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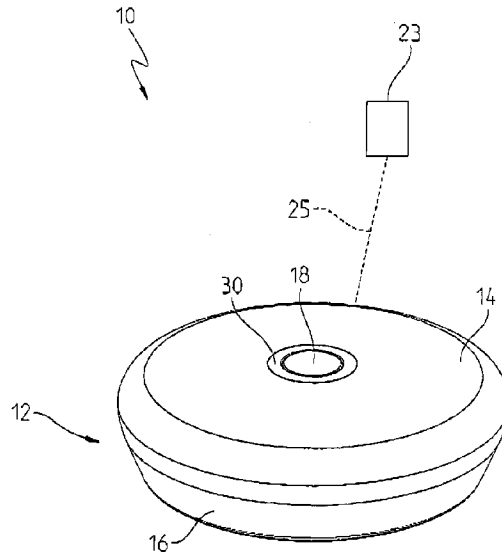
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(57) **Abrégé/Abstract:**

A water sensor comprises a housing including a top portion and a bottom portion; a controller positioned within the housing; a power source electrically coupled to the controller to energize the controller; and a continuity sensor electrically coupled to the controller and including an inner arcuate portion and an outer arcuate portion, the inner arcuate portion having an electrically conductive surface spanning at least 300 degrees, the outer arcuate portion having an electrically conductive surface spanning at least 300 degrees and substantially surrounding the inner arcuate portion to define an gap therebetween, wherein the water sensor is structured to transition from a first logical state to a second logical state responsive to water bridging the gap, and wherein the controller is structured to transmit a wireless water detection signal responsive to the water sensor transitioning to the second logical state.

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(54) Title: WATER SENSOR

(57) Abstract: A water sensor comprises a housing including a top portion and a bottom portion; a controller positioned within the housing; a power source electrically coupled to the controller to energize the controller; and a continuity sensor electrically coupled to the controller and including an inner arcuate portion and an outer arcuate portion, the inner arcuate portion having an electrically conductive surface spanning at least 300 degrees, the outer arcuate portion having an electrically conductive surface spanning at least 300 degrees and substantially surrounding the inner arcuate portion to define a gap therebetween, wherein the water sensor is structured to transition from a first logical state to a second logical state responsive to water bridging the gap, and wherein the controller is structured to transmit a wireless water detection signal responsive to the water sensor transitioning to the second logical state.



WO 2017/115145 A1

WATER SENSOR

[0001]

TECHNICAL FIELD

[0002] The present invention relates generally to a water sensor for detecting the presence of water in a particular area and, more particularly, to a water sensing system including the water sensor and configured to provide remote alarms.

BACKGROUND

[0003] A water sensing device generally senses flood conditions caused by a water level rising above the ground sufficiently to contact electrodes of the sensing device. Improved water sensors are desirable to detect water before a flood condition occurs.

SUMMARY OF DISCLOSED EMBODIMENTS

[0004] The present invention relates generally to a water sensor for detecting the presence of water in a particular area. In some embodiments, the water sensor comprises a continuity sensor, and a controller to configure the water sensor and communicate signals generated by the water sensor to a web service. The web service can then transmit alarms and status alerts. The continuity sensor has electrically conductive elements and an electrical circuit configured to change logical state responsive to water bridging an elongate gap between the electrically conductive elements.

[0005] In some embodiments, the water sensor comprises a housing including a top portion and a bottom portion; a controller positioned within the housing; a power source positioned within the housing and electrically coupled to the controller to energize the controller; and a continuity sensor electrically coupled to the controller and including a first elongate member adjacent a second elongate member with an elongate gap therebetween, the first

elongate member and the second elongate member extending along one or more surfaces of the housing, and control logic structured to transition from a first logical state to a second logical state responsive to water bridging the elongate gap, wherein the controller is structured to transmit a wireless water detection signal responsive to the continuity sensor transitioning to the second logical state.

[0006] In some embodiments, a method of detecting water is provided which is implemented with a water sensor comprising a housing including a top portion and a bottom portion; a controller positioned within the housing; a power source positioned within the housing and electrically coupled to the controller to energize the controller; and a continuity sensor electrically coupled to the controller and including a first elongate member adjacent a second elongate member with a elongate gap therebetween, the first elongate member and the second elongate member extending along one or more surfaces of the housing, and control logic structured to transition from a first logical state to a second logical state responsive to water bridging the elongate gap, wherein the controller is structured to transmit a wireless water detection signal responsive to the continuity sensor transitioning to the second logical state. The method comprises, by the water sensor, wherein the controller comprises a wireless personal area network (WPAN) controller communicatively coupled to a wireless local area network (WLAN) controller: the continuity sensor transitioning from the first logical state to the second logical state responsive to the water bridging the elongate gap; the WPAN controller transitioning from the inactive state to the active state responsive to the continuity sensor transitioning from the first logical state to the second logical state; the WLAN controller transitioning from an inactive state to an active state responsive to a signal from the WPAN controller transmitted while the WPAN controller is in the active state; and the WLAN controller transmitting a water detection signal after transitioning to the active state and transitioning to the inactive state after transmitting the water detection signal.

[0007] In some embodiments, a method of detecting water is provided which is implemented with a water sensor a housing including a top portion and a bottom portion; a controller positioned within the housing; a power source positioned within the housing and electrically coupled to the controller to energize the controller; and a continuity sensor

electrically coupled to the controller and including a first elongate member adjacent a second elongate member with a elongate gap therebetween, the first elongate member and the second elongate member extending along one or more surfaces of the housing, and control logic structured to transition from a first logical state to a second logical state responsive to water bridging the elongate gap, wherein the controller is structured to transmit a wireless water detection signal responsive to the continuity sensor transitioning to the second logical state. The method comprises: positioning a water sensor in a desired location; pairing the water sensor with an electronic device to form a wireless personal area network (WPAN); obtaining networking information from a web service with the electronic device, the networking information corresponding to an access point communicatively coupled to the web service; the electronic device transmitting the networking information to the water sensor through the WPAN; the water sensor detecting a presence of water; and the water sensor transmitting a wireless water presence signal to the access point.

[0008] Additional features and advantages of the present invention will become apparent to those skilled in the art upon consideration of the following detailed description of the illustrative embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The detailed description of the drawings particularly refers to the accompanying figures in which:

[0010] FIG. 1 is a perspective view of an embodiment of a water sensor;

[0011] FIGS. 2 to 5 are top elevation, bottom perspective, bottom elevation, and plan views of the water sensor of FIG. 1;

[0012] FIGS. 6 and 7 are top and bottom exploded perspective views of the water sensor of FIG. 1;

[0013] FIG. 8 is a first cross-sectional plan view of the water sensor of FIG. 1;

[0014] FIG. 9 is a second cross-sectional plan view of the water sensor of FIG. 1, rotated 90 degrees from the view of FIG. 8;

[0015] FIG. 10 is schematic diagram of an embodiment of a water sensor;

[0016] FIG. 11 is schematic diagram of an embodiment of a water sensing system including the water sensor of FIG. 10;

[0017] FIGS. 12 to 19 are schematic diagrams of an embodiment of a graphical user interface communicatively coupled with the water sensor of FIG. 10;

[0018] FIGS. 20 and 21 are bottom elevation and plan views of another embodiment of a water sensor;

[0019] FIGS. 22 to 24 are top and bottom perspective, and bottom elevation views of a further embodiment of a water sensor;

[0020] FIGS. 25 and 26 are top and bottom exploded perspective views of the water sensor of FIGS. 22 to 24;

[0021] FIG. 27 is a plan view of the water sensor of FIGS. 22 to 26;

[0022] FIG. 28 is a first cross-sectional plan view of the water sensor of FIGS. 22 to 27;

[0023] FIG. 29 is a second cross-sectional plan view of the water sensor of FIGS. 22 to 27, rotated 90 degrees from the view of FIG. 28;

[0024] FIGS. 30 and 31 are perspective views of yet another embodiment of a water sensor; and

[0025] FIGS. 32 to 47 are screenshots of another embodiment of a graphical user interface operable with a water sensor.

[0026] Corresponding reference characters indicate corresponding parts throughout the several views. Although the drawings represent embodiments of various features and components according to the present invention, the drawings are not necessarily to scale and certain features may be exaggerated in order to better illustrate and explain the present invention.

DETAILED DESCRIPTION OF DISCLOSED EMBODIMENTS

[0027] The embodiments of the invention described herein are not intended to be exhaustive or to limit the invention to precise forms disclosed. Rather, the embodiments elected for description have been chosen to enable one skilled in the art to practice the invention. It will be understood that no limitation of the scope of the invention is thereby intended. The invention includes any alterations and further modifications in the illustrated devices and described methods and further applications of the principles of the invention which would normally occur to one skilled in the art to which the invention relates.

[0028] Except where a contrary intent is expressly stated, terms are used in their singular form for clarity and are intended to include their plural form.

[0029] As used herein, the terms "comprises," "comprising," "containing," and "having" and the like denote an open transition meaning that the claim in which the open transition is used is not limited to the elements following the transitional term. The terms "consisting of" or "consists of" denote closed transitions.

[0030] The terms "first," "second," "third," "fourth," and the like in the description and in the claims, if any, are used for distinguishing between similar elements and not necessarily for describing a particular sequential or chronological order. It is to be understood that any terms so used are interchangeable under appropriate circumstances such that the embodiments described herein are, for example, capable of operation in sequences other than those illustrated or otherwise described herein. Similarly, if a method is described herein as comprising a series of steps, the order of such steps as presented herein is not necessarily the only order in which such steps may be performed, and certain of the stated steps may possibly be omitted and/or certain other steps not described herein may possibly be added to the method.

[0031] Occurrences of the phrase "in one embodiment," or "in one aspect," herein do not necessarily all refer to the same embodiment or aspect.

[0032] As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and

unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

[0033] Referring to FIGS. 1 to 9, an embodiment of a water sensor 10 includes a housing 12 having a top portion 14 and a bottom portion 16, an actuating mechanism 18, and a visual indicator 30 surrounding actuating mechanism 18. To facilitate communications and perform the functions described below, water sensor 10 includes a controller 20, a power source 22, and conductive elements to, described below with reference to FIGS. 6, 7, and 10. Water sensor 10 is structured to form a wireless connection 25 with an electronic device 23. Communications between water sensor 10 and various electronic devices are described below with reference to FIGS. 10 and 11.

[0034] FIG. 3 is a bottom perspective view of water sensor 10 illustrating a plurality of supports 32, and an access cover 34 disposed about the bottom surface of bottom portion 16. Water sensor 10 generally includes a continuity sensor 24 comprising at least two electrically conductive elements disposed with an elongate gap therebetween. When water bridges the elongate gap between the two electrically conductive elements, an electrical circuit of continuity sensor 24 transitions from a first to a second logical state and controller 20 detects the transition. The electrically conductive elements may comprise a pair of elongate elements arranged with an elongate gap therebetween, wherein the elongate gap may be about or less than 3.0 millimeters and may extend substantially along the entire length of the elongate elements. The elongate gap may be constant along the length of the elongate elements. In some embodiments, the first elongate member and the second elongate member extend along one or more surfaces of the housing. The first and second elongate members may extend minimally from the surfaces or may be flush with or embedded in the surfaces. As shown in FIG. 8, one elongate member extends about the bottom surface of the housing and is substantially flush therewith, while the other is embedded in a radiused corner between the bottom and lateral surfaces of the housing. As used herein, elongate refers to an element having substantially longer length than width. In one example, at least one of the elongate elements is on a common plane with a bottom surface of housing 12 of water sensor 10. In another example, both elongate elements are disposed on a

lateral wall of housing 12. If housing 12 comprises a circular bottom surface, the elongate elements may span at least 300 degrees about a center of the bottom surface. If housing 12 comprises an oval bottom surface, the elongate elements may span at least 70% of the length of the major axis of the oval. More generally, the length of the elongate elements is greater than 50% of a bottom surface length to increase the likelihood of detection of water falling on housing 12. In some examples, the elongate elements are segmented, in which case the length of the elongate elements shall be construed as the sum of the lengths of the segments. The segments may be electrically coupled or isolated from each other.

[0035] In some embodiments, the two electrically conductive elements extend substantially circumferentially (i.e., generally in a circumference or spanning 360 degrees) about the bottom surface of bottom portion 16 of housing 12. In the present embodiment, the at least two conductive elements include an electrically conductive inner loop 26 and an electrically conductive outer loop 28, wherein outer loop 28 is separated by an elongate gap from inner loop 26. In various illustrative embodiments, inner loop 26 and outer loop 28 may be molded into the bottom surface or lateral surface of bottom portion 16. When water bridges the elongate gap, continuity sensor 24 transitions logical states and the transition is detected by controller 20.

[0036] Supports 32 are generally spaced about a bottom surface of bottom portion 16, and hold the bottom surface of water sensor 10 above a support surface. In one example, supports 32 hold water sensor 10 a distance "d" above a support surface level denoted as "H0" as described more fully with reference to FIG. 21. In one example "d" is about 2.5 millimeters, or 0.100 inches. Advantageously, water is detected before a flood sufficient to cause the water level to rise by "d" over the entire support surface (e.g. a basement floor). In variations of the present embodiment, at least one of inner loop 26 and outer loop 28 may include an upper portion and a lower portion, wherein the lower portion extends below the bottom surface of bottom portion 16. In one embodiment, the lower portion defines supports 32 and holds water sensor 10 on the support surface. In another variation of the present embodiment, both loops 26 and 28 are shaped as waveforms including lower and upper portions such that the lower portions support water sensor 10 above the support surface, wherein the lower portions of loops 26, 28 include approximately 3 or 4 protrusions that form supports 32. Access cover 34 is positioned flush with the bottom surface of bottom portion 16. Access cover 34 provides access to a power

source 22 (shown in FIG. 9) comprising a power source, to enable replacement of the power source. Access cover 34 may be coupled to bottom portion 16 via a conventional fastener, such as a clip.

[0037] As best seen in FIG. 5, top portion 14 is curved to direct water from the top surface of top portion 14, along the side walls of bottom portion 16, to loops 26, 28 to trigger detection of the presence of water. In various illustrative embodiments, the top surface of top portion 14 may be convex (i.e., curved in multiple planes), while the bottom portion includes inwardly angled or tapered side walls configured to cause water droplets to follow the contour of water sensor 10, as described in detail with reference to FIG. 27.

[0038] FIGS. 6 and 7 are exploded views of water sensor 10. As seen therein, top portion 14 of housing 12 has an aperture through which actuating mechanism 18 protrudes. Intermediate actuating mechanism 18 and top portion 14 is a visual indicator 30, which is comprised of translucent material to permit a light source to emit a light therethrough. The light source may comprise one or more light emitting diodes (LEDs). The LEDs may emit light of various colors. In various illustrative embodiments, the LEDs emit a green color when water sensor 10 is in operating condition and blink and/or emit a different color when water sensor 10 is not in operating condition. Furthermore, during the pairing/coupling process between water sensor 10 and electrical device 23 (described with reference to FIGS. 10 and 11), visual indicator 30 may visually alert the user when the pairing/coupling has been successfully completed by changing colors and/or blinking or if an error has occurred in the pairing/coupling process by changing colors and/or blinking. A spacer 36 is positioned between actuating mechanism 18 and controller 20 and supports a periphery of actuating mechanism 18. In various illustrative embodiments, actuating mechanism 18 may be a button centered about top portion 14. Furthermore, actuating mechanism 18 in an extended position may be flush with the top surface of top portion 14. Spacer 36 is supported by controller 20 by resilient means which elevate spacer 36 and actuating mechanism 18 but also permit retraction thereof upon actuation by a user. Upon said retraction actuating mechanism 18 actuates a switch 40 (described with reference to FIG. 8) coupled to controller 20 which controller 20 senses to detect actuation of actuating mechanism 18.

[0039] Actuating mechanism 18 may be engaged or depressed to cause several different events to occur. First, if water sensor 10 is not yet wirelessly coupled to electronic device 23, the engagement of actuating mechanism 18 may cause water sensor 10 to pair or connect with electronic device 23 via wireless connection 25. If the connection between electronic device 23 and water sensor 10 has been interrupted or is in error, the engagement of actuating mechanism 18 may cause the connection between water sensor 10 and electronic device 23 to be reset or repaired. Furthermore, the engagement of actuating mechanism 18 may be used to cause water sensor 10 to wake-up and/or check-in with electronic device 23 via wireless connection 25. When water sensor 10 is checking-in with electronic device 23, it may transmit a signal strength representative of a wireless local area network (WLAN) signal received from a WLAN access point, a detection signal or a status signal, among others. The signal strength may be designated in bars, as a percentage, as strong/weak, or any other designation indicative of signal strength. Also, actuation of actuating mechanism 18 may silence an audible alarm generated by water sensor 10. A signal strength of 80% is illustrated in FIG. 41. An example WLAN technology utilizes IEEE 802.11 standards and is marketed under the Wi-Fi brand name.

[0040] Controller 20 may generally be mounted on a circuit board positioned within housing 12. In various embodiments, controller 20 may be positioned above power source housing 38. In one embodiment, controller 20 is positioned intermediate actuating mechanism 18 and power source 22. Example power sources comprise one or more batteries, including rechargeable batteries. Controller 20 may be communicatively coupled to audible indicator 80 (shown in FIG. 10) to command audible indicator 80 to emit a sound when water has been detected or an error has occurred. Example audible indicators include a speaker and a buzzer. The sound may be caused by vibration of the audible indicator. The audible indicator may be reset or turned off by pushing actuating mechanism 18. A schematic diagram of an embodiment of controller 20 is described with reference to FIG. 10.

[0041] Referring to FIG. 10, in some embodiments controller 20 comprises a wireless personal area network (WPAN) processor 50 commutatively coupled to a WLAN processor 56. Example WPAN technologies include Bluetooth, ZigBee, Z-Wave, and IrDA technologies. Generally, WPAN technologies have a range of a few (<5) meters while WLAN technologies

have much longer range. WPAN processor 50 is coupled to an antenna 52 configured to transmit wireless signal 25. Electrically coupled to WPAN processor 50 are a programmable memory 60, illustratively an electrically erasable programmable memory (EEPROM), a battery voltage level sensor 62 to sense a voltage level of power source 22, a temperature sensor 68, and a continuity sensor 24 comprising the previously described two or more electrical conductive elements. Power source 22 is electrically coupled to power WPAN processor 50 and WLAN processor 56. Continuity sensor 24, actuating mechanism 18, and visual indicator 30 are connected to WPAN processor 50 via general purpose input/output (GPIO) contacts and are programmed to interrupt a running program responsive to activation of actuating mechanism 18 or transition of a logical state of a detection circuit of a continuity sensor as described above. Temperature sensor 68 and battery voltage level sensor 62 are connected to contacts in WPAN processor 50 connected to analog to digital converters (ADC) comprised in WPAN processor 50. The ADCs convert voltages corresponding to the temperature and battery voltages and convert the voltages to digital signals read by programs processed by WPAN processor 50 at periodic intervals. Also, WPAN processor 50 comprises control logic structured to interrupt a running program if the GPIO input coupled to continuity sensor 24 indicates the presence of water. Universal asynchronous receiver/transmitters (UARTs) communicatively couple WPAN processor 50 to WLAN processor 56 over a communication line 90. WPAN processor 50 communicates a WLAN enable command over a WLAN enable line 92.

