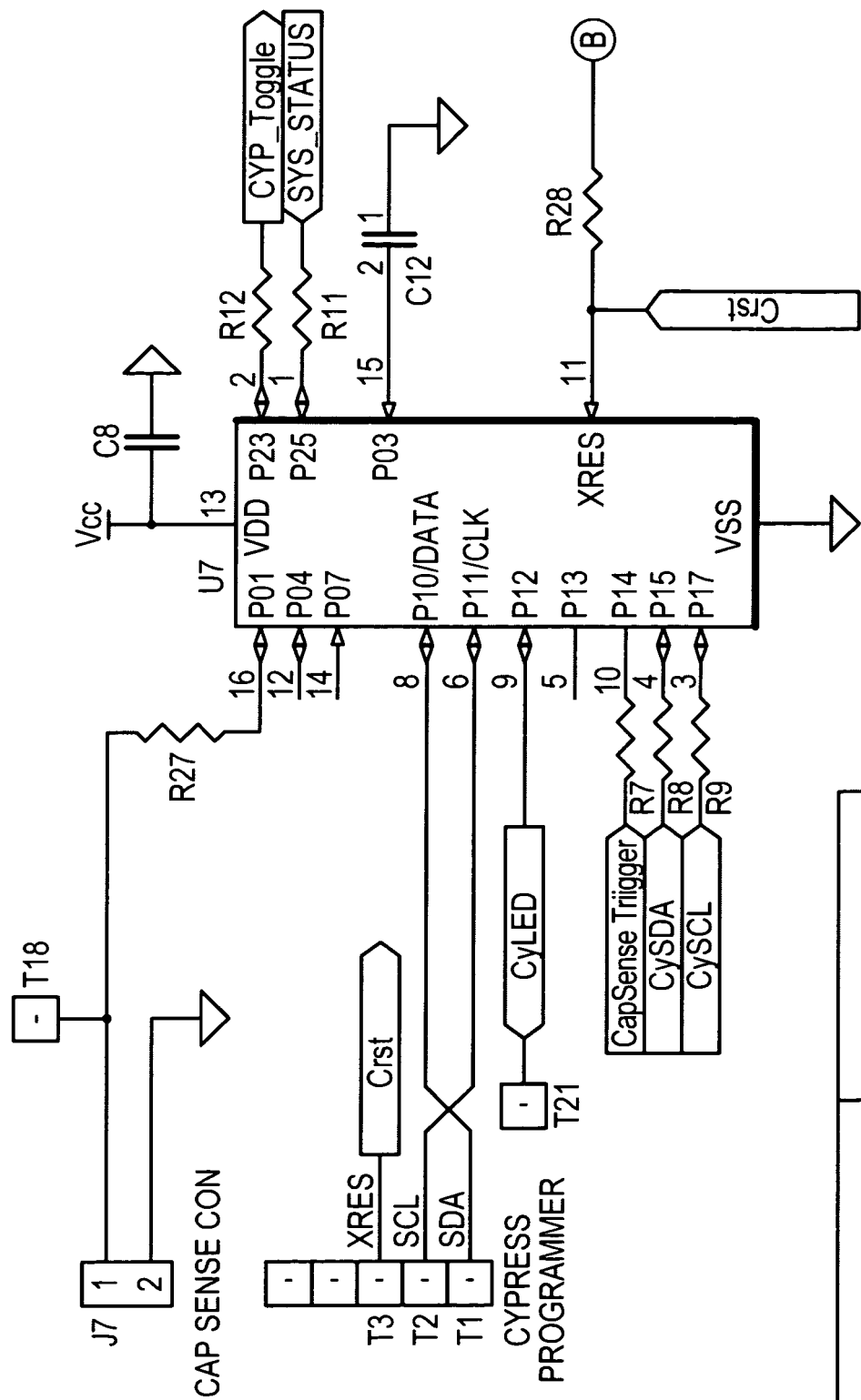


FIG. 16C-I

FIG. 16C-I FIG. 16C-II

FIG. 16C

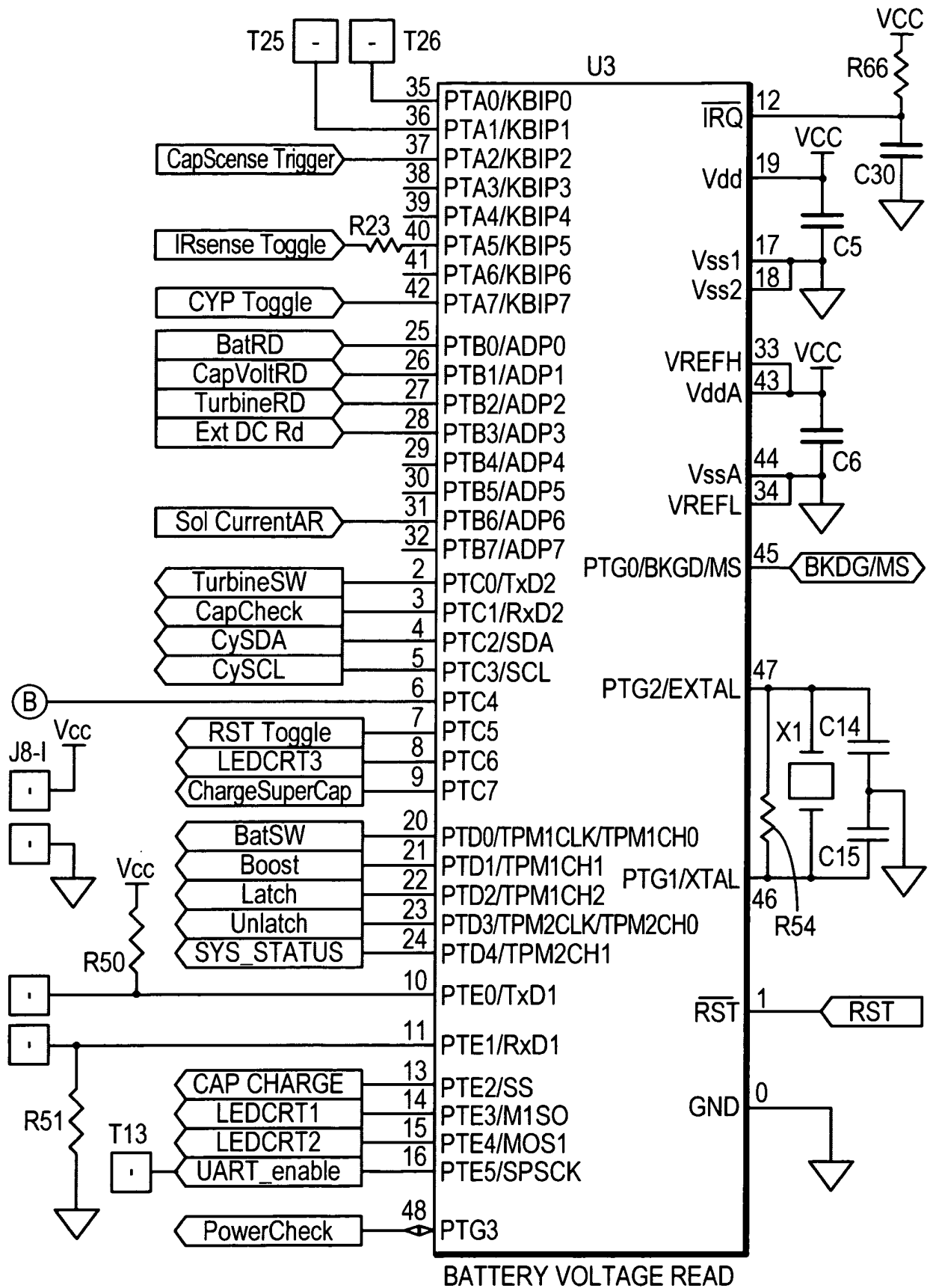


FIG. 16C-II

