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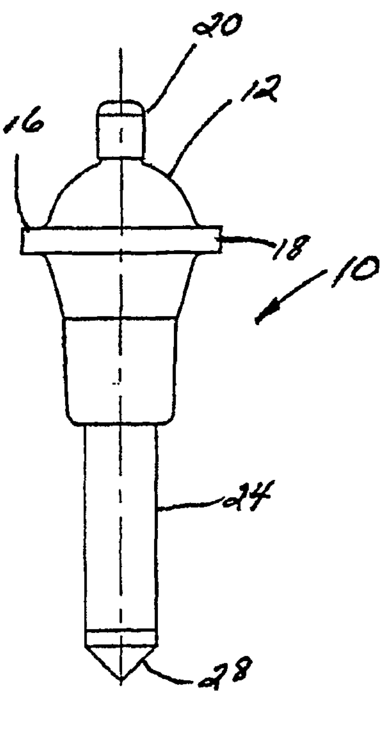
(54) Title: APPARATUS FOR MONITORING AND REGULATING SOIL MOISTURE



(57) Abstract: A water moisture sensing and watering apparatus including a housing having a water chamber that is at least partially evacuatable. A porous sensor is communicably connected to the chamber. When the moisture in the soil is sufficiently high, the pores of the sensor filled sufficiently to become plugged so that a vacuum or low-pressure region and water are maintained within the chamber. When the moisture of the soil drops below a predetermined level, the moisture in the pores is pulled out by the soil and plant roots sufficiently for air to be transmitted through the pores of the sensor into the chamber, increasing pressure in the chamber and providing an indication that water is needed in the soil and, in certain embodiments, automatic watering the soil and plant roots.

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TITLE OF THE INVENTION

APPARATUS FOR MONITORING AND REGULATING SOIL MOISTURE

CROSS-REFERENCE TO RELATED APPLICATIONS

Not applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not applicable

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates generally to an apparatus for monitoring soil moisture and, more particularly, to an apparatus for sensing when the soil supporting a plant requires watering and for automatically watering the plant when a sufficient lack of moisture is detected.

Description of Related Art

Virtually all plants require periodic watering. Providing the soil that supports a plant with the proper amount of water is very important. Applying too little or too much water may interfere with the growth of the plant or even kill the plant. Constantly monitoring the soil condition of the plant is usually tedious, time consuming and annoying. Oftentimes, the plant owner neglects this task and, as a result, plants suffer from lack of water. On the other hand, an inattentive plant owner may inadvertently over water the plant, which can be just as damaging. Even if the soil condition of the plant is properly monitored, it can be often difficult to accurately judge precisely how much watering is required. This results in guesswork which can lead to either underwatering or over watering and the harmful consequences described above.

Even if performed at proper intervals, hand-watering plants can be tedious and time consuming. Although many types of automatic watering systems are known, these tend to be fairly complicated and expensive. Many are only suitable for outdoor or green house use or for use with large numbers of plants. Most conventional automatic watering systems are not appropriate for use with potted plants or a small number of plants.

As additional problem with conventional automatic watering systems is that many of these devices are time dependent and a plant's need for water is often not solely a function of time. Typically, the plant's demand for water varies with the condition of the soil, the atmospheric temperature, the humidity, etc. Accordingly, Lohoff, United States Patent No. 3,916,678, discloses a device for detecting when the soil supporting a plant is sufficiently dry to indicate that the plant needs to be watered. One device disclosed by Lohoff simply provides a visual indication that the soil is dry and requires watering. This apparatus employs a fairly complicated construction with a number of small parts including a flexible diaphragm, a coil spring and a protruding check valve. The numerous parts and relatively high cost of manufacturing this item renders it commercially impracticable. Lohoff also discloses various items that automatically dispense water when the sensed soil moisture is sufficiently low. However, typically these devices provide for only a single watering. Water is not repeatedly provided to the soil as needed. Rather, each time the water is automatically dispensed, it must be manually replenished. This is time consuming and inconvenient.

Other related prior art devices are disclosed in US 4,274,583 to Hunter teaching a complicated moisture and pressure responsive irrigation system, in US 5,596,839 to Ellis-El disclosing self-feeding planter, and in US 6,198,398 invented by Velasquez teaching a soil moisture monitoring device which emits a variable frequency LED advising of soil moisture/dryness levels.

BRIEF SUMMARY OF THE INVENTION

This invention is directed to an apparatus for monitoring the moisture of soil supporting a plant. The apparatus includes a housing having an evacuatable air chamber for accommodating a vacuum or at least a low pressure region therein. As used herein "vacuum" should be understood to include at least a partial vacuum and "low pressure" should be understood to mean sub-atmospheric pressure. A porous sensor is attached to the housing in communication with the air chamber. The sensor mechanism is introducible into the soil supporting the plant having a porosity that attracts soil moisture to the element and which permits the attracted soil moisture to be removed from the sensor by the soil when soil dryness increases moisture tension above a predetermined level. With the chamber in an evacuated or low pressure condition and with moisture accumulated in the pores of a sensor, the pores of the sensor are plugged to maintain the vacuum or low pressure condition in the chamber. When the soil moisture tension exceeds the predetermined level, the water is drawn from the pores of the sensor by the soil to unplug the pores. This causes air to enter the chamber through the porous sensor and eliminate the vacuum or low pressure region. An indication is thereby provided that the soil is dry and that the plant requires watering.

In one embodiment, the housing includes a resiliently collapsible bulb that is attached directly and communicably to the sensor such that the sensor communicates with the chamber, which is formed within the bulb. An indicator element may be carried by the bulb extending from an upper end thereof. The sensor may be attached to an opposite lower end of the bulb. The bulb may carry a check valve, which may comprise a slit in the bulb. More specifically, the bulb may carry a generally annular rib that circumferentially surrounds the bulb. The slit may be formed in the rib to define the check valve.

Initially, the chamber is evacuated by depressing the indicator element downwardly such that the upper end of the bulb deflects into the chamber. Air is evacuated through the check valve and/or through the porous sensor carried by the bulb. The sensor may then be introduced into the soil. When the soil contains adequate moisture to provide water to the plant, the sensor pulls water from the soil into the pores of the sensor by capillary action. This water plugs the pores and holds the chamber of the bulb in a pressure reduced, evacuated condition. The check valve remains closed so that air does not enter the chamber through the wall of the bulb. Eventually, the soil dries sufficiently until the soil moisture tension of the soil pulls the moisture held in the sensor out of the pores. This opens the pores and allows air to enter the bulb. The upper end of the bulb expands upwardly and the indicator projects from the bulb to indicate that the plant needs to be water.

In an alternative embodiment, the housing comprises a bellows shaped element that is seated in a support structure. The support structure may carry a disc shaped porous sensor that communicates with the chamber formed within the bellows. A check valve may be formed proximate the upper end of the bellows.

In another version of this invention, water is also dispensed automatically into the soil as needed. The housing may include an elongated tube that is at least partially filled with a supply of water. The interior of the tube defines the chamber. The tube may include a base at its lower end and a removable cap at its upper end for sealably closing the chamber such that a vacuum or low pressure region is created therein.

The porous sensor may be communicably connected through the base to an elongated conduit that extends through the chamber to a location proximate the cap and above the water within the tube. A dispensing conduit may be communicably connected to the chamber, typically through the base. When the pores of the sensor are plugged with water, as previously described, the low pressure region within the sealed chamber holds the water within the chamber and water is not dispensed through the dispensing conduit. However, when the soil is sufficiently dry such that the predetermined soil moisture tension is exceeded, the water within the pores is pulled out of the pores by the soil. This opens the pores and allows air to enter the low pressure region of the chamber through the sensor and the elongate conduit. This breaks the suction or vacuum within the chamber so that water is dispensed through the dispensing conduit. This occurs until the soil is moistened sufficiently that the soil moisture tension drops below the predetermined level and moisture is again pulled into the pores to plug the sensor. At that point, suction is again drawn within the chamber and no further water is dispensed.

The tubular housing may be transparent so that the water supply can be conveniently monitored. One or more supporting spikes or stakes may be carried by the housing to mount the apparatus in the soil with the sensor inserting into the soil.

Still another version of this invention features a float element that is mounted in the housing between upper and lower support members. Each of the upper and lower support members carries magnetic means; each end of the float element carries complementary magnetic means that releasably adhere to the magnetic means carried by the upper and lower support members respectively. An evacuatable air chamber portion is formed between the upper end of the float element and the upper support member. A water accumulating chamber is formed between the upper end of the float element and the lower support member. The porous sensor is connected communicably through the upper support member to the air chamber portion. The water chamber is connected to a dispensing conduit that extends through the lower support member. The water chamber portion is also connected through a valve to a water supply inlet.

When the soil is sufficiently moist and the pores of the sensor are plugged, a suction or vacuum is drawn on the air chamber, which prevents water within the water chamber from leaking out through the water dispensing conduit. The float element is supported by the water in the chamber and the upper magnetic means carried by the upper support member engages the magnetic means carried by the upper support member. This holds the float element in an elevated condition within the chamber and the float, in turn, holds the valve closed. As the pores of the sensor dry, air is introduced into the air chamber portion. This releases the low pressure of suction, which allows water to be dispensed through the dispensing conduit. The water level within the water chamber portion thereby drops. The weight of the float eventually causes the upper float magnetic means to disengage from the magnetic means of the upper support member. Eventually, the lower magnetic means of the float element engages the magnetic means of the lower support element such that the float element snaps down and again opens the valve so that water is introduced through the inlet conduit into the water chamber. A snap action is necessary to prevent leakage during a slow transition of the float and may also be provided within the scope of this invention by an over-center type spring. The water may be supplied from a gravity container, a regulated pressure source (e.g. the utility or municipality water source) or a pump. In this manner, water is replenished as required and the soil moisture is maintained automatically at a desired level. The upper support member may carry a check valve for evacuating air from the chamber as the water level and the level of the float element rise. An elongated conduit may communicably interconnect the sensor and the chamber. One or more elongated support members may secure the housing to the soil or be bent and shaped to hold the assembly on the rim of the pot or planter.

It is therefore an object of the present invention to provide an apparatus for monitoring soil moisture, which provides a prompt, reliable indication that the soil supporting a plant is dry and that the plant needs to be watered.

It is a further object of this invention to provide an improved apparatus for conveniently and automatically monitoring the moisture content of soil supporting a plant so that the plant may be properly watered.

It is a further object of this invention to provide an apparatus for monitoring soil moisture, which exhibits an improved, simplified and low-cost construction as well as an extremely reliable operation over repeated watering cycles.

It is a further object of this invention to provide an apparatus for monitoring soil moisture that accurately delivers an appropriate amount of water to a plant each time the plant requires such water.