[0042] As used herein the term "control logic" includes software and/or firmware executing on one or more programmable processors, application-specific integrated circuits, field-programmable gate arrays, digital signal processors, hardwired circuits, or combinations thereof. For example, in various embodiments controller 20 may comprise or have access to the control logic. Therefore, in accordance with the embodiments, various logic may be implemented in any appropriate fashion and would remain in accordance with the embodiments herein disclosed. A non-transitory machine-readable medium comprising control logic can additionally be considered to be embodied within any tangible form of a computer-readable carrier, such as solid-state memory, magnetic disk, and optical disk containing an appropriate set of computer instructions and data structures that would cause a processor to carry out the techniques described herein. A non-transitory machine-readable medium, or memory, may

include random access memory (RAM), read-only memory (ROM), erasable programmable read-only memory (e.g., EPROM, EEPROM, or Flash memory), electronically programmable ROM (EPROM), magnetic disk storage, and any other medium which can be used to carry or store processing instructions and data structures and which can be accessed by a general purpose or special purpose computer or other processing device.

[0043] Continuity sensor 24 may comprise a first detection circuit comprising an output contact coupled to the GPIO input of WPAN processor 50 and an input contact coupled to one of the conductive elements. The other of the conductive elements is connected to a voltage supply. When water bridges the elongate gap between the conductive elements, electrons flow from the voltage supply to the first conductive element, and through the water to the second conductive element. The elongate gap between the conductive elements and the impurity of the water determines the amount of current that flows through the gap. The first conductive element may be connected between a Zener diode and the voltage supply, with the Zener diode coupled to ground. The second conductive element may be connected between a Zener diode (grounded) and a resistor (R1) that is connected to the base of a first transistor. The collector of the first transistor is connected to a second resistor (R2) that is connected to the base of a second transistor. The second transistor's collector is connected to the voltage supply and its emitter is connected to the output contact and through a third resistor (R3) to ground. Thus, water bridging the gap turns on the first transistor, which turns on the second transistor. The current drawn by the GPIO input is drawn through the second transistor only and can be controlled by the third resistor. Generally, any circuit component (e.g. transistor, opto-coupler, inductor) may be coupled to the output contact and the conductive members in any known manner that will produce two different voltage levels responsive to the presence or absence of water between them, which levels are sufficiently high or low to be recognized as logical high or low signals (e.g. ON or OFF) by WPAN processor 50.

[0044] WLAN processor 56 is coupled with an antenna 58 configured to transmit a wireless signal 54 to a web service 112 via an access point 104 (both shown in FIG. 11) and Internet 110. WLAN processor 56 is communicatively coupled to audible indicator 80, to a number of light emitting diodes (LEDs) 82 provided to facilitate debugging of water sensor 10,

and to an external flash memory 84 which comprises programs processed by WLAN processor 56 as described herein. WPAN processor 50 may cause WLAN processor 56 to emit an alarm via a command transmitted over a GPIO line 94 or via communication line 90.

[0045] WPAN processor 50 is programmed to cause an alarm if water is detected, and to periodically communicate status information including temperature and voltage levels. Control logic is structured to compare the voltage of the battery level to a threshold indicative of a minimum charge and the signal from the temperature sensor to a threshold indicative of a high temperature. If the GPIO input coupled to continuity sensor 24 indicates the presence of water, WPAN processor 50 interrupts processing of the control logic and promptly commands WLAN processor 56 over line 92 to wake up, then commands WLAN processor 56 to communicate a water detection signal to web service 112 indicating a water alarm. Water sensor 10 may communicate the status information and also trigger an audible alarm via audible indicator 80. In a first example, the actual values of temperature and voltage are transmitted periodically by the control logic, and web service 112 determines whether to issue an alarm corresponding to the battery or temperature values. In a second example, the comparison to the thresholds is performed by WPAN processor 50 and values indicative of a temperature above the high temperature threshold or battery voltage below a low battery voltage are transmitted periodically to the web service. In the second example, WPAN processor 50 may generate the low voltage or high temperature alarm even when disconnected from the WLAN connection. In addition to detecting and communicating the leak alarm, WPAN processor 50 may generate an audible alarm, even when disconnected from the WLAN connection.

[0046] In some embodiments, a user may program the low voltage and high temperature thresholds via electronic device 23 and wireless connection 25. Actuating mechanism 18 may be actuated to silence or acknowledge the alarm. In one example, a low temperature threshold may also be programmed.

[0047] In some embodiments, a user may program the low voltage and high temperature thresholds via web service 112. In one example, a low temperature threshold may also be programmed.

[0048] Advantageously, WPAN processor 50 and WLAN processor 56 are configured to minimize energy consumption. WPAN processor 50 may comprise a Bluetooth low energy (BLE) processor which comprises a sleep state and an active state. In the sleep state, the BLE processor merely monitors selected parameters, such as the water sensor GPIO input or an internal clock, and upon detecting a transition therein transitions from the sleep to the active mode. WLAN processor 56 also includes a sleep and an active mode, and consumes significantly more energy to transmit wireless WLAN signals than the BLE processor consumes to transmit WPAN signals. Upon transitioning to the active mode, the BLE processor issues a command to wake-up WLAN processor 56 and transmit the respective signals. WLAN processor 56 transmits the signals via WLAN antenna 58, performs various communications related functions, and then transitions back to the sleep state, to conserve energy. Therefore, WLAN processor 56 is only in the active state when communication of data to web service 112 is mandated by WPAN processor 50, and WPAN processor 50 is only active responsive to detection of water or expiration of various clock intervals. Accordingly, water sensor 10 can operate for long periods of time as energy consumption is substantially reduced in contrast with devices not configured as described herein.

[0049] Operation of water sensor 10 will now be described with reference to FIG. 11. In general, a method of using water sensor 10 includes positioning water sensor 10 in a desired location, pairing water sensor 10 with electronic device 23, using electronic device 23 to configure water sensor 10 to communicate with web service 112, activating water sensor 10 to detect leaks, and receiving an alert responsive to detection of water by water sensor 10. Positioning water sensor 10 in a desired location may comprise positioning multiple water sensors 10 in multiple locations, and configuring water sensor 10 may comprise identifying the desired location of each of the multiple water sensors 10. A system 100 comprises a water sensor 10a and a water sensor 10b. Water sensors 10a, 10b may comprise any embodiment of a water sensor described herein. The nomenclature "a" and "b" merely denotes the presence of two water sensors, although additional water sensors may be included. Water sensors 10a, 10b may be, at different times or concurrently, be wirelessly commutatively coupled to electronic device 23 by wireless signal 25 and/or to web service 112 via wireless signal 54 through access point 104 and the Internet 110. Web service 112 may be commutatively coupled via Internet 110

to an electronic device 120 having a graphical user interface (GUI) 122. Electronic device 23 comprises a GUI 106 and may be commutatively coupled to web service 112 via a wireless signal 108 or a telecommunications cellular signal (not shown). In one example, electronic device 23 is wirelessly commutatively coupled to water sensors 10a, 10b via a Bluetooth protocol and to web service 112 via a Wi-Fi protocol. Similarly, water sensors 10a, 10b are wirelessly commutatively coupled via the Bluetooth protocol to electronic device 23 and to web service 112 via a Wi-Fi protocol. Access point 104 may be comprised by an internet switch or router. A local environment 102 is denoted, including water sensors 10a, 10b and access point 104. Local environment 102 may comprise a building including a house, factory, business office, or any other building comprising water systems. Web service 112 is located remotely from local environment 102 and is outside the reach of wireless connection 25.

[0050] Water sensors 10, 10a, 10b, and any other water sensor in accordance with the present disclosure, are configured via electronic device 23 to communicate with web service 112. Configuration comprises pairing of electronic device 23 with a water sensor using GUI 106. An example pairing process will now be described with reference to FIGS. 12 to 15, in which a screen 130 of electronic device 23 displays pages of GUI 106. FIG. 12 illustrates a page ("Add Product") in which electronic device 23 presents an image 132 to communicate detection of a water sensor. The water sensor emitted a "ping" signal to enable devices within range of wireless signal 25 emitted by the water sensor to detect the ping, as is well known in the art of personal area networks, including Bluetooth networks. The ping signal may have been emitted responsive to actuation by a user of actuating mechanism 18. The user may then recognize the detected water detection by touching screen 106 over image 132. Responsive to such recognition, a data entry field 134 is presented by GUI 106 (shown in FIG. 14) with which the user can enter a serial number of the water sensor. Upon entry of a serial number in the correct format, GUI 106 then displays a screen including an image 138 (shown in FIG. 14) to show that the water detector was paired. Image 138 shows the default name of the paired water sensor. GUI 106 may present a page including images 146 and 148 to enable the user to select a paired water sensor (e.g. by touching screen 130 over image 148 to select the corresponding sensor) and may then present a data entry field (not shown) with which the user can rename the paired water sensor. Multiple images 148 may be presented corresponding to multiple paired water sensors

(e.g. 10a and 10b). The user may rename the water sensors with reference to their location. When web service 112 transmits alarms, it will do so utilizing the names of the water sensors. Thus the user may select names that enable the user to recognize the water sensor and determine how to respond to the alarm based on the location of the water sensor.

[0051] Examples of electronic device 23 include cellular phones, tablets, and personal computers, each including at least a WPAN transceiver. Electronic device 23 is communicatively coupled to web service 112 either via access point 104 or directly via cellular communications. After pairing, electronic device 23 transmits the serial number or other unique identification information of water sensor 10 to web service 112 and web service 112 provides to electronic device 23 web service access information which electronic device 23 communicates to the water sensor. The web service access information may comprise, for example, a universal resource locator (URL) and access codes with which the water sensor may transmit and receive information through access point 104. Thereafter, the water sensor can communicate with web service 112 through access point 104 independently of electronic device 23. In some embodiments, GUI 106 presents an image 136 to show the name of the network connection point to which the water sensor has been coupled. It should be understood that in a local environment there may be multiple access points and also multiple range extenders to which the water sensor may electronically couple, thus presentation of the network connection point may be helpful, for example to troubleshoot the connection if the wireless connection is unreliable or difficult to establish.

[0052] Advantageously, the user may place a water sensor in a location where WLAN reception is strong. The WLAN processor of the water detector can detect a WLAN signal from access point 104. Upon or during pairing, the water sensor communicates a WLAN signal strength to electronic device 23. If desired, the user can then move the water sensor to a location with improved signal strength so that the water sensor can more reliably communicate with access point 104. Once water sensors 10a and 10b receive the web service access information and establish communication with access point 104, they are able to communicate status updates at regular intervals or alarm signals as needed. In turn, web service 112 receives the status and alarm signals and determines whether a message is to be transmitted to selected users based on a

database configured in cooperation with the administrator of environment 102. For example, the database may indicate that certain family members receive certain messages but not others, or whether a message is to be sent. Electronic device 23 may be the same or different than electronic device 120.

[0053] FIG. 16 illustrates a page presented by GUI 122 on a screen 150 of electronic device 120. Page 150 presents images 152, 154, showing the names of two water sensors named "On the Desk" and "By file Cabinet". The images include icons to indicate that no leaks have been detected. The user may touch over one of images 152, 154 to view a status thereof, as shown on FIG. 17, where an image 153 identifies the selected water sensor, an image 162 shows that a leak has not been detected (e.g. a drop with a line through it), and a text box 163 may present additional information, for example the time and date of the last status transmission of the water sensor. Text box 163 may also indicate the temperature and battery voltage of the water sensor.

[0054] If a water sensor detects a leak, it communicates the water detection signal to web service 112, and web service 112 transmits an alert to electronic device 120. FIG. 18 shows an alert window 164 presented by GUI 122 responsive to a water detection signal and alarm. The user can acknowledge receipt of the alarm by touching screen 150 over an image 165. Thereafter GUI 122 presents, as shown on FIG. 19, an image 166 to show that water has been detected (e.g. a drop without a line through it). Image 166 may be color-coded to indicate whether the user has or has not acknowledged the alarm. Web service 112 may periodically transmit the alarm signal until it is acknowledged. The alarm signal may be transmitted to any number of electronic devices registered in a database of web service 112, and may be color-coded as acknowledged upon receipt of the first acknowledgment on any one of said electronic devices.

[0055] FIGS. 20 and 21 are elevation and plan views, respectively, of another embodiment of a water sensor, denoted by numeral 200. Water sensor 200 is identical in most respects to water sensor 10 and, additionally, includes electrically conductive elements 202 and 204 extending perpendicularly from the bottom surface of housing 12 below a plane H2 defined

by the bottom surface of water sensor 200. A plane H0 represents the support surface upon which water sensor 200 rests. The distance "d" between planes H0, H2 is indicative of the amount of water that would have to fill the space below water sensor 200 to cause water sensor 200 to detect a flood or leak with continuity sensor 24. Instead, water sensor 200 may detect a flood or leak sooner with conductive elements 202 and 204. Conductive elements 202 and 204 are electrically coupled to a second detection circuit analogous to the first detection circuit described with reference to continuity sensor 24. Controller 20 comprises control logic structured to detect water at a first stage, responsive to a state transition of the first detection circuit, and at a second stage, responsive to a state transition of the second detection circuit.

[0056] In some embodiments, conductive elements 26, 28 are substituted by conductive elements 26', 28'. FIGS. 22 to 29 illustrate another embodiment of a water sensor, denoted by numeral 220. Water sensor 220 is identical in most respects to water sensor 200, except that conductive elements 202 and 204 have been removed. Conductive elements 26', 28' are shown, each comprising four arcuate segments, with two leg portions extending from each arcuate segment. Conductive element 26' comprises segments 232, 234, 236, and 238 (best shown in FIG. 25), and conductive element 28' comprises segments 222, 224, 226, and 228. The leg portions extend from the arcuate segments into water sensor 220 to couple with continuity sensor 24. Assembly of conductive element loops from arcuate segments may facilitate assembly of water sensor 220.

[0057] In a variation of the present embodiment, the arcuate segments do not contact each other, thus presenting small gaps between the arcuate segments, which enable the control logic in controller 20 to detect connections between any one of the eight arcuate segments and thereby determine an orientation of the water connection relative to the center of the water sensor. More or less arcuate segments may be provided to form each of the conductive element loops. The spacing between the conductive element loops may also be adjusted to define a detection sensitivity of the continuity sensor.

[0058] Referring to FIGS. 25 and 26, water sensor 220 comprises an actuation mechanism comprising components 250, 252, and 254, which are assemble with screws 256 to secure component 254 to top portion 14 with components 250, and 252 therebetween.

Component 252 comprises an elastic membrane and is configured to activate switch 40 when component 250 is depressed by the user. A seal 258 is disposed between top portion 14 and bottom portion 16 to form a water tight seal therebetween. A plurality of spacers 262, 264, and 266 support controller 20. A power supply housing 268 is formed on bottom portion 16. Supports 32 extend from the bottom surface of bottom portion 16. A gasket 270 is interposed between bottom portion 16 and a power supply cover 240.

[0059] The water sensors described herein, including water sensors 10, 200, 220, and variations thereof, may be sized and configured to enable water droplets to follow the contour of the water sensor housing and reach the conductive elements. Referring to FIG. 27, top portion 14 comprises an upper portion 272 having a periphery 276 and a frustoconical surface 278 extending from periphery 276. Top portion 14 also comprises a lower portion 274 connected to periphery 276. Frustoconical surface 278 is defined by two parallel planes cutting through an imaginary cone comprised by an infinite number of lines extending from the first plane through the second plane to an apex. The segments of the lines connecting the first and second planes define frustoconical surface 278. The lines may be straight. In the present embodiment the lines are arcuate. A line tangential to frustoconical surface 278 and extending between its peripheral edges, and comprised by a plane cutting through frustoconical surface 278 orthogonally to periphery 276, is denoted by T1. Periphery 276 is on a plane H1 parallel to planes H0 and H2. An angle A1 formed by T1 and H1 represents the curvature of frustoconical surface 278.

[0060] Lower portion 274 is radiused with a radius A3. Bottom portion 16 comprises an upper portion 282 having a periphery 286 and a lower portion 284. A sealed edge 280 is formed by top portion 14 and bottom portion 16 of housing 12. Bottom portion 16 has a frustoconical surface extending from sealed edge 280 to outer conductive element 26, 26' (best shown on FIG. 28), which is elevated relative to conductive element 28, 28' by a distance D3 (from plane H2 to a plane H3 parallel to H2 and comprising conductive element 26, 26'), to enable a droplet of water to follow the frustoconical surface at a velocity sufficiently slow to prevent separation from housing 12. The droplet of water then extends over conductive element 26, 26' to reach conductive element 28, 28' and close the water sensing circuit. In the present embodiment, the frustoconical surface of lower portion 284 has a straight profile that forms an angle A2 to the horizontal plane H2. Angle A2 may comprise angles in a range of about 55-80 degrees, more

preferably in a range of about 60-75 degrees, and even more preferably in a range of about 65-70 degrees.

[0061] In some embodiments, radius A3 is between about 5 and 15 millimeters, is more preferably in a range of about 6-10 millimeters, and is even more preferably in a range of about 7-9 millimeters.

[0062] In some embodiments, angle A1 comprises angles in a range of about 2-15 degrees, more preferably in a range of about 3-10 degrees, and even more preferably in a range of about 5-8 degrees.

[0063] In one embodiment, angle A1 is between about 5-8 degrees, and angle A2 is between about 65-70 degrees. In one variation thereof, radius A3 is between about 6-10 millimeters.

[0064] While water sensors 10, 200, and 220, and variations thereof have been described with reference to a support surface, water sensors comprising controller 20 and conductive elements may also be supported by other structures, including a water pipe. Referring to FIGS. 30 and 31, shown therein is a water sensor 300, comprising a latch 302, a hinge 304 opposite latch 302, an cover 306 and a base 308 attached to cover 306 by hinge 304 and latch 302. A notch 320 extends from a periphery of water sensor 300 to its center, the width of notch 320 configured to match a pipe diameter. A plug 324 is also shown including slots 326, 328 configured to receive opposing walls of water sensor 300 defined by notch 320. After water sensor 300 is positioned around a pipe 330, plug 324 is inserted into notch 320 to retain water sensor 300 in place. Between cover 306 and base 308 is positioned a water absorbent material. Cover 306 comprises apertures on its surface that permit water to pass therethrough to be absorbed by the absorbent material. A pair of conductive elements contact the absorbent material. When a sufficient amount of water is absorbed, the absorbent material wicks the water to an area adjacent the conductive elements, at which time the water sensing circuit is closed through the absorbent material. The sensitivity of the water sensor can be defined by the distances between the conductive elements, the absorbency of the absorbent material, and the proximity of the conductive elements to the closest aperture. In one example, controller 20 is positioned between cover 306 and base 308. In another example, a pair of connectors 310, 312

are provided to connect water sensor 300 to a controller 20 that is not positioned between cover 306 and base 308.