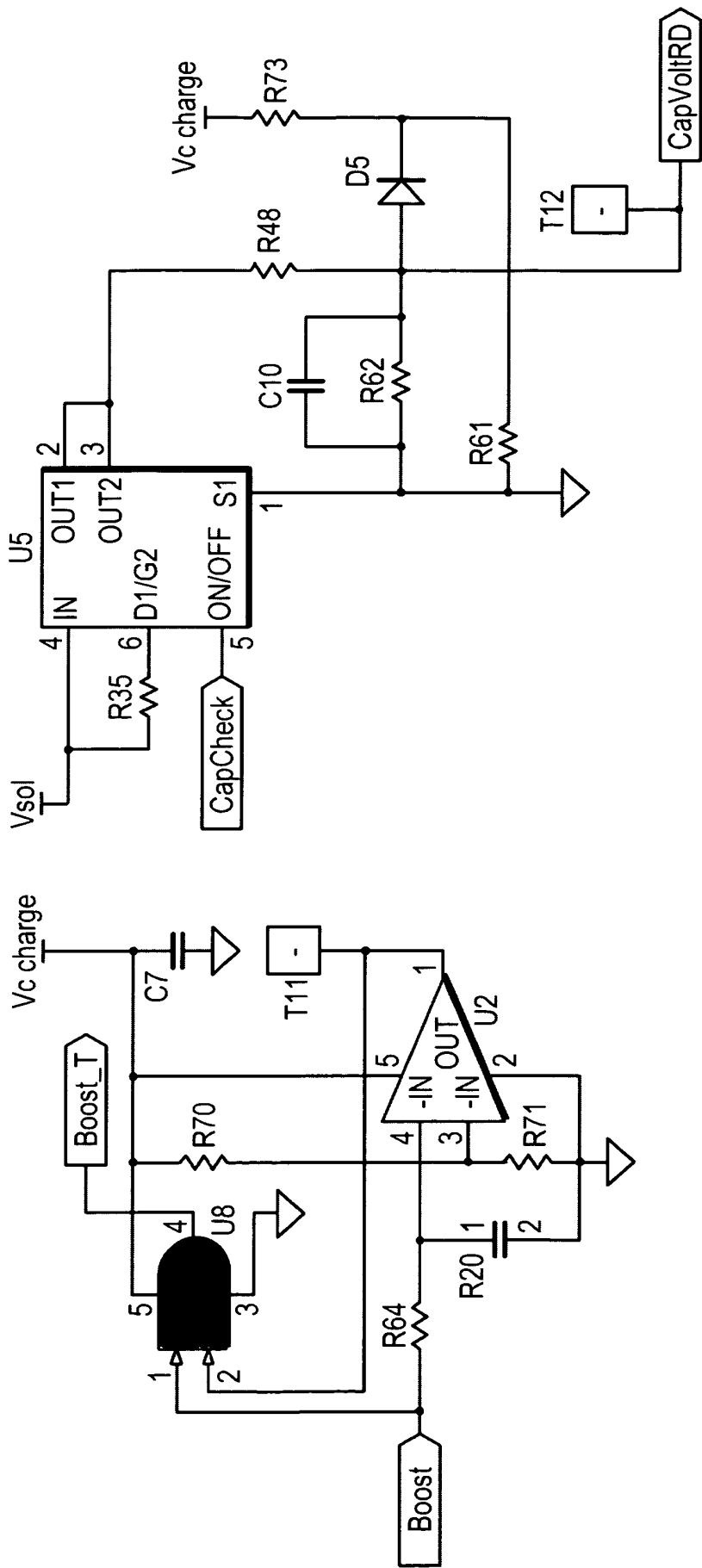


FIG. 16D

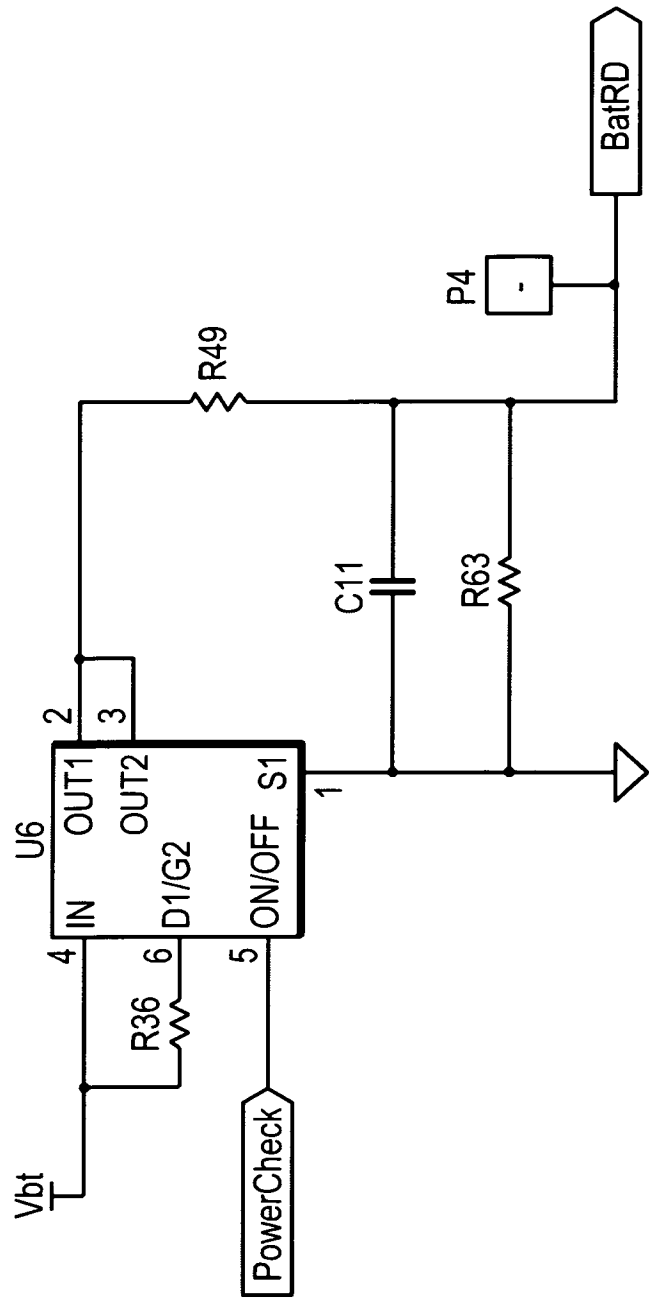
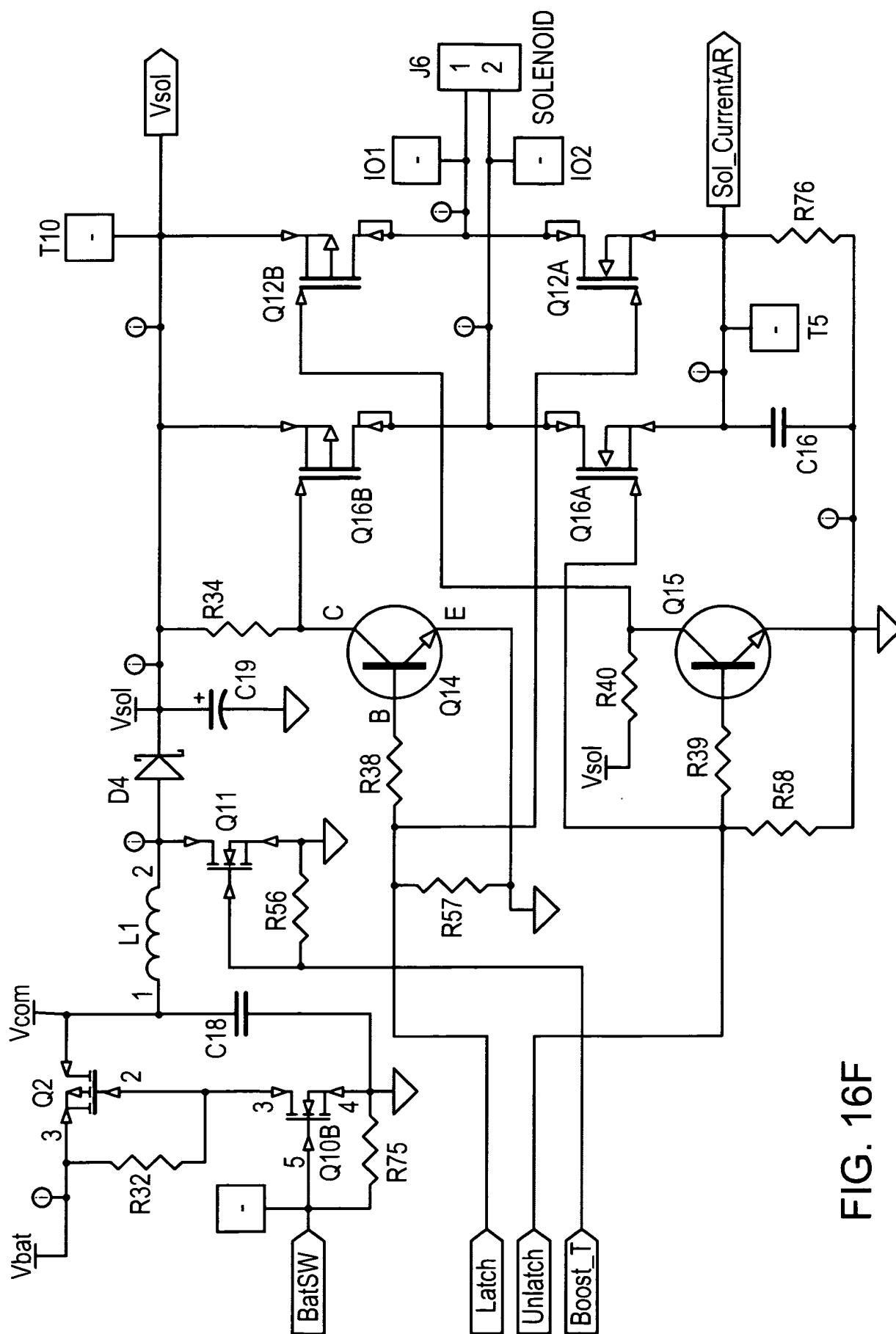