It is a further object of this invention to provide an apparatus for monitoring soil moisture that delivers controlled amounts of water to the soil supporting a plant so that the plant is neither underwatered nor overwatered and so that proper plant growth is maintained.

It is a further object of this invention to provide an apparatus for monitoring soil moisture that significantly reduces the time, tedium and guesswork normally associated with monitoring the water needs of a plant.

It is a further object of this invention to provide an apparatus that is particularly effective for monitoring the soil moisture of potted planters and indoor plants.

In accordance with these and other objects which will become apparent hereinafter, the instant invention will now be described with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Figure 1 is an elevational front view of an apparatus for monitoring soil moisture according to this invention.

Figure 2 is a top plan view of the apparatus of FIGURE 1.

Figure 3 is a cross sectional view in the direction of arrows 3-3 in Figure 2.

Figure 4 is a view of Figure 3 with the bulb in an actuated condition indicating that water is not required.

Figure 5 is an elevational side view of an alternative monitoring apparatus.

Figure 6 is a cross sectional view of the apparatus of Figure 5 in an extended condition indicating that water is required.

Figure 7 is a perspective view of an alternative monitoring apparatus, which automatically waters a plant when soil moisture conditions warrant.

Figure 8 is an exploded perspective view of Figure 7.

Figure 9 is a perspective view of a sensor for holding moisture from soil and allowing passage of air therethrough when sufficiently dried.

Figure 10 is a side elevation view of Figure 9.

Figure 11 is a view of area 11 in Figure 10.

Figure 12 is atop plan view of Figure 9.

Figure 13 is a perspective view of another plant watering apparatus in accordance with the present invention.

Figure 13A shows an alternate embodiment of the apparatus of Figure 13.

Figure 13B shows an alternate embodiment of the apparatus of Figure 13.

Figure 14 is a front elevation view of Figure 13.

Figure 15 is a side elevation view of Figure 13.

Figure 16 is a section view in the direction of arrows 16-16 in Figure 15.

Figure 17 is a section view in the direction of arrows 17-17 in Figure 14.

Figure 18 is a side elevation view of still another soil moisture monitoring apparatus in accordance with this invention which supplies water as required to plants.

Figure 19 is a front elevation view of Figure 18.

Figure 20 is an exploded view of Figure 18.

Figure 21 is a section view in the direction of arrows 21-21 in Figure 18.

Figure 22 is a section view in the direction of arrows 22-22 in Figure 19.

Figure 23 is an enlarged view of area 23 of Figure 24.

Figure 24 is an enlarged view of area 24 of Figure 22.

Figure 25 is an enlarged view of area 25 in Figure 22.

Figure 26 is a section view in the direction of arrows 26-26 in Figure 28.

Figure 27 is a section view in the direction of arrows 27-27 in Figure 29.

Figure 28 is a front elevation view of still another and preferred embodiment of a plant watering device in accordance with this invention.

Figure 29 is a side elevation view of Figure 28.

Figure 30 is a perspective view of Figure 28.

Figure 31 is an enlarged view of area 31 in Figure 26.

Figure 32 is a pictorial view of an alternate and preferred embodiment of the invention shown in Figures 26 to 31 disposed within a potted plant.

Figure 33 is a schematic view of a siphon overflow surge monitoring and watering system.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, and firstly to Figures 1 to 4, a soil moisture monitoring apparatus **10** for monitoring the watering needs of potted plants and various other types of plants is there shown. Apparatus **10** comprises a housing **12** in the form of a flexibly resilient dome or bulb. This bulb **12** may be composed of assorted types of resilient plastic and also may comprise rubber or other natural materials. Typically, bulb **12** is injection molded. A suction chamber 14, which is at least partially evacuatable of air, is formed within bulb **12** as best seen in Figures 3 and 4. An annular rib **16** is formed circumferentially and unitarily about the bulb **12**. A check valve in the form of a razor slit **18** is formed in the rib and in communication with interior chamber **14**. An elongated indicator member **20** is carried by the upper end of bulb **12** and has a readily recognizable color such as red. Indicator element **20** may comprise a tubular element that is attached to the upper end of the bulb **12** or alternatively may be formed integrally with the bulb.

Still referring to Figures **1** to 4, a porous sensor **24** comprising a tubular ceramic member is attached to the lower end of bulb **12**. In particular, ceramic sensor **24** includes a central opening **26** that communicates with the interior chamber **14** of bulb **12**. Sensor **24** is received by the lower end of the bulb as best shown in Figures 3 and 4. The lower end of sensor **24** carries a pointed sensor tip **28**, which may be composed of a suitable plastic.

In operation, apparatus **10** is planted in the soil adjacent to the plant or plants whose water moisture condition is being monitored. In particular, pointed tip **28** carried by sensor **24** is inserted into the soil **S1** in the manner shown in Figure 3. If necessary, the soil is watered (in some cases, the soil may already be sufficiently moist to meet the plants needs). The force of adhesion between the water and the soil is known as "soil moisture tension". That force must be overcome for the plant to draw water out of the soil. As the plant requires water, its roots extract water from the soil by pulling it into the plant body by capillary action. It is known that a plant's roots can exert forces of **20** psig to draw water from the soil into the plant. As with the roots and the soil itself, the sensor **24** attracts moisture into its pores through capillary action. The pores are selected to correspond to a soil moisture tension of about 1 to 3 psig. At this level, the sensor **24** will hold water in its pores only when there is sufficient water in the soil for the roots of the plant to obtain water from the soil. When the soil is sufficiently dry that the roots encounter difficulty in extracting moisture from the soil, the soil moisture tension will typically exceed 3 psig and will therefore pull the moisture out of the pores of the sensor **24**. This unplugs the pores of sensor **24** and allows air to enter through the pores into a central air passage **26** and suction chamber **14**. As a result, apparatus **10** maintains the fully pressurized (i.e. atmospheric pressure) condition shown in Figure 3.

Apparatus **10** is actuated for use in a manner shown in Figure 4. With the sensor **24** inserted into soil S, cap **20** is pushed downwardly in the direction of the arrow to deflect the upper end of the bulb **12**. Air within bulb **12** is at least partially evacuated through check valve **18** to create a vacuum, low pressure or suction region within chamber **14**. When the soil is sufficiently moist to satisfy the needs of the plant, there is adequate moisture within the soil to be attracted by the capillary action of sensor **24** (e.g. the soil moisture tension is below 3 psig). As a result, the pores of the sensor remain plugged keeping air from passing therethrough from the soil into the air passage **26** and bulb **12** is held in the collapsed, low pressure condition. Check valve **18** remains closed and does not permit air to be pulled in through the slit.

Eventually, when the soil dries due to water being drawn into the roots of the plant or through evaporation, the pores of sensor **24** then also dry as the soil moisture tension exceeds 3 psig and moisture is pulled from the sensor **24** into the surrounding soil. Eventually, the pores unplug in the manner previously described and air enters the interior chamber **14**. This increases the pressure in the bulb **12** to atmospheric pressure and causes the bulb **12** to reinflate such that the indicator cap **20** is projected upwardly in the manner shown in Figure 3. This signals that the plant requires watering. After watering is performed, indicator **20** is pushed downwardly to return the apparatus to the condition shown in Figure 4. Once again, the plugged pores of the sensor hold the bulb collapsed until the pores dry. This cycle may be repeated for as long as required so that timely indications are given when the plant requires watering.

An alternative indicator **30** is shown in Figures 6 and 7. Indicator **30** comprises a plastic or metal support stand **36** and a cup shaped body **32**, the stand **36** that depends from body **32**. Body **32** nestably supports a bellows **38**, which includes an interior vacuum chamber **39**. The upper end of the bellows carries a duckbilled check valve **40**.

A disk-shaped, porous sensor **42** is mounted on stake **36**. A channel **44** communicably connects sensor **42** with an interior passageway **34** of stake **36**. This passageway **34** is, in turn, connected to interior chamber **39** of bellows **38**. Sensor **42** comprises a porous ceramic that attracts moisture through capillary action in a manner similar to the previously described embodiment. Once again, the pore size of element **42** is selected for a particularly desired soil condition. For dry or arid conditions, relatively small pore sizes are desirable; for moist or wet conditions, larger pore sizes are preferable.

In operation, stake **36** of apparatus **30** is inserted a desired depth into the soil **S2**. If the moisture level of soil is sufficiently high (which depends upon the size of the pores), the sensor **42** draws excess moisture from the soil into its pores until the sensor **42** is plugged. The user depresses or cocks the bellows into the nesting body. Air from chamber **39** is expelled through valve **40**. Because the pores of the sensor are plugged, the bellows are maintained in the contracted or cocked condition. Eventually, as the soil dries, the soil moisture tension exceeds the level to which the sensor **42** is set (typically approximately 3 psig) and the soil then pulls the trapped moisture out of the pores of the sensor **42**. Air is consequently transmitted through the sensor and into chamber **39**. The bellows **38** "pops" or expands upwardly to indicate that the plant requires additionally watering.

There is shown in Figures 7 and 8 a monitoring apparatus **50** that also waters the plant and its supporting soil as required. Apparatus **50** includes an elongated tubular housing **52** that is sealably enclosed by a lower base **54** and an upper cap **56**. A porous ceramic sensor **58**, analogous to the sensors previously described herein, is mounted to and depends from base **54**. More particularly, sensor **58** is communicably connected to a channel **60**, which extends through base **54**. A connector **62** is communicably connected to channel **60** and extends upwardly from the interior surface of the base. An elongated tubular conduit **64** is communicably attached to connector inlet **62** and thereby sensor **58**. Conduit **64** extends upwardly through interior chamber **69** of tubular housing **52**. A second channel **67** also extends through base **54**. An elongated dispensing hose (not shown) is attached to channel **70** and thereby communicates with the interior chamber **69**. A pair of support stands **74** and **76** are attached to respective receptacles **78** and **80** formed in the bottom of base **54**. These stands help to support apparatus **50** upright in soil **S2**.

Base **54** is plugged into or otherwise sealably attached to the lower end of tubular housing **52**. Cap **56** is sealably and releasably engaged with tie opposite upper end of the tubular housing **52**. In particular, cap **56** includes a plug portion **80** that is received in the upper end of the tubular housing **52** and a flange portion **82** that abuts the upper end of the housing **52**. Plug includes an open interior cavity **85** and an orifice **81** that interconnects cavity **85** and the interior of chamber **69**. The upper end of conduit **64** is open and terminates within cavity **85**. Plug portion **80** has a relatively snug fit within the housing **52** such that the interior of this chamber **69** is sealed and effectively forms a vacuum or low pressure region when the cap **56** is attached. This supports a column of water to be supported within the closed tube as long as pores of sensor **58** remain plugged with moisture.