[0065] FIG. 31 shows a variation of the embodiment of water sensor 300 in which an elongate semi-circular element 360 extends from base 308 and is sized and configured to match the diameter of pipe 330 to provide additional support.

[0066] FIGS. 32 to 47 are screenshots of another embodiment of a graphical user interface operable with a water sensor. The screenshot shown in FIG. 32 illustrates an image presented by the GUI with text indicating that the electronic device is searching for devices. The screenshot shown in FIG. 33 illustrates that two water sensors were found, respectively named “Delta Leak 39487” and “Delta Leak 12984”. A user may touch the screen of the electronic device above either name to pair the respective water sensor with the electronic device. The screenshot shown in FIG. 34 presents a confirmation window with which the user can confirm said pairing and FIG. 35 presents a user the opportunity to choose a Wi-Fi network for the water sensor.

[0067] The screenshot shown in FIG. 36 provides a data field with which the user can rename a water sensor and FIG. 37 illustrates a plurality of icons corresponding to the location/use case in which the water sensor will be used. The user can select an icon to associate it with the water sensor. A laundry washer icon has been selected. The screenshot shown in FIG. 38 provides a data field with which the user can name a local environment. Example local environments include a home and a beach house. The user can define multiple local environments and place multiple water sensors in each defined local environment. The user can also associate a picture of a local environment with its name, as shown in FIG. 39.

[0068] The user can also associate a use case icon with a defined local environment, as shown in FIG. 40. The user may then associate a water sensor with a selected use icon of the defined local environment. In one example, the user can check the Wi-Fi signal strength of a water sensor, as shown in FIG. 41 (80%) to assist in placement of the water sensor to achieve the a strong WLAN connection. As shown in FIG. 42, the user may also program the low and high temperature thresholds of water sensors, thus use the water sensors to detect when the heating/ventilation and air conditioning system has failed, for example. FIG. 43 illustrates a

plurality of images with which the user can select a local environment and then visualize the status of the water sensors therein, as shown in FIGS. 44 and 45. FIG. 44 illustrates that a leak has been detected by the water sensor proximal to the washing machine (a warning sign is shown over the image of the main home and also over the image of the water machine, denoting a leak), and FIG. 45 illustrates that no leaks were detected in the beach house (a checkmark is shown over the image of the beach house denoting no leaks).

[0069] The user can navigate to a screen associated with a use case icon to view status information including battery level, signal strength, and the dates of the preceding status updates. Said screen is illustrated in FIG. 46 with reference to a washing machine. Alternatively, if a leak is detected, an image of the icon with a warning sign is shown, and also shown is an object labelled “dismiss” with the user can activate to acknowledge the leak and the respective alarm.

[0070] The foregoing screenshots exemplify a method of associating water sensors with local environments, programming of the water sensors, and water detection alarms. The screenshots are generated with electronic device applications in ways that are well known in the art. Example electronic devices may comprise operating systems such as the Apple iOS operating system and Google’s Android operating system.

[0071] Some examples of embodiments described above and variations thereof are summarized below:

[0072] Example 1 - A water sensor comprising: a housing including a top portion and a bottom portion; a controller positioned within the housing; a power source positioned within the housing and in electrical communication with the controller; and a continuity sensor coupled to the bottom portion of the housing and in electrical communication with the controller, the continuity sensor including an electrically conductive inner loop and an electrically conductive outer loop surrounding the inner loop, wherein water between the inner loop and the outer loop electrically couples the inner loop and the outer loop to provide an electrical circuit which is detected by the controller.

[0073] The water sensory device of example 1, further comprising an actuating mechanism supported by the top portion of the housing and in electrical communication with the controller.

[0074] The water sensor of example 1, wherein the actuating mechanism is a button.

[0075] The water sensor of example 1, further comprising a plurality of supports spaced about the bottom surface of the bottom cover and supporting the sensor above a supporting ground surface.

[0076] The water sensor of example 1, wherein the top portion of the housing is convex to direct water from the top portion to the bottom portion.

[0077] The water sensor of example 1, wherein a bottom surface of the bottom cover is approximately 2.5 millimeters from a lateral surface.

[0078] The water sensor of example 1 further comprising a visual indicator surrounding the actuating mechanism. A variation of the present example, wherein the visual indicator is an LED light.

[0079] The water sensor of example 1, wherein the power source comprises a battery.

[0080] The water sensor of example 1, further comprising an audible indicator within the housing.

[0081] The water sensor of example 1, further comprising a wireless transmitter in electrical communication with the controller and configured to communicate an alert signal to a wireless network when water is detected between the inner loop and the outer loop. A variation of the present example, further comprising a remote electronic device in communication with the wireless network.

[0082] The water sensor of example 1, further comprising first and second downwardly extending electrically conductive protrusions.

[0083] Example 2 - A water sensor comprising: a housing including a top surface and a bottom surface; a controller positioned within the housing; a power source positioned within the housing and in electrical communication with the controller; an actuating mechanism supported by the top surface of the housing and configured to be in communication with the controller; a sensor coupled to the bottom surface of the housing configured to measure an electrical property between at least two conductive elements and to determine a presence of water from the measured electrical property; and a low-power wireless connection configured to communicate information from the water sensor to an electronic device.

[0084] The water sensor of example 2, wherein the top surface is convex to allow water to be directed from the top surface to the bottom surface.

[0085] The water sensor of example 2, wherein the at least two conductive elements extend substantially circumferentially about the bottom surface of the housing.

[0086] The water sensor of example 2, wherein the bottom surface of the housing is approximately 2.5 millimeters from a surface.

[0087] The water sensor of example 2, wherein at least one of the at least two conductive elements includes at least one upper portion and at least one lower portion, wherein the lower portion supports the water sensor above a surface.

[0088] The water sensor of example 2, wherein the electronic device is a mobile device.

[0089] The water sensor of example 2, wherein the at least two conductive elements are configured to distinguish between different quantities of water.

[0090] Example 3 - A method for sensing a presence of water comprising the steps of: providing at least one water sensor including a housing with a top surface and a bottom surface, a controller positioned within the housing, a power source positioned within the housing and in communication with the controller, and a sensor coupled to the bottom surface of the housing including at least two conductive elements configured to measure an electrical property between the conductive elements and to determine a presence of water from the measured electrical

property in a detection zone, wherein each of the conductive elements spacedly extends substantially circumferentially about the bottom surface of the housing; activating the water sensor; coupling the water sensor to an electronic device via a wireless connection; and transmitting information between the water sensor and the electronic device.

[0091] The method of example 3, further comprising a button disposed about the top surface of the housing and capable of communicating with the controller.

[0092] The method of example 3, wherein the step of coupling the water sensor to the electronic device includes the step of pushing the button of the water sensor.

[0093] The method of example 3, further comprising the step of pushing the button of the water sensor such that the water sensor transmits a signal strength reading to the electronic device.

[0094] The method of example 3, wherein the wireless connection is a low-power wireless connection.

[0095] The method of example 3, wherein the step of coupling the water sensor to the electronic device via a wireless connection includes the steps of: downloading an application to the electronic device; adding the water sensor to the application; and transmitting information between the water sensor and the electronic device.

[0096] The method of example 3, wherein the information transmitted between the water sensor and the electronic device includes at least one of a signal strength, a detection signal and a status signal.

[0097] Example 4 - A water sensor comprising: a housing including a top portion and a bottom portion; a controller positioned within the housing; a power source positioned within the housing and in electrical communication with the controller; a first continuity sensor coupled to the bottom portion of the housing and in electrical communication with the controller; and a second continuity sensor coupled to the bottom portion of the housing and in electrical communication with the controller.

[0098] The water sensor of example 4, wherein the first continuity sensor includes an electrically conductive inner loop and an electrically conductive outer loop, wherein water between the inner loop and the outer loop electronically couples the inner loop and the outer loop to provide an electrical circuit which is detected by the controller. A variation of the present example, wherein the second continuity sensor includes first and second downwardly extending electrically conductive protrusions, wherein water between the first protrusion and the second protrusion electrically couples the first protrusion and second protrusion to provide an electrical circuit which is detected by the controller.

[0099] The water sensor of example 4, further comprising an actuating mechanism supported by the top portion of the housing and in electrical communication with the controller.

[00100] The water sensor of example 4, further comprising a plurality of supports spaced about the bottom surface of the bottom cover and supporting the sensor above a supporting ground surface.

[00101] The water sensor of example 4, the top portion of the housing is convex to allow water to be directed from the top portion to the bottom portion.

[00102] The water sensor of example 4, further comprising an audible indicator within the housing.

[00103] The water sensor of example 4, further comprising a wireless transmitter in electrical communication with the controller and configured to communicate an alert signal to a wireless network when water is detected between the inner loop and the outer loop.

[00104] Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the spirit and scope of the invention as described and defined in the following claims.

CLAIMS:

1. A water sensor comprising:
 - a housing including a top portion and a bottom portion;
 - a controller positioned within the housing;
 - a power source positioned within the housing and electrically coupled to the controller to energize the controller;
 - a continuity sensor electrically coupled to the controller and including a first elongate member adjacent lengthwise to a second elongate member forming an elongate gap therebetween, the first elongate member and the second elongate member extending along one or more surfaces of the housing; and control logic structured to transition from a first logical state to a second logical state responsive to water bridging the elongate gap;
 - wherein the controller is structured to transmit a wireless water detection signal responsive to the continuity sensor transitioning to the second logical state; and
 - a first protrusion and a second protrusion, the first protrusion and the second protrusion extending from and perpendicular to a bottom surface of the housing and forming a second elongate gap therebetween, wherein the conductivity sensor is configured to detect a second water level with the second elongate gap different than a first water level detectable with the elongate gap between the first elongate member and the second elongate member.
2. The water sensor of claim 1, wherein the first elongate member comprises an inner arcuate portion and the second elongate member comprises an outer arcuate portion, wherein the housing comprises an oval or circular bottom surface, and wherein the inner arcuate portion extends along and adjacent a periphery of a bottom surface of the housing.
3. The water sensor of claim 1, wherein the first elongate member comprises an inner arcuate portion and the second elongate member comprises an outer arcuate portion, wherein the inner arcuate portion comprises an electrically conductive surface spanning at least 300 degrees about a center of the housing, and the outer arcuate portion comprises an electrically conductive surface spanning at least 300 degrees about the center of the housing and surrounding the inner arcuate portion.

4. The water sensor of claim 3, wherein the outer arcuate portion comprises an outer loop, the inner arcuate portion comprises an inner loop, and the elongate gap comprises a radial distance between the inner loop and the outer loop.
5. The water sensor of claim 4, wherein the radial distance is constant.
6. The water sensor of claim 4, wherein the radial distance is 3.0 millimeters or less.
7. The water sensor of claim 4, wherein at least one of the outer loop or the inner loop comprises a circular shape centered on the center of the housing.
8. The water sensor of claim 3, wherein the bottom portion of the housing comprises a lateral surface and a bottom surface, and the inner arcuate portion is positioned within an area defined by the bottom surface.
9. The water sensor of claim 8, wherein the electrically conductive surface of the outer arcuate portion lies on a first plane that is parallel and spaced apart from a second plane on which the electrically conductive surface of the inner arcuate portion lies.
10. The water sensor of claim 9, wherein the first plane intersects the lateral surface of the bottom portion.
11. The water sensor of claim 10, wherein the lateral surface of the bottom portion is frustoconical and comprises a large periphery and a small periphery, wherein the small periphery is adjacent the bottom surface, and wherein an angle of the lateral surface lying on a plane orthogonal to the first plane is in the range of 50-89 degrees to the first plane.
12. The water sensor of claim 9, wherein the lateral surface is angled at an angle in the range of 60-80 degrees to the first plane.

13. The water sensor of claim 3, wherein at least one of the outer arcuate portion or the inner arcuate portion comprises a plurality of arcuate segments.
14. The water sensor of claim 13, wherein the outer arcuate portion comprises the plurality of arcuate segments and the plurality of arcuate segments are electrically coupled to each other.
15. The water sensor of claim 14, wherein the inner arcuate portion comprises the plurality of arcuate segments and the plurality of arcuate segments are electrically coupled to each other.
16. The water sensor of claim 3, wherein the bottom portion of the housing comprises a lateral surface and a bottom surface, and wherein the electrically conductive surface of the inner arcuate portion spans 360 degrees about a center of the bottom surface
17. The water sensor of claim 3, further comprising a plurality of supports elevating the housing above a support structure, the second water level defined by distal ends of the first protrusion and the second protrusion and being intermediate the bottom surface and the support structure, wherein the first water level is intermediate the bottom surface and the second water level.