FIG. 16E



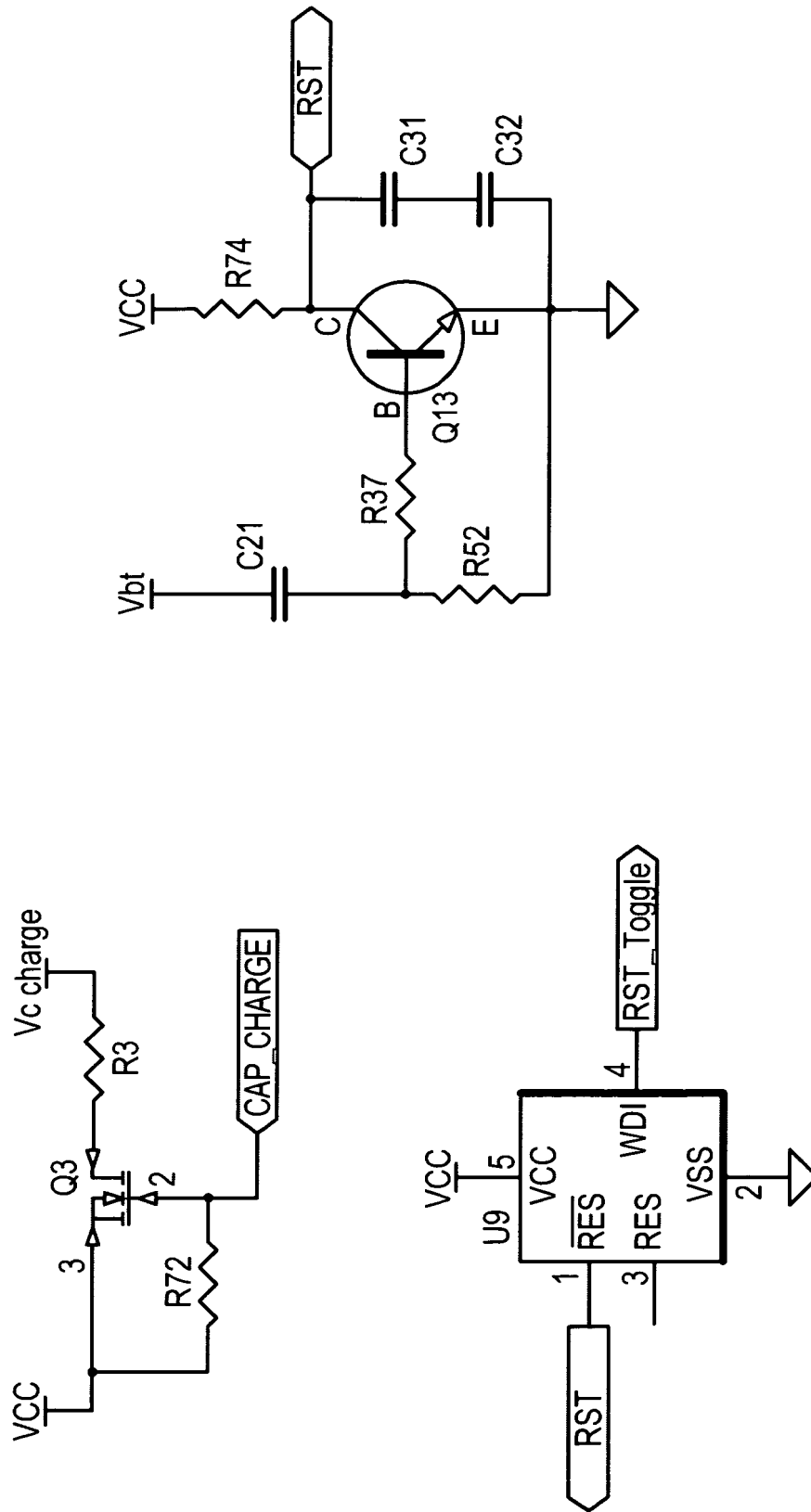


FIG. 16G

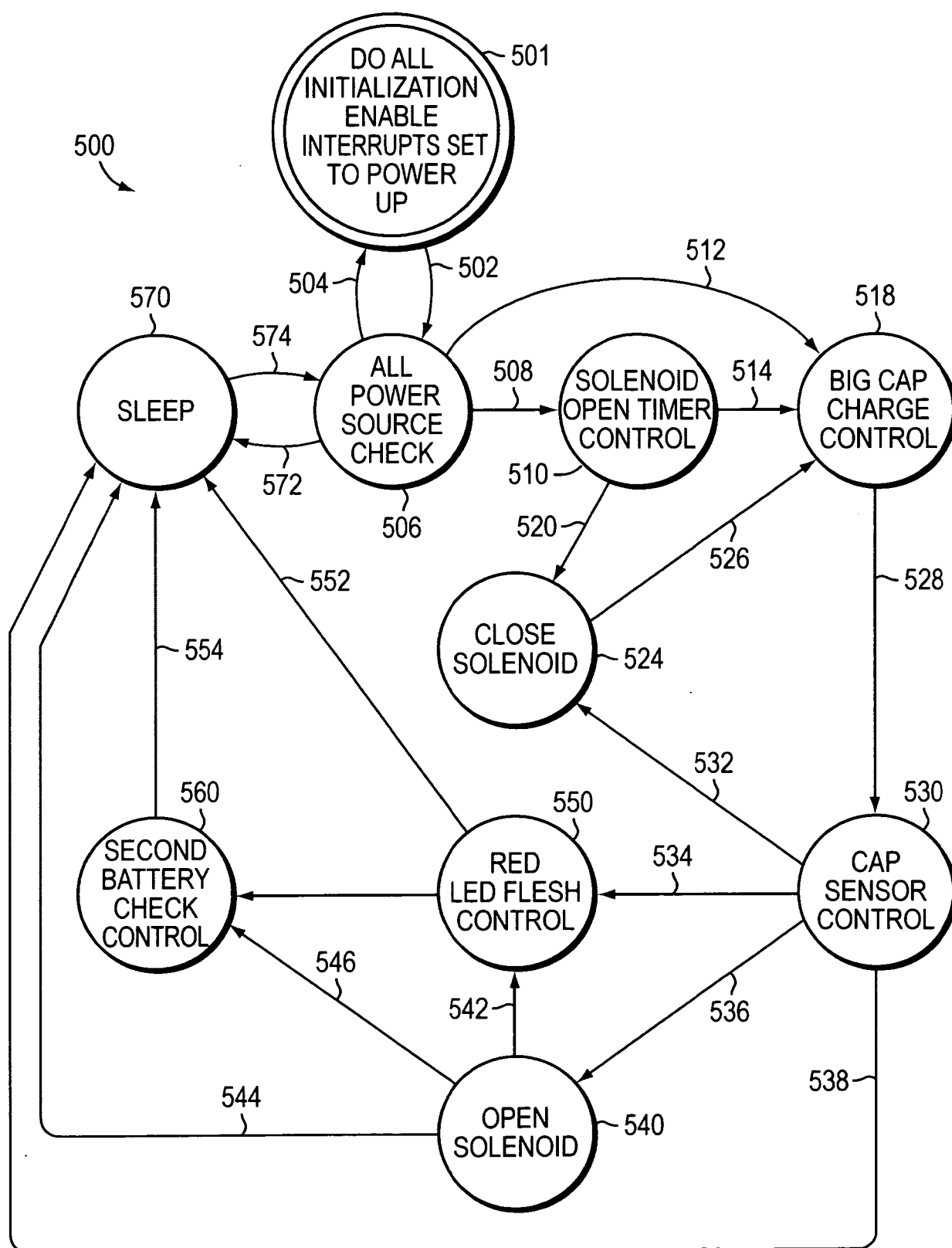


FIG. 17