Apparatus **50** is deployed upright in soil. Stands **68** and sensor **58** are inserted into the soil. The dispensing hose (not shown) is attached to channel **70** and positioned proximate a plant (not shown) to provide a desired degree of watering. Cap **82** is opened and water is introduced into chamber **69**. When soil contains adequate moisture to satisfy the plant, sensor **58** attracts sufficient moisture from the soil to plug its pores in the manner previously described. Accordingly, while cap **82** remains engaged with housing **52**, a low-pressure region or vacuum is effectively formed within the upper end of chamber **69** above water. This supports the column of water within housing **52** and prevents water from being dispensed through hose **72**.

Eventually, when soil dries sufficiently such that the soil attracts water out of the pores of ceramic sensor **58**, air will pass through the sensor **58** and conduit **64** and then into the top of chamber **69** to allow water to be dispensed from channel **69** and the dispensing base. Once again, the rate of dissipation of water from the sensor **58** may be controlled by varying the size of the ceramic pores. When the water dissipates from the pores, air enters the ceramic sensor **58** and travels through channel **60**, inlet **62** and conduit **64** into cavity **85** of plug **80**. This effectively breaks the vacuum within the upper end of chamber **69**. Water is thereby allowed to drain from chamber **69** through channel **60** and dispensing hose. Excess air pressure escapes from check part **83**.

Eventually, the moisture of soil increases sufficiently such that the soil is adequately moistened and ceramic sensor **58** again attracts excess moisture into its pores through capillary action. This causes the pores to replug such that a vacuum is again created within the chamber to halt the flow of water through dispensing hose. In the foregoing manner, water is added to the soil automatically whenever the apparatus senses that additional water is required. Periodically, the tubular housing **52** may be replenished with water by simply opening cap **82** and adding additional fresh water into chamber **69**.

Referring now to Figures 9 to 12, the preferred embodiment of the sensor is there shown generally at numeral **70** and is formed of a permeable ceramic material that "wets", i.e. has molecular attraction to water. As shown, the preferred configuration is in the form of a disc having a locator step **74** and a tapered exposed outer edge **78** which extends from the circular perimeter margin **76** to the generally flat front face **72**.

The sensor **70** has openings defining the porosity thereof between contacting structural fragments that are limited to a distance of separation such that the molecular attraction of water bridges the openings and blocks air passages through the sensor **70**. The preferred porosity that promotes healthy growth for most house plants was set to hold water in the structure until a pressure of 1.5 psig ± 0.7 psig (as determined by bubble testing) is applied across the thickness of the sensor **70**. Water cannot be drawn through the sensor **70** because the head of the reservoir that acts on the sensor **70** is less than the set pressure for water to be pulled or pushed through the sensor **70**. At 1.5 psig which corresponds to an equivalent value of soil moisture tension, a plant's roots need water. Testing and growth evaluation on the various plants was used to establish this negative pressure value. Other values outside this range are suitable. However, this setting provided the most desirable for producing the healthiest plants.

The sensor **70** functions as an "on/off" valve for incoming air. When the roots draw water out of the soil, moisture tension increases. Soil moisture tension is a measure of the negative pressure or suction that must be applied by the roots to acquire water out of the soil. Some plants are claimed to be able to pull up to two atmospheres or about 30 psig vacuum to draw water from the soil thereinto. When the level of soil moisture tension reaches 1.5 psig, water is extracted from the sensor **70** that is in surface contact with the soil. That is to say that the sensor **70** may be considered to be contiguous with the porous soil. When sufficient water is removed by soil moisture tension from sensor **70**, an open air path through the sensor **70** will exist. At this point, atmospheric pressure allows air to penetrate the soil and pass through the sensor **70** to vent the sealed reservoir chamber of the apparatus in which the sensor **70** is operably placed. This allows water to flow out of the outlet tube from the water filled chamber and into the soil. The water migrates by capillary action through the soil and back to the sensor **70** and, when the moisture in the sensor **70** is sufficiently penetrated into the sensor **70**, airflow is interrupted and water flow from the apparatus ceases. Thus the sensor **70** repeats this cycle of returning the air flow on and off and thereby controls the water flow from the apparatus and the plant is watered according to its needs with healthy timing.

This preferred embodiment of the sensor **70** is purchased from Homexx International of Corona, California. The ceramic material used is a proprietary ceramic designated G-2 which may be modified with a 10% walnut flower having a mesh size of approximately 325 and available under the trademark designation WF-5 from MS Abrasive Cleaning Equipment, Inc. of Yomalinda, CA. The material is marbled in a tumbler and loaded in a die where it is compressed approximately 25% before being fired at a temperature of approximately 1600° - 1700°F. Preferably, a cereal binder may be added to the G-2 ceramic clay in an amount generally equal to 4% by weight of the total G-2 clay powder and used as a binder. This binder (available from Porter Warner #CB-201 4%) has a 200 mesh size and results in a porosity of the sensor of approximately 15 to 20 microns after being fired.

The total surface area is also established within a fairly narrow preferred range, the sensor having a minimum active area of about 0.1 in^2 or .25cm^2. The thickness of the active area is preferably held between about 0.12" and 0.2" or approximately 3 to 5mm. Note that although any other shape, e.g. including a tubular configuration. The sensor **70** must be sealed or glued around the step area **74** into a mating cavity formed into the lower below ground stake portion of a watering apparatus which will be described more fully herebelow.

Referring now to Figures 13 to 17 and 13A and 13B, another embodiment of the invention which both monitors soil moisture level and limitedly waters the soil **S3** shown at numeral **80**. In this embodiment **80**, an elongated tubular chamber **82** supports an upper cap **84** having a funnel **86** disposed at the upper end of the tubular chamber **82**. Chamber **82** is preferably transparent so that the buoyant sealing ball **98** is viewable therethrough.

A funnel-shaped cap **84** is formed of opaque material and includes a funnel **86** for filling the chamber **82** through the base opening **106** which includes obstruction means for preventing the sealing ball **98** from floating up and out of the apparatus.

A stake **88** carrying a porous sensor **70** as previously described is connected to the lower end of the chamber **82** and includes an air passageway **94** from cavity **92**, the upper end of passageway **94** being sealed by sealing ball **98** when in the downward position shown in solid in the drawings. The cycle of this apparatus begins by filling the chamber **82** with water as may typically occur during watering of the soil **S3**. When the soil is saturated or water-laden, water will be absorbed into the porous structure of the sensor **70**. As the soil moisture tension increases during drying, water is pulled out from the sensor **70** as well as the surrounding soil. During this period, the sealing ball **98** as best seen in Figure 16 is floating within the upper cap**84** and is not visible. However, a small amount of water will trickle outwardly through the sensor **70** into the soil to accomplish a distribution of a small amount of water into the immediately surrounding soil. When the water level in the chamber **82** drops sufficiently, a plant caretaker will again see the sealing ball **98** to be alerted that it is time to water the plant by hand and to simultaneously refill the chamber **82** through funnel **86**.

Referring particularly to Figure 13A and 13B, two forms of lenses at **102** and **104** are provided to enhance the visibility of the sealing ball **98** when it gets to the bottom of its displacement and water within the chamber **82** is totally drained therefrom. Lens **102** magnifies the sealing ball image viewable through the transparent chamber **82** while lens **84** spreads out the color of the sealing ball **98** making it easier to view from above the soil surface.

Figures 18 to 25 depict still another version of the monitoring and watering apparatus shown generally at numeral **110** which again includes a tubular or cylindrical housing **112**. It should be noted that the shape of the housing in any of the embodiments of this invention may be varied within the scope of the invention. Housing **112** carries a molded upper support member **114** and a lower support member **116** that is fixedly attached to the cylindrical housing. A pair of lower support stakes **120** are carried by lower support **116** for supporting apparatus **110** in soil **S4**.

The interior construction of apparatus **110** is best shown in Figures 21 to 25. In particular, lower support **116** carries a dispensing outlet **124**. A water inlet fitting **126** is connected to a lower end of lower support **116**. The inlet fitting is connected to a water supply such as a gravity feed container, a regulated pressure source or a pump (not shown). An inlet valve assembly **128** permits water from this water source to be introduced through fitting **126** into the interior chamber **130** of cylindrical housing **112** as required. Valve assembly **128** includes an inlet ball valve **132** and a return spring **134** best seen in Figure 24 that releasably hold the ball valve **132** in a closed condition sealed against lower support **116** to prevent water from being introduced through the lower support into the housing chamber **130**. The return spring is seated upon inlet fitting **126**. Upper support element **114** includes a sensor inlet fitting **140** and a check valve disc **182**. The sensor inlet fitting **140** is connected through an elongated flexible tube **144** to a ceramic sensor **70** sealingly attached to a stake **150** in a manner previously described herein whereby the sensor **70** is in airtight communication with the interior of the tube **144** and the upper portion **180** of chamber **130**.

A float element **152** is mounted in chamber **130** between upper and lower support members **114** and **116**. Float element **152** includes a cylindrical body **154** and a lower insert portion **158** that carries ball valve **132**. The upper end of float element **152** carries an upper ring-shaped magnet **160**, which is selectively interengagable with complementary upper ring-shaped magnet **162** carried by upper support **114**. Likewise, the insert **158** of float element **152** and lower support **116** include respective, a complementary set of lower magnets **170** and **172**. The corresponding upper and lower magnet pairs permit the float element **152** to be held in provisional, snap-action attachment to either the upper support or the lower support during operation of the apparatus **110** as shown by arrow **B**.

Apparatus **110** is connected to a relatively low pressure water supply (not shown) at inlet fitting **126** to introduce water into the apparatus **110** in the direction of arrow **D**. When chamber **130** is empty, or nearly empty, and float **152** is in a lowered position within chamber **130**, the lower pairs of magnets **170** and

172 attract and interengage one another to hold the float in the lower position. In this position, the ball valve is open (i.e. unseated from the lower support) by shaft **174** attached to lower support member **116** and water is introduced at low pressure through the open valve shown in solid lines in Figure 23 into the chamber **130** through longitudinal passage **174** and in the direction of arrows **E** in Figure 24. If excessive water pressure is introduced, this will force the ball valve **132** to close. As a result, a "failsafe" operation is achieved. This provides regulated, low pressure water to chamber **130.**

Apparatus **110** is mounted in the soil in a manner similar to the previously described embodiments. Particularly, supports **120** are inserted into the soil **54** proximate the plant to be monitored and sensor **70** sealingly attached to spike **150** is likewise inserted into the soil at a desired placement. Initially, the chamber **130** is filled sufficiently with water to raise the level of float **152** until the upper magnet sets **160** and **162** operably interengage and hold the float in an elevated condition. If sufficient moisture is contained in the soil to satisfy the plant, the pores of sensor **70** absorb water and are plugged. This creates at least a partial vacuum within the region **180** of chamber **130** above the water level. As a result, water is not allowed to drip from dispensing outlet **124.** The plant thereby utilizes the water already in the soil.