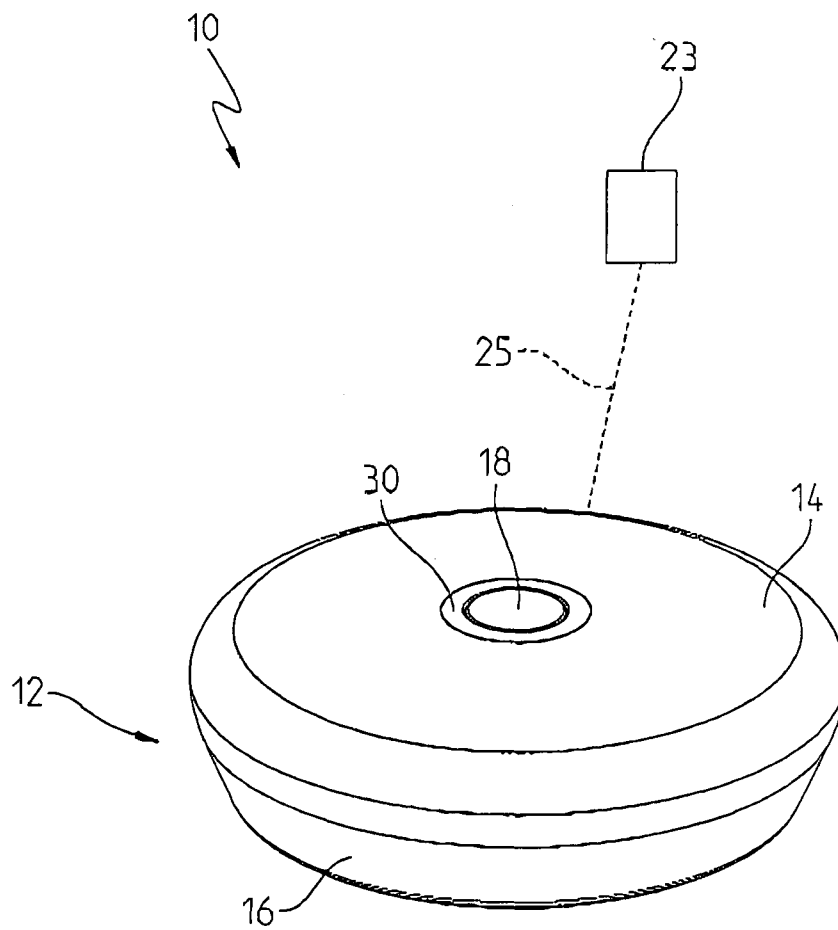


Fig. 1

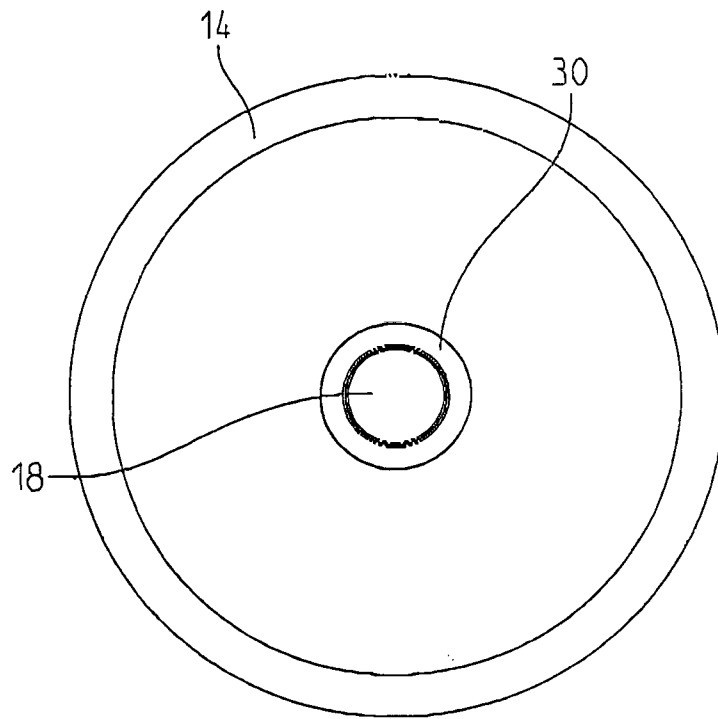


Fig. 2

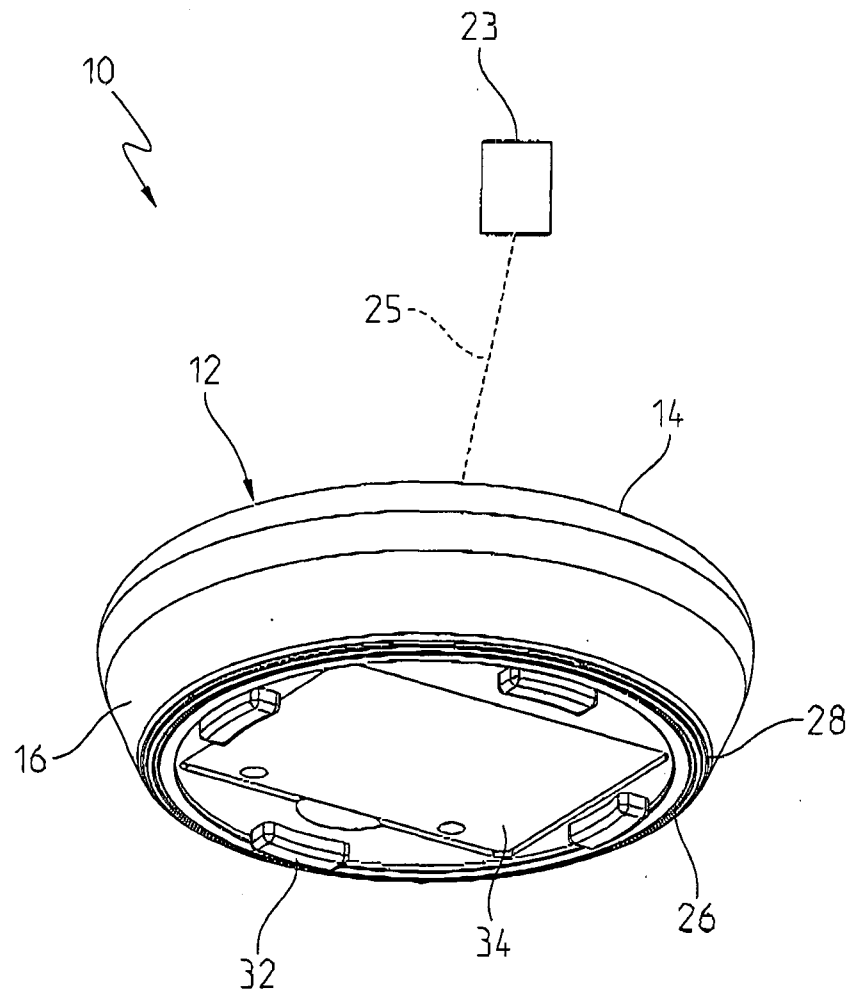


Fig. 3

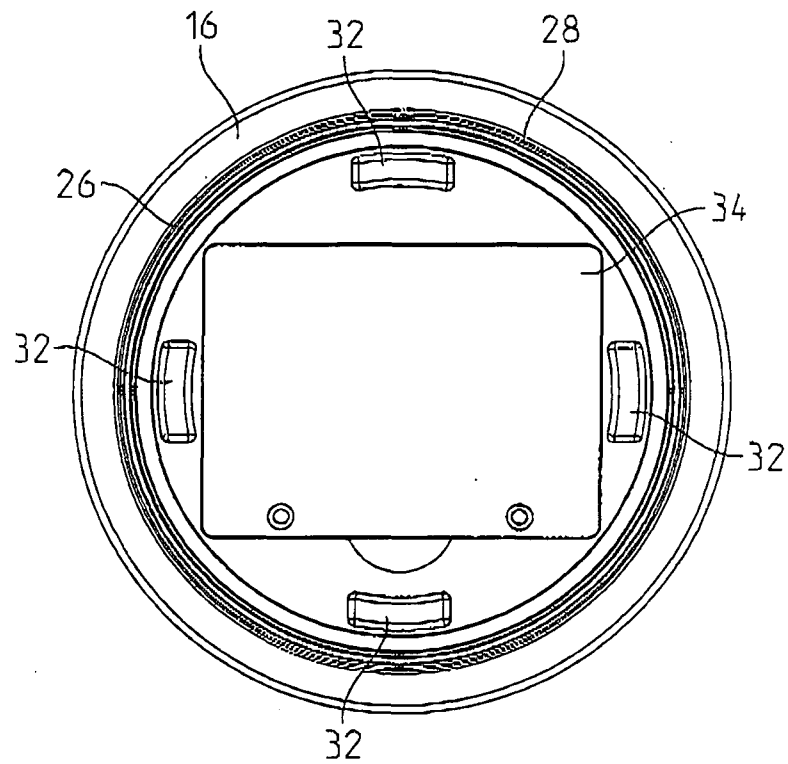


Fig. 4

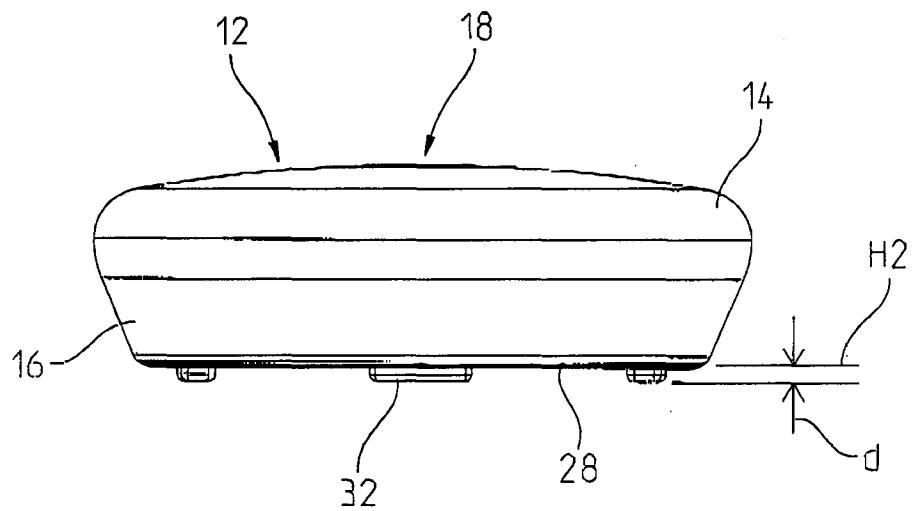


Fig. 5

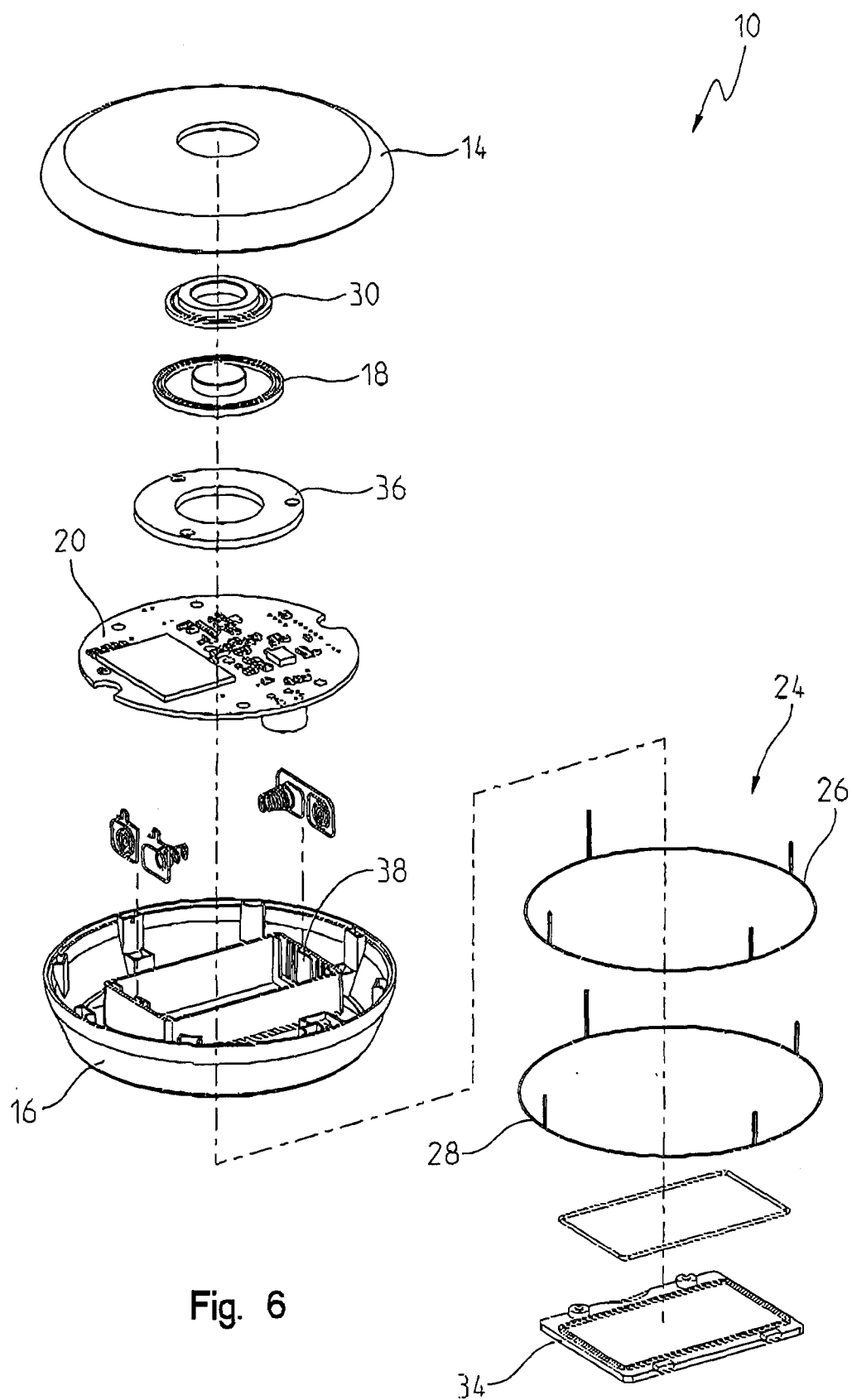


Fig. 6

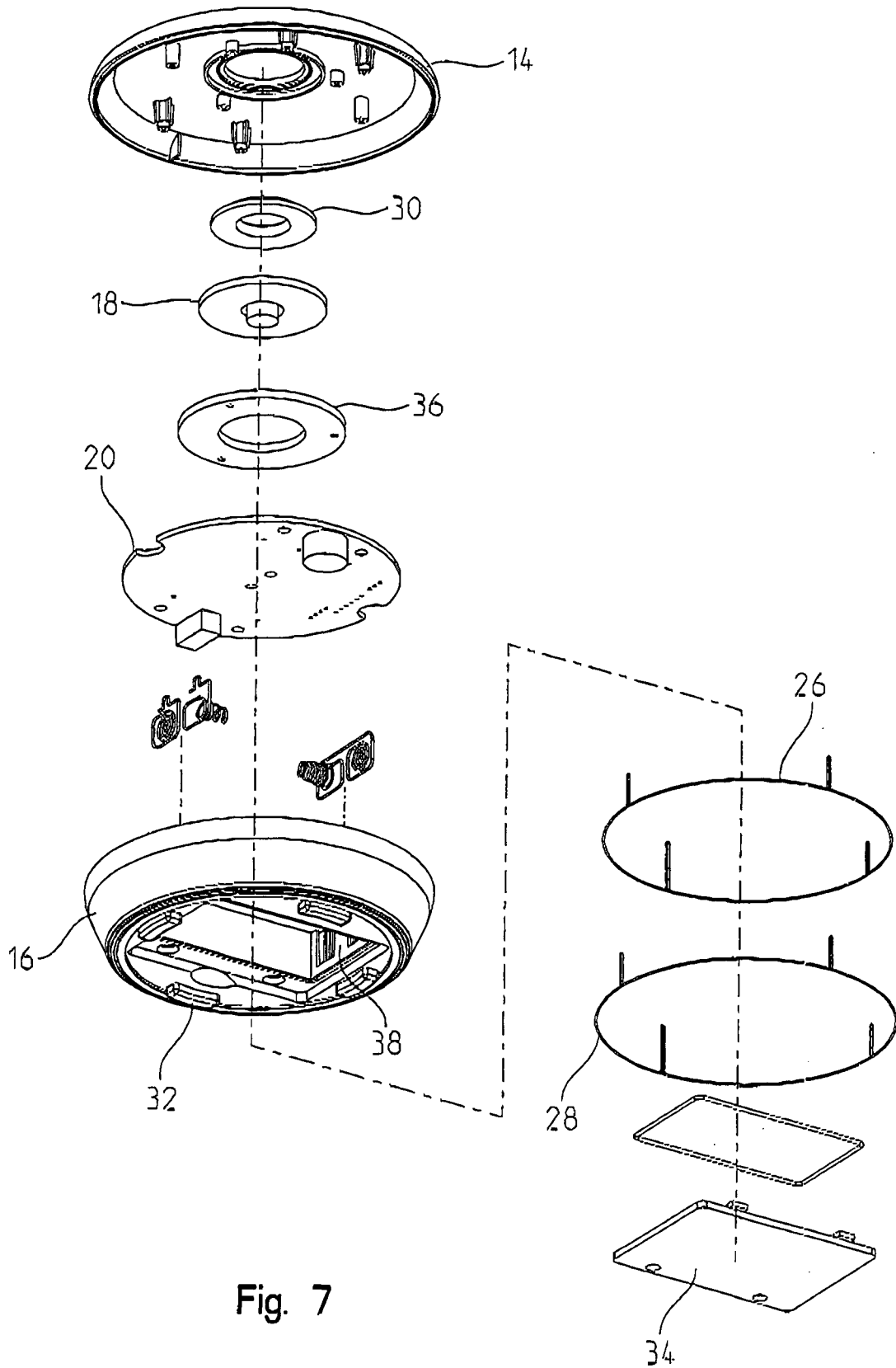


Fig. 7

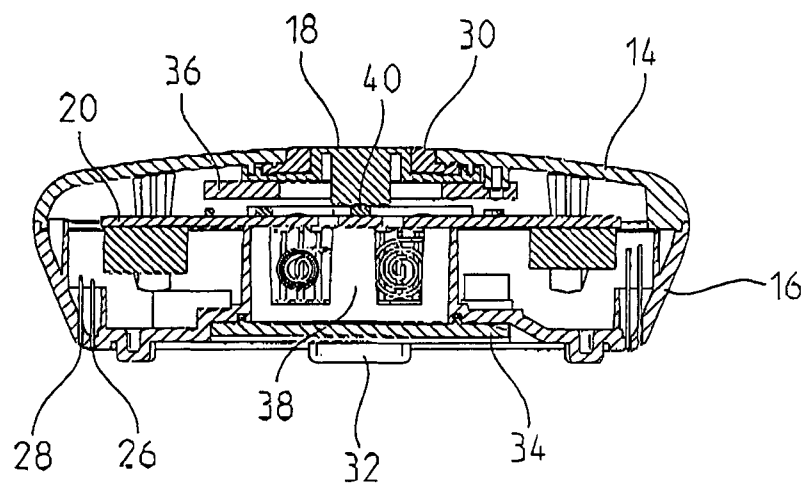


Fig. 8

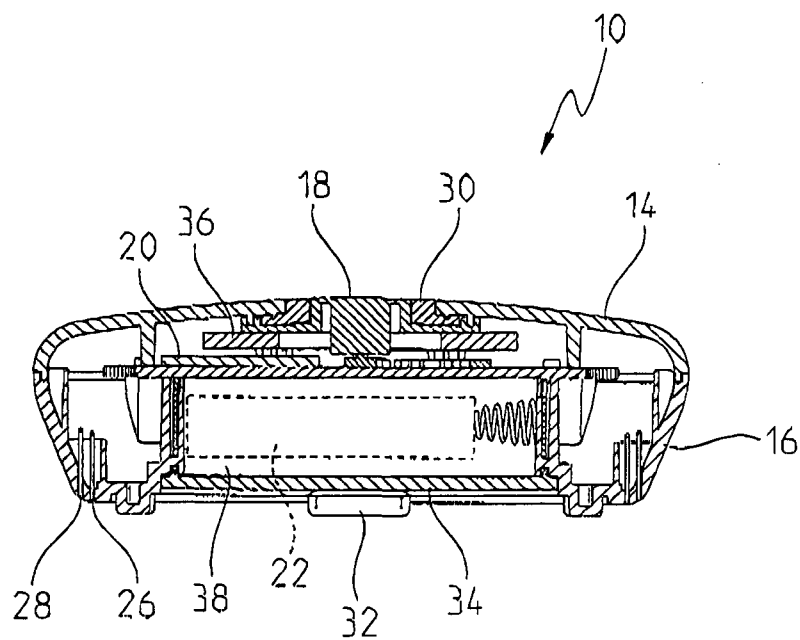


Fig. 9

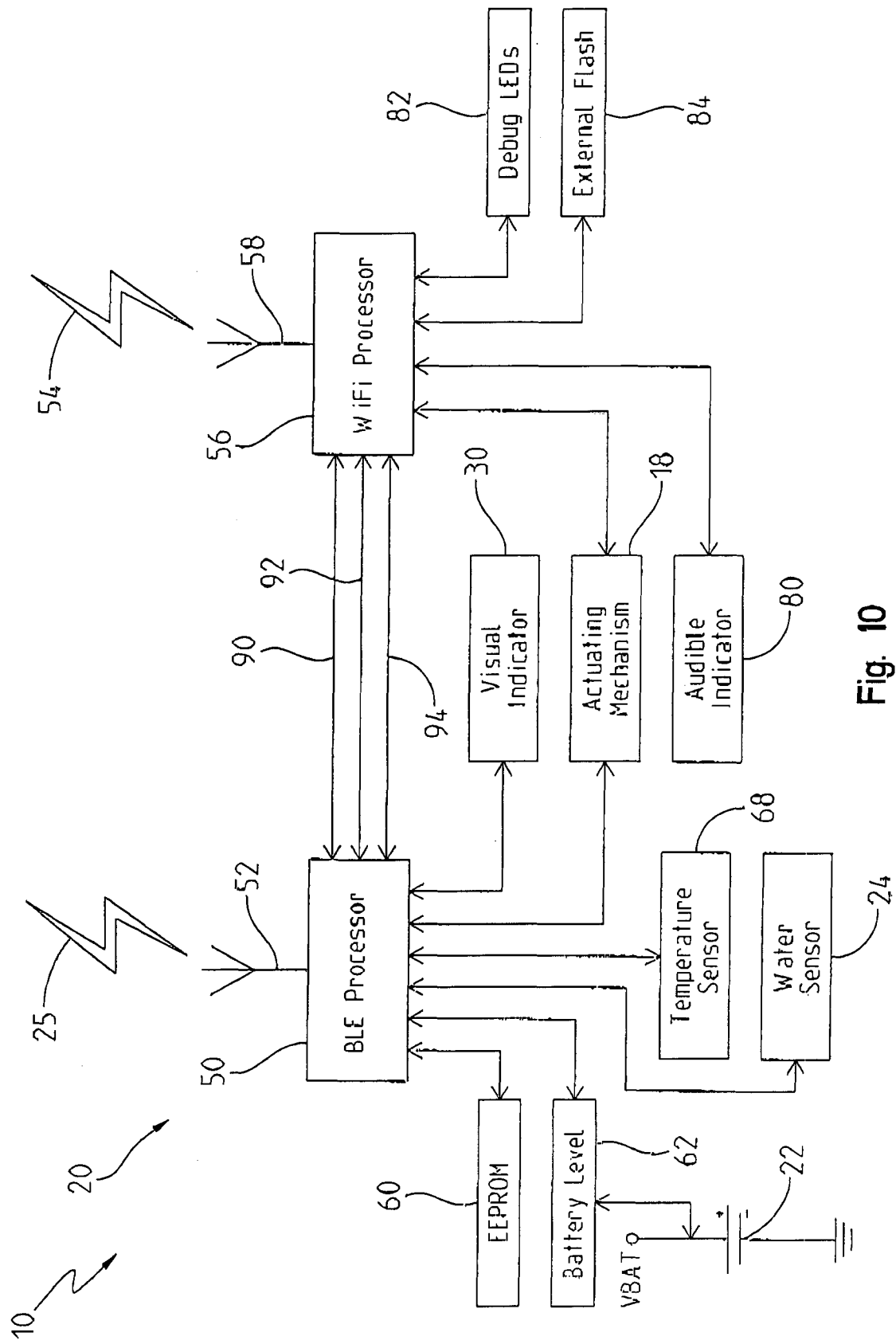


Fig. 10

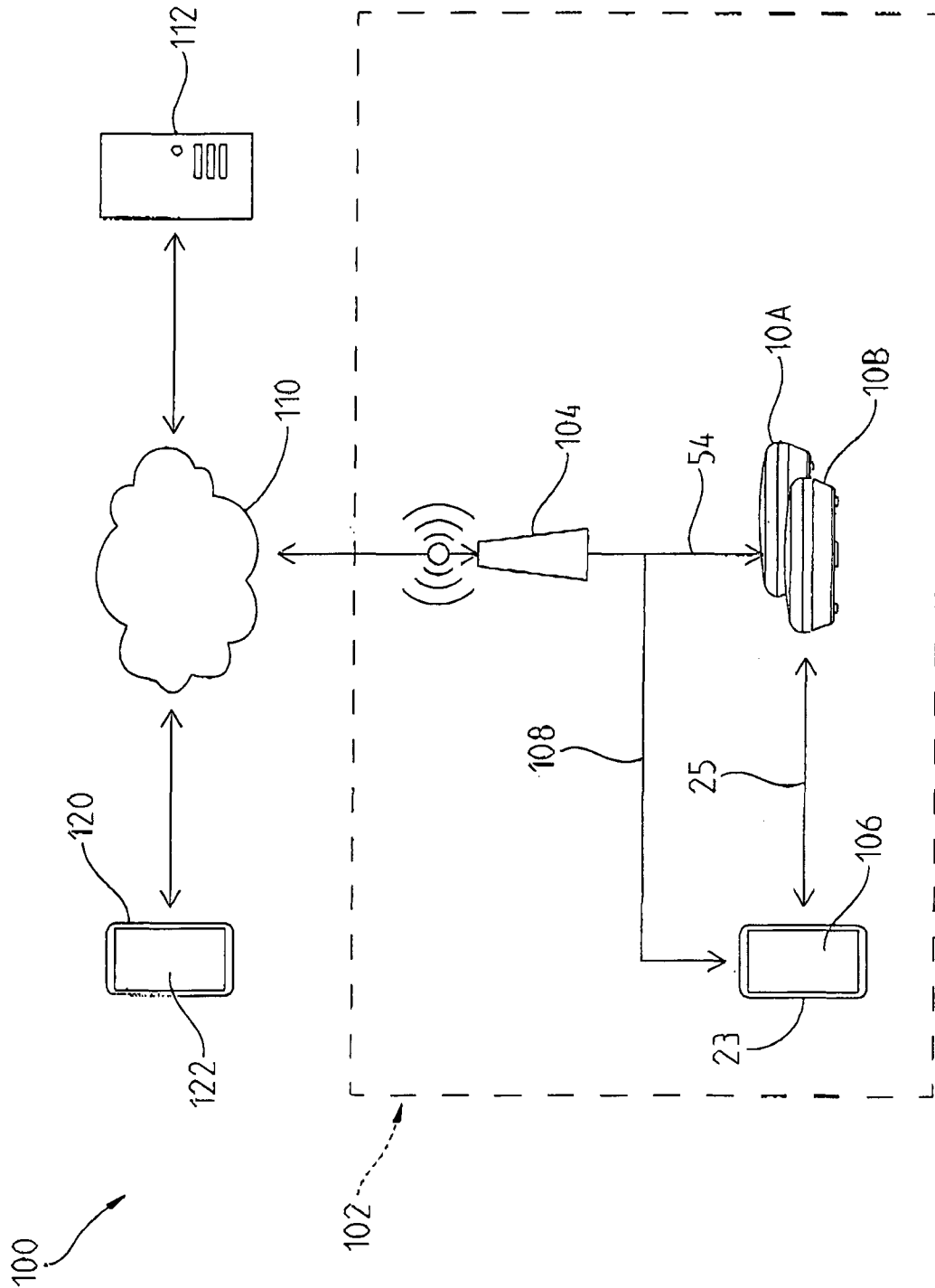


Fig. 11