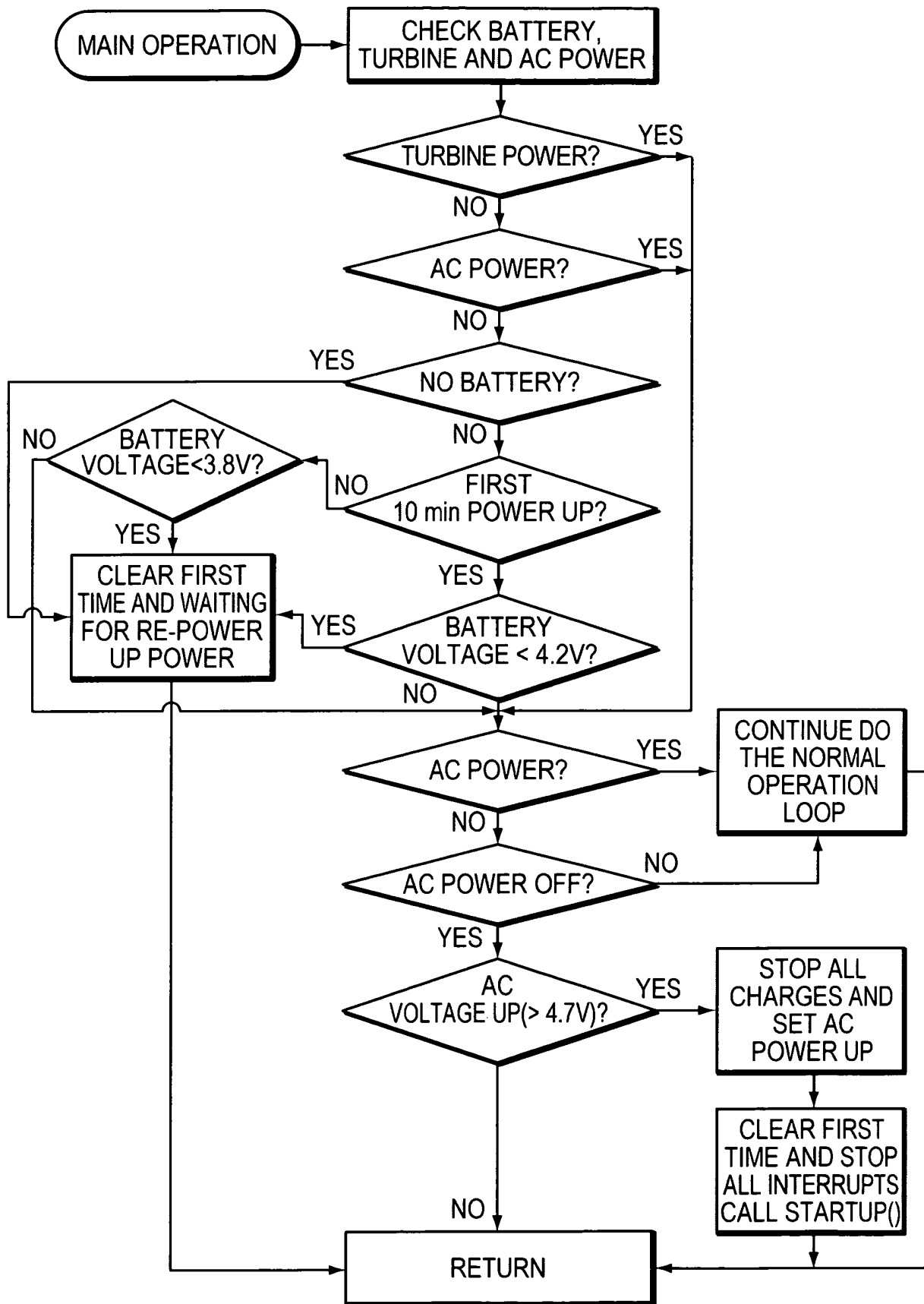


FIG. 18

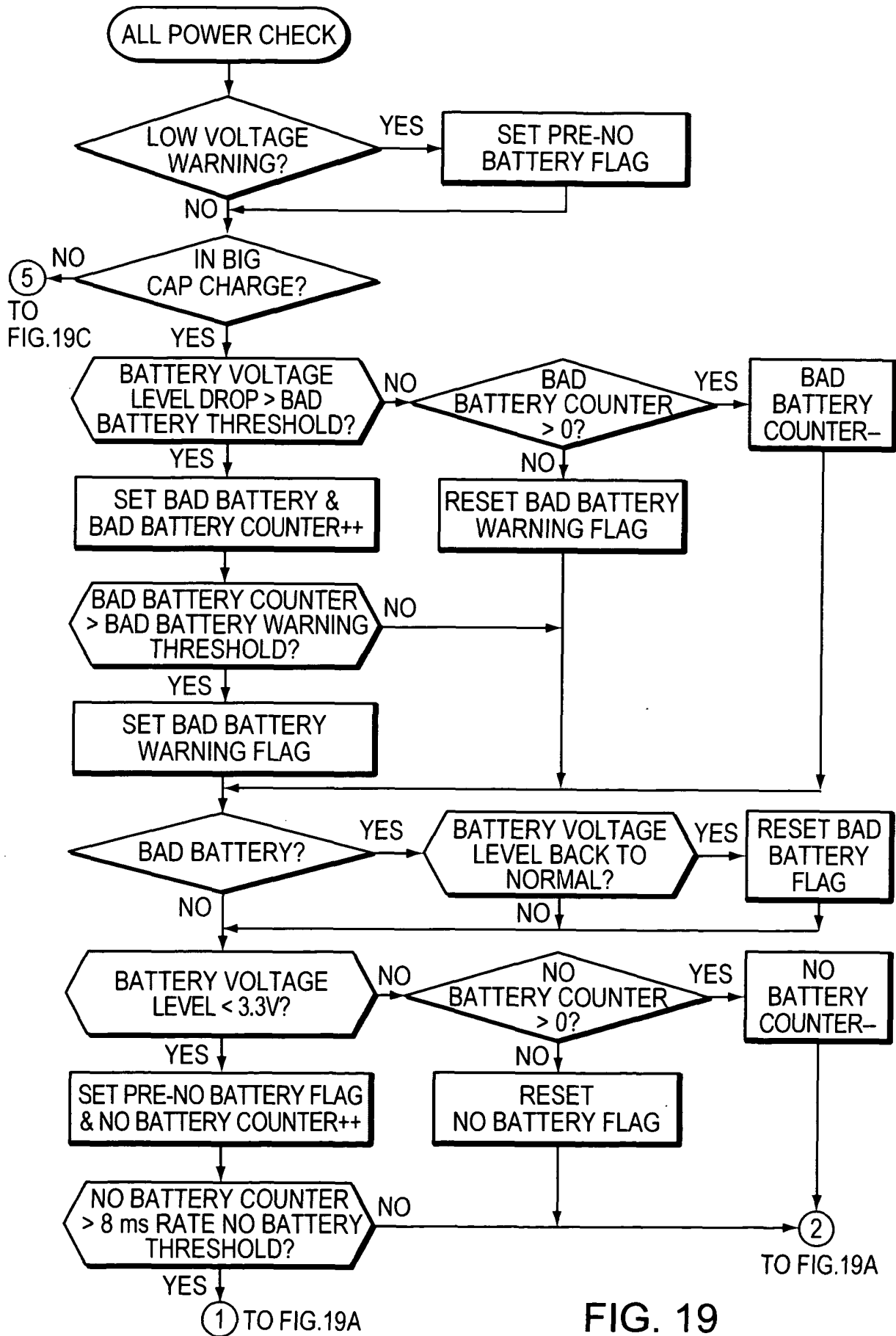


FIG. 19

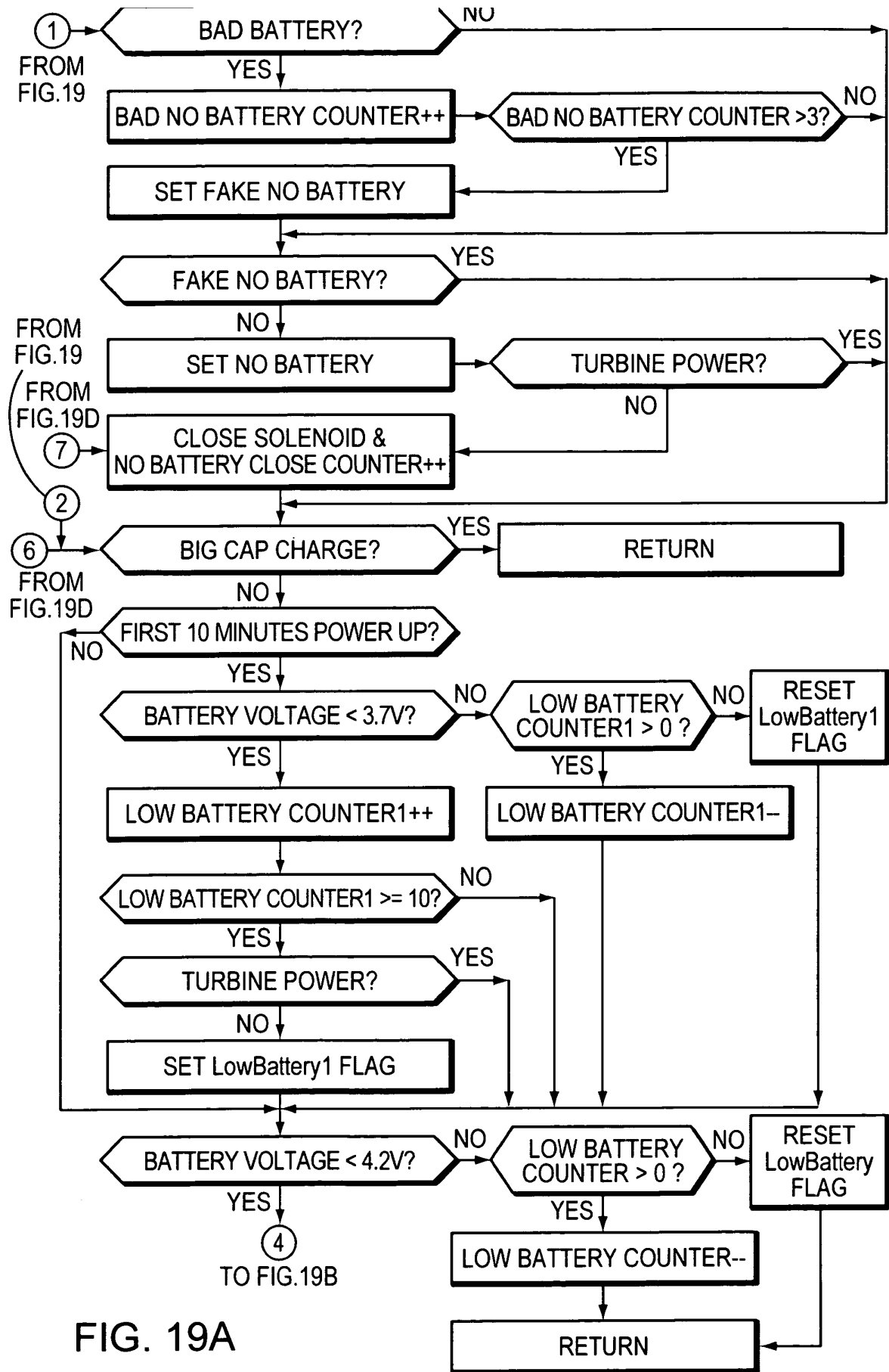