Gradually, the plant dissipates the available water from the soil **S4** and the soil dries sufficiently such that it pulls the water from the pores of sensor **70.** This unplugs the pores and allows air to enter chamber region **180** in the direction of arrow **A.** The partial vacuum within the chamber **130** is broken and, as a result, water is dispensed from the apparatus **110** through dispensing outlet **124** in the direction of arrow **C** into soil **S4** and the water level within chamber **130** gradually drops. Eventually, the weight of float **152** causes a break of magnetic contact with upper support **114** and the float **152** drops within housing **112** until the lower end of the float **152** approaches lower support member **116**. Lower magnets **170** and **172** eventually attract one another and the float **152** is pulled by snap action into engagement with the lower support member **116**. This urges the ball valve **132** to open so that low pressure water is again introduced into the chamber **130**. The water level rises and the buoyancy of the water thereby returns the float **152** to its raised condition where it magnetically interengages the upper support **114**. At that point, the ball valve is closed so that no further water is added. At about the same time, sufficient water should be dispensed through outlet **124** so that the soil is sufficiently moistened and the pores of sensor **70** become replugged. As a result, a vacuum is effectively formed and the dispensing of water is halted. Apparatus **110** may continuously cycle in the foregoing manner so that water is provided to the soil only as required. This embodiment **110** features the further advantage that water under low pressure is continuously provided to the apparatus. The apparatus does not require manual refilling.

The apparatus shown in Figures 26-31 generally at **190** utilizes principles analogous to the previously described embodiment and includes only 4 parts, 3 of which are preferably composed of a durable plastic. A water container **192** defines an interior cavity **208** that accommodates water and an integrally molded tube or channel **196** which communicably connects the interior **208** of container **192** with a sensor **70** as previously described. Sensor **70** is mounted within a recess **204** of a ground spike **194** molded integrally with the container **192**. By molding the channel **196**, the spike **194** and recess **204** for sensor **70** integrally with container **192**, the number of parts are reduced and the cost of the item is lowered considerably. In addition, the design provides for a very pleasant and easy to hide shape. Apparatus **190** is expected to be a transparent or translucent green color.

A water inlet **212** is provided in the top of container **192** to introduce water into the container. This water inlet **212** is selectively and sealably closed by a plug **202** that is attached by ears or a projection to the top of the container. Plug **202** may be selectively and sealably closed and opened with respect to the water inlet **212** as required.

A molded, restricted outlet **198** is formed proximate the lower end of container **192**. A restricted outlet of approximately .08 inches in diameter is formed or molded into the end of the outlet **198** to keep the water from escaping too fast while filling the container. The restriction also makes the outlet hole small enough so that air cannot travel beside the water that is flowing through the outlet **198**. Thus, only water can flow in the direction of arrow **G**.

Apparatus **190** operates in the following manner. An outlet tube **204** having an accordion-style extension **210** is attached to outlet **302**. Spike **194** is inserted into the soil **S5** in the vicinity of a plant to be watered. When there is sufficient water in the soil **S5**, sensor **70** is blocked by the water held within its porous ceramic structure so that air cannot penetrate the chamber **208** through tube **196** and water is held within chamber **208** of container **192**. No water is allowed to drain from outlet **198**. Alternatively, when the soil is dry, air enters tube **196** through cavity **206** from sensor **70** in the direction of arrow **H** and the resulting increased air pressure within the container **192** allows the water to drain through outlet **198** in the direction of arrow **G** and from outlet tube **204** into the plant area to be watered.

The foregoing apparatus operates analogously to the manner in which water is held within a drinking straw. If a person holds a finger over the end of the straw, and the straw is held upright, water cannot escape from the lower end of the straw. However, when the person's finger is removed from the upper end of the straw, this permits air to enter the straw so that the straw is drained of water.

Plug **202** is both airtight and watertight and is easily flipped up and retained beside the water filler inlet hole by either a single projection, or a pair of ears carried by the plug **202**. After filling the container **192**, the plug is ready to be inserted back into the inlet hole. An alternative construction is for the plug to be spring loaded upwardly so that it opens automatically, thereby allowing the container **192** to be filled with water. After the container **192** is filled, the plug is held briefly until the water develops enough pressure to hold it down.

Referring now to Figure 32, an alternate embodiment of the invention previously described in Figures 26 to 31 is there shown generally at numeral **190'**. This embodiment **190'** is substantially identical to embodiment **190** except that a screw cap **202'** is provided in lieu of the resilient plug **202** previously described. This embodiment **190'** is shown embedded within soil **S6** within a planting pot **R** adjacent the plant **P** to be watered.

Referring lastly to Figure 33, another embodiment of the invention is there shown generally at numeral **220** which incorporates a siphon overflow surge tank **230** coupled to and positioned below a main water chamber **222**. After the main chamber **222** has been filled with water at **226** through the sealable opening **224** and the soil **S6** within planter **T** has become sufficiently moist so as to plug the flow of air through the sensor **70** of the soil spike **250** as previously described, the water **234** contained within the siphon tank **230** is there held without leakage or distribution therefrom.

As previously described, when the sensor **70** becomes sufficiently dried of moisture to allow air to pass therethrough in the direction of arrow **Q**, the air flow continues in the direction of arrow **V** within a molded air passage **228** formed as an integral part of the water chamber **222** and siphon tank **230**. The air is drawn into the interior of main chamber **222** in the direction of arrow **W** whereupon water is allowed to be distributed into the siphon tank at **234** in the direction of arrow **J** through connecting tube **232**. When sufficient water has been distributed into the siphon tank **234** to reach a height sufficient to fill the upper portion of the siphon loop **240** of flexible conduit **236**, water will then begin to flow by siphon action in the direction of arrow **M** for distribution through all of a plurality of tubular outlets **256** in the direction of arrow **N** typically. Because the siphon action has started, virtually all of the water **234** within the siphon tank **230** will be distributed very quickly and will more uniformly and effectively saturate the soil **S6** whereupon moisture will find its way into the sensor **70** to interrupt air flow and essentially interrupt water flow from the main water chamber **222** through the connecting conduit **232** until the next dryness cycle.

Note that the siphon loop **240** is adjustable in height in the direction of arrow **C** within a molded cavity **238** of this apparatus **220** to vary the amount of water required to be contained within the siphon tank **230** before the siphon action will begin to water the soil **S6**. Thus, the siphon tank **230** will be automatically filled by water **226** from the main chamber **222** to a height controlled by the height of the top **240** of the siphon tube.

From the foregoing it may be seen that the apparatus of this invention provides for an apparatus for monitoring soil moisture and more particularly to an apparatus for sensing when the soil supporting a plant requires monitoring. While this detailed description has set forth particularly preferred embodiments of the apparatus of this invention, numerous modifications and variations of the structure of this invention, all within the scope of the invention, will readily occur to those skilled in the art. Accordingly, it is understood that this description is illustrative only of the principles of the invention and is not limitative thereof.

While the instant invention has been shown and described herein in what are conceived to be the most practical and preferred embodiments, it is recognized that departures may be made therefrom within the scope of the invention, which is therefore not to be limited to the details disclosed herein, but is to be afforded the full scope of the claims so as to embrace any and all equivalent apparatus and articles.

CLAIM OR CLAIMS

1. A soil moisture sensing and watering apparatus comprising:

an elongated soil spike;

a porous moisture sensor carried on said soil spike for blocking the passage of air therethrough when moist;

a housing carried on an upper end of said soil spike and having a sealable opening for filling said housing with water;

said moisture sensor capable of absorbing a quantity of moisture from soil;

an air passage connecting an interior surface of said moisture sensor with the interior of said housing above the water level of the housing;

a water outlet formed at a lower end of said housing for dispensing water from said housing atop the ground or soil into which said spike is inserted;

said moisture sensor having porosity sufficient to allow air from the soil to pass therethrough into said air passage and the interior of said housing when the soil moisture tension exceeds a predetermined level due to soil dryness and moisture buildup in said sensor is drawn into the soil.

2. A soil moisture sensing and watering apparatus as set forth in Claim 1 wherein:

said outlet is sized in the range of about 0.06" in diameter whereby air cannot enter into the interior of said housing when water is flowing from said outlet.

3. A soil moisture sensing and watering apparatus as set forth in Claim 1 wherein:

said soil spike carrying said moisture sensor is separate from said housing and operably connected thereto by a flexible air conduit.

4. A soil moisture sensing and watering apparatus as set forth in Claim 1 wherein:

said moisture sensor has a porosity sized to pass air therethrough in the pressure range of 1.5 psig ± 0.7 psig across the thickness of said moisture sensor.

5. A soil moisture sensing and watering apparatus as set forth in Claim 1, wherein:

said moisture sensor has a porosity size in the range of 15 to 20 microns for proper air volume passage therethrough when said moisture sensor becomes substantially dry of moisture.

6. A soil moisture sensing and watering apparatus as set forth in Claim 1, wherein:

said moisture sensor has a thickness in the range of 0.1 to 0.2in and an active surface area of at least about $0.2in^2$.

7. A soil moisture condition sensor and watering apparatus comprising:

a rigid soil spike carrying a porous moisture sensor on said spike so as to place said sensor in contact with the soil and near the root regions of a plant when said spike is inserted into the soil;

said sensing device composed of a non-organic, capillary type material having a plurality of pores of predetermined diameter wherein said sensor acts as an air valve to restrict air movement from the soil through said sensor when the soil in contact therewith has reached a predetermined high moisture level within the soil has closed said pores and to permit the passage of air from the soil through said sensor when the soil has reached a predetermined low moisture level;

a housing carried on the other end of said spike, said housing having a water inlet for controlledly receiving water from a low-pressure water supply for substantially filling said housing with water;

a water outlet on a lower end of said housing;

said sensor and said housing operably connected to maintain or release a pressure differential therebetween responsive to the predetermined soil moisture levels wherein water in said housing is maintained or released from said water outlet.

8. A soil moisture sensing and watering apparatus as set forth in Claim 7, wherein:

said outlet is sized in the range of 0.06" in diameter whereby air cannot enter into the interior of said housing when water is flowing from said outlet.

9. A soil moisture sensing and watering apparatus as set forth in Claim 7, wherein:

said soil spike carrying said moisture sensor is separate from said housing and operably connected thereto by a flexible air conduit.