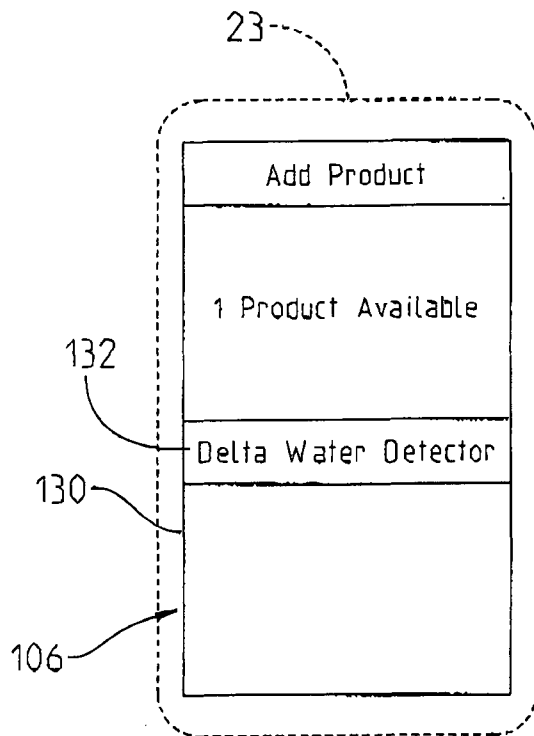


Fig. 12

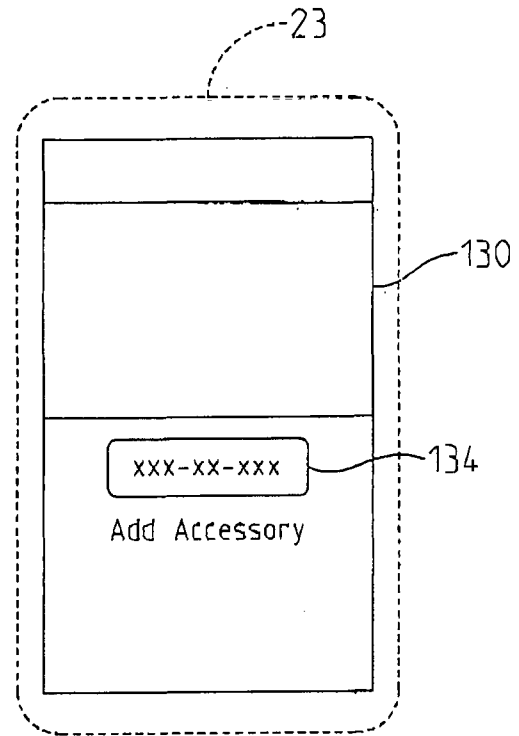


Fig. 13

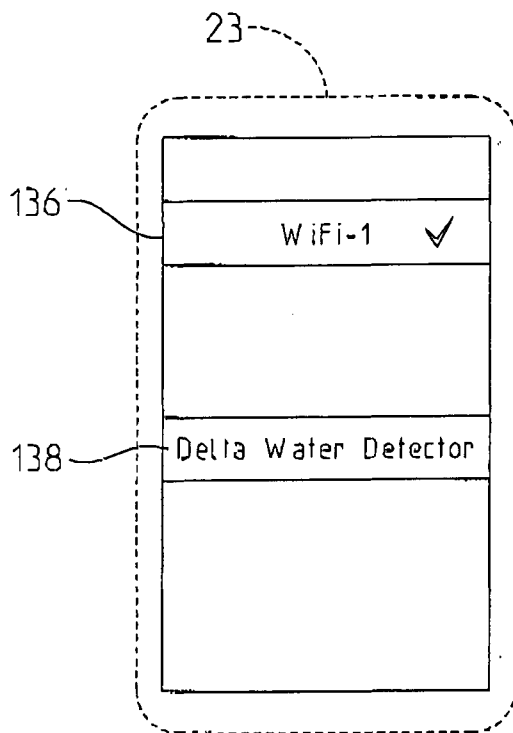


Fig. 14

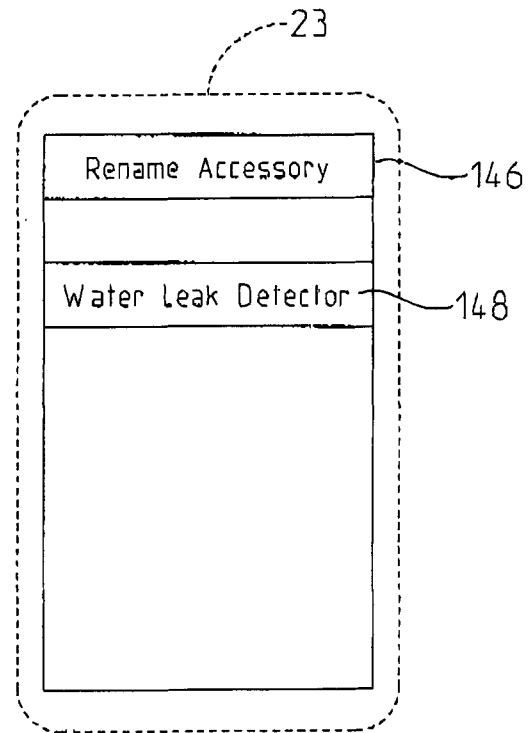


Fig. 15

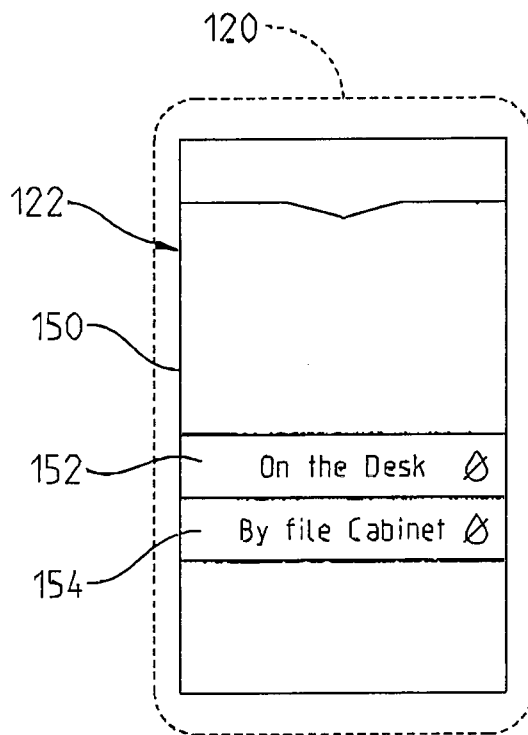


Fig. 16

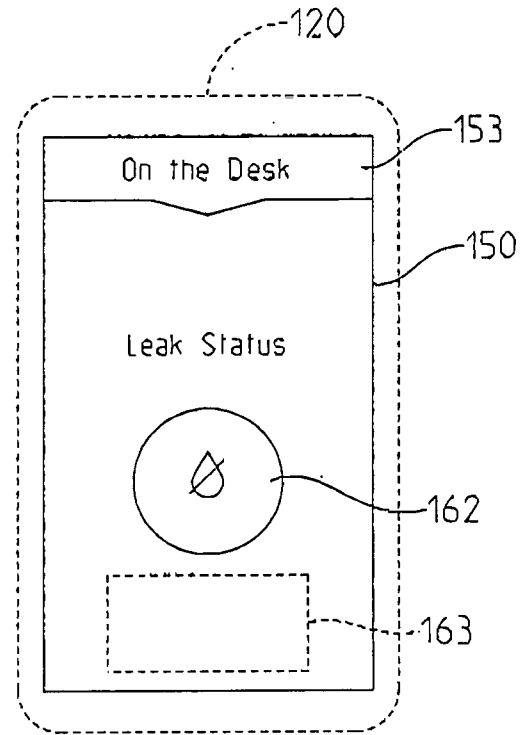


Fig. 17

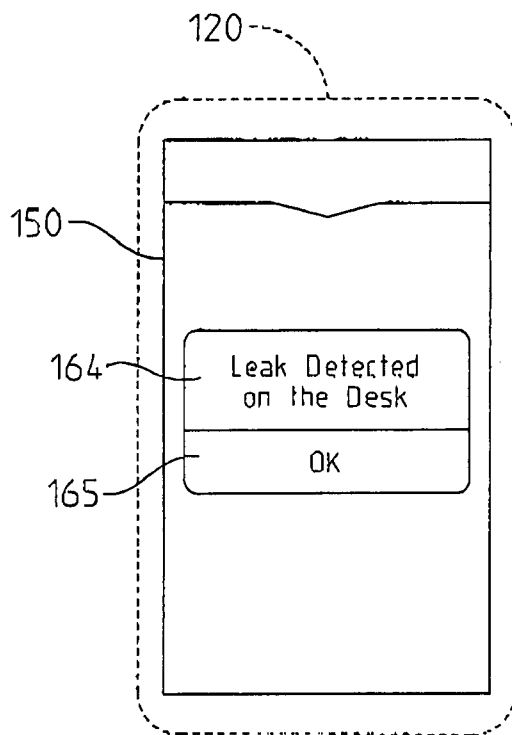


Fig. 18

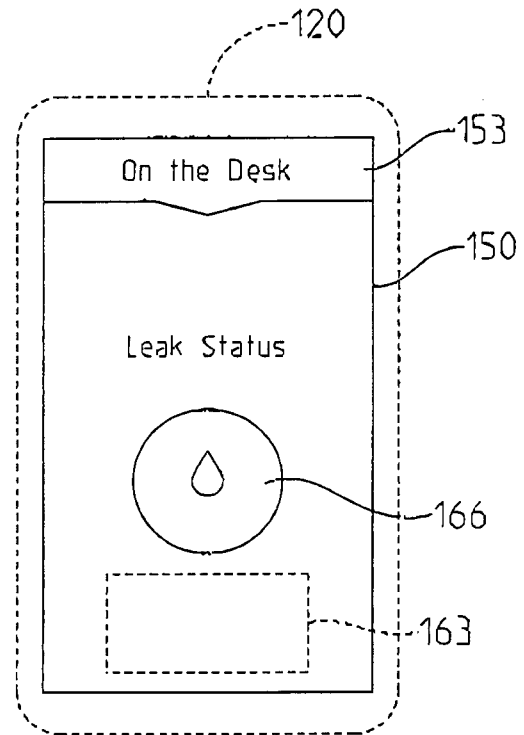


Fig. 19

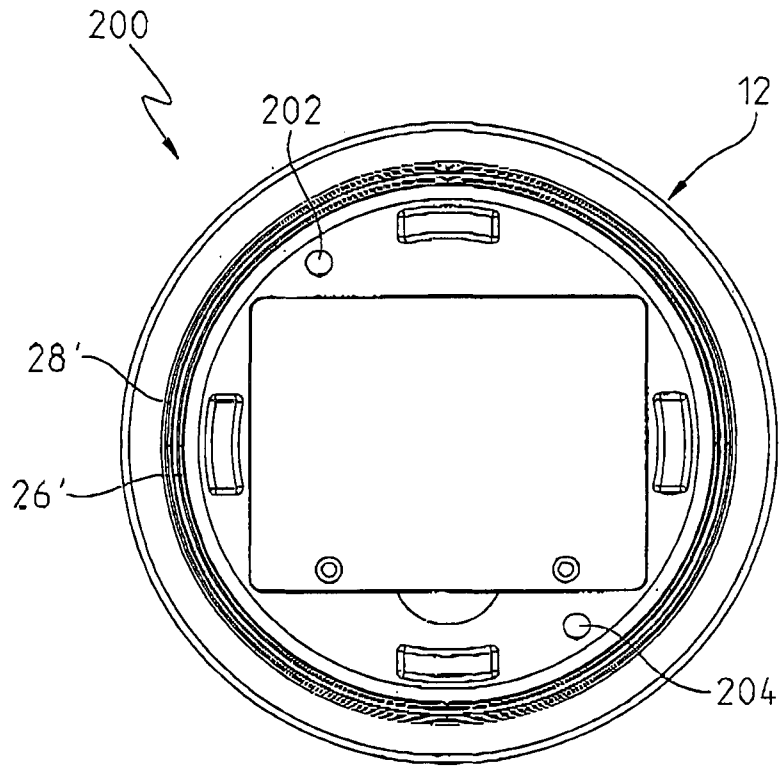


Fig. 20

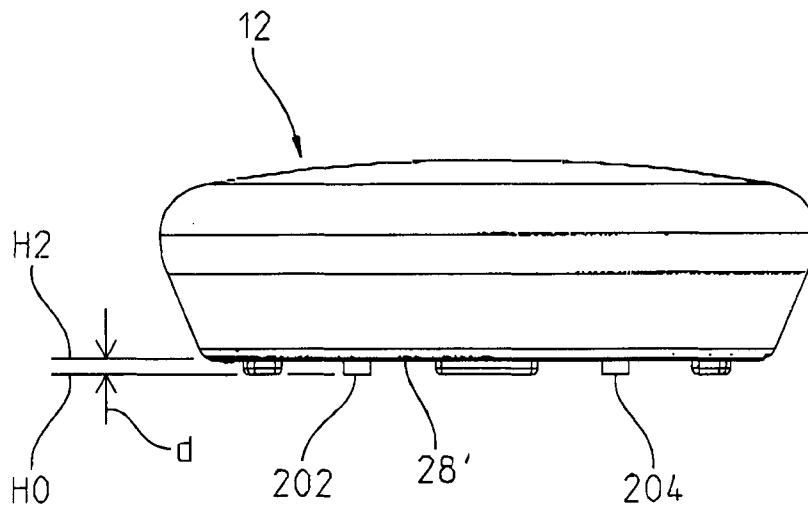
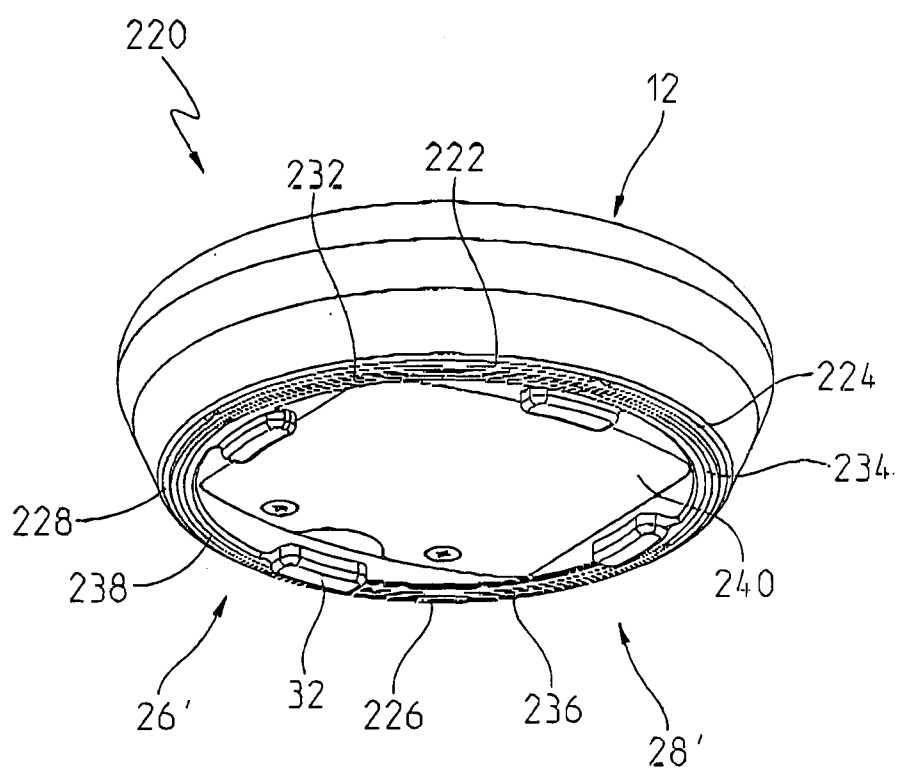
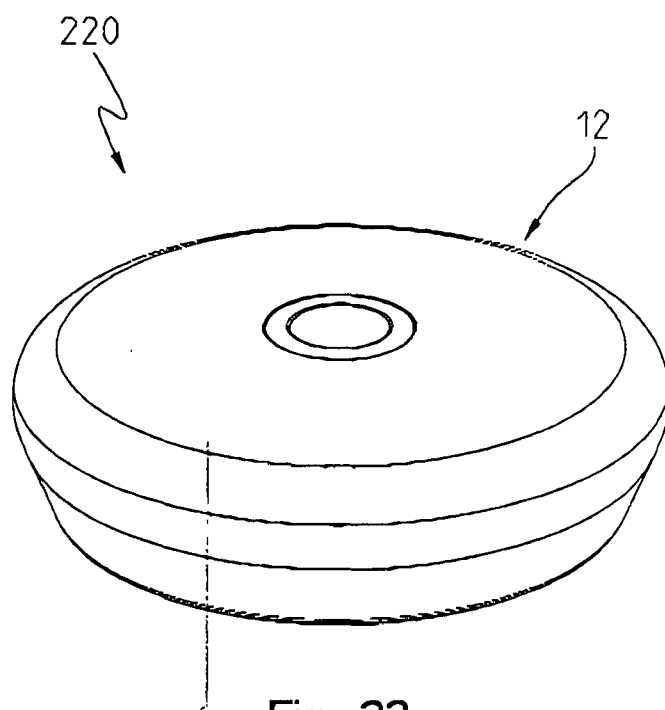