FIG. 19A

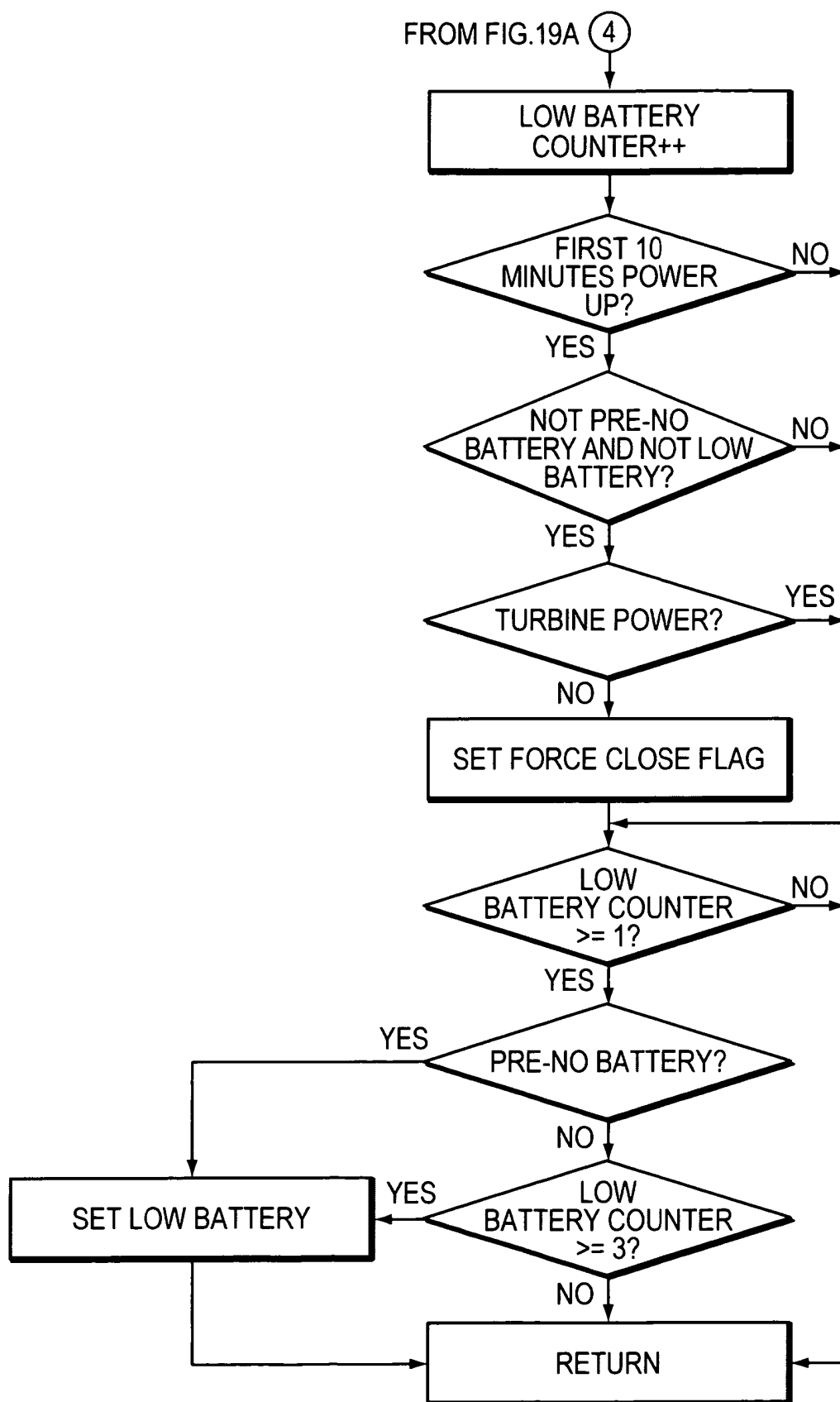
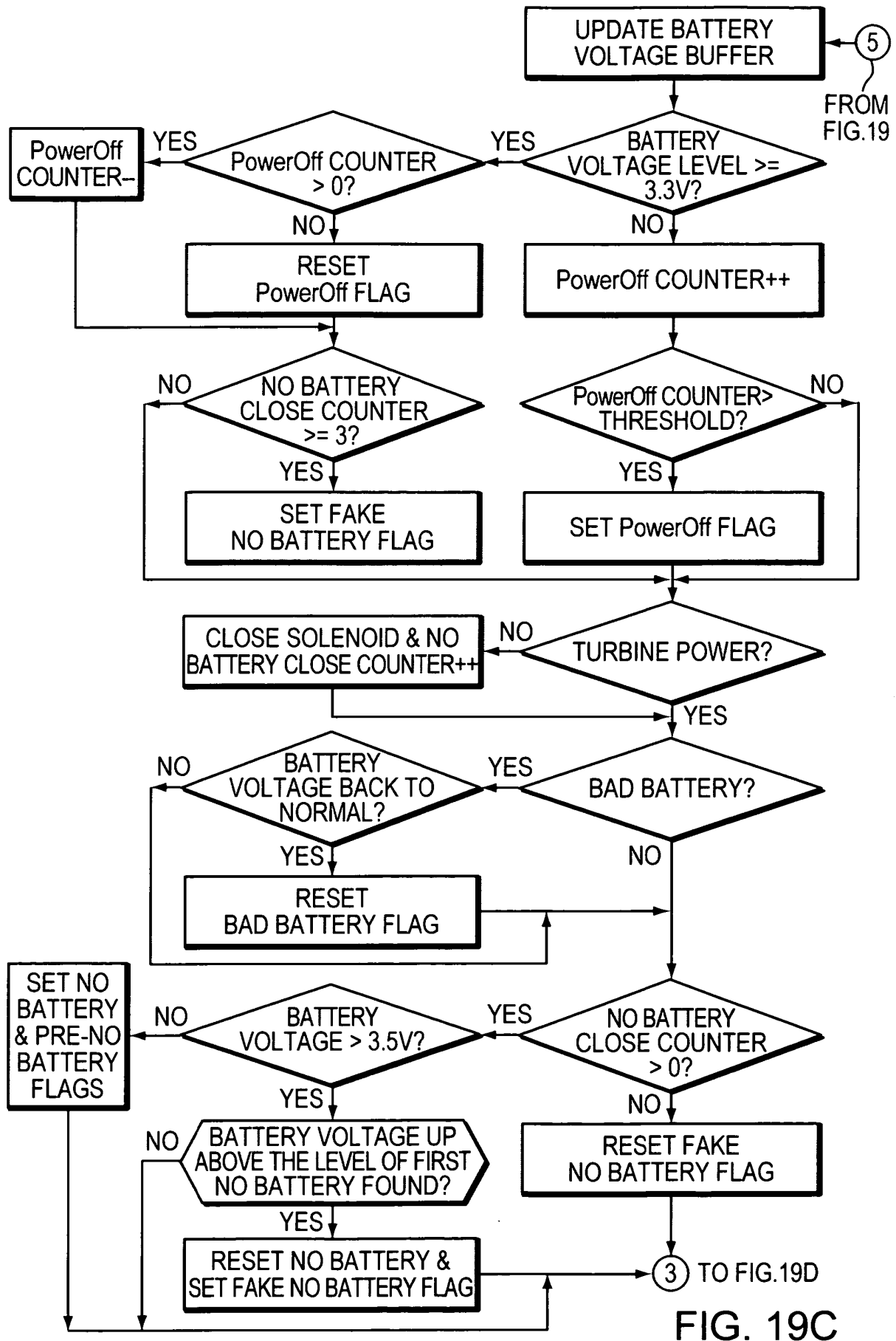
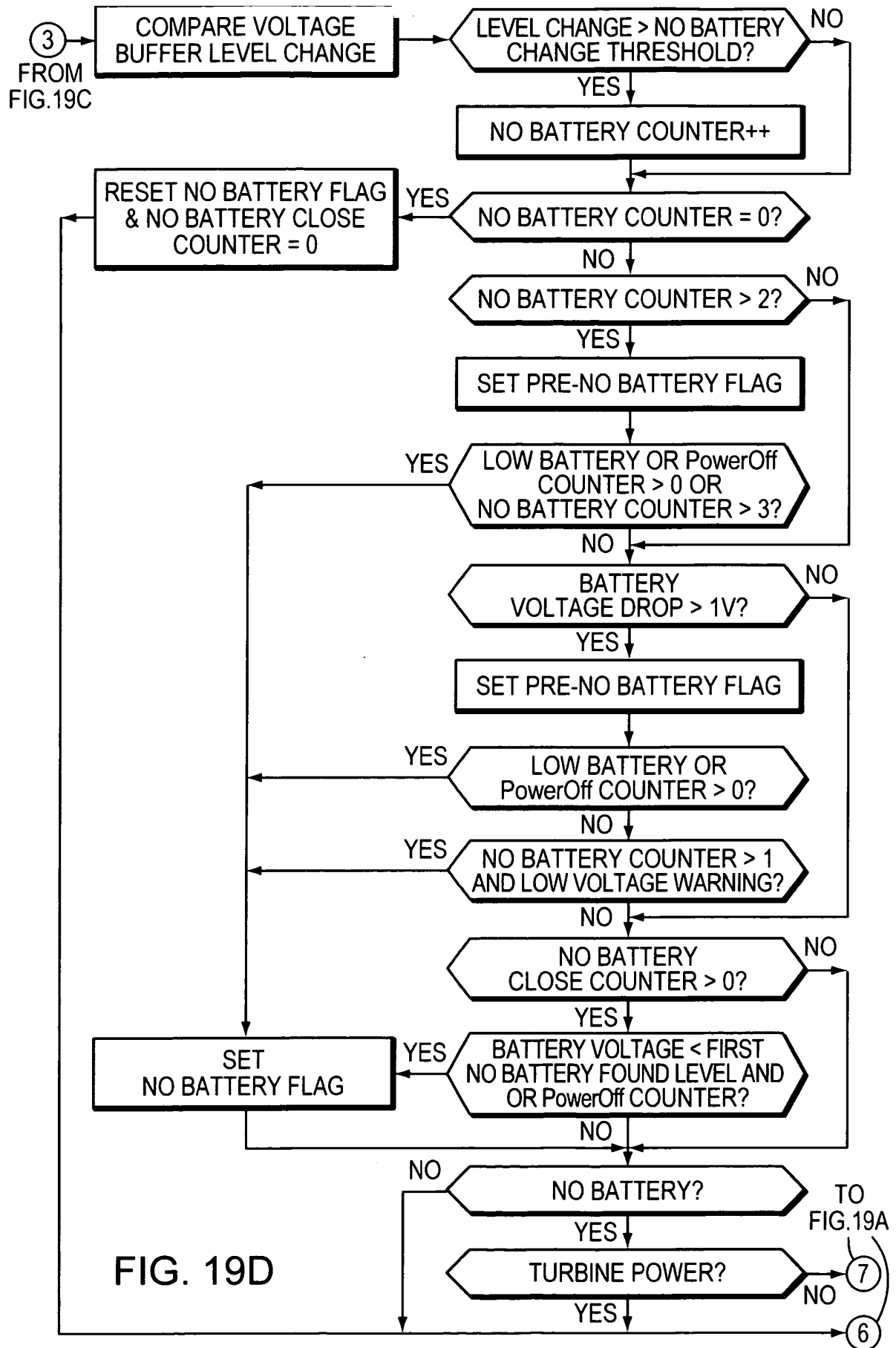