10. A soil moisture sensing and watering apparatus as set forth in Claim 7, wherein:

said moisture sensor has a porosity sized to pass air therethrough in the pressure range of 1.5 psig ± 0.7 psig across the thickness of said moisture sensor.

11. A soil moisture sensing and watering apparatus as set forth in Claim 7, wherein:

said moisture sensor has a porosity size in the range of 15 to 20 microns for proper air volume passage therethrough when said moisture sensor becomes substantially dry of moisture.

12. A soil moisture sensing and watering apparatus as set forth in Claim 7, wherein:

said moisture sensor has a thickness in the range of 0.1" to 0.2"(in.) and an active surface area of at least about $0.1 in.^2$

13. A soil moisture sensing and watering apparatus as set forth in Claim 9, further comprising:

a float positioned within said housing and a water inlet flow control valve positioned at a lower end of said housing adjacent said water inlet;

said float moving to a downwardly position in said housing and opening said flow control valve when said housing is substantially empty of water;

said float moving to an upwardly position in said housing and closing said flow control valve when said housing is substantially filled with water;

magnet means positioned at each end of the interior of said housing and said float and arranged to positively hold said float in said downwardly or said upwardly position.

14. A moisture sensing and watering apparatus comprising:

a porous moisture sensor carried on a soil spike insertable into soil;

said sensor coming in contact with, and absorbing moisture from, soil into which said soil spike is inserted;

a housing for holding a quantity of water within an airtight sealed or sealable interior or chamber thereof;

said sensor blocking airflow therethrough when sufficient moisture is held within the porous structure thereof;

said sensor having porosity sufficient to allow air from the soil to pass therethrough into the interior or chamber of said housing when the soil moisture tension exceeds a predetermined level due to soil dryness and moisture buildup in said sensor is drawn into the soil thereby releasing water into the soil from said housing through a water outlet formed at a lower end of said housing;

said outlet is sized sufficiently small in diameter to prevent air from entering into the interior of said housing when water is flowing from said outlet.

15. A moisture sensing and watering apparatus as set forth in Claim 14, wherein:

said moisture sensor has a thickness in the range of 0.1 to 0.2(in.) (2.5 to 5.0mm).

16. A moisture sensing and watering apparatus as set forth in Claim 15, wherein:

said moisture sensor has a porosity sized to pass air therethrough in the pressure range of 1.5 psig ± 0.7 psig across the thickness of said moisture sensor when said sensor is water saturated or one surface thereof is submerged in water.

17. A moisture sensing and watering apparatus as set forth in Claim 16, wherein:

said moisture sensor has a porosity size in the range of 15 to 20 microns for proper air volume passage therethrough when said moisture sensor becomes substantially dry of moisture.

18. A moisture sensing and watering apparatus as set forth in Claim 14, further comprising:

a secondary siphon tank operably positioned between said chamber and said outlet;

said siphon tank receiving water from said chamber and substantially emptying said siphon tank of water from said outlet when a predetermined water level in said siphon tank is reached.

FIG 4

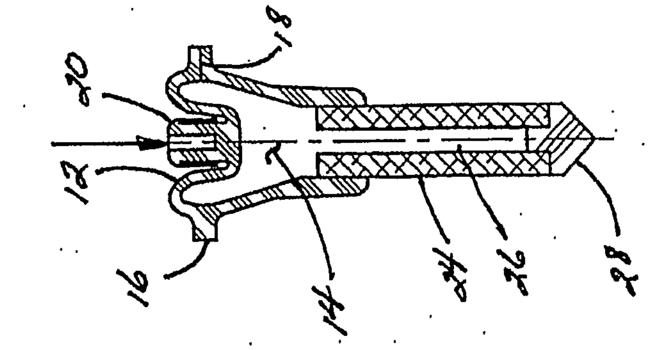


FIG 3

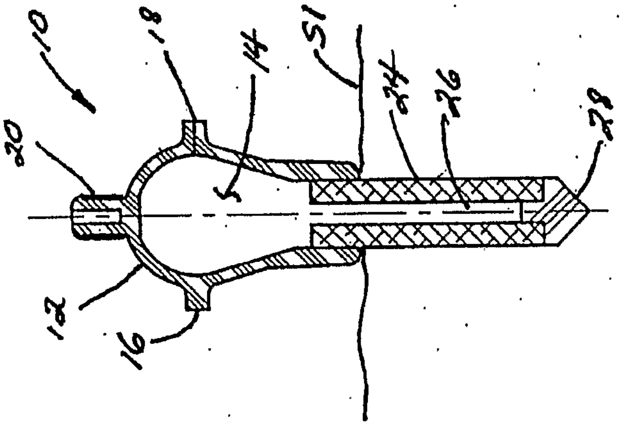


FIG 2

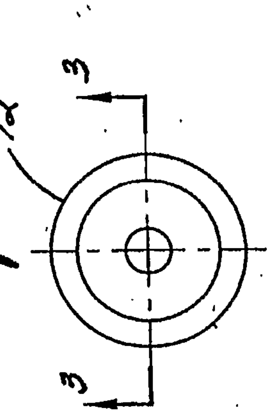


FIG 1

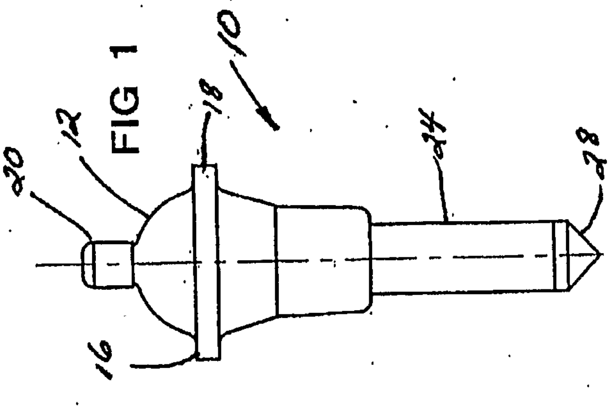


FIG 5

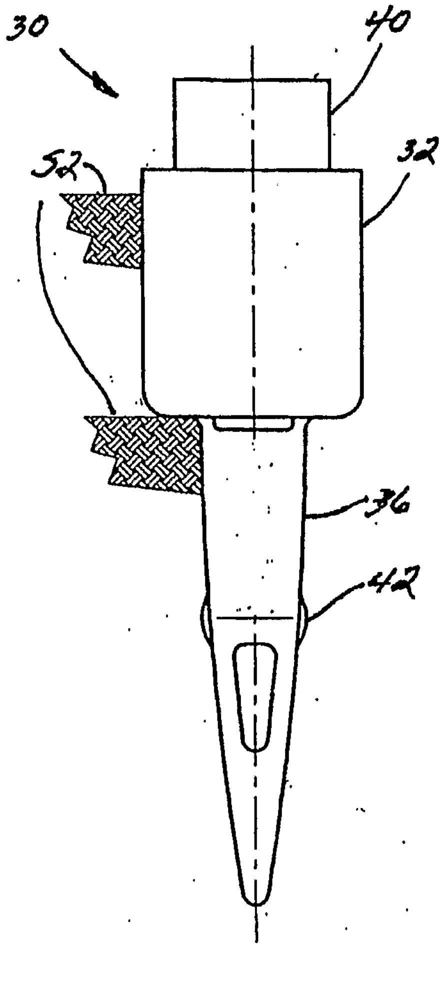
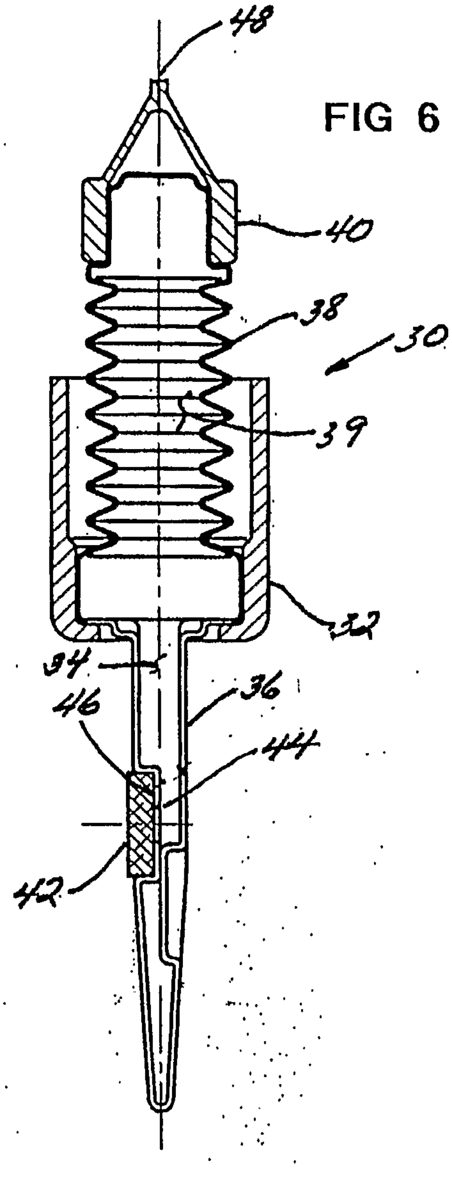