Fig. 21



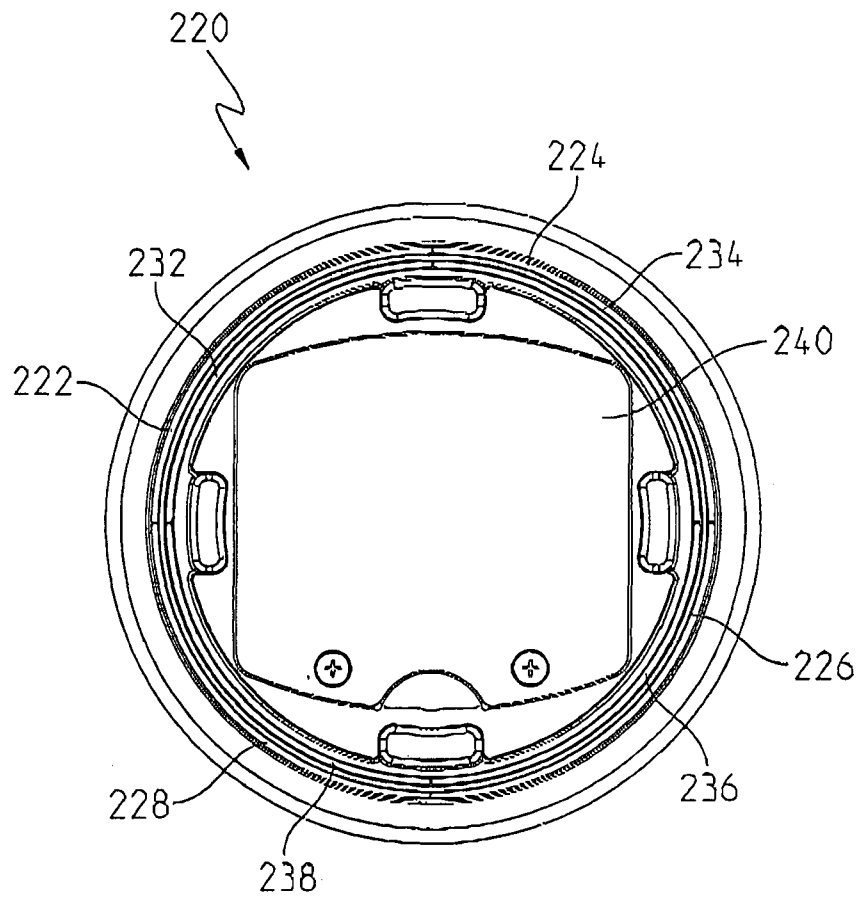


Fig. 24

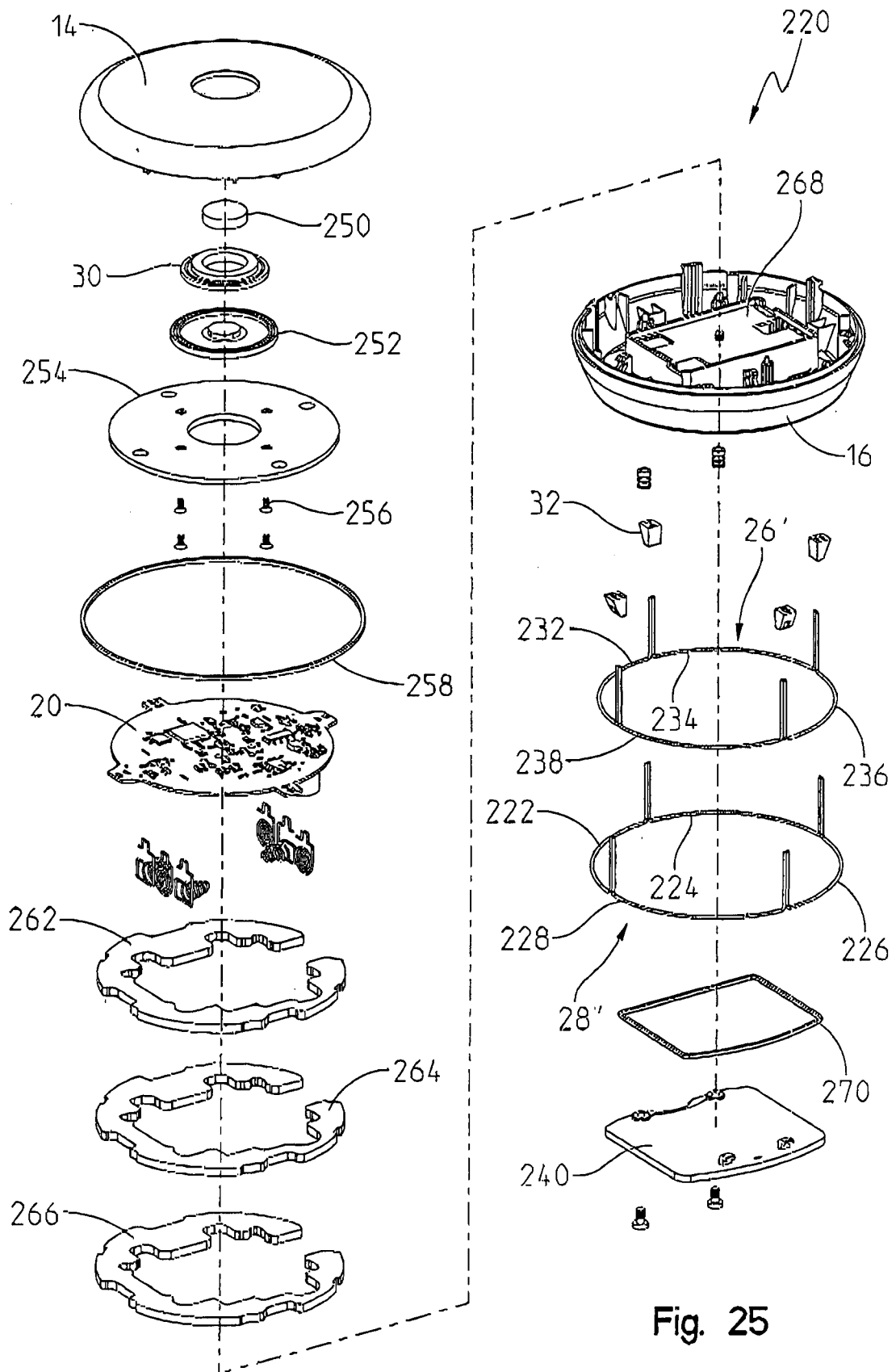


Fig. 25

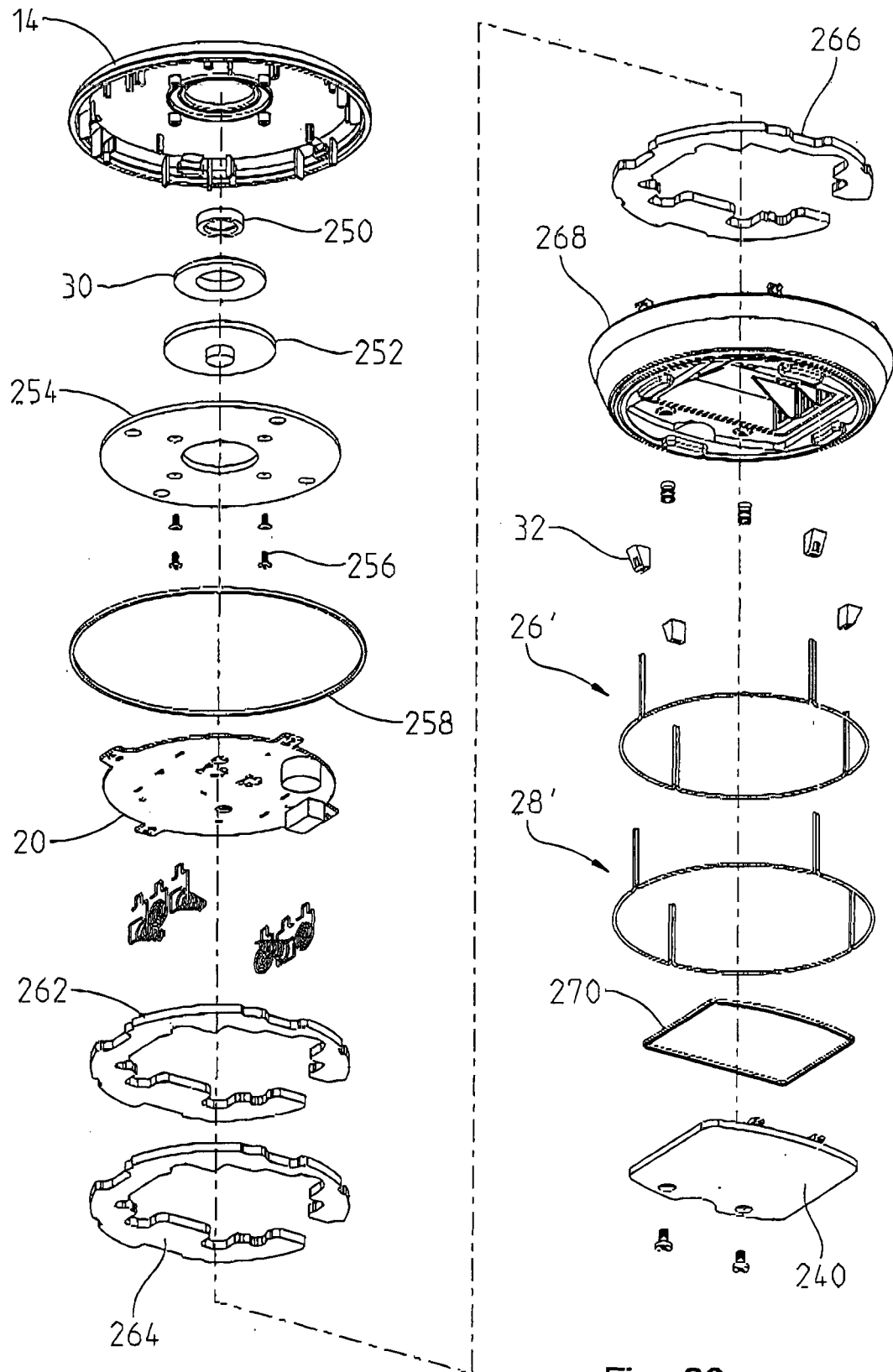
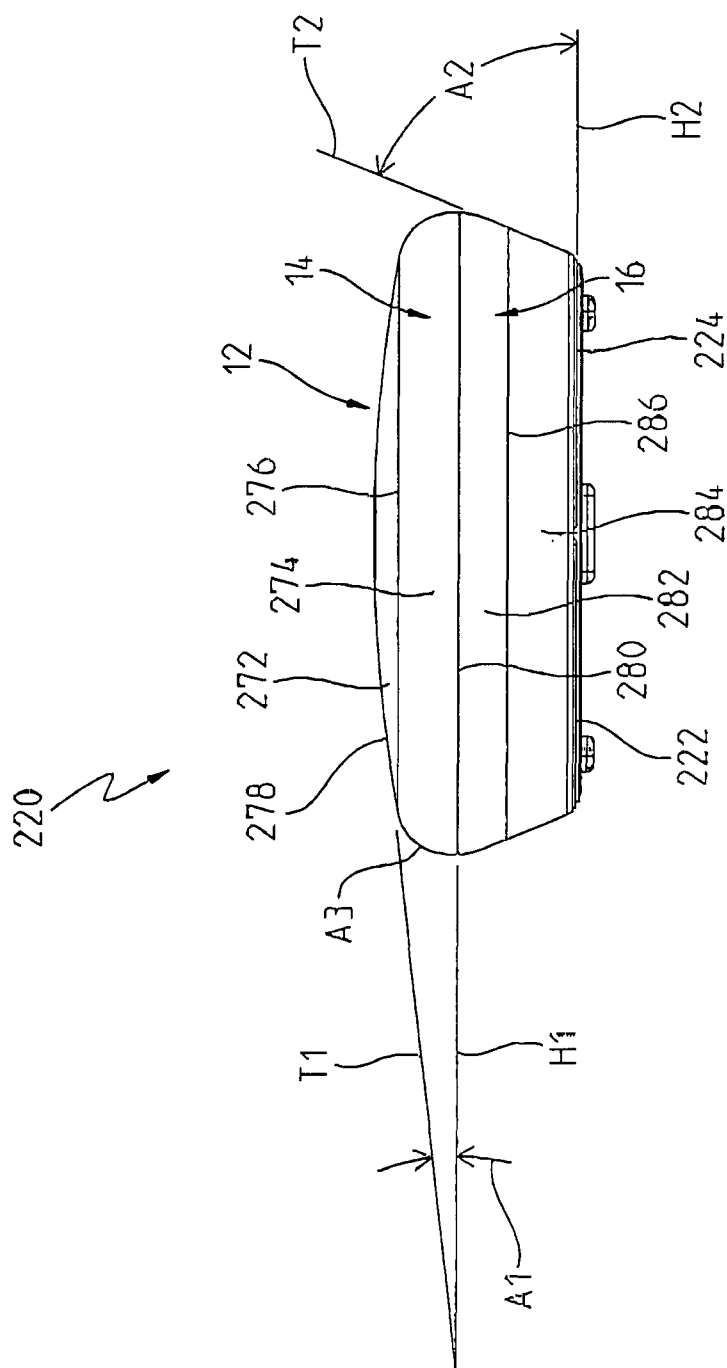