FIG. 19B





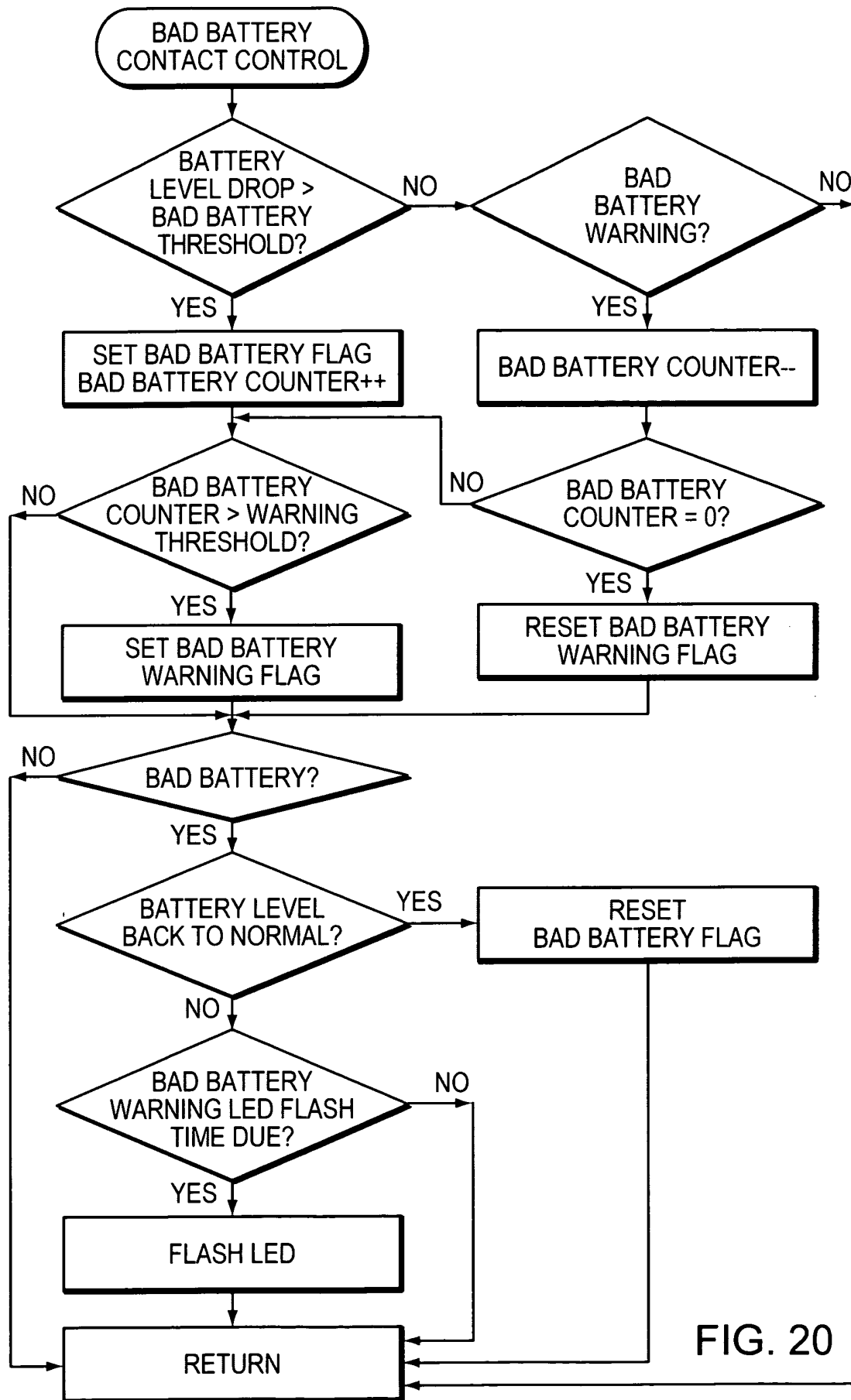


FIG. 20

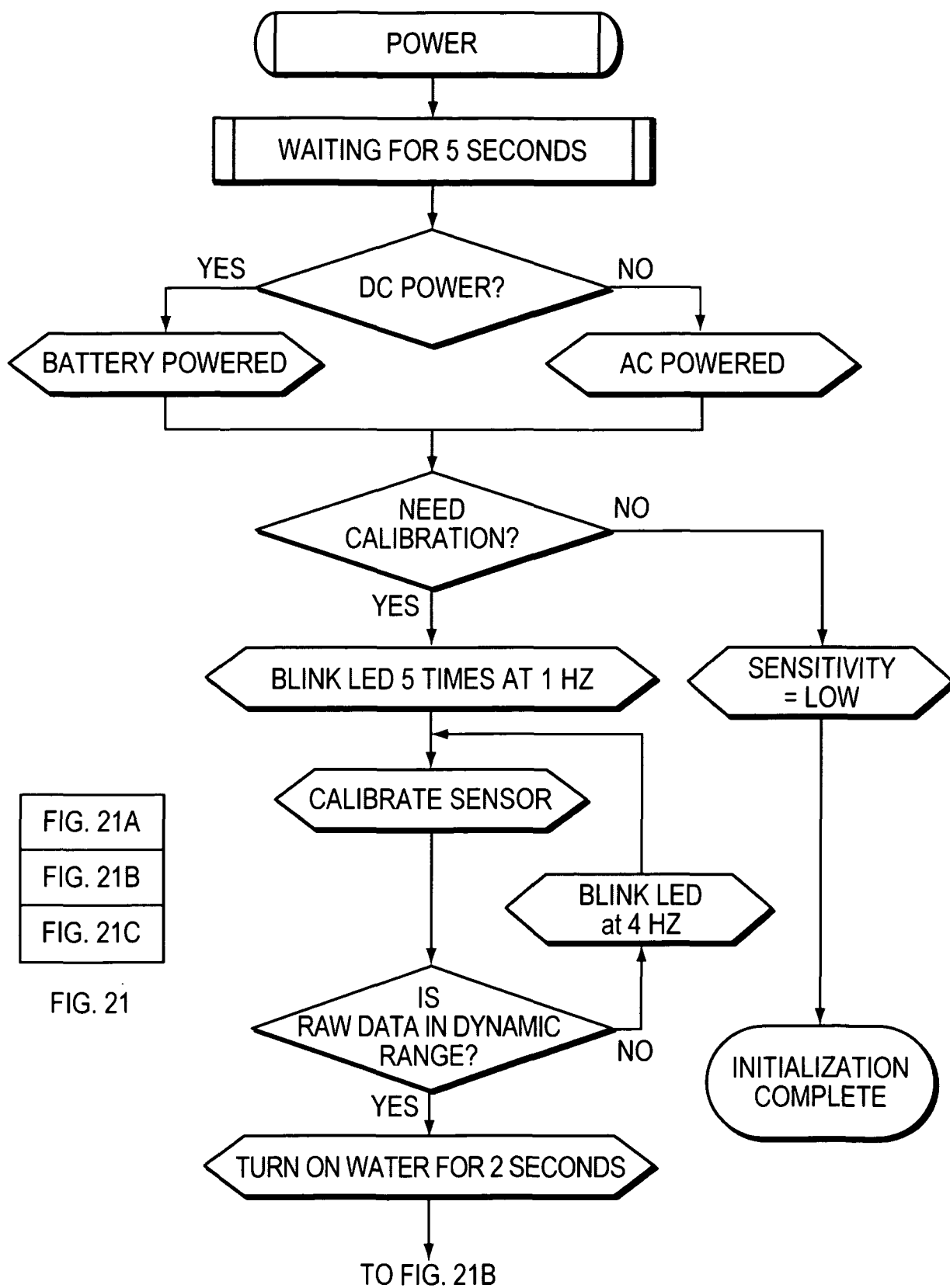


FIG. 21A

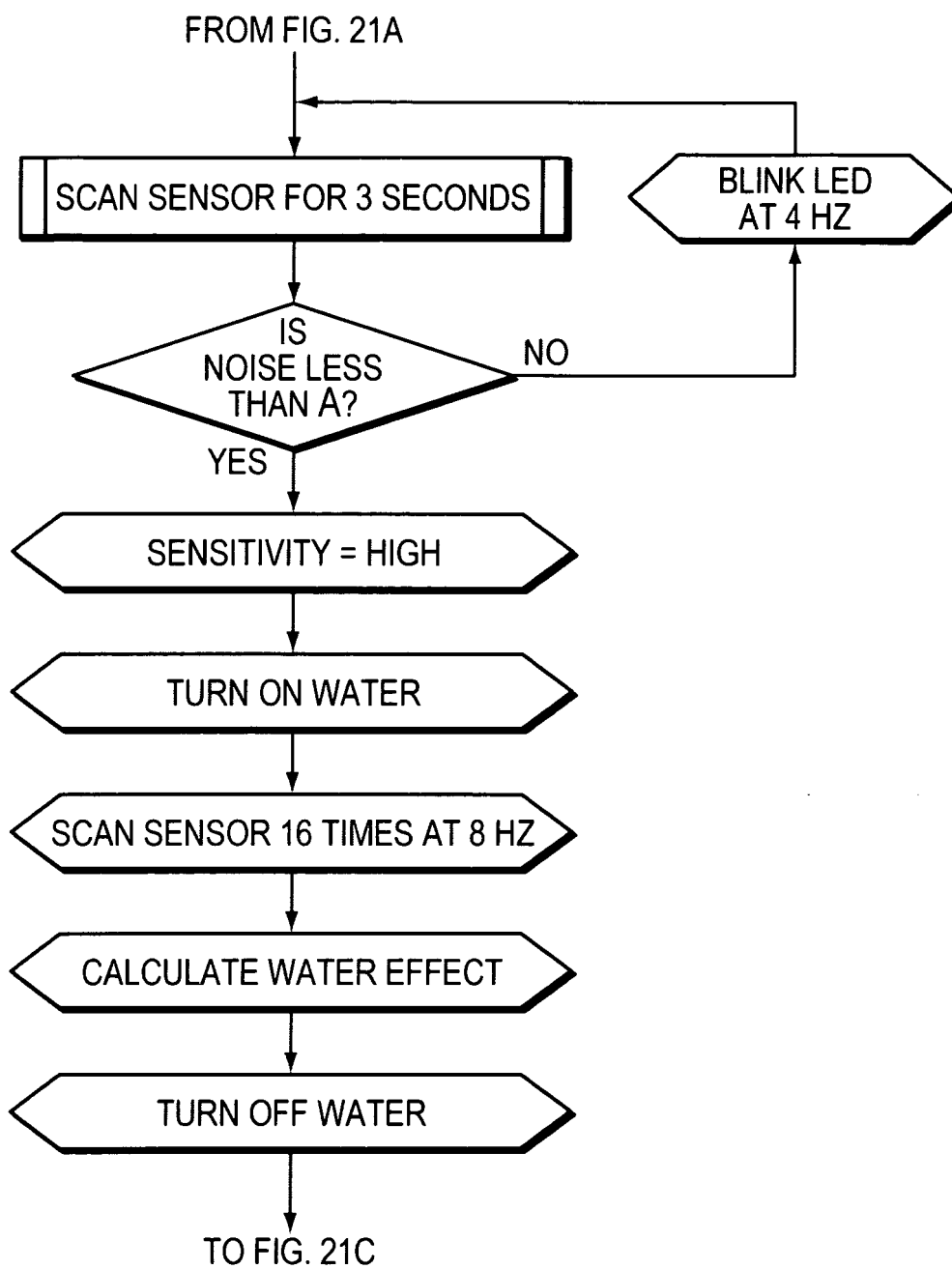


FIG. 21B

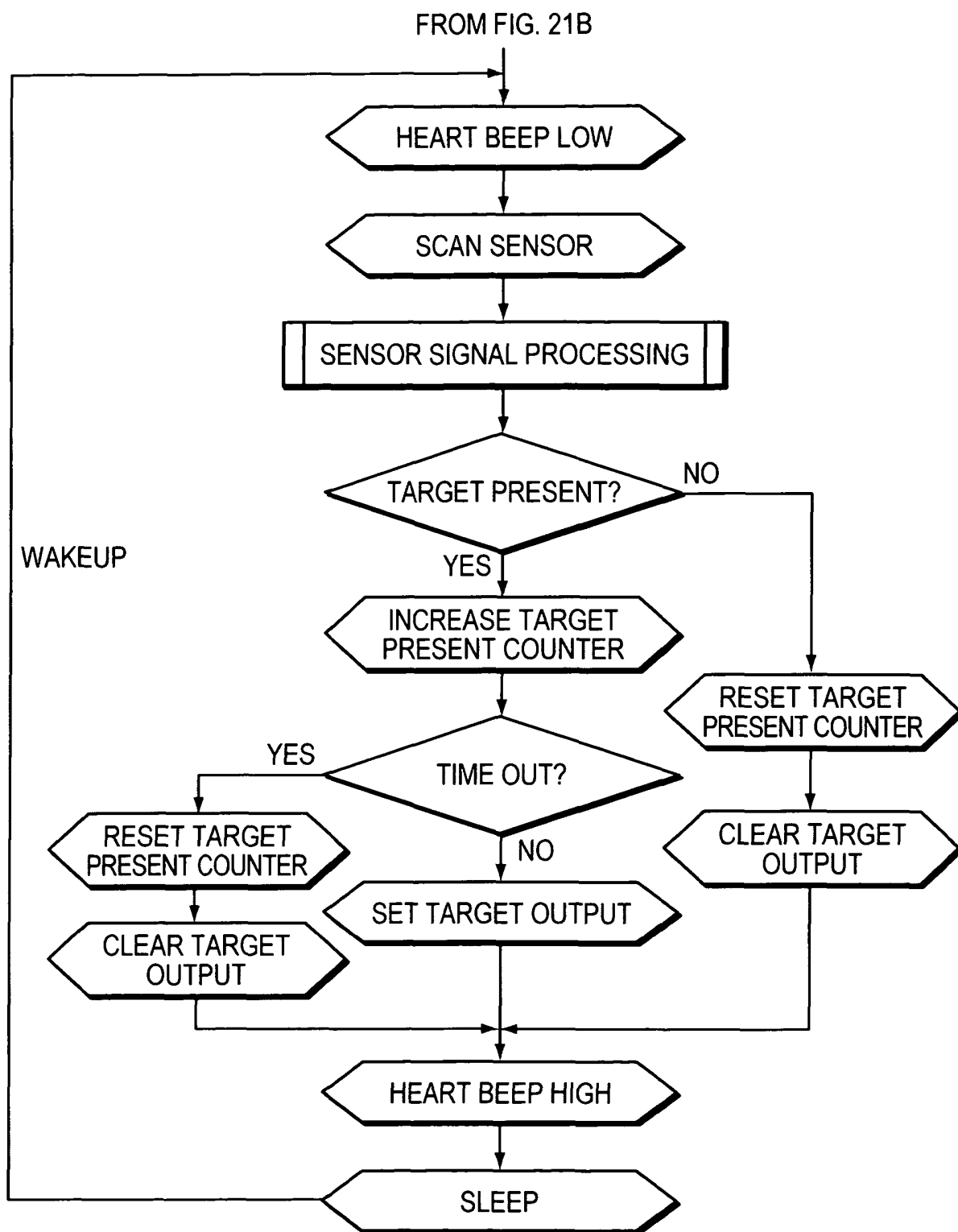


FIG. 21C

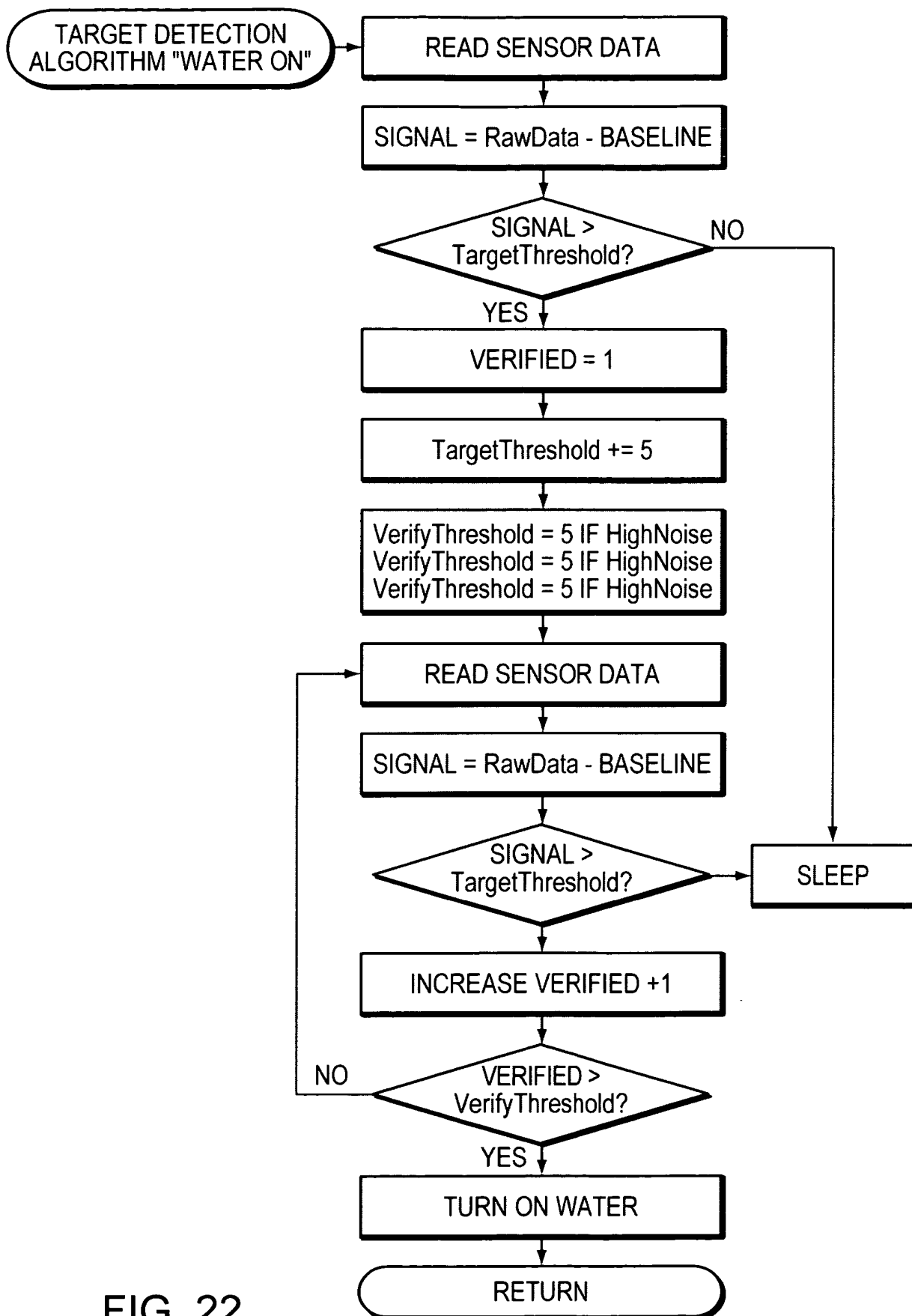


FIG. 22

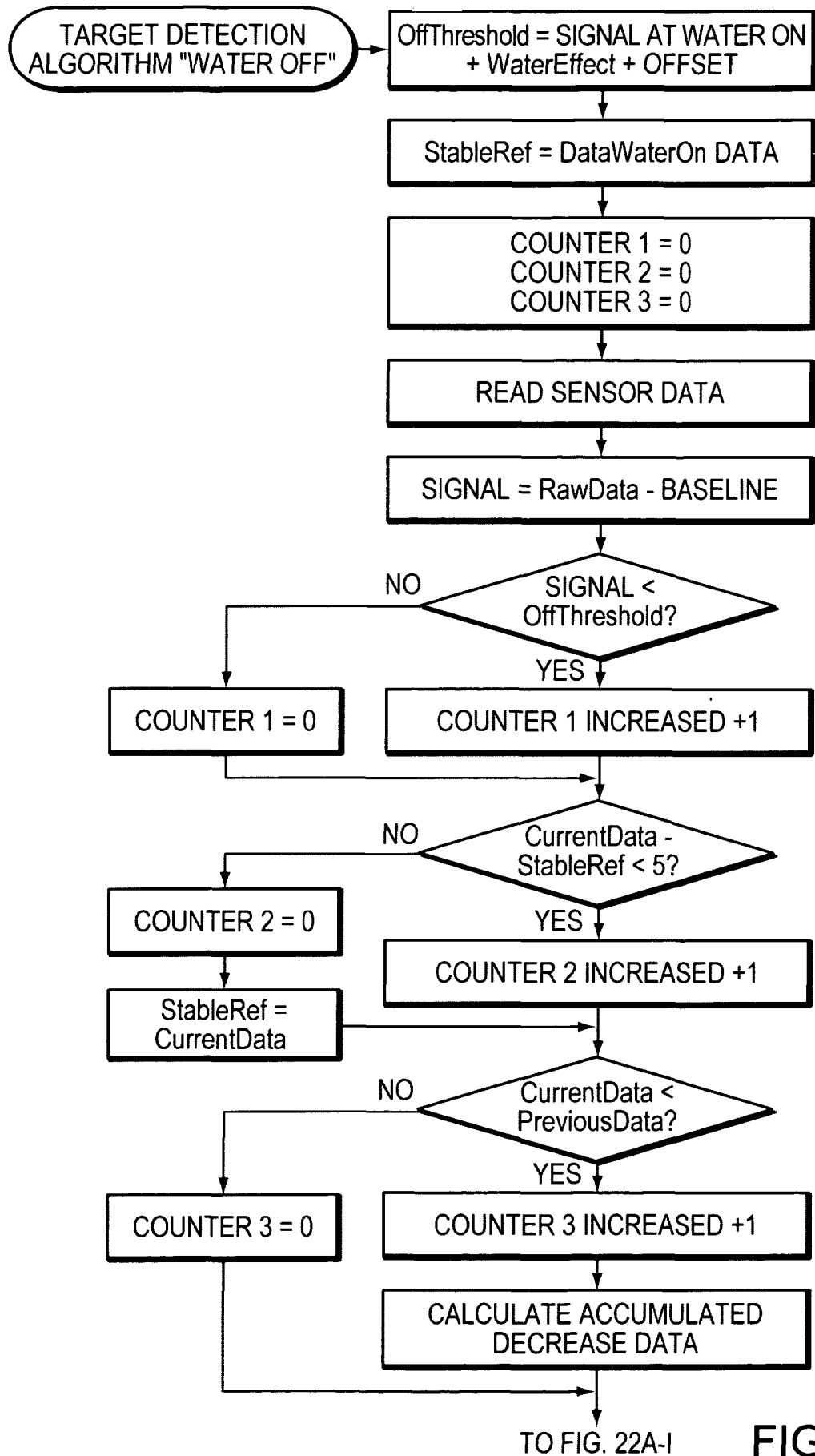