FIG 6



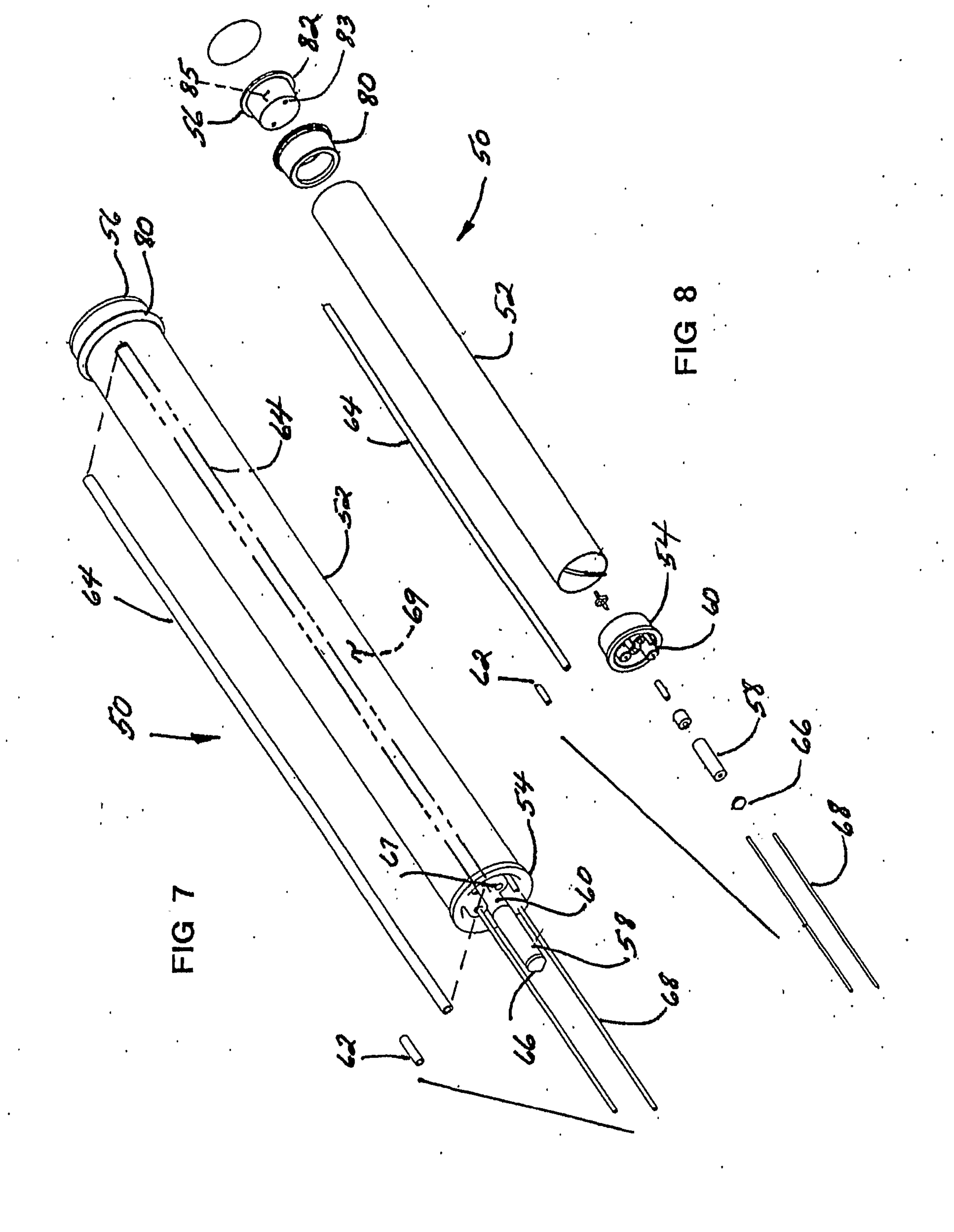


FIG 7

FIG 8

FIG 9

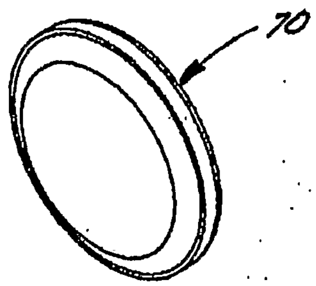


FIG 10

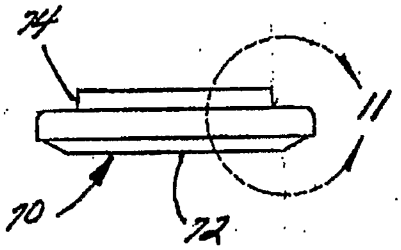


FIG 11

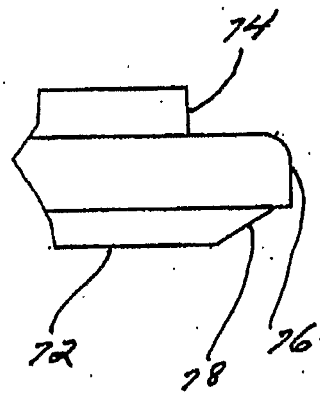
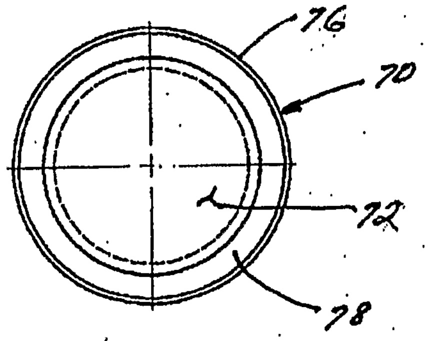