Fig. 26



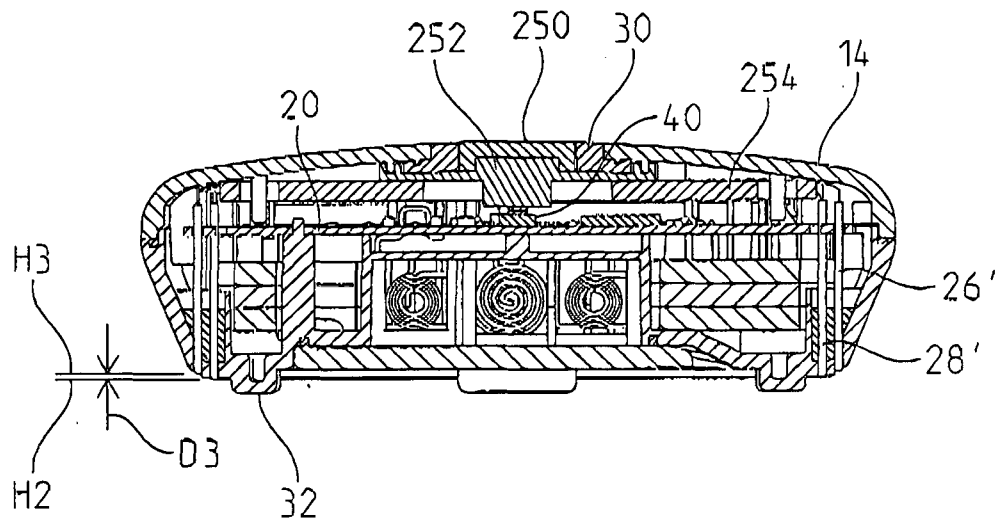


Fig. 28

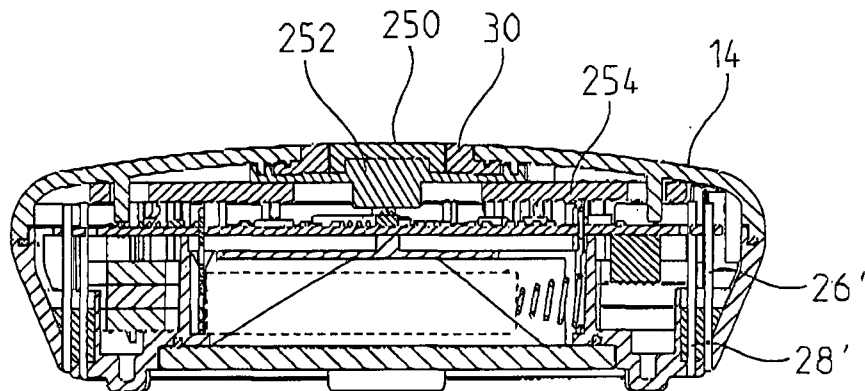


Fig. 29

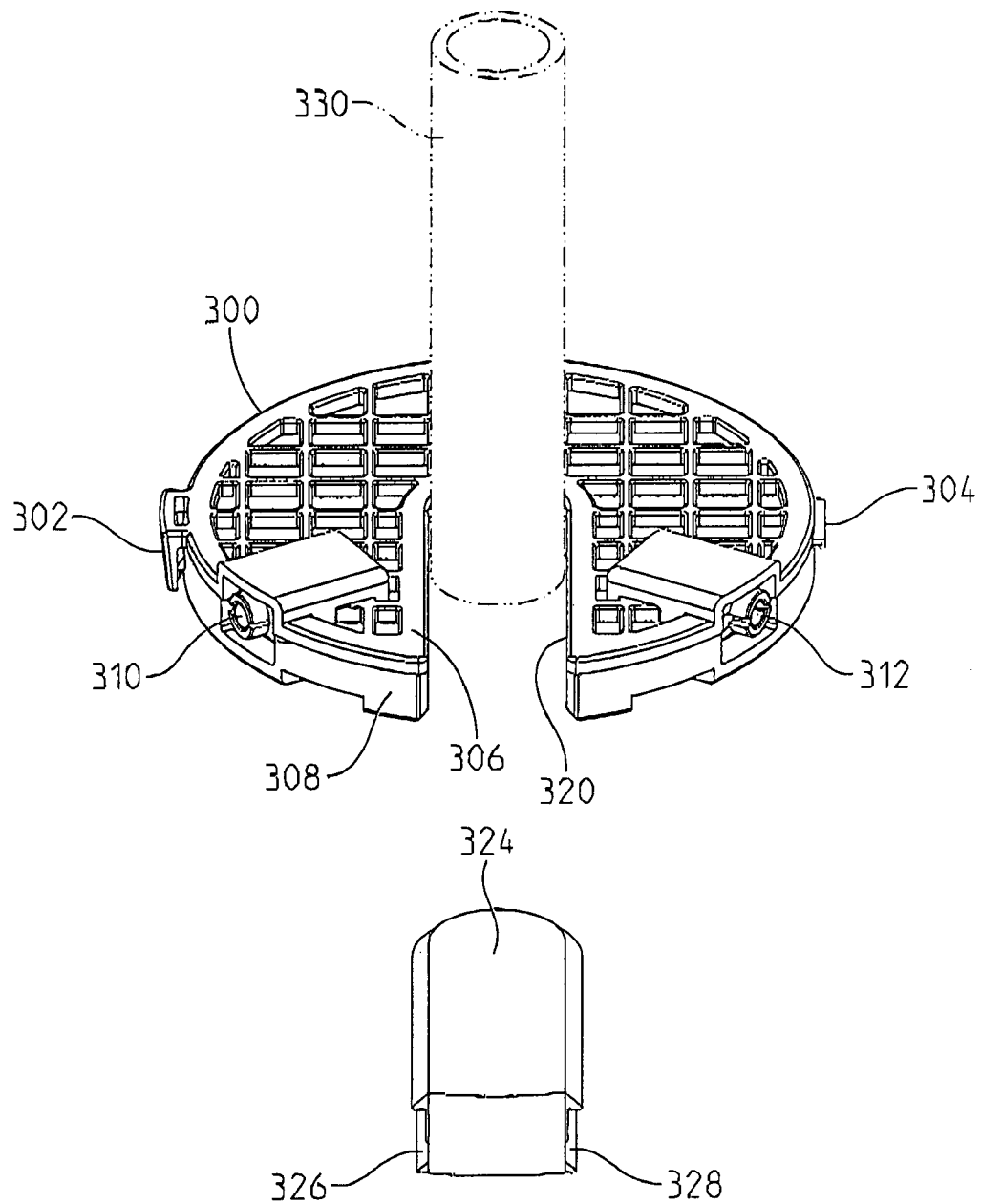


Fig. 30

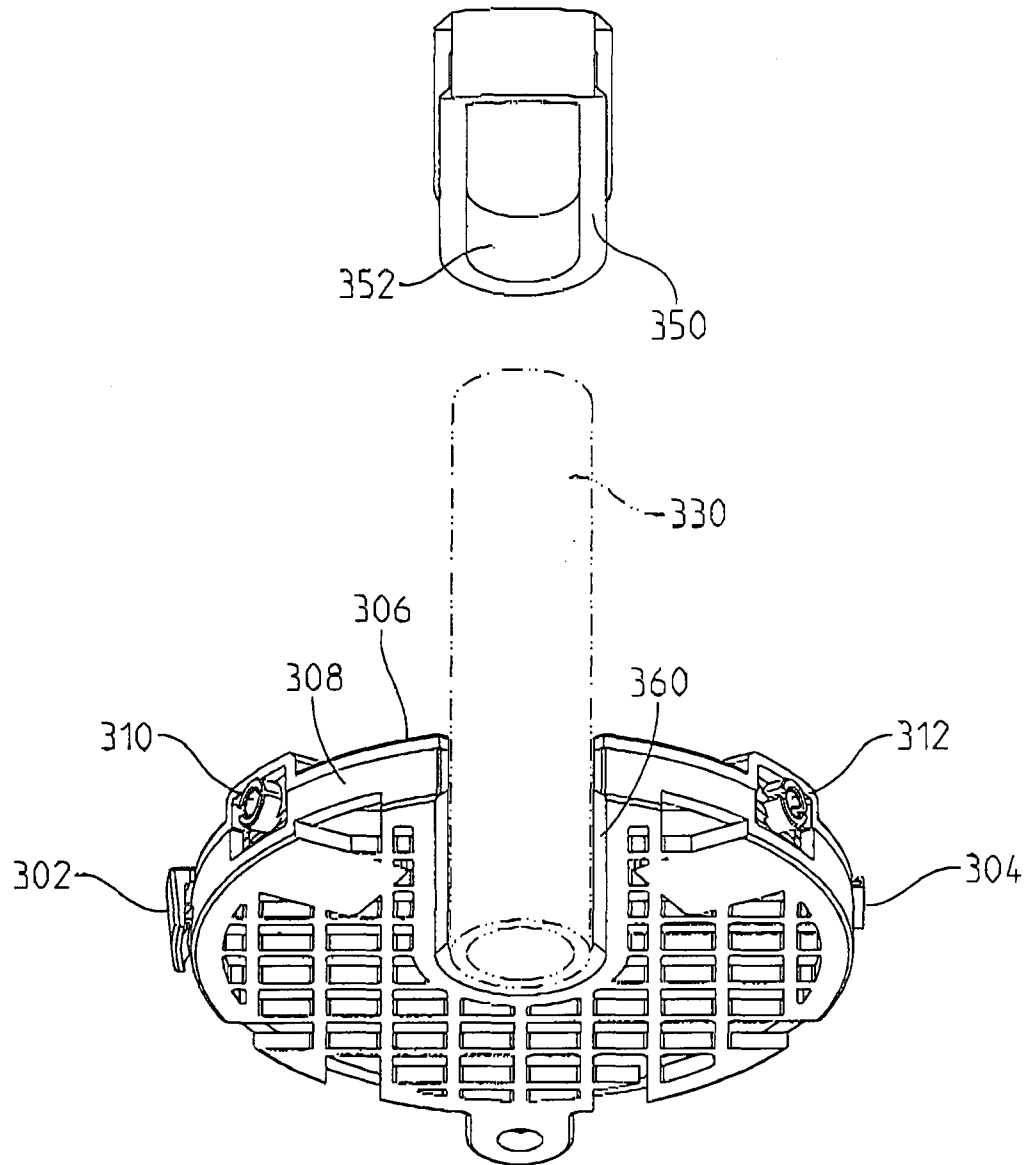


Fig. 31

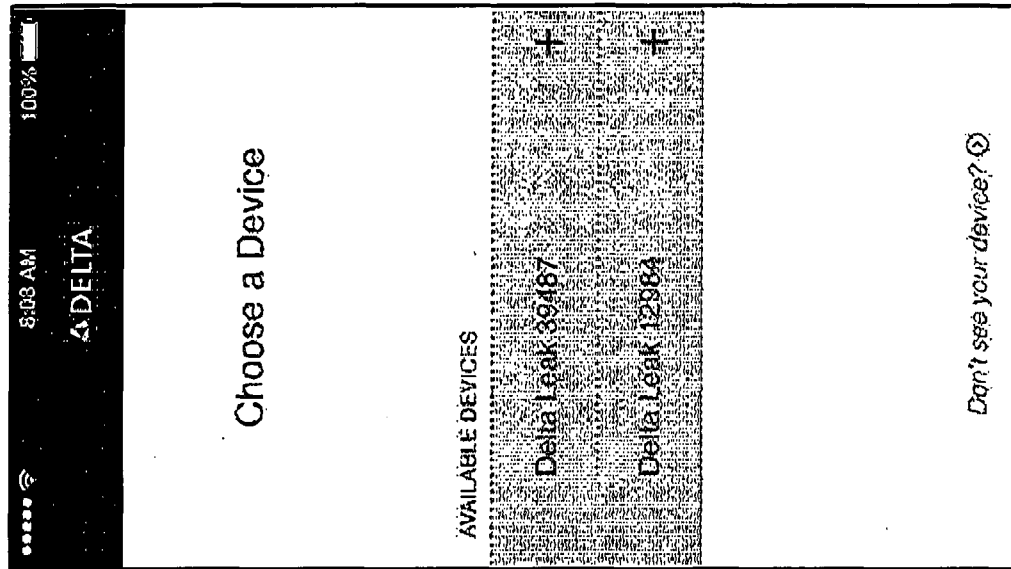


Fig. 33

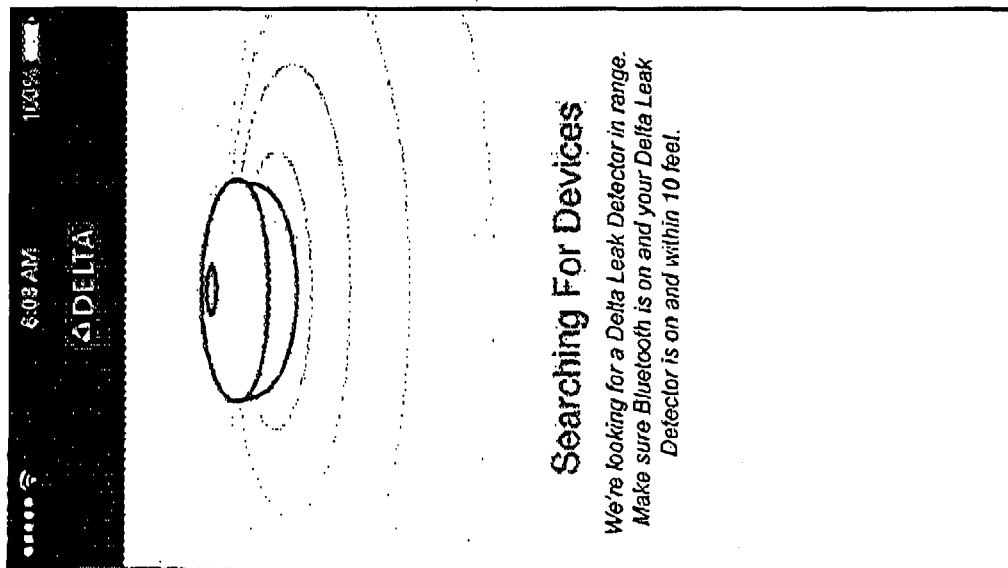


Fig. 32

22/28

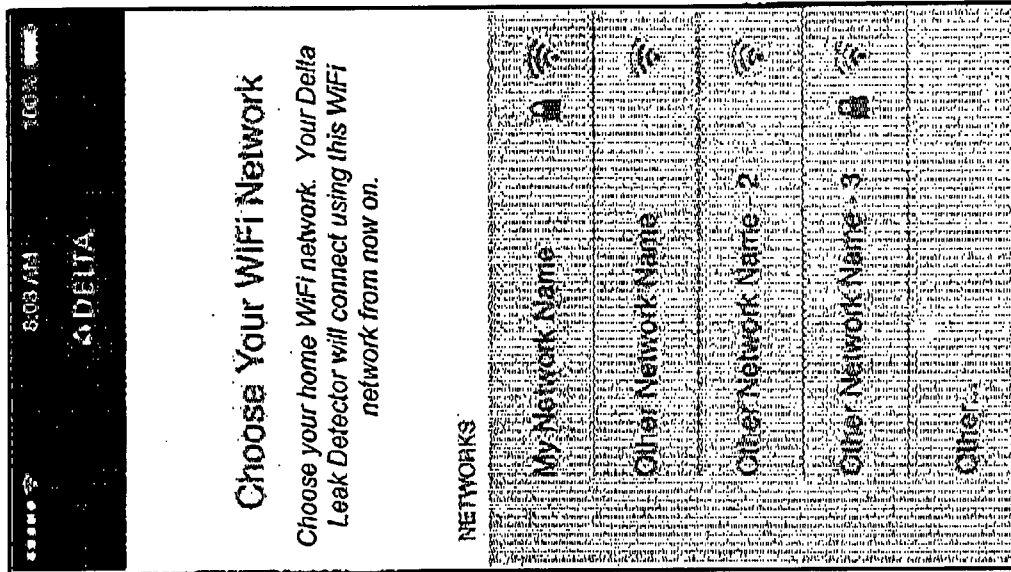


Fig. 35

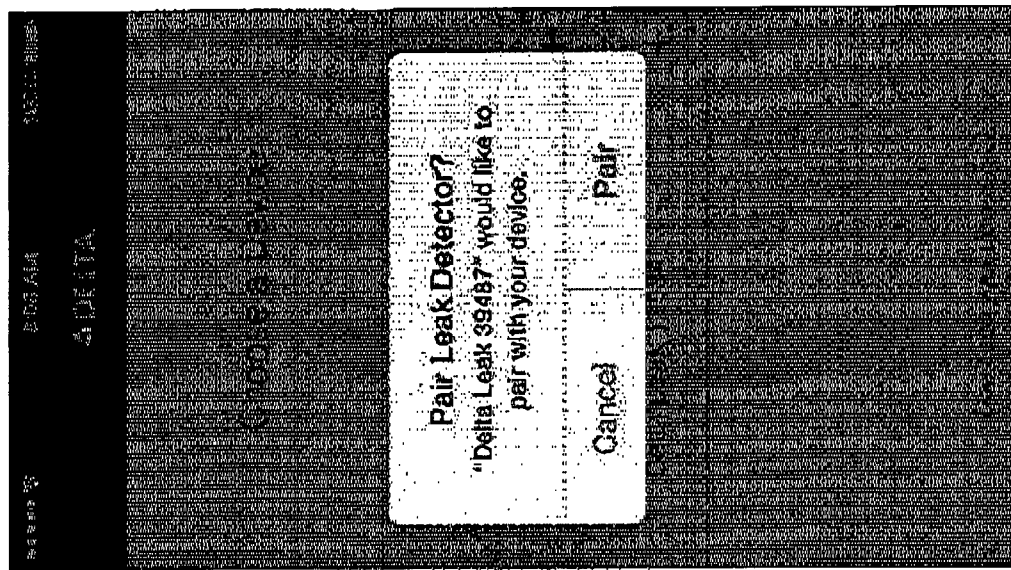


Fig. 34

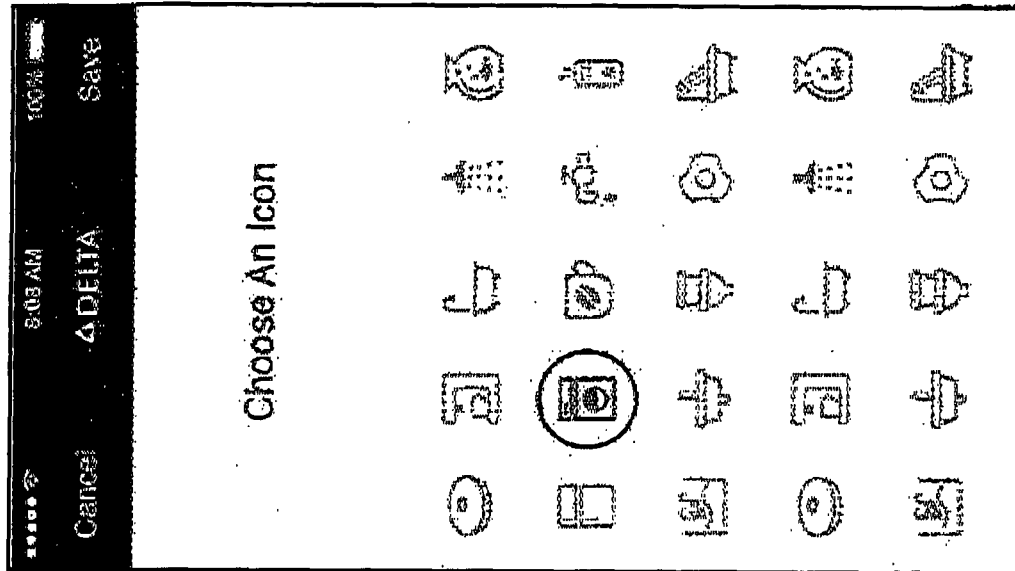


Fig. 37

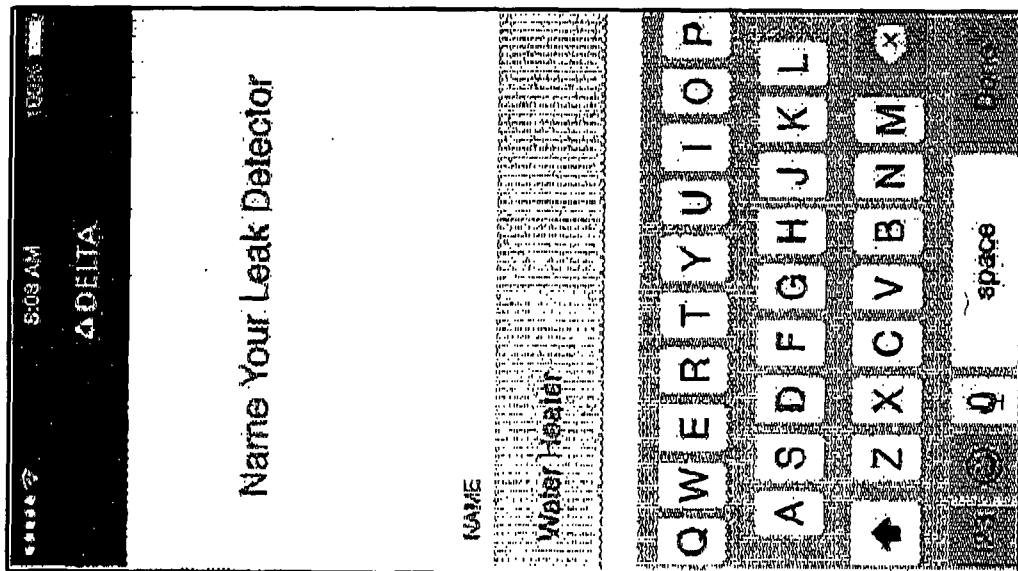