FIG. 22A

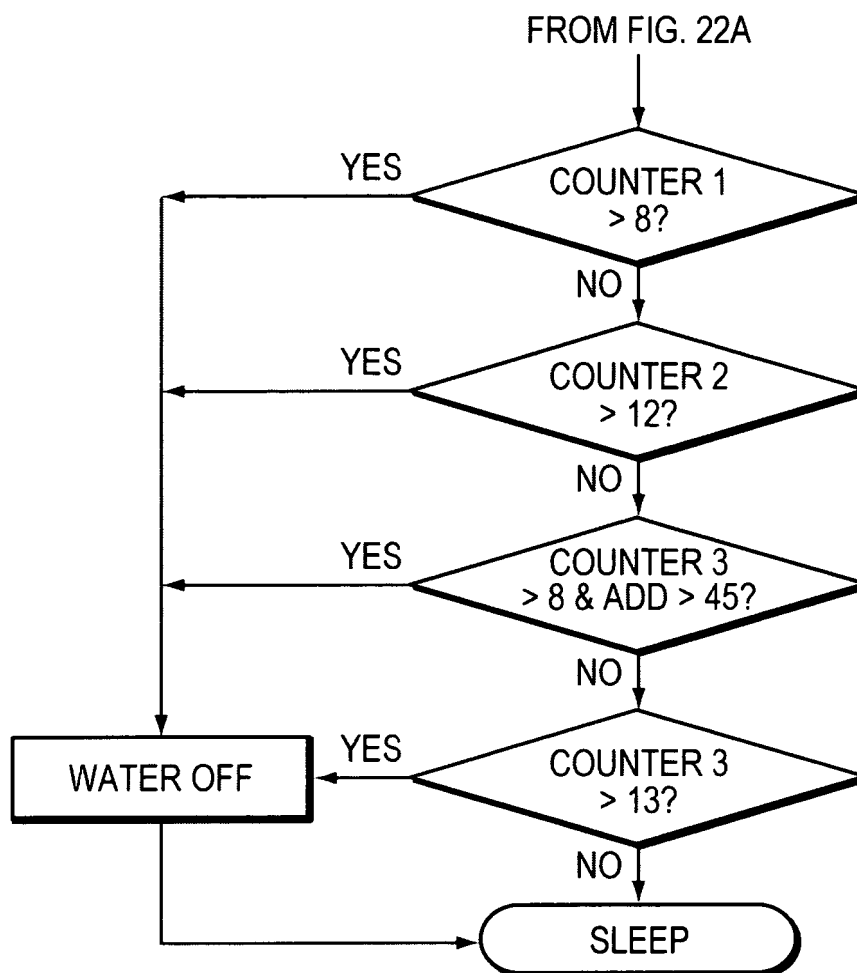


FIG. 22A-I

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 2012000150 W [0001]
- US 61574345 [0001]
- JP 2008248474 B [0007]
- US 20130167953 A [0008]
- DE 102010009215 [0009]
- DE 102011110092 [0010]
- US 20090188995 A [0011]
- DE 103206368 [0012]
- US 0143277 W [0038]
- US 6293516 B [0063]
- US 6305662 B [0063]
- US 0151098 W [0063]
- US 6874535 B [0063]
- US 0338730 W [0071]
- US 0341303 W [0071]
- WO 2005056938 A [0078]
- WO 2004061343 A [0078]
- US 2008008242 W [0080]
- US 5979500 A [0105]
- US 5984262 A [0105]
- US 10012252 B [0105]
- US 10012226 B [0105]