FIG 12



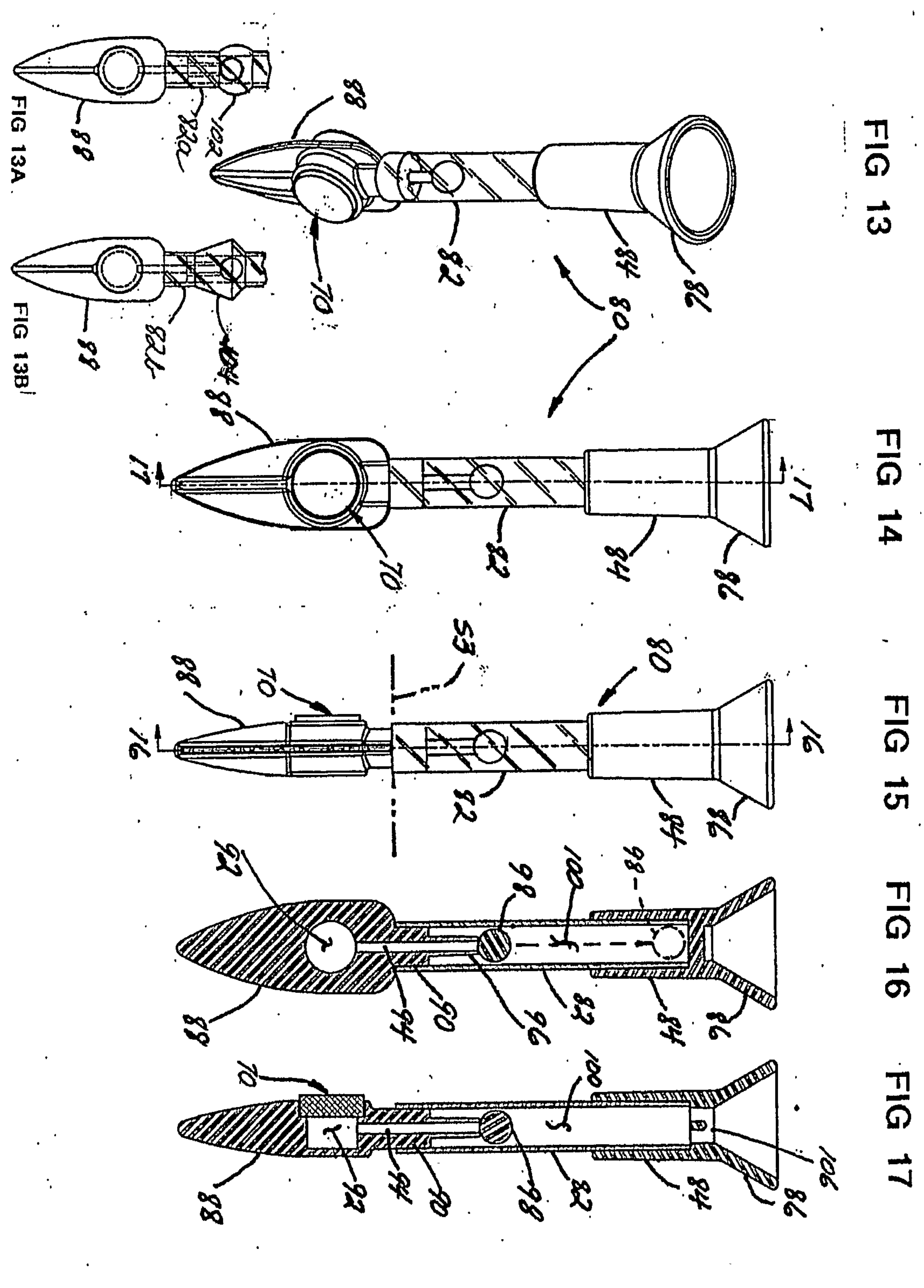


FIG 13

FIG 13A

FIG 13B

FIG 14

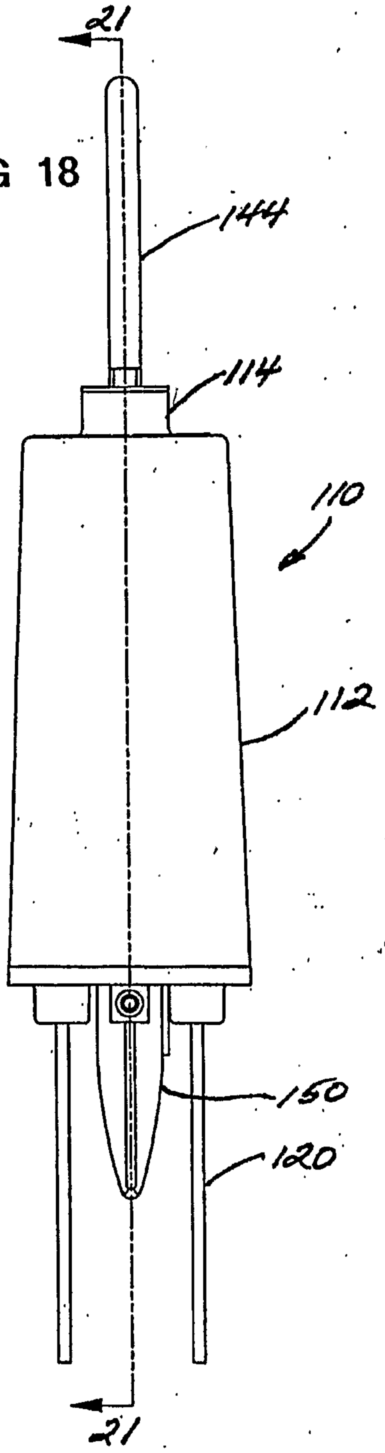
FIG 15

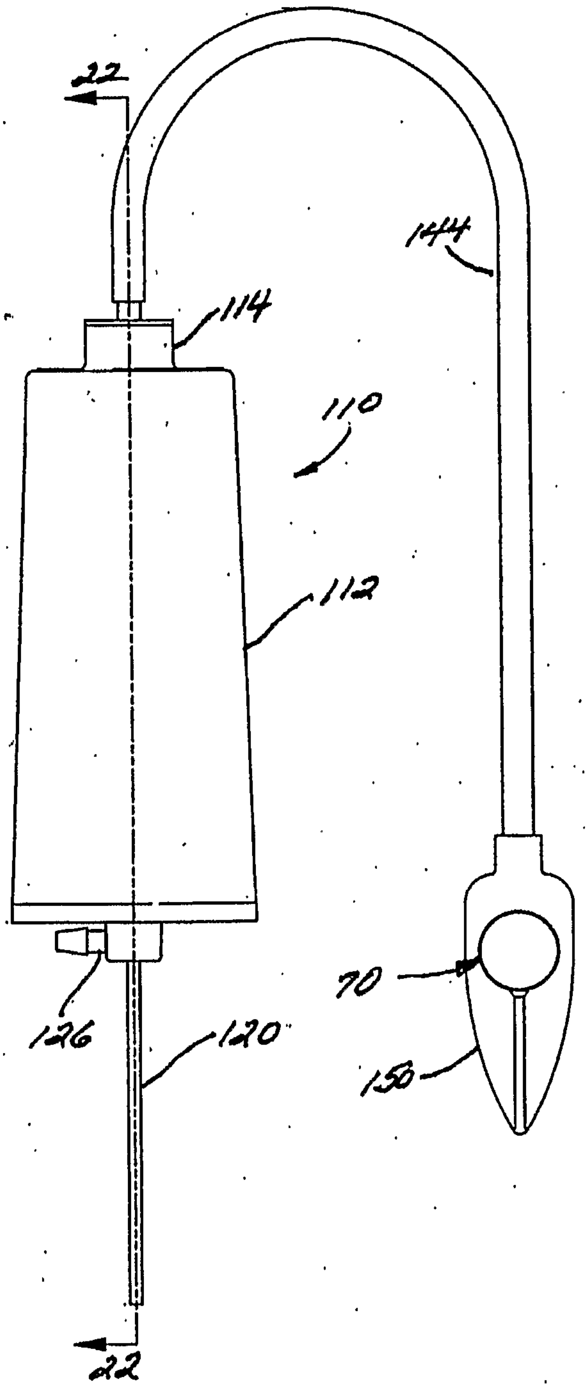
FIG 16

FIG 17

FIG 19

FIG 18





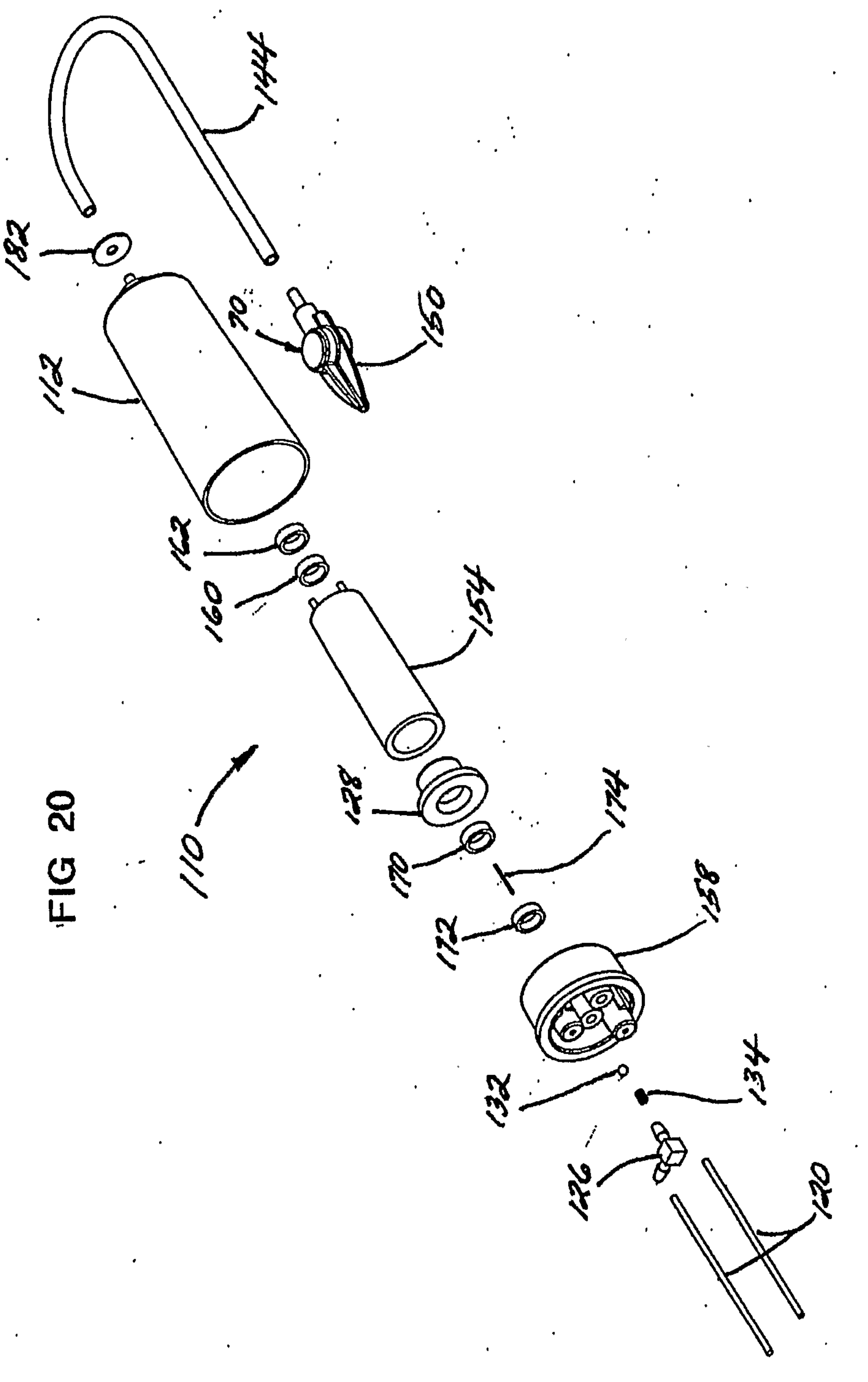

144
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FIG 20

FIG 21

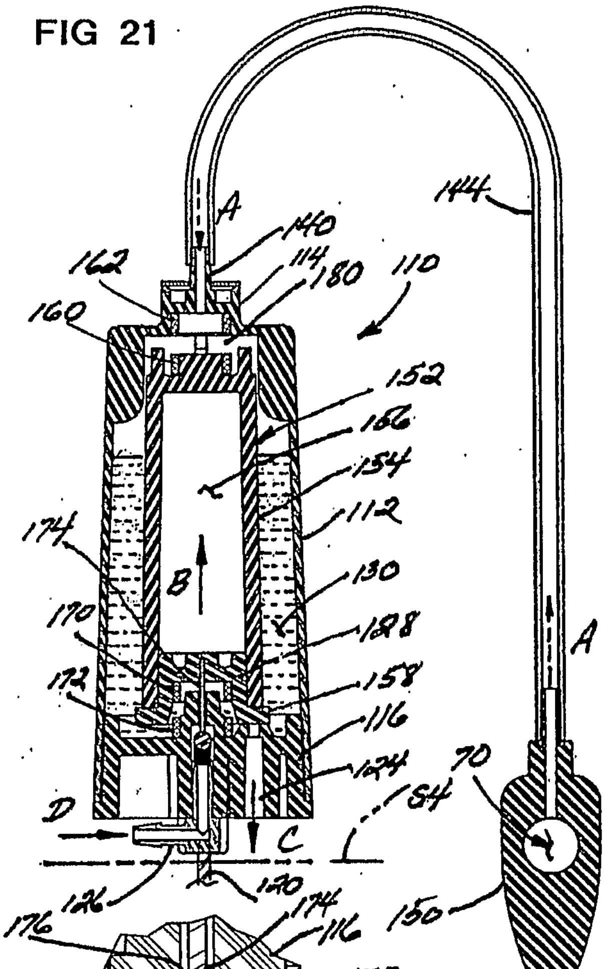
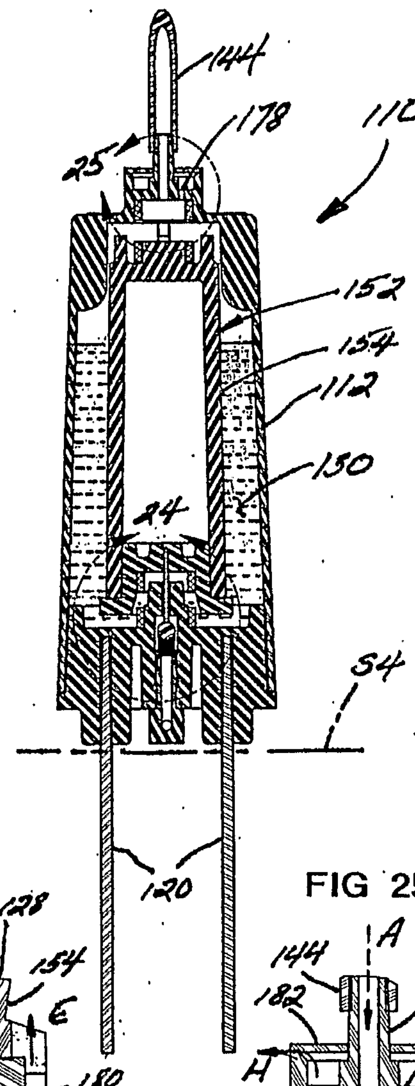


FIG 22



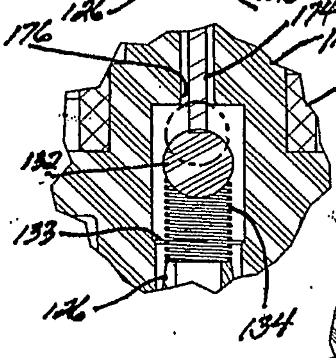


FIG 23

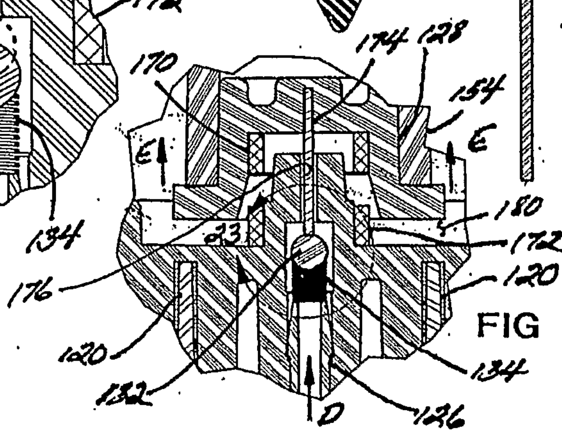
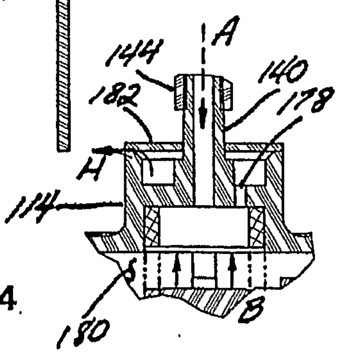