Fig. 36

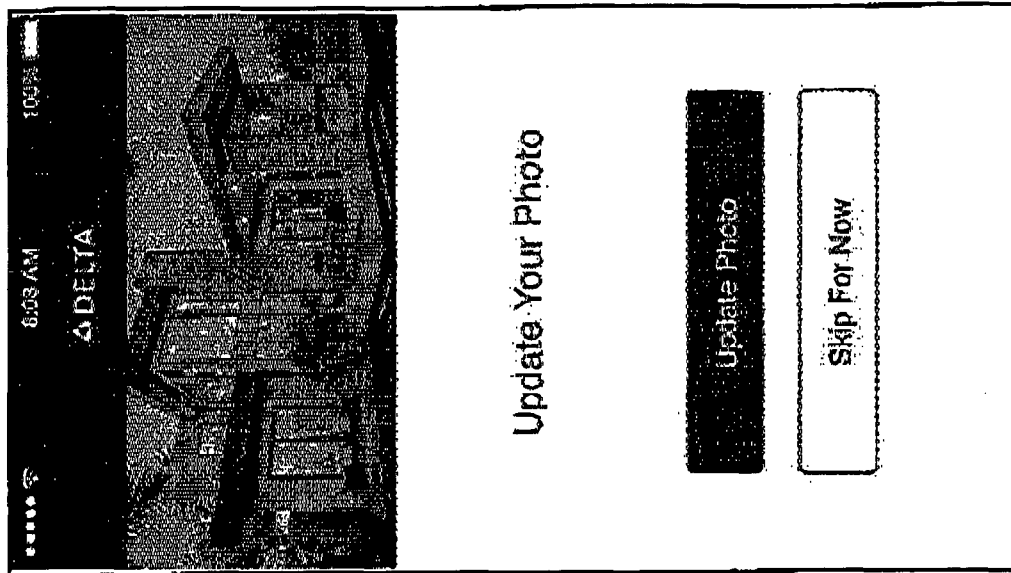


Fig. 39

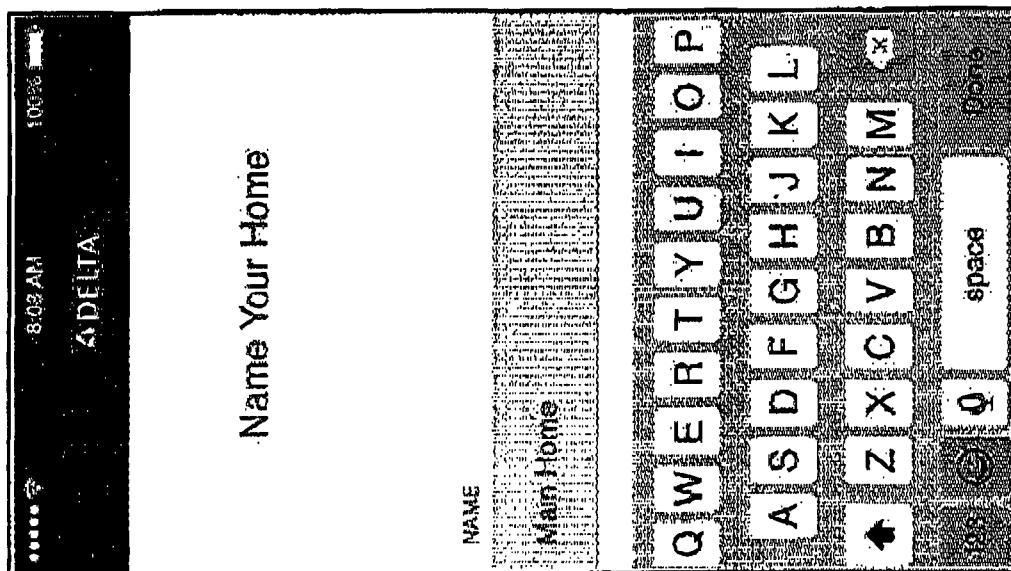


Fig. 38

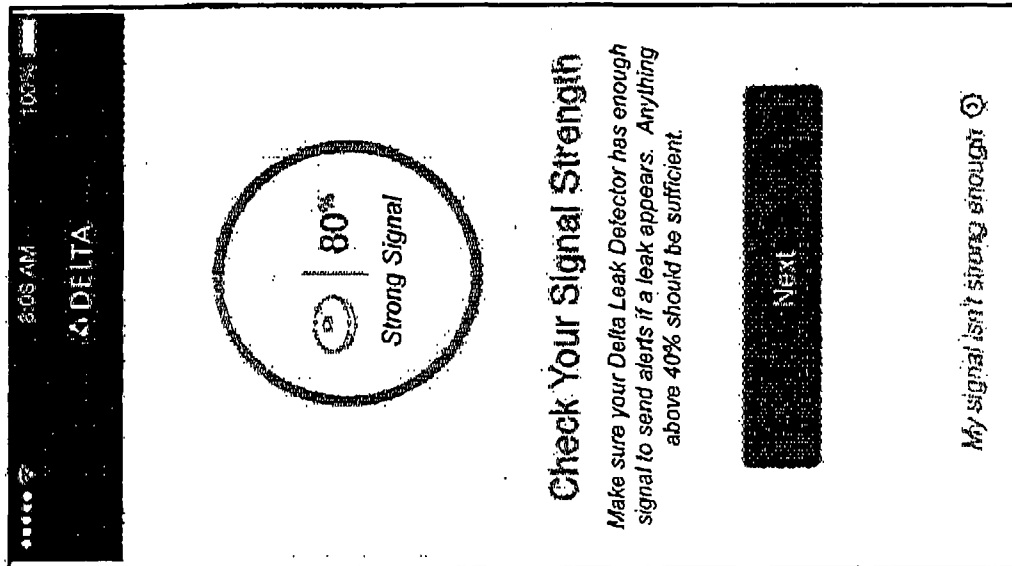


Fig. 41

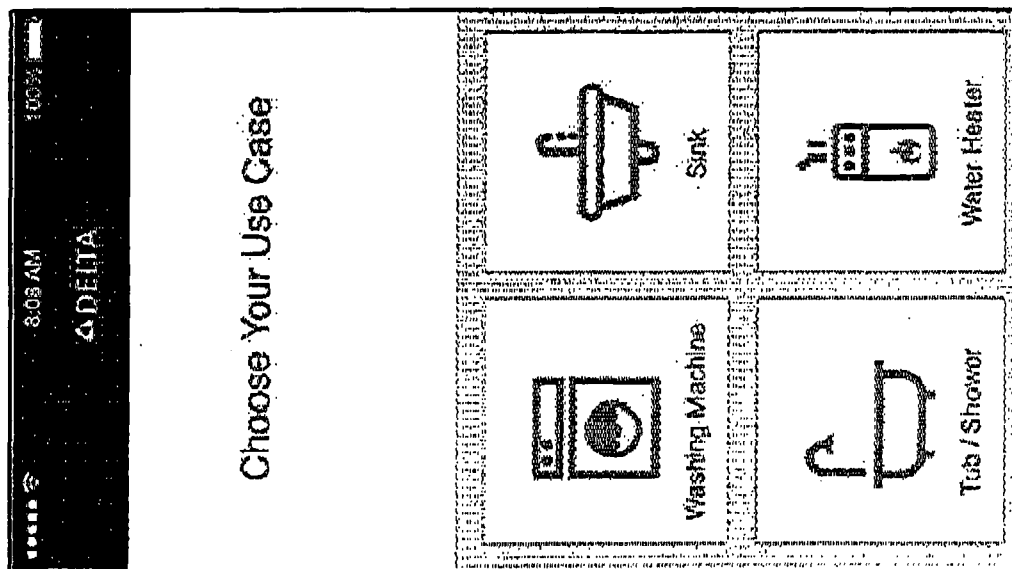


Fig. 40

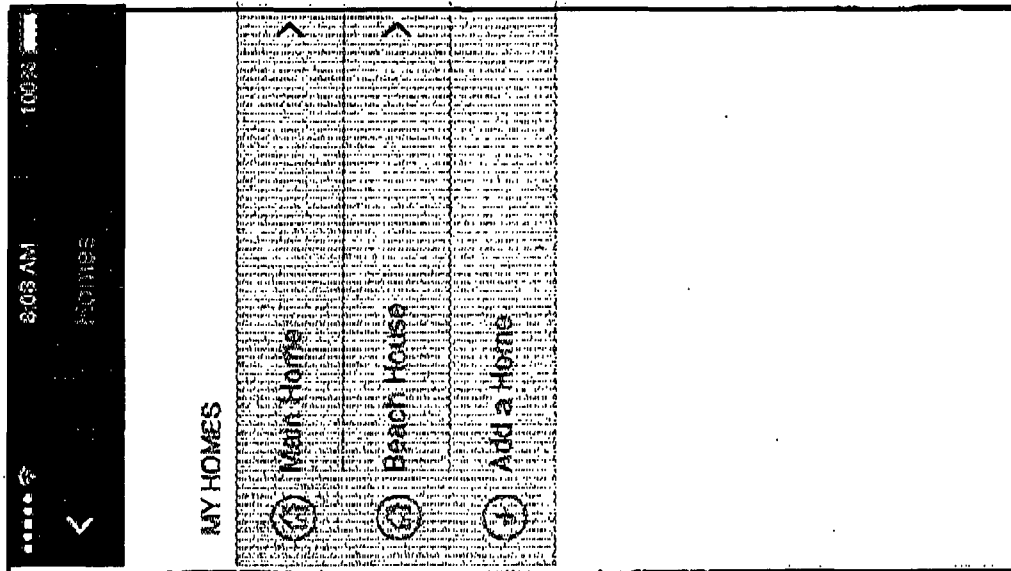


Fig. 43

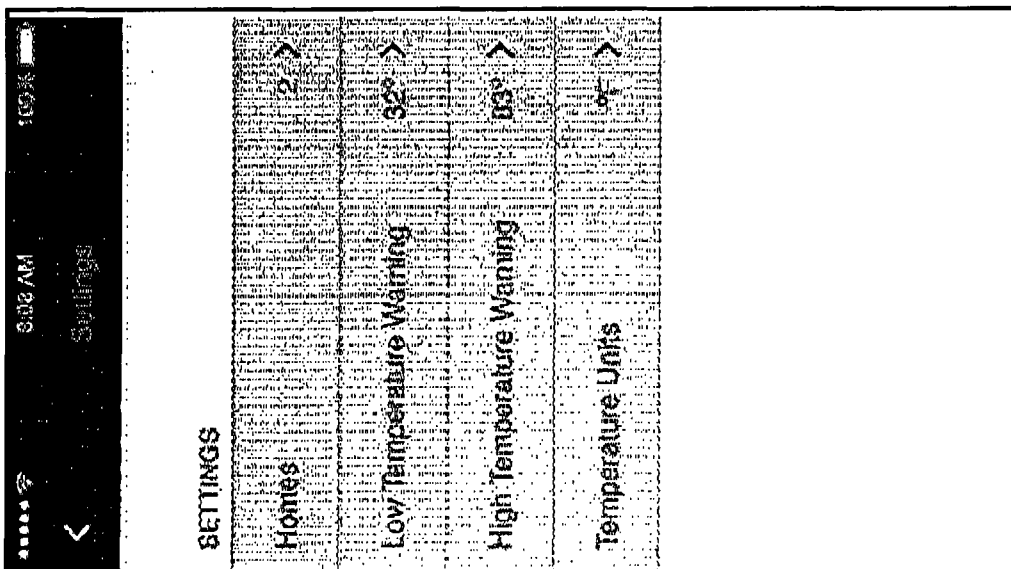


Fig. 42

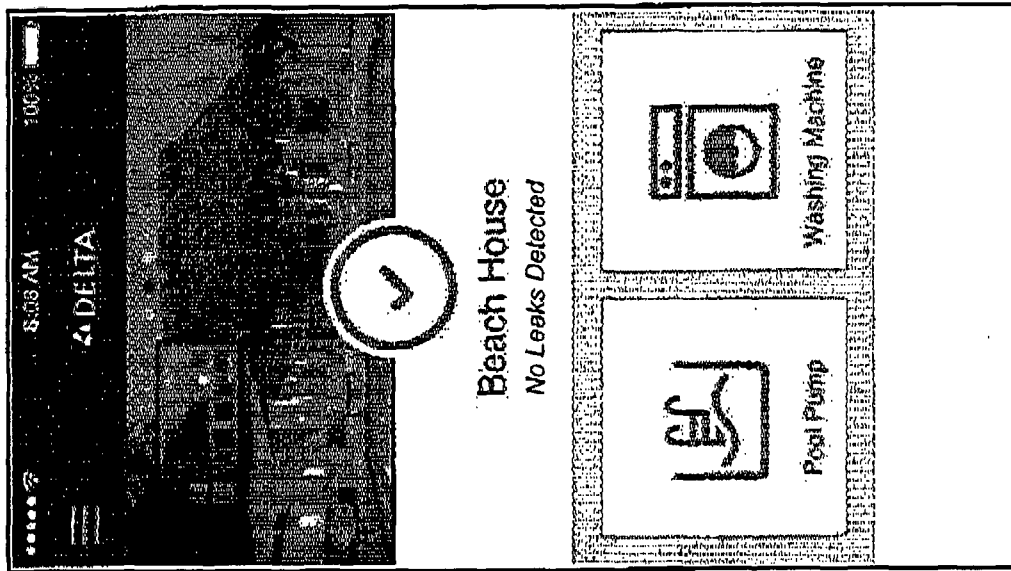


Fig. 45

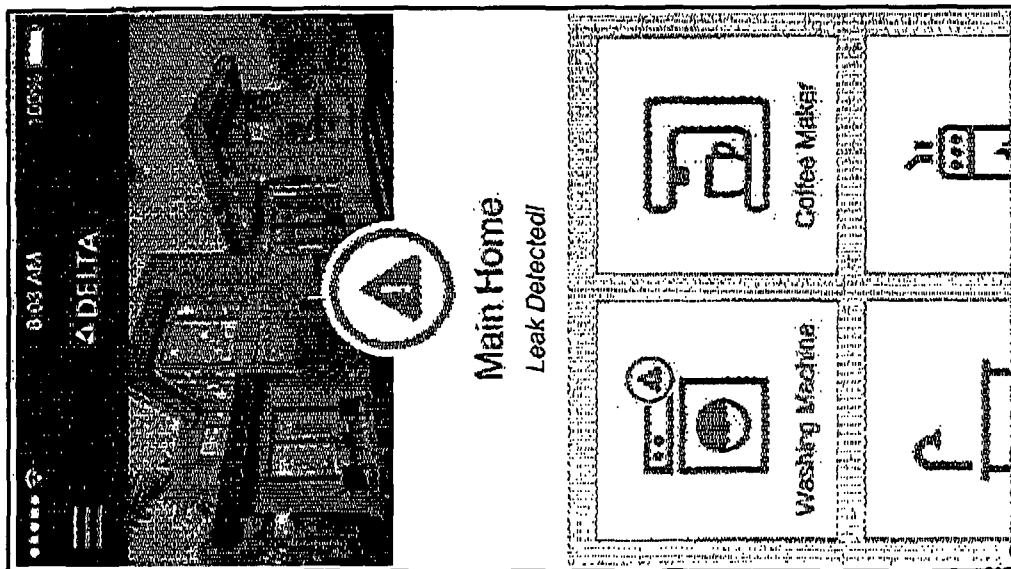


Fig. 44

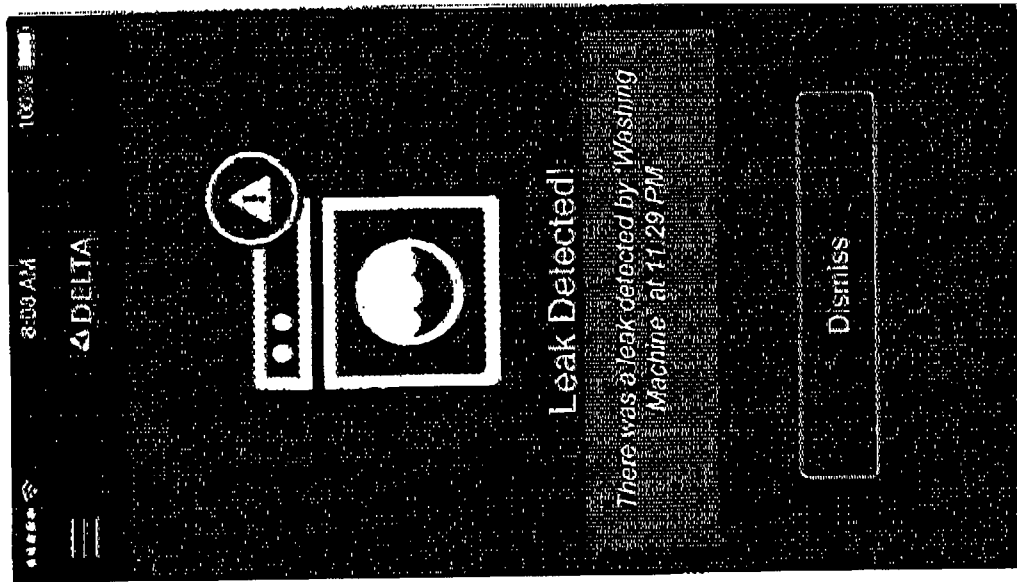


Fig. 47

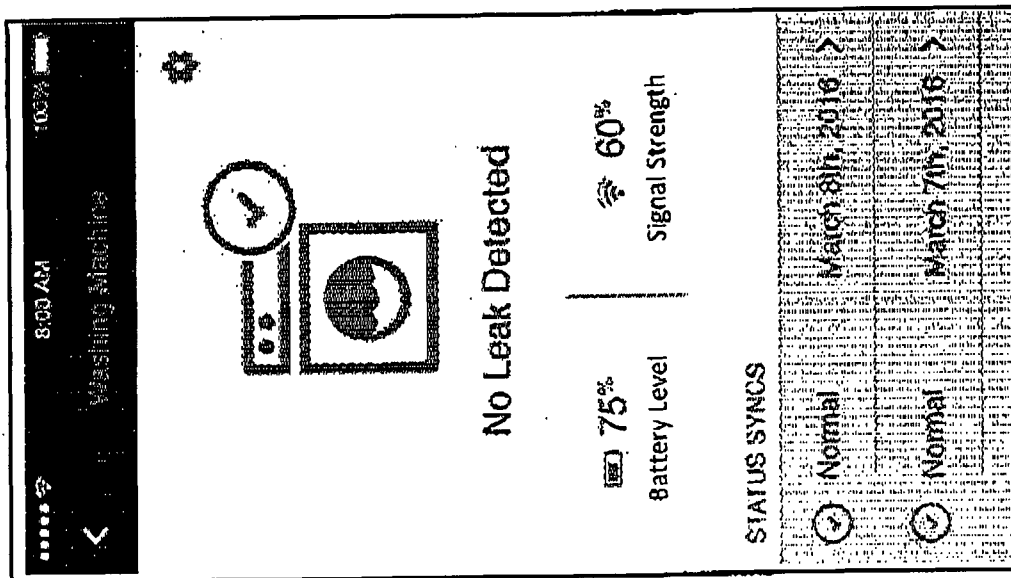


Fig. 46