FIG 24

FIG 25



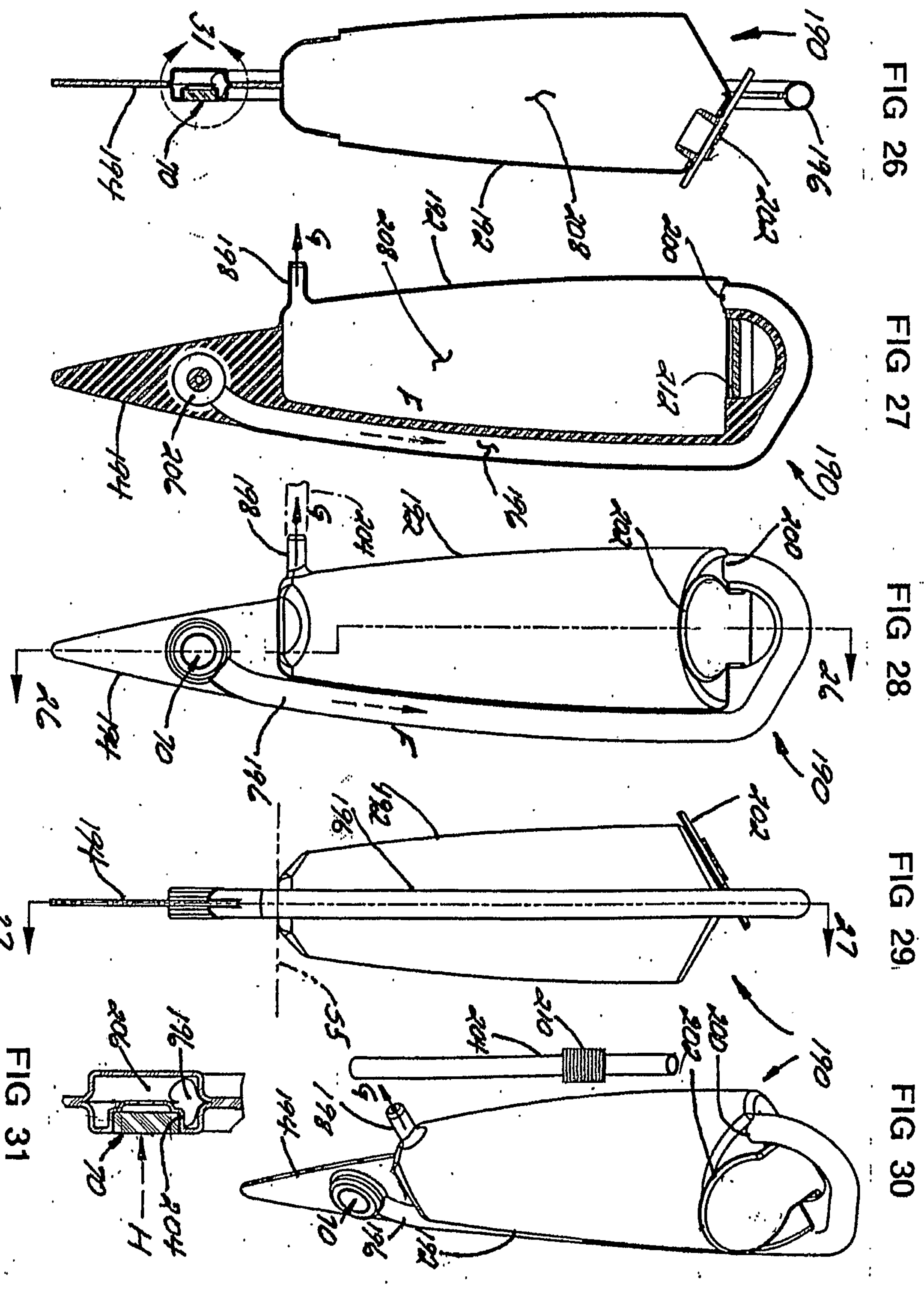


FIG 26
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FIG 28
FIG 29
FIG 30
FIG 31

FIG 32

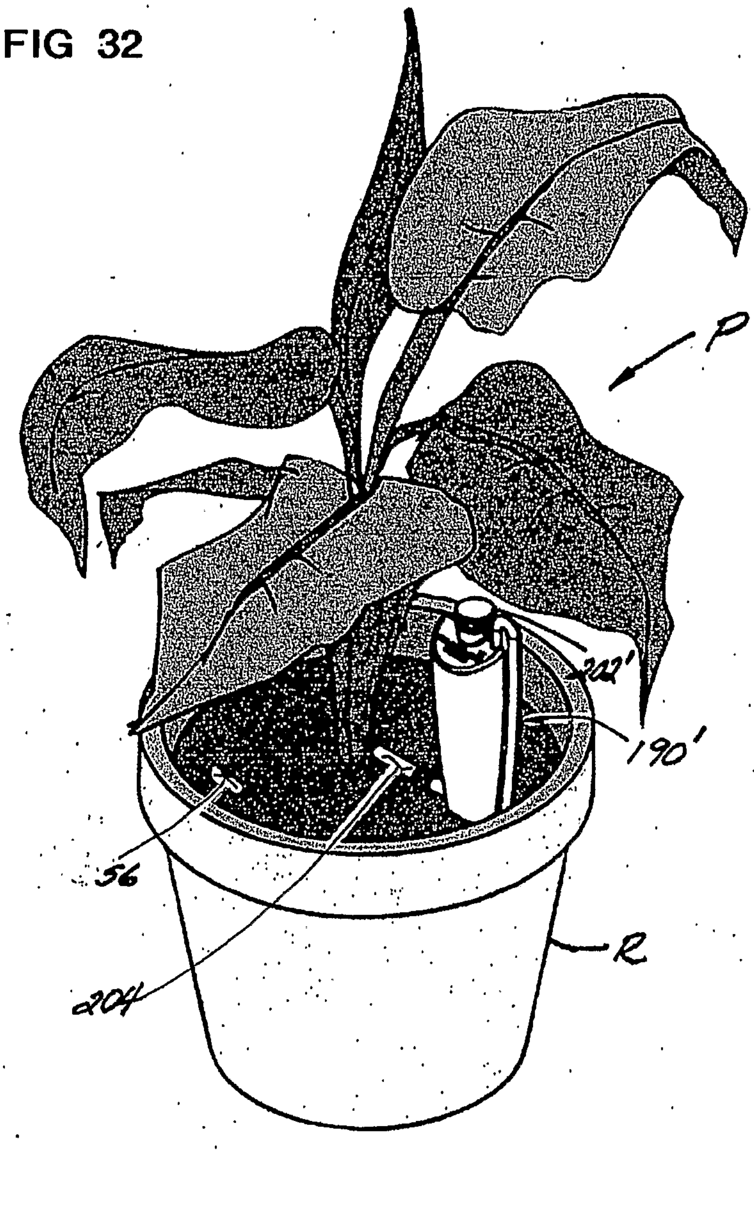
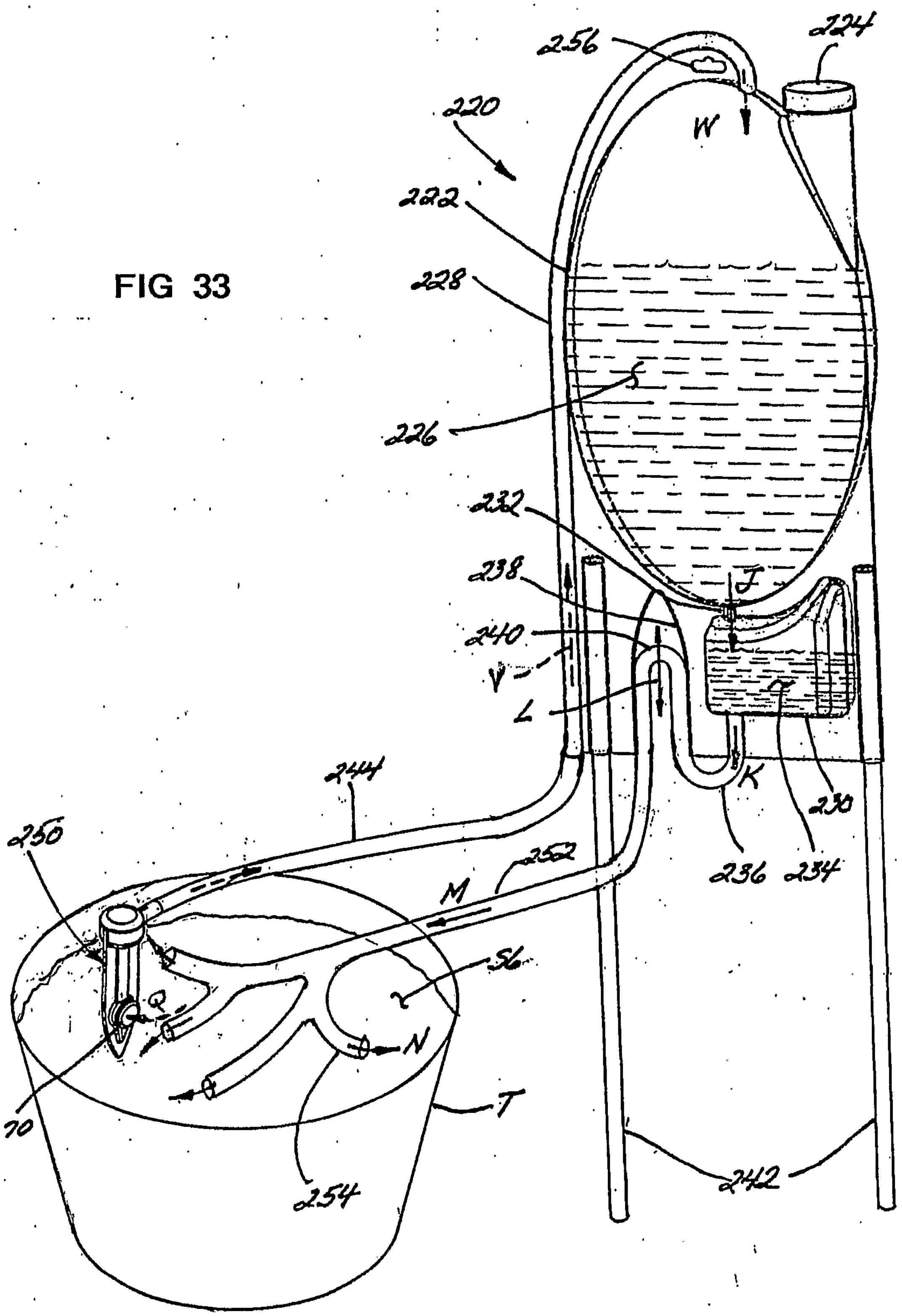


FIG 33